Case study – the global maritime knowledge hub

by

Torger Reve and Marius Nordkvelde

Forskningsrapport 1/2010

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Research Report 1/2010
ISSN: 0803-2610

BI Norwegian School of Management
N-0442 Oslo

Phone: 4641 0000
www.bi.no

Printing: Nordberg

The report may be ordered from our website
www.bi.no/research

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PREFACE

MARINTEK is currently conducting a pilot project to develop a new maritime knowledge center, World Ocean Space Center, as part of the vision project "The Third Wave”. Based on this project, MARINTEK (Trondheim) has asked BI Norwegian School of Management to conduct this case study. The case study is a follow-up to the research report, “Norway - a global maritime knowledge hub” (Reve 2009).

We want to thank everyone who have contributed and made this case study possible by interviews and answering questionnaires. We want to give special thanks to Eivind Dale and Egil Rensvik , MARINTEK for their valuable insights regarding the R & D environment in Trondheim. We will also like to thank Asgeir Sørensen , CEO of Marine Cybernetics for his valuable contribution to the case study, Marine Cybernetics. Finally, we will make a very special thank to Kåre Syvertsen, Sevan Marine for his outstanding contribution to the case study, Sevan Marine.

Marius Nordkvelde, BI Norwegian School of Management has been responsible for data collection, interviews and case study write ups. Herman Ness and Nicolai Alexander Kirkeng, BI Norwegian School of Management have made significant contributions to the following case studies in the form of write ups and interviews: DNV, Hywind, Ulstein Group, Sway, Fugro OCEANOR and Kongsberg Maritime. Torger Reve has provided the theoretical and methodological framework of the study. The case study has been conducted as part of the large national research project, “A Knowledge-Based Norway” at BI Norwegian School of Management, led by professor Torger Reve.

January 2010

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FORORD

MARINTEK gjennomfører for tiden et forprosjekt for å utvikle The World Ocean Space Center, fremtidens maritime kunnskapssenter, i forbindelse med visjonsprosjektet " Den tredje bølgen”. På bakgrunn av visjons-prosjektet er Handelshøyskolen BI bedt om å gjennomføre denne casestudien, med finansiering fra MARINTEK (Trondheim). Case studien er en oppfølging til forskningsrapporten, ”Norway - a global maritime knowledge hub” (Reve 2009).

Vi vil takke alle som har bidratt og gjort denne case studien mulig å gjennomføre ved å delta på intervjuer og besvare spørreskjemaer. Vi vil rette en spesiell takk til Eivind Dale og Egil Rensvik, MARINTEK for deres verdifulle innsikt vedrørende FoU miljøet i Trondheim. Vi vil også rette en spesiell takk til Asgeir Sørensen, Marine Cybernetics for hans meget verdifulle bidrag til casestudien. Til slutt vil vi rette en stor takk til Kåre Syvertsen, Sevan Marine for hans enestående bidrag til utviklingen av caset, Sevan Marine.

Marius Nordkvelde, Handelshøyskolen BI har hatt ansvaret for data-innsamling, intervjuer og utskriving av casestudiene. Herman Ness og Nicolai Alexander Kirkeng, Handelshøyskolen BI har gjort betydelige bidrag i form av utskriving og intervjuer til følgende casestudier: DNV, Hywind, Ulstein Group, Sway, Fugro OCEANOR og Kongsberg Maritime. Torger Reve har stått for det teoretiske og metodiske rammeverket for studien. Studien er gjennomført som del av det store nasjonale forskningsprosjektet ”Et kunnskapsbasert Norge” som gjennomføres ved Handelshøyskolen BI under ledelse av professor Torger Reve.

INTRODUCTION

This case study will focus on how the R & D environment in Trondheim has contributed to innovation and increased the competitiveness of the maritime industry in Norway. Norway has been able to maintain its global knowledge position within the maritime industry due to its strengths in research and innovation. In this case study, we will try to show that some of the main technological developments in the maritime and offshore industries have to a large extent their roots in R&D performed at NTNU and MARINTEK in Trondheim.

The case study starts with the core of the Global Maritime Knowledge Hub, which is the PRO's (Public Research Organizations) and the RDI (R&D Infrastructure). This part of the study will focus on NTNU and MARINTEK, (The SINTEF Group) located in Trondheim, and Det Norske Veritas, (DNV) located in Oslo. Figure 1 presents a summary of the global maritime knowledge hub (Reve 2009). Furthermore, there will be a case study which illustrates that a large international corporation like Statoil can also serve as a PRO in the maritime and offshore industry. The next step will be case studies of different companies which represent MKF's (Maritime Knowledge Firms) in the Global Maritime Knowledge Hub. The innovation that has been made in the collaboration with the PROs and by using the RDI from the R&D environment in Trondheim will be the focus of these cases. We present brief case studies of the following MKFs: Sevan Marine, Marine Cybernetics, Ulstein Group, Sway, Fugro Oceanor and Kongsberg Maritime.

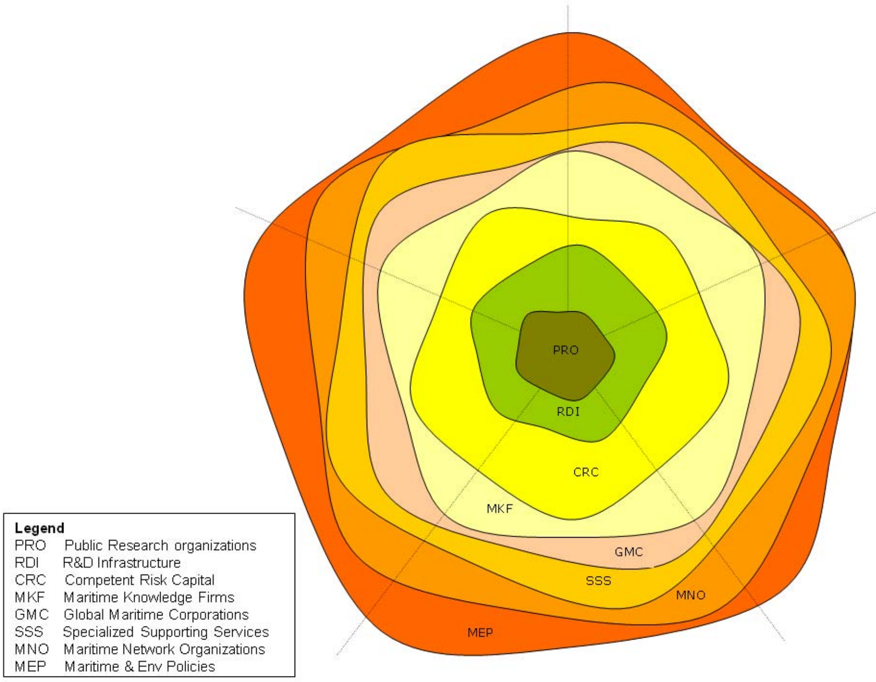


Figure 1: Global Maritime Knowledge Hub

THE TRONDHEIM R&D ENVIRONMENT – THE PROS AND THE RDI

Trondheim is a small town in a European context, but there are few cities that have such a highly educated population. Trondheim also has a high proportion of young people. The population’s high expertise and the many young people make Trondheim a "clever" city with a lot of innovation and creativity. The Trondheim region benefits from the country's foremost expert environment in education at NTNU, HiST, and Scandinavia's largest independent research institute SINTEF. The city has an extensive entrepreneurial, incubator, - and venture capital environment that is working to reinforce Trondheim's position as the No. 1 innovative city in Norway.

In the period from 2001-2004, while the IT industry was lying with a broken back, there was an IT bonanza in Trondheim, creating over 50 percent of the jobs in the city. The number of IT people increased from 1041 to 1576. Turnover in the companies grew by 33 percent, to 1.540 million NOK, and the number of businesses rose by 5 percent to nearly 200. The search giants Google, Yahoo and Fast were betting heavily on research and development in Trondheim.

Trondheim is the technology capital of Norway. NTNU is one of the country's largest universities and has through former NTH trained most of the country's engineers over the last hundred years. Trøndelag has 35,000 students and 4,500 researchers. SINTEF is one of Europe's leading research institutions in contract research. The activities at SINTEF and NTNU have been the basis for over a hundred technology companies over the past 20 years.

A lot of the technological knowledge in Norway is located at NTNU in Trondheim. In addition to technology and natural science, the University has a rich offering of subject in areas such as social sciences, humanities, sciences, medicine, architecture and arts.

We shall now take a closer look at the most important public research organizations for the maritime industry in Trondheim, NTNU, SINTEF, MARINTEK, and the cooperation between them, which, among other things, has contributed substantially to the Norwegian maritime industry.

Norwegian University of Science and Technology (NTNU)

NTNU is the second largest of the six universities in Norway. NTNU was founded in 1996 when the Norwegian Institute of Technology (NTH), College of General Sciences (AVH), the Science Museum (VM), Faculty of Medicine (DMF), Trondheim Academy of Art and the Music Conservatory of Trondheim were merged.

Today, NTNU consists of seven faculties and a total of 54 departments. The institution has about 22,000 students and 4,900 staff in teaching and research, of which approx. 60% in academic positions. NTNU's two largest campuses are Gløshaugen (former NTH) and Dragvoll.

Centre for Ships and Ocean Structures (CeSOS)- a world leading center

CeSOS is located in Trondheim and hosted by NTNU. It is the world's leading research institute in hydro dynamics and maritime technology, attracting researchers and PhD candidates from around the world. The centre was created by the Norwegian Research Council (NFR) as a dedicated Centre of Research Excellence. Today the centre consists of 50 full time researchers and professors. In total, there has been roughly 100 candidates affiliated with the centre, and 80% of these have continued their work in Norwegian maritime firms and institutions.

The research at CeSOS aims at generating essential knowledge about how structures behave in the ocean environment by using analytical and experimental studies. This knowledge is vital for the development of safe, cost effective, environmentally friendly structures and in the execution of marine operations. The following stresses the importance of such work: in tonnage terms 95 percent of all international transport is by sea; and 20 percent of the world's oil and gas is produced from subsea reservoirs via offshore structures and pipelines. In the future, food production in aquacultural plants and exploitation of renewable energy from the oceans is expected to play a growing role.

The research carried out in the centre takes account of such needs, and extends current knowledge. The emphasis is on hydrodynamics, structural mechanics and automatic control, and in the synergy between them. In each of the past years, the research projects have proved valuable basis for the innovative design of structures, risers and automatic control systems.

SINTEF

SINTEF is Scandinavia's largest independent research organization. Every year, SINTEF supports the development of approx. 2000 Norwegian and foreign firms through research and counseling. SINTEF is an abbreviation of "Foundation for Industrial and Technical Research at the Norwegian Institute of Technology". SINTEF offers research-based knowledge and related services in technology, natural science, medicine and social sciences to Norwegian and international customers. SINTEF was originally established to be the then NTHs extended arm toward the industry with the vision "Technology for a better society".

SINTEF currently operates contract research in the disciplines Health, Information and Communication Technology; Marine operations; Materials and Chemistry, Petroleum and Energy, Technology Management, Construction and Transportation. In order to make knowledge available to society, SINTEF also provides advisory services. In addition, they perform testing and certification in several areas, both within the corporation, through the firms it holds interests in, and through cooperation with others.

SINTEF has approx. 1800 employees, of which approx. 1300 are located in Trondheim and approx. 450 in Oslo. The Foundation also has branch offices in Bergen, Stavanger and Ålesund, in addition to offices in Houston, Texas (USA), Skopje (Macedonia), Warsaw and Krakow (Poland) and a laboratory in Hirtshals (Denmark). Corporate Administration is located in Trondheim. SINTEF is organized in corporate areas defined in terms of value chains and industrial market clusters:

- SINTEF Building and Infrastructure
- SINTEF Health
- SINTEF IKT
- SINTEF Marine (MARINTEK AS and SINTEF Fisheries and Aquaculture AS)
- SINTEF Materials and Chemistry
- SINTEF Petroleum and Energy (SINTEF Energy Research AS and SINTEF Petroleum Research AS)
- SINTEF Technology and Society

MARINTEK

MARINTEKs primary research and innovation areas are the development and operation of ships and offshore structures and operations. The main customers are Norwegian and international oil companies, shipping companies, consultants and shipyards. The following are examples of research and innovations, as well as some important assumptions and opportunities for success.

RDI: The first wave and the first assumption for success

In 1913, Professor Hans Ramm Mørch conceived a plan of constructing a ship model tank in Trondheim. The shipyard and shipping industry in Norway also identified the need for increased knowledge and competence in competition with the international market. Politicians and the industry gathered in a collective national effort to strengthen the research in maritime technology. The result was the opening of the ship model tank at Tyholt in Trondheim on the 1st of September 1939. This effort enabled Norway to develop the world's foremost maritime research and educational environment, and Norway to become the world's leading nation in ship construction and operation of ships. See figure 2 and 3. Since Germany invaded Poland on the same day and with that marked the start of the Second World War, there are three empty seats on picture in black and white (Picture 1). The Norwegian Royal Family, that was given the empty seats, had to make other priorities that day.

Figure 2: The opening of the ship model tank in 1939.

Figure 3: The ship model tank today

RDI: The second wave and the second assumption for success

When the oil exploration in the North Sea took off in the 1970s, there was a new need for knowledge and technology. In 1979 the ocean basin laboratory was opened, after yet another national effort for maritime research and technology development. The ocean basin laboratory made it possible to test offshore operations under real life conditions and gave Norway the competence that was crucial for the development of Norway as a petroleum nation. See figure 4.

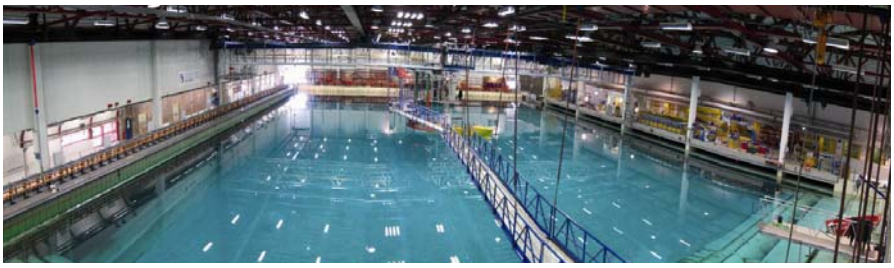


Figure 4: The ocean basin laboratory at MARINTEK

Propulsion and guidance systems

MARINTEK has for many years worked with the propulsion and steering of ships. During recent years, new complicated offshore operations, has given new challenges to accurately and safely operate vessels. MARINTEK and NTNU have conducted a long-term development program with all propeller manufacturers in Norway. In addition, Rolls Royce has established a University Technology Center - UTC, a long-term collaboration with NTNU and MARINTEK with ambitions to develop knowledge through doctoral students and to attract young talents to the industry. Another example is the cooperation with the shipping company Teekay for development of next-generation shuttle tankers to find new and safer ship technical solutions for operation in harsh weather conditions.

LNG and gas engines

MARINTEK has from the early 1970s researched and developed combustion engines for use on ships. This has been in close cooperation with leading engine suppliers such as Wärtsilä in Finland and with Rolls Royce engine factory in Bergen. MARINTEK had through the 1990s had several projects for the two aforementioned engine manufacturers to develop their marine engines to run on natural gas. Motor providers now have their solutions available in the market, both on board ships and in power plants on land. The knowledge developed at MARINTEK in natural gas / LNG is then used as a basis for development of regulations when building the first gas ferries and supply vessels, including Eidesviks' "Viking Energy". LNG is natural gas that has been cooled to -162 degrees Celsius, changing it from a gas into a liquid 1/600th its original volume. This dramatic reduction in size allows it to be shipped safely and efficiently aboard specially designed LNG vessels. The need for natural gas in "small" quantities has provided the basis for the development of the concept of "Coastal Gas", for distribution of LNG to various regions of Norway, local industrial facilities, ferries, etc. Today, the knowledge of the risks of LNG has been reviewed, and technology efficient distribution with containers and smaller vessels is available in the market.

Installations and offshore operations

There have been significant challenges in the installation, pipe laying and operation of floating production ships in the North Sea. Developments of several knowledge areas have been vital to the development of for instance the Ormen Lange field. A two-phase flow laboratory was put into operation in Trondheim in the mid 80s. Experience and knowledge that were developed at that time has been central to the Norwegian industry and the oil companies' ability to lay pipelines for the Ormen Lange gas field. MARINTEK has in recent years used the knowledge of the vessel maneuverability and hydrodynamics for planning and simulating the laying of pipelines on the seabed. Again has knowledge of materials, strength and flexibility of the tubes in combination with hydrodynamics been central to the work.

Floating production - FPSO

An example of knowledge from the marine engineering environment NTNU / MARINTEK, that has yielded results, is the development of the first floating production vessels Petrojarl. People who had worked on advanced marine technical systems had the opportunity to be pioneers in the development of the FPSOs. This has provided significant spin off effects, and given Norway a leading position internationally.

Innovation in the collaboration between NTNU and SINTEF

SINTEF's commercialization unit Sinvent and NTNU Technology Transfer Office are currently co-located. These cooperate with the incubator company Leiv Eiriksson Innovation AS, where NTNU and SINTEF are owners. Innovation Center Gløshaugen was established following a joint initiative of NTNU, SINTEF and SIVA. In addition to its own establishment, the technologies from NTNU and SINTEF formed the basis for the opening of several new business areas and new ventures from existing businesses. Examples of this are: Vingmed Sound AS, Dynal Biotech ASA, Powel ASA, Revolt Technology AS and the firms which are more fully analyzed in this report and many, many more. This type of new venture has created several thousand jobs. NTNU and SINTEF have also had great significance for development of other important parts of Norwegian industry. Within the petroleum industry the institutions have contributed greatly to the development solutions for the Snøhvit and Ormen Lange - two of Europe's largest and most innovative industrial projects.

DNV - DET NORSKE VERITAS – PRO

From ship inspector to global provider of truth

An old lady

The foundation DNV is a technology and service provider with a particular specialty in the maritime sector. Founded in 1864 as an initiative from several insurance companies who were experiencing huge losses due to shipwrecks and lost cargo, the first service offered was inspecting and evaluating the technical condition of Norwegian merchant vessels. With this background DNV has a rich heritage of maritime competence.

In the early 1950s, DNV was still a relatively small marine classification society with about 200 employees around the world, primarily supporting Norwegian shipping interests. DNV's services and classification rules, upon which its business activities were based, were largely copied from those of major international competitors, and had been little updated since 1919. This was clearly an unsustainable position: DNV faced two options, subsequently expressed by its first head of Research - and later president - Egil Abrahamsen, as to expand or die. The strategy underlying this expansion was spelled out in 1951 by the newly appointed president Georg Vedeler: *"We have no choice; whether we like it or not, we have to do research"*. George Vedeler had been professor and vice principal of the NTNU and hired his former student from NTNU, Egil Abrahamsen in 1952, who after short time established DNV research. Egil Abrahamsen was not the only person he hired from NTNU, soon Georg Vedeler hired almost a whole graduation class from NTNU.

From that new beginning, DNV grew from a small company serving primarily the Norwegian market to an international corporation.

Until the 1970s DNV was mostly concerned with service deliveries to the maritime sector, but in the last four decades the firm has branched out, and is now a large player in the energy sector and cross industrial services such as system certifications.

Under the motto: “Managing risk” they perform ship classification, statutory services, certification of materials & components, consulting, design and logistics services, fuel testing and support software solutions for the maritime sector. They are a global player with 9000 employees covering roughly a 100 countries offering their full spectrum of services wherever they are needed. DNV sells knowledge, and their dedication to excellence in the field is only matched by the meaning of their name: Veritas (truth).

Obtaining the truth

Research and development has always been an important part of DNVs activities, and it still is. They have had their own research department since 1954. Today they have 65 employees in the unit, working on strategic research and innovation. Around 80% of the total R&D effort is done internally in DNV. The remaining effort is done in cooperative research projects.

Spending roughly 6% of their annual revenue on R&D, DNV has a broad network of research partners. With a strategic cooperation with NTNU they sponsor several maritime professorships. An important output stemming from this is the cooperation on research projects, that is of great value to DNV. The competence that NTNU has in maritime technology is especially evident within integrated operations, renewable energy, carbon capture and arctic technology. These are areas that DNV has identified NTNU as their preferred partner.

In the past, and the present, CeSOS has been important as an international center of research excellence. The competence in maritime technology has been valuable for DNV as it has had a very positive impact on the development of maritime competence within the firm.

A second and just as valuable resource from NTNU is the education of competent people for DNV to employ. Of the 2500 employees in Norway, 750 (30%) are MSc graduates from NTNU. 1382 other university degree holders are from other universities, and keeping with their global presence, the offices in Norway is represented by 62 nationalities

Developing and maintaining strong competencies in ship hull technology, hydrodynamics, machinery systems, and risk and software technologies continue to be pillars of DNVs long-term technology strategy. Part of this work is done by running several research projects in cooperation with MARINTEK.

Of the 9000 employees worldwide there is a total of 76% who hold a university degree, giving the following educational company profile:

- 4% PhD
- 37% MSc
- 35% BSc

Keeping close relations with competent research communities is important for the success of DNV. In addition to the resources they have access to in Trondheim they gain knowledge through the following endeavors:

- Strategic cooperation with NTUA, National Technical University of Athens, Greece
- Cooperation with the Maritime Knowledge Hub Initiative at BI Norwegian School of Management, Oslo
- Cooperation with University of Oslo and CICERO on environmentally friendly shipping
- Cooperation with leading European universities and industrial partners through EU projects
- Contact with other Nordic universities

DNV is big in energy, and would like to see more research and innovation on clean energy take place in Norway, but at the time the leading work in this area is done in other countries.

Continued success - knowledge delivered

As history has shown, DNV has stood the test of time. With a solid base of maritime competences, which in later years has been complemented with other sectors, the foundation feel very confident that they will adapt to and exploit new markets as they emerge. DNV has strong relational ties to ship-owners, shipyards and oil and gas companies. For this work to continue at the high level of knowledge deliverance DNV provides to its customers, it is absolutely critical that DNV has access to the best people and the best research done within its sectors of expertise. The value DNV can provide is the result of the knowledge it can acquire and distribute. DNV will go wherever that knowledge is available. Thanks to the research community and initiatives with CeSOS and MARINTEK, today this knowledge is to a large extent found in Trondheim.

STATOIL SERVING AS A PRO

The Hywind consept - The first of its kind

From withstanding the elements to exploiting them

The next time you fly from Bergen to Stavanger you might want to book a window seat on the right side of the plane. If the weather is clear you might catch a glimpse of the world's first full scale floating wind turbine, Hywind. Stretching 65 meters over the ocean surface and with a rotor diameter of 82,4 meters it should not hard to spot standing in solitude off the island of Karmøy. See figure 5 and 6.

Figure 5: Hywind tugged to location outside Karmøy

Figure 6: Hywind

With the Hywind project, Statoil wanted to merge two known technologies and solve one of the toughest problems in regard to wind turbines as a renewable energy source. That is that everybody would like more renewable energy from wind turbines, but no one wants to have the turbines near them. Wind turbines are big and noisy, and the best wind conditions are usually also where we would least like to see a great white pole with hug rotor blades ruining the scenery. Offshore wind turbines would solve all that. They can be placed where the optimal wind conditions exists, and away from people and real estate conflicts.

Statoil chose a concept of drawing on existing technology and experience. Both Statoil and the Norwegian maritime research community possess great knowledge and experience based on floating offshore constructions. Especially CeSOS have come far on this field with calculations and models for such constructions. In addition, the wind turbine technology is quite developed in terms of land and inshore mounted wind turbines.

Statoil didn’t want to make a new invention, but to make a new innovation. The goal for Statoil was to create a floating construction with a motion characteristic that could carry a wind turbine from inshore concepts. This way Statoil could focus its effort on the part of the technology where it had the strongest competence and where they could draw on the strong maritime research community in Trondheim. One of the biggest differences to earlier offshore floating constructions, when testing the constructions, was that this construction was not only supposed to withstand the rough wind, weather and ocean conditions, but it was also supposed to optimally obtain energy from the wind.

The premises were set by history

At this point Statoil's Hywind project has come further than any others in the world in the field of offshore floating wind turbines. Some of the reasons have to do with geography. The climate in the North Sea and the Norwegian Sea is among the roughest in the world. This has created the need to build constructions that can withstand and be operational under such circumstances. The knowledge and experience drawn from years of design and operation in this environment has made a perfect foundation to solve the challenges in the Hywind project. For Statoil, it was important to know how to design the floating construction optimally with regard to how it would behave in the ocean. Statoil leaned on the maritime research community in Trondheim which the companies believe are among the leading on the field in the world. Statoil needed to perform hydrodynamic analysis and wind analysis. Without the numerical tools and the experience at the maritime research institutions in Trondheim, Hywind would probably not have come so far so fast.

Another critical part of the project had to do with physical test of scale models in the Ocean Basin Laboratory run by MARINTEK. Building a full size model of Hywind would probably not been approved by Statoil if they didn't have had these testing facilities, given the great costs and risks involved in such a project. Scale model building is almost seen as a science in itself. For example, the blades became very thin and light to ensure the right scale of every element in the model. With the basin facilities, Statoil could expose the construction of different wind, wave and stream conditions, and observe and analyze the results. To do more extensive research on wind models they used the Institute for Energy Technology (IFE) outside Oslo.

Statoil draws experience and knowledge from the maritime community in Trondheim on how they have had and should design and build the Hywind, analyzing how it would behave and operations around it. In addition to the competence of the Norwegian maritime community, the Statoil organization was critical of the leading position Hywind has gained. Statoil is an experienced actor when it comes to offshore operations and has a very skilled organization for carrying out offshore construction projects. The high level of integration in the company is important when the responsibility is transferred from research and development to the independent project. This experience ensures that the competence and the key resources stay with the project.

Norway has the competence base

Most of the research and skills that Statoil needed on this project they found in Norway, either in the Trondheim maritime research community or at the Institute for Energy Technology (IFE). The rest of the competence they found in-house. Only the actual turbine and blades come from outside of Norway. In their own words, Statoil had their best and brightest on this project. The people working on Hywind had at least an MSc degree in the field of study, but most had a PhD. Most of them had NTNU as their educational background.

Statoil generally does about 45-50% of the research and development of projects in-house. On the Hywind project they hired in a larger fraction. The development of the Hywind project also emphasizes the importance of having an offshore giant like Statoil when it comes to research and development. About 80% of the project is financed by Statoil, and governmental funding through Enova only constitutes about 20%. A capital intensive project like Hywind demands a long term, patient and competent financial backer like Statoil or similar Global Maritime Corporations (GMCs).

Maintaining a competitive advantage

Norway as a knowledge nation in the field of maritime industry has been carved from a long tradition of using the ocean and by the exploration of new technologies and by gaining new knowledge from the industry. Statoil is crediting CeSOS highly for the strong stand of the maritime R&D in Trondheim today. Statoil emphasizes that without that center Norway would have been a much more vulnerable maritime community. Everything would have been on a lower technological level. The community would have been smaller, and the risk of key functions in the community disappearing would increase. One of the key outputs from CeSOS is a more robust community in terms of technology, research and development in Norway.

It will be important for the future development of Hywind that the Norwegian research community keeps their stand as one of the leading maritime knowledge communities in the world. In the competition of developing an offshore wind turbine technology, second place is not sufficient. Although Statoil is in the lead today, there is one big issue that needs to be resolved, that is the economics of the technology. Today, Hywind is far from profitable. The technology is too costly. This issue needs to be addressed by the best and the brightest in order to be resolved. That is why the R&D environment in Trondheim is so important. The PROs in Trondheim are acknowledged as some of the best in their fields on a global scale and that is exactly what attracts the best talents. Unfortunately it is not given that this situation will last if not Norway continues to prioritize the development and the upgrading of these environments.

THE MARITIME KNOWLEDGE-BASED COMPANY (MKF): SEVAN MARINE

The importance of sophisticated RDI

The cylinder shaped floater

Sevan Marine is a Norwegian company listed on Oslo Børs that is most known for having developed a cylinder shaped floater, suitable in all offshore environments. See figure 7.

Figure 7: Cylinder shaped floater

Sevan Marine have their headquarter in Arendal, Norway, but has also offices in Oslo (Asker), Trondheim, Bergen, in Brazil, Singapore and UK. Presently, Sevan Marine has four Floating Production, Storage and Offloading (FPSO) contracts. An FPSO is a collective term for floating vessel used by the offshore oil and gas industry for the production and storage of hydrocarbons. It is designed to receive oil or gas produced from nearby platforms or templates, process it, and store it until the oil can be offloaded onto a tanker and the gas exsported through a pipeline or used as fuel gas. FPSOs can be derived from conversion of oil tankers, or can be built specially for the application.

Pusnes

The story of Sevan Marine has relations back to when the first shuttle tanker operations started on the Statfjord field in 1979. Statfjord is an oil and gas field in the Norwegian sector of the North Sea. The bow loading equipment installed onboard the shuttle tanker was supplied by Pusnes where Arne Smedal was actively involved. Pusnes in Arendal is today a wholly-owned subsidiary of Aker Solutions. Arne Smedal had graduated from the University of Trondheim in 1974 with a master's degree in hydrodynamics. Having completed studies in 1974 he began working for DNV, where he worked for 5 years. Then he began in Pusnes in 1979. The first load transfer systems were complicated in operations and the overall design was complex at that time, Arne Smedal therefore took the initiative to develope a simplified and more robust solution for cargo operation systems (Bow Loading System, BLS). This system was eventually accepted by Pusnes, and this was the start of what today has become the industry standard for cargo transfer systems for offshore shuttle tanker loading. The solution consists of a coupling half which sits on the loading hose and a coupling device that is mounted in the bow of the shuttle tanker. Testing of flow conditions, pressure loss, etc. in the coupling was carried out at SINTEF's laboratories. See figure 8.

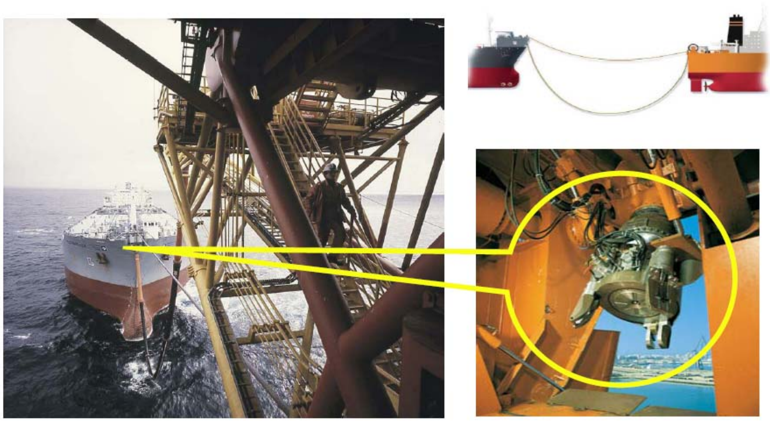


Figure 8: Coupling device that is mounted in the bow of the shuttle tanker

MCG and Hitec Marine

Arne Smedal left Pusnes and established MCG (Marine Consulting Group) in 1989, and in 1990 he got Kåre Syvertsen, professor in Marine Technology at the Norwegian University of Natural Science and Technology (NTNU) on board. Arne Smedal and Kåre Syvertsen had been close friends since the MSc program at NTNU.

MCG started to develop a new generation of bow loading systems for the North Sea shuttle tankers. Some loading stations had installed cargo hoses with increased weight and stiffness. The existing coupling systems had problems with large loads especially from moment loads. MCG developed a solution with a moment free coupling device. It consists of a ball joint which provides the freedom to rotate, and at the same time it is robust. The main competitor at the time was Pusnes which eventually came into the market with a moment free coupling based on a cardan type joint. These two moment free connectors have become the industry standard after they came on the market.

In 1991 there was a request from the transportation department at Statoil where they asked for ideas that could help to increase the limit for offshore loading under extreme weather conditions. Several companies received the enquiry, but MCG was selected with the best proposal, a loading station which consisted of a conical buoy, which was pulled in and locked in a receiving arrangement in the shuttle tanker. MCG was supported by Statoil's Vendor Development Program (LUP) to develop the concept. See figure 9.

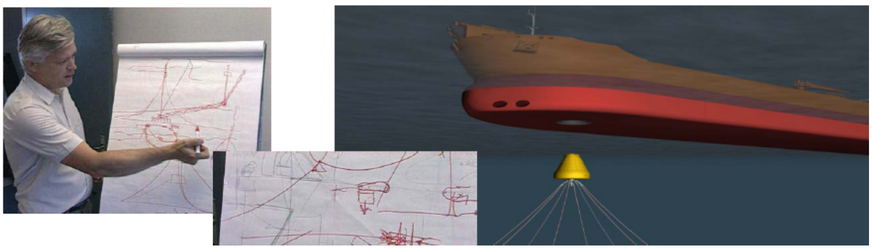


Figure 9: Offshore loading under extreme weather conditions

One of the first things that were put on the list of necessary qualifications was an extensive test program in the Ocean Basin Laboratory at MARINTEK. 3 weeks of testing was conducted at various depths. It was tested both the ability to be anchored as well as the disconnection of the buoy. Disconnection was done even in the most extreme sea conditions with good results.

The development of system was named STL (Submerged Turret Loading) and went very quickly and even before MCG had completed the development program, they were in contract negotiations with Shell for the delivery of the first system. The most important thing during this period was that the tests in the Ocean Basin Laboratory at MARINTEK were carried out with very good results. STL system was tested in "100-year storms" at various water depths and the tests in the tank showed that a shuttle tanker can be safely and receiving oil even under these extreme conditions.

Contract Negotiations with Shell began less than 12 months after the first ideas was sent to Statoil. One important condition for Shell to finally choose MCGs solution was to carry out further tests at MARINTEK, with a model of the actual ship and with the specified ocean conditions for the Fulmar Oilfield situated 312 km east of Dundee, Scotland, United Kingdom. Shell and Exxon who were participants in the Fulmar field where present in Trondheim with their experts from Houston, London and Amsterdam.

MCG had carried out optimalization of the mooring system and was very optimistic about the results. The first test that was done turned out to be a disaster. With the delegation on the poolside, it appeared that the anchoring system did not work at all. The theoretical optimization on the computers had clearly not detected all the effects. The forces in the mooring lines were more than twice than the calculated values. The guests from Shell and Exxon asked for explanation with a deadline 8 a.m. next morning. They guests probably had little faith in that they would succeed, because they had already bought new plane tickets for a quick return. After a search in the corners at MARINTEK, MCG found an anchoring system that was used half a year earlier (that was not optimized). A few hectic hours followed. MARINTEK replaced the mooring lines and started repeating the test program. At 5 o’clock in the morning, the critical tests were done, and the results were good. Reports and presentations were made, and representatives for MCG showed up at the hotel at 8 a.m. The presentation went well, and the tests were approved. It was like Christmas Eve, and the best Christmas gift they could have got. If they not had succeed in these tests in the Ocean Basin Laboratory at MARINTEK, the STL system and later STP (Submerged Turret Production) and the companies APL and Hitec Marine would never have been established. The contract with Shell was an important and a crucial opener for all that happened after this.

The next step for the company was a loading system for "direct shuttle loading, DSL" on the Heidrun oil field at Haltenbanken. The field development consisted of a production platform of TLP type without storage. As an alternative to installing a storage vessel, MCG proposed 2 STL buoys to which the shuttle tanker could connect. With one tanker always connected, the operation could continue without any stop. Savings relative to a solution with storage vessels were many hundreds of millions. The American oil company Conoco (Today Conoco Philips) was responsible for development and was positive to the company's proposal. Statoil was a partner, but did not have the same enthusiasm. Several new elements were introduced in this early phase. Extensive model tests in the Ocean Basin at MARINTEK were conducted to document the functionality. After several series of tests of connection, disconnection, and operation in the 100 years of storms of various types, the STL system was selected for direct loading to shuttle tankers. The Heidrun STL system has since it was installed in 1995 had 100% availability. More than 1000 shipments have been made by shuttle tankers with about 100 000 tons of oil in each shipment.

APL

As part of the Heidrun contract, it came a desire to split the STL system into two parts. The shuttle tanker equipment remained with MCG. APL was established to supply the field equipment with MCG and Statoil as owners.

STL system was developed further for use in a production vessel (FPSO). The company tried first to market itself with an extended STL buoy and a swivel purchased from outside. It came clear messages back that made it clear, that APL had to have its own swivel design. Again with the support of the LUP program at Statoil, there was initiated a development program. The company managed to develop a swivel which was considerably simpler (STP) and more robust than those used by their competitors.

The first STP system was installed in the “Berge Hugin” FPSO at the Lufeng oil field in South China Sea. A thorough model test in the Ocean Basin Laboratory at MARINTEK was a clear prerequisite for the approval by the partners for the operation at the deep water field.

STL and STP systems have gradually been applied to "all" oceans. More than 30 systems are installed, and applications range from simple loading system, production vessels, gas terminals, and more.

Virtually all the developments that have been completed, have prior to this undergone rigorous testing in the Ocean Basin Laboratory at MARINTEK. Also the development of other systems such as SAL (Submerged Anchor Loading) and BTL (Buoy Turret Loading) are systems that after thorough testing at MARINTEK have been introduced for offshore loading of fields ranging from the icy waters of Russia to the deep waters in West Africa.

APL is currently established with offices in Arendal, Singapore, Kuala Lumpur and Houston. Number of employees in Norway is today above 200.

MCG and Hitec Marine

In 1995 MCG was acquired by Hitec and changed its name to Hitec Marine. Hitec Marine was some years later acquired by APL. APL is currently owned by BW Shipping headquarted in Singapore and Hong Kong, the same company (Worldwide Shipping) that some years earlier acquired one of the largest Norwegian shipping companies, Bergesen Shipping, a leader in Gas Tanking Shipping.

NAVIS

As part of the deal, when Hitec bought the MCG, was an obligation that Arne Smedal joined Hitec. As a part of the Hitec strategy he took the initiative to establish the company NAVIS, with the purpose to build and operate a drillship, designed jointly between LMG Marine and Hitec. LMG Marine developed the basic hull design and Hitec developed the drilling system with special focus on automation and data management.

Kåre Syvertsen and Jan Erik Tveterås joined NAVIS after the establishment. Jan Erik Tveterås had his background from commercial and financing activities as Chief Financial Officer in Transocean, today the world's largest offshore drilling company. The main focus for NAVIS was to develop a drilling vessel with the best possible operation. Favorable motions, and especially the roll motion, is important in order to gain efficiency of a drill ship. Based on suggestions from LMG Marine in Bergen, a systematic work to find a hull form that could improve the roll motion was established. The work was closely linked to MARINTEK and NTNU. To be able to do as many calculations as possible in advance of the model test, Professor Nick Newman from MIT in Boston, was also involved. He is the one who has developed today's numerical methods for calculating ship motions. Model tests in the Ocean Basin Laboratory were ordered and the tests were carried out with Nick Newman on the basin side. Here NAVIS managed to capture the important parameters that gave them a thorough understanding of the effects that are important for controlling the motions. Tests were done for different hull forms, which gave a good basis for choosing the final design.

After rounds of further development of both ships and systems that were in place, new rounds of tests in the ocean basin laboratory at MARINTEK were conducted by the requested hull design. Once again, the ship had almost no roll motion. The tests at MARINTEK were crucial for the project to proceed, and for the project to be financed.

The drillship, which eventually was named Navis Explorer, was built by Samsung in Korea. Most of the drilling equipment and other equipment were shipped from Norway. The company managed to get the contract for drillship with BP (British Petroleum) and Petrobras for operations in Brazilian waters. The ship was delivered from the shipyard and sailed half way around the world to Brazil. Favorable motions that were predicted in the model tests had been verified by full-scale motions. The ship has virtually no roll motions. See figure 10.

Figure 10: Drilling vessel, Navis Explorer

The technical part of the Navis project proved to be the nice part. The company was met by the previous financial crisis and managed through the turmoil by entering into an agreement with Reading & Bates (R&B), a Houston-based drilling company. They came in as a major shareholder (almost 40%). But this only helped for a while. It turned out that R&B was also in a financial crisis. In order to improve their liquidity, R&B chose to sell NAVIS to Fred Olsen Energy (FOE). However, FOE wanted the ship and not the NAVIS Company. Navis Explorer that way became Belford Dolphin and is today one of the best "money machines" for FOE. R&B was able only to exist 2 months extra on the sale and was then taken over by Transocean..

Arne Smedal, Jan Erik Tveterås and Kåre Syvertsen were unemployed and decided to try the luck once again. The Navis letters were turned over and adjusted a bit, and thus Sevan Marine became a reality in 2001.

SEVAN MARINE

Strategy for Sevan was made after it was completed a thorough market analysis of what the next few years requested. Although the market in 2001 was dead for all types of offshore entities, the conclusion was that the market for offshore production vessel (FPSO) would probably return.

With experience in the development of the turret and the swivel system and the hull of the drillship, creative ideas were put on the table. Turret and swivel systems are complicated and should be avoided, a favorable roll motion is good and speed is not the priority for an FPSO unit, etc were discussed. The conclusion was simple. A circular unit will not need to rotate with the weather, i.e. no turret or swivel needed; experiences from NAVIS could be used to provide favorable motions; an FPSO will be moored in the same place and have no need to maintain a high speed through the water.

Sketches were made, which was simple, only a few dimensions were required to define the unit. The dimensions were selected and MARINTEK was contacted for testing in the Ocean basin. After a few weeks, the tests started and the results were surprisingly good. The test had shown that even in extreme weather conditions in northern seas, the companies circular drive had very favorable motions. The tests in the ocean basin were conducted with systematic studies in which key parameters were varied to provide the best possible basis for the choice of the final hull design.

With good results from the model tests, marketing started both in Brazil, Norway and UK. A company was established in Brazil with 3 employees. Studies and reports were made for a number of developments, but the market was skeptical as nobody wanted to be the first to adopt a new design.

Several series of new tests were conducted in the ocean basin at MARINTEK. The company tested for the Skarv oil field on the Haltenbank and for the Campus oil field in Brazil, all at their own expense. But it did not help to get someone on the hook. Petrobras was most positive to the technology. A cooperation agreement was established with the research department of Petrobras, CENPES and Sevan Marine. The objective was to jointly develop circular units for the production of oil in deep water.

After a couple of years without getting any positive results from the marketing, the company took initiative to try to finance the construction of a hull. With a background in development and introduction of new technology through a number of companies, Sevan Marine had built up confidence in the market. This was probably an important requirement for Sevan to be able to put in place financing in this difficult period. The contract was signed with a Chinese yard, and Sevan was back on track. Soon, possible clients from both Brazil and the UK signaled their interest.

Sevan FPSO

After the hull was close to completion, Petrobras chose to enter into a contract for a development at 1000 m water depth. Sevan Piranema FPSO was about to become a reality. It turned out to be a demanding development with large amounts of gas that were reinjected with a range of requirements from Petrobras, which had to be satisfied. The process plant was planned and detailed by the design and engineering company Kanfa which eventually came in as a wholly owned subsidiary. Different modules and equipment that were required were mainly constructed and completed in Norway. The hull, which was built in China, (See figure 11), was transported on a heavy lift vessel from China to Rotterdam. Equipment from Norway was transported to Rotterdam, and integration and completion was done at the Keppel Verolme in Rotterdam. After completion, the completed FPSO was towed with two tug boats from Holland to Brazil. It had a full crew along for the ride that went with an average speed of 7 knots.

Figure 11: Sevan Piranema FPSO, built in China

The British-based oil and gas exploration and production business, Venture Production, became the next to book an FPSO for the UK sector of the North Sea. This followed the same completion sequence as Sevan Piranema and was anchored at 120 m in the middle of the North Sea, under the name Sevan Hummingbird.

After a while, Oilexco went into a contract on unit No. 3, Sevan Voyageur, for operation on 90 m water depth, in the North Sea. Same arrangements as for the previous two units were conducted. After the FPSO was anchored on the field and ready for start-up, arose problems. Oilexco was hit by financial crisis and went bankrupt. After thrilling months of uncertainty, Shelley field was taken over by Premier Oil and production was started over six months behind schedule.

Goliat (offshore oilfield in the Barents Sea)

Results eventually came, after an active promotion of Sevan FPSO. The whole industry was gradually familiar with the Sevan Marine design and the company was in a pre-qualification for Goliat development in the Barent Sea. Ice, snow, cold and darkness were presented as clear challenges. Sevan Marine got through the first round and was in a bid competition together with Aker Solution, who also provided a circular device, but had chosen to build of concrete. Sevan Marine won the competition offered in collaboration with Samsung, Korea, but the global energy company, ENI, chose to do an alternative approach to project implementation. Based on the financial crisis and the decline in shipyard activity, ENI selected the Sevan FPSO concept, but opened for a new bidding round in which several yards groups were invited to join. The offers are now received and the company is waiting for the winner. These days Sevan Marine participates as part of ENIs team and is not a provider. Aker Solutions is now working as bidder together with former partner of Sevan Marine, Korean Samsung.

In the early phase of the Goliat project, it was proposed some solutions that would ensure good working conditions. Additionaloptimization of the rig, both with respect to motions and amooring system were carried out. Winterization was done with a protection wall that was transparent. Air flow calculations were made with latest in numerical simulation (CFD) for estimating rain and snow penetration in addition to the air flow. To verify these calculations wind tunnel tests may be made.

A series of model tests have been made of the Goliat FPSO. First, it started to demonstrate that the company can operate under weather conditions that are north of Hammerfest. This was part of the initial qualification to go forward. See figure 12.

Figure 12: Goliat FPSO

The next phase of model tests was conducted to optimize the hull. Significant improvements were achieved. None of these improvements would have been possible without the use of the ocean basin at MARINTEK. Cost savings that were achieved are a multiple of what was paid for the model tests. This is a typical experience, which is done through what Sevan has been doing - the cost of model tests is almost always small compared to the gains they provide. Sevan Marine has therefore as a principle that, every project they are participants in, they have to go through rigorous testing in the Ocean Basin Laboratory at MARINTEK.

Sevan FLNG (Floating LNG production)

Sevan Marine's strategy is to be technologically ahead of their competitors. The company has managed well so far. But the company itself realizes that there is just a matter of time before the competition will be harder.

As part of their strategy, it was for just over two years ago taken the initiative to develop a concept for floating production of LNG (Liquefied Natural Gas). The company’s circular hull was well suited for this. Sevan did a market survey of what was available of technology for tank farms for storage of LNG. None of the designs that were in use would suit Sevan. Sevan therefore developed their own LNG containment system (LNG tank). MARINTEK was engaged to test the tank's properties. The best expertise from MARINTEK, both in Houston and Trondheim, was engaged to best describe and document what happens to the liquid in the LNG tank. The tests gave positive results, and the tank design has come far.

Beside concept development for the hull, tanks and operations, it was taken initiative to ensure the competence of the processing plant for the cooling of the gas. See figure 13.

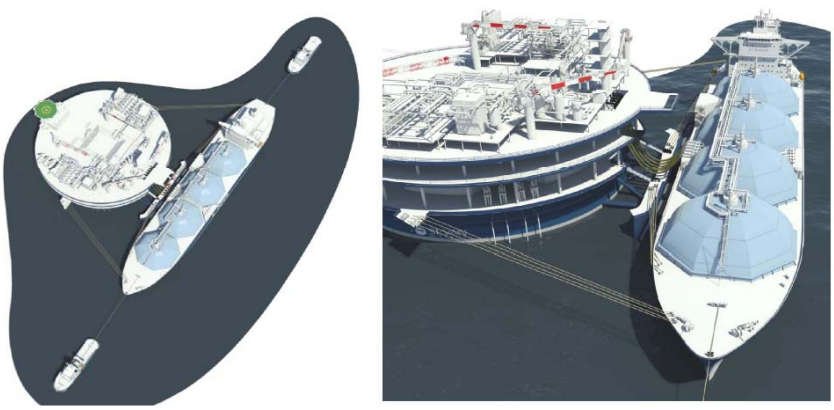


Figure 13: Floating production of LNG

The company Aragon, which is now is named Kanfen Aragon, joined the team. They are now part of Sevan Marine Group, owned 50% by Sevan. They have today a contract with Samsung for the delivery of the first facility for LNG production at a Floating LNG production unit (FLNG). The FLNG unit is contracted by FlexLNG and based on "conventional" ship hulls.

Sevan Ice

The company has in 2008 completed a development project, funded by Statoil, in order to qualify their cylindrical hulls for operation for one of the world's largest natural gas fields located in the Barents Sea, Shtokman field. See figure 14.

Figure 14: Cylindrical hulls for operation for the Shtokman field

Tests were done in the ocean basin at MARINTEK and in an Ice test basin in Hamburg, Germany. Operations during periods of ice and ice ridges represent the main challenge for the Shtokman field. Tests of the unit in ice are crucial to document the operation. All criteria's that formed the design basis for the operation at the Shtokman Field were satisfied.

For unknown reasons the Sevan Marine concept has not been proposed as an alternative to the Shtokmen consortium (Gasprom, Total and Statoil).

Sevan FPSO with steel risers (SCR)

A major development program financed by Statoil is completed for use of the Sevan FPSO with steel risers in deep water. The results of the study are very positive, and the final documentation will be made with tests in the Ocean Basin Laboratory at MARINTEK. The test will recreate the conditions on the Vøring Plateau with about 1250 m water depth. Here it must be made "truncated" anchor and riser system when the Ocean Basin Laboratory at MARINTEK is not deep enough. Also, the wave height that is to be simulated is on the limit of what can be produced in the ocean basin. Again, the Ocean Basin Laboratory at MARINTEK is the key to verification.

If the company succeeds with this, a whole new market will be available. Sevan will in all deepwater areas be able to compete with SPAR buoys and other "deep floaters" which all represent costly and complicated structures. See figure 15.

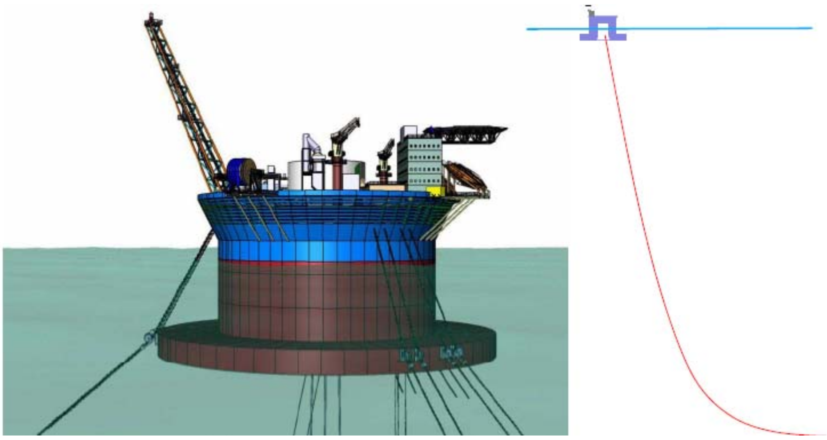


Figure 15: SCR- Steel Catenary Risers

Sevan FPSO with "dry trees" in shallow water

A combined solution, with Sevan FPSO and fixed platform, was launched about a year ago. The two devices will be connected by a bridge, which can be lifted up by extreme weather. It has gradually emerged an international interest for this solution. The combination allows for continuous access to oil wells through the "dry" trees. For many projects, this is very important and can improve recovery from a field considerably. See figure 16.

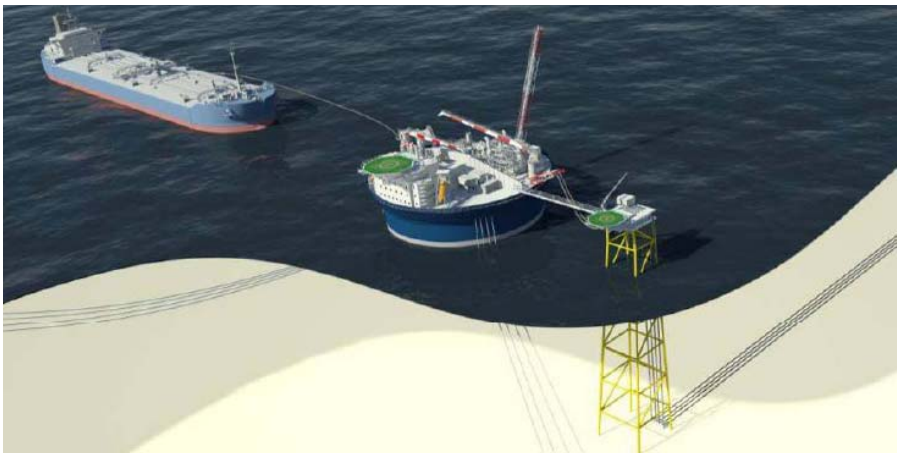


Figure 16: Sevan FPSO with "dry trees" in shallow water

Two paid studies for oil fields on the Norwegian and British sectors are on going. The next phase for verification is the Ocean Basin Laboratory at MARINTEK.

Sevan GTW (Gas to Wire)

Offshore power plants were initially a project that started with a MSc thesis at NTNU. It has further developed in collaboration with Siemens. In order to meet Norwegian requirements, it is in cooperation with SINTEF developed a CO 2 capture facility that will be placed in the tank area of a "standard" Sevan hull. Sevan GTW can be placed in an area with access to gas (e.g. ,"Offspec" gas that can not be exported by pipeline), and CO 2 can be injected into the nearby reservoirs. See figure 17.

Figure 17: Sevan GTW (Gas to Wire)

Currently this project has not been realized, but there is much positive interest. The companies "geostationary" device enables efficient transfer of power to nearby platforms.

Sevan MODU (Mobile Offshore Drilling Unit)

Piranema was completed in Rotterdam and towed to Brazil with two tug boats. To ensure that the tow could be conducted without any surprises, model tests were made at MARINTEK. The tests were carried out with surprisingly positive results. The main problem with the towing of a vessel is that it often becomes unstable, i.e. that the vessel chasing from side to side. Sevans circular hull followed a straight line during the tow and the towing resistance was less than expected.

Model Testing is time consuming, and Sevan representatives were staying up all night during the tests, where the speed came up in 12 knots without any drama. So why not imagine the circular hull used for other purposes?

With experience from NAVIS, it is tempting for the company to think of a circular drill ship. The idea was made, sketches were made, discussions started with shipyards and equipment suppliers and financing initiated. Only a few months after the idea was there, the company was ready to launch the building of the first circular drilling rig.

To document the rig's capabilities, extensive testing was done in the Ocean Basin Laboratory at MARINTEK. There was a focus for both motions to ensure that the drilling facility will be effective and to test that it had enough thrust of the propellers to keep the rig in position. Further, the model tests in wind tunnel were carried out in Copenhagen, this in order to have control of air forces.

The company was awarded the first MODU contract with Petrobras, and the construction was started at China Ocean Shipping (Group) Company (COSCO), in China. The rig is now delivered from the shipyard and is on its way to Brasil sailing with its own propulsion.

A summary of Sevan Marines strong relation with PROs in Trondheim

Sevan Marine has since it was established had a close and strong relation to the research environment in Trondheim. Already a few days after the idea for the circular hull was outlined, contacts with MARINTEK were made. The first model tests were then carried out after a few weeks. The tests confirmed that the idea the company had, worked. This was significant and necessary tests to be able to proceed with development. Without MARINTEK and NTNU, Sevan would never have had developed their cylindrical platform.

In the further development of the concept, MARINTEK has participated actively with both the model tests, calculations and evaluations of various aspects of the design. The environment in other SINTEF departments and not at least the research at the Marine Technology Department at NTNU made important contributions regarding this. The environment has been drawn in to verify e.g. riser solutions, collision analysis, calculation of ice loading, etc.

Moreover, beyond the development of the concept of Sevan's, other professional communities at SINTEF and NTNU have been involved. This applies both to adaption and to operation on ice and the development of offshore power plants with CO2 capture.

The model testing at MARINTEK has been crucial to be able to verify that the company has developed and tested through theoretical calculations, but the Trondheim environment is also an important resource to make theoretical advancements and to be active discussion partners through the process of developing new products.

The company has until now not had any activity directly linked with CeSOS, but the company looks at CeSOS as an essential resource for the development of basic skills within their industry. The direct benefit will in the long term be better knowledge of their field that will most likely strengthen the Norwegian business position. Researchers, who now take a PhD within their field, will be more interesting for recruitment.

As described earlier, the availability of Ocean Basin at MARINTEK was crucial for MCG, APL, Navis, and Sevan Marine. Although the company these days has access to advanced and efficient computer program for calculations of both motions, mooring system and station keeping capacities, there are still very many effects and parameters that can not be described, unless they can be determined from the model tests.

Model tests also had and still have, a crucial importance, when it comes to marketing new products for a firm like Sevan Marine. A conservative industry will never be convinced by only calculations. Model tests are very often what are needed to give credibility, both through the results and through the fact that customers can be there and check out the tests themselves. Here is the confidence to the institution, crucial. The Ocean Basin Laboratory at MARINTEK has confidence in the market. With a commitment to a new generation of test facilities, this will further be strengthened in the future.

Today unskilled employees represent 5% of the company, 15% skilled, higher education, 80% (included engineers with Bachelor degrees). Out of the 80% percent with higher education, 50% comes from NTNU in Trondheim and 5% comes from abroad.

The company uses between 4 and 8% of their revenue on R&D each year. The bulk of R & D is performed within the company. Both in 2008 and

2009, the company used external assistance from MARINTEK to model testing, from NTNU and Barlindhaug for ice calculations and testing the ice in Hamburg. The proportion carried out by SINTEF/MARINTEK and other external partners is about 30% out of their total R&D spending. A large part of this is the model tests at MARINTEK, which costs a few millions for each round. The rest of the R&D is done inside the company. All development work is done in Norway. The main reason for this is the strong position of the SINTEF/MARINTEK/ NTNU environment in Trondheim with respect to all development of offshore structures and operations.

The company and their corporate relations

Today, Sevan has its head office in Norway, but has in addition offices in different countries all over the world. Below are the different activities to each office location described.

UK: Offices in Aberdeen with responsibility for the operation of two rigs in the UK sector

Brazil: Office in Aracaju for operation of the Sevan Piranema; office in Rio de Janeiro for the operation of a drilling rig in Brazil plus general marketing and product development towards the Brazilian market.

Singapore: Office is established to retain ownership of the rigs that are in operation. The office will also be active in marketing and product development.

China: Site team at the shipyards for participating in the "detail design" and to follow the construction of the rigs to ensure that that quality is satisfied.

The company’s focus is to create products and solutions to the offshore industry, utilizing its core competencies within the areas of design, engineering and project execution by using the Sevan technology. The company has concentrated its efforts in utilizing this technology for floating production and drilling applications and floating LNG as well as developing its topside- and process-technology. However, due to its versatility, the Sevan design may in the future also be used for other applications, including Gas to Wire (GTW), FDPSO (Floating Drilling & Production) and accommodation.

The business model has traditionally been based on a build-own-operate scheme, which means that the company takes the responsibility for the construction, ownership and operation of the Sevan units. The company continuously considers co-ownership with third-party partners in the units if it is considered beneficial.

The Sevan operations may be carried out by in-house personnel or in cooperation with recognized operations and maintenance contractors. With this model, the Sevan units will most typically be leased to clients under multi-year contracts, of which the Sevan Marine Group undertakes to carry out the production or drilling activities on a specific offshore location. With the build-own-operate scheme, Sevan's remuneration typically consists of an agreed day rate the customer (i.e. the oil company) pays for the bareboat or time charter of the unit. Such day rate will typically consist of one operating element and one capital element.

An alternative business model is the license model, which is very attractive these days given the current financial market conditions. If the customer wants to be the owner of a Sevan unit, the company will evaluate this on each case by taking factors such as risk, profitability, availability of financing, construction and engineering capacity into consideration. The Goliat FPSO contract is made according to this model. The oil company ENI will be the owner of the FPSO. See table 1 for an illustration of Sevan's business model.

<table>
<tr><th></th><th>DESIGN</th><th>ENGINEERING</th><th>CONSTRUCTION</th><th>OWNERSHIP</th><th>OPERATION</th></tr>
<tr><td>FOCUS</td><td colspan="2">• Proprietary technology
• In-house expertise
- Hull
- Topside (Kanfa)
</td><td>• Long-term construction capacity secured with key yards
• In-house expertise in project management and execution</td><td>• Ownership to be decided on a case-by-case basis
• Ownership of units (BOO) or license model</td><td>• Operation & maintenance (O&M) responsibility
• Combining internal and external resources
• Lease contracts</td></tr>
<tr><td>RATIONALE</td><td colspan="2">• The Sevan technology forms the basis for the Company's core competencies and competitive advantages
• In-house marine and process expertise provides optimization and flexibility through project execution</td><td>• Construction capacity is a critical success factor
• Construction program requires key competence in execution</td><td>• Retain full control of own technology
• Depends on size of project and availability of financing sources</td><td>• In-house O&M expertise secures ownership and feedback from operations (lessons learnt)</td></tr>
</table>

Table 1: Business model of Sevan Marine

Next to NTNU and MARINTEK, the company has today strong relations with ship and offshore yards, ship brokers, financing and insurance companies and oil and gas operators.

Below are Sevan Marines strongest relations to different groups of firms listed:

Yards: Cosco (china), Samsung (Korea), Keppel Verolme (Holland)

Equipment makers: Siemens (Norway), Rolls Royce (Norway), Aker Maritime Hydraulic (Norway), Aker Pusnes (Norway), Kongsberg Maritime (Norway), National Oilwell Varco (US), and a number of small suppliers.

Ship Brokers: Lorentzen & Stemoco (Norway)

Financing and Incurance: GIEK, (Norway) and a number of international banks

Universities: NTNU, Trondheim (Norway), University of Agder (UIA), Grimstad (Norway)

Oil/gas operators: Petrobras (Brazil), Statoil (Norway), ENI (Italy), Venture Production (UK), Premier Oil (UK), Chevron (US), Det Norske (Norway)

In addition the company has strong relations, but to a less extent than those mentioned above, with several ship owners, ports and maritime logistics, ship consultants and ICT companies.

Within the offshore industry, the Norwegian financial environment has been essential. The different Norwegian financial houses have a leading position internationally within this industry. For Sevan Marine, they have been and are a very important element in the development of the company. Without trust and access to this environment, it would be almost impossible to develop and carry out the real product of the kind the company is doing. Development and introduction of new product aimed at a conservative offshore environment is time consuming and costly and are completely dependent of opportunities for funding.

Status today

The market for offshore floating production units, FPSO and drilling rigs are currently positive. There have been a period the last year with few contracts, but from the number of inquires; the company has today a clear impression that there is a change for the better to come.

When it comes to devices from Sevan Marine today, the company has a solid position in the market. Their cylindrical design is accepted, and Sevan is now invited into studies also for the large well-established oil companies. An important milestone that the company went through was a qualification of their design for the Goliath development in the Barents Sea. Here they were through a thorough qualification process with ENI and Statoil.

Their market position in the Norwegian sector is currently very favorable for FPSO solutions. The government has put a pressure on builders to use electricity from land as the main source of power supply on an FPSO. This excludes FPSOs based on ship hull with turret, where a large power transmission is in practice not possible.

Sevan's market position in the international market is good. Their technology is known by most of the players in market. They have two units in the British sector that has worked very well. Motions have been documented through calculations, model tests and full scale recordings. Sevan is currently in the process of conducting studies aimed towards new FPSO contracts in the UK sector.

Their first drilling rig, Sevan Driller 1, has a contract with Petrobras to drill in the large oil field off the coast of Brazil, Tupi. The rig is based on their cylindrical hull. Sevan has a contract with Petrobras on a second drilling rig for the same type of operation, ultra-deep water on the Tupi field. A third rig contract is made in India. This is under renegotiation.

Sevan Marine began operations with a focus on Brazil. The first FPSO, Sevan Piranema, was installed at 1000 m water depth in Brazil in 2007.

Their toughest competitors are today, SBM - Single Buoy Mooring, Teekay, Bluewater, Modec, Maersk, BW Offshore, Fred Olsen Energy, Seadrill, and Technip.

See figure 18 and 19 for contract status for the FPSOs and the drilling units. See table 2 for key figures from 2005 to 2008 , figure 20 for stock performance and figure 21 for number of employees from 2001 to 2008.

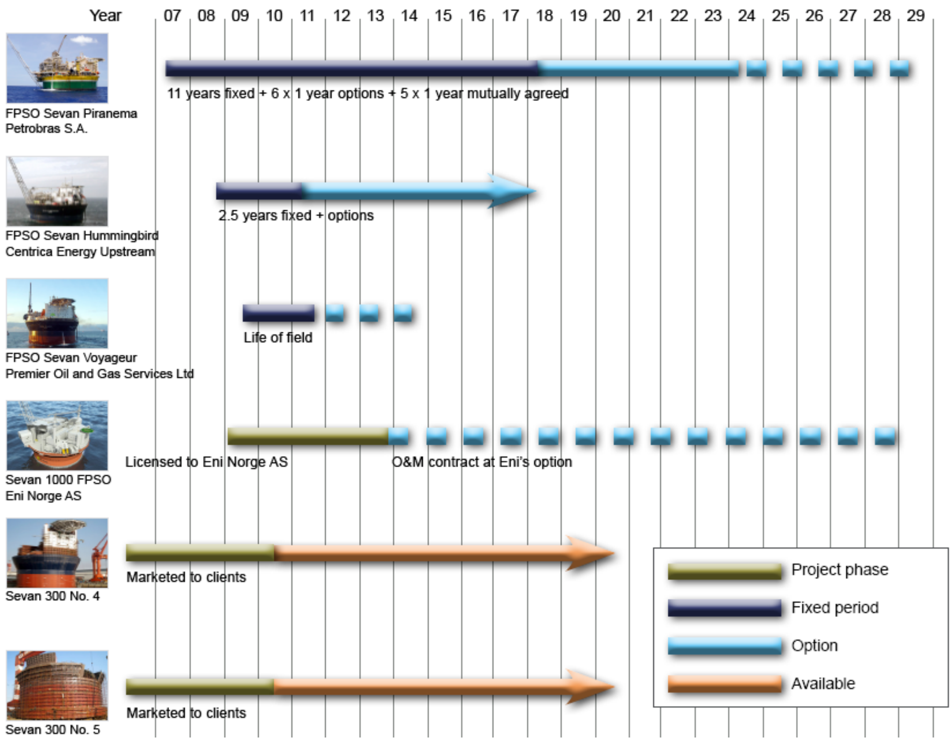


Figure 18: Contract status FPSOs

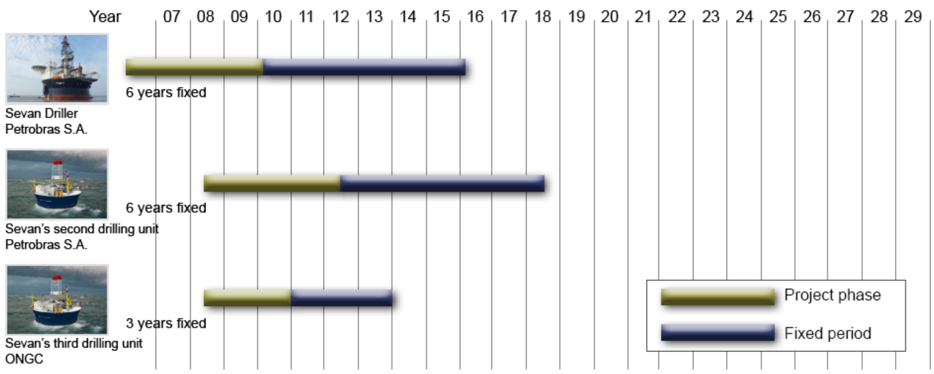


Figure 19: Contract status drilling units

INCOME STATEMENT	2008	2007	2006	2005
Amounts in USD million				
Operating income	120.5	82.2	21.9	22.4
Total operating expense	-219.0	-175.6	-45.9	-29.7
EBITDA	**-98.5**	**-93.4**	**-24.0**	**-7.3**
Depreciation/write-down	-31.6	-13.2	-0.7	-0.7
Operating profit/(loss)	**-130.1**	**-106.6**	**-24.8**	**-8.0**
Financial income	138.6	53.2	10.4	0.2
Financial expense	-122.4	-98.3	-6.6	-0.1
Share of profit/(loss) from associates	0.8	1.0	0.4	0.5
Net financial gain/(loss)	**17.0**	**-44.0**	**4.3**	**0.6**
Profit/(loss) before tax	**-113.1**	**-150.6**	**-20.5**	**-7.5**
Tax income/(expense)	5.2	35.6	5.1	1.2
Annual net profit/(loss)	**-107.9**	**-115.0**	**-15.4**	**-6.2**

Table 2: Key figures 2005 -2008

28.12.2009: Bide price: 10.00

Figure 20: Stock performance 2005-2009

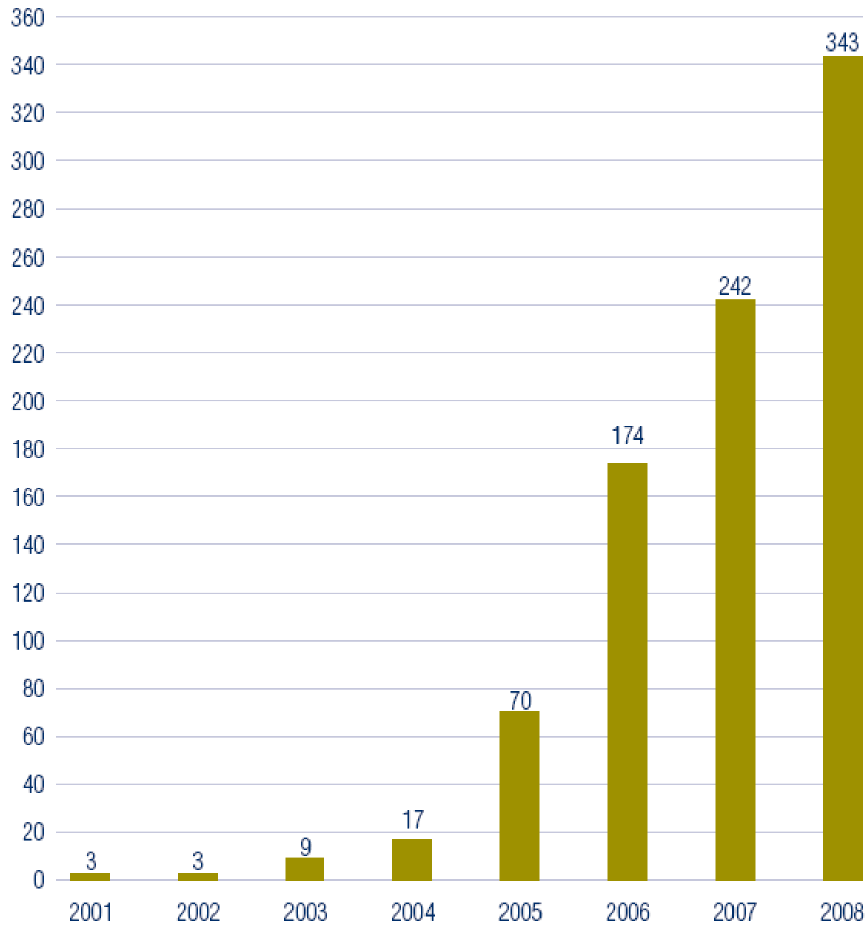


Figure 21: Number of employees 2001 - 2008

The way forward

MARINTEK has today an Ocean Basin Laboratory, which was at the time it was build, planned for the offshore developments that were known and that seemed to come in the "foreseeable" future. This means in practice that it covers the model testing down to depths of 300 - 400 m. The current offshore operations applies water of depth of over 3000 m. Testing of floating structures with risers and mooring lines at greater depths is not possible to perform in today's tank. Approaches with "truncated" risers and mooring are currently used. There will be a clear wish to test in a tank that has a greater depth.

Activities have started in the Arctic areas with ice challenges. There are today a small number of facilities abroad (Germany, Finland and Canada) where it is possible to do tests with ice. Norwegian companies are today among the most active in the development of drilling rigs, production rigs and other vessels and equipment for operations in arctic climate. A national tank for testing with ice will help to increase expertise and provide the Norwegian industry a positive advantage. NTNU and SINTEF are also the first front when it comes to understanding the ice, ice loads and the development of models to describe ice and ice loads. This environment will be enhanced with access to new test facilities.

THE MARITIME KNOWLEDGE-BASED COMPANY (MKF): MARINE CYBERNETICS

From the knowledge cathedral to the stock exchange

Cyber Sea: Hardware-In-the-loop (HIL) Testing

Marine Cybernetics (MC) utilizes Hardware-In-the-Loop (HIL) technology to test and verify control systems using its CyberSea Simulator Technology. HIL testing is commonly used in automotive and aerospace industries as the best practice method for testing of control systems. HIL testing results in a more thorough and relevant verification of the control system compared to other available solutions, allowing efficient simulation of scenarios that is difficult, dangerous or expensive to test in real life. MC uses its HIL CyberSea Simulator technology by connecting a simulation PC in the system's communication network. HIL testing is accomplished by connecting the control system to a vessel specific simulator of the ship or offshore installation. The computer system is then tested by simulating realistic operating and failure conditions. See Figure 22.

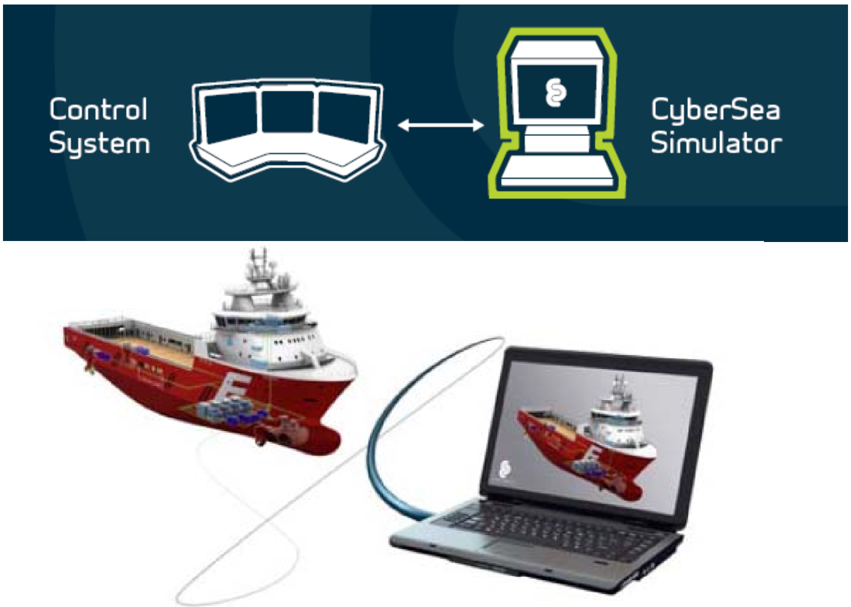


Figure 22: Hardware-In-the-loop (HIL) Testing

Further, software or hardware configuration errors are then exposed trough the simulation. Currently, Marine Cybernetics is the only provider of independent HIL testing in the world within the offshore and maritime industry. Its technology is protected by a series of patents.

The introduction of a new technology-based service like HIL testing of computerized systems on ships and offshore installations are a major innovation with regard to safety and profitable operations at sea. Through this technology, the company has added a new chapter in the maritime and offshore industry. The testing helps to strengthen the regime for the class and certification of computerized systems since the independent HIL testing ensures quality and reliability to the existing regulations. Today, ships and rigs that are operating for Statoil must execute HIL testing. In other countries, the trend is going towards stricter safety requirements at sea. Petrobras are for example on the way of doing the same as Statoil for the intake of offshore vessels in Brazil, but the strict security requirements from a global offshore company like Statoil and other Norwegian Global Maritime Corporations (GMCs), are still unique in Norway. These strict requirements are partly given by the sophisticated regulatory bodies at the national levels, developing and implementing Maritime and Environmental Policies (MEP).

The creation of the company

Marine Cybernetics (MC) had its origin from the Norwegian University of Science and Technology (NTNU) in Trondheim, with 4 professors as entrepreneurs. One of the founders and CEO, Asgeir Sørensen had 10 years of industry experience from ABB, both nationally and internationally in R & D, sales and supply of automation, dynamic positioning, power and propulsion systems. In the late 1980s and the 1990s the maritime and offshore technology went through a technological shift from mechanical to computer technology. The regime of testing and certification of software based systems did not work properly. The main technology changed too fast in relation to testing and verification technology. For a company such as Statoil and various shipping companies this resulted in costly business interruption as well as increased risk of accidents. It was a need for development of new independent testing regime for the improvement of security and profitability for advanced ships and offshore installations. In cooperation with DNV, Statoil, some shipping companies and suppliers, the business plan was trimmed, and Marine Cybernetics was created in 2002.

Global player

MC services is a niche with a global demand. MC's most important customers are oil companies, shipping company owners, yards and equipment suppliers from all over the world:

- Europe: Norway, Denmark, Finland, Sweden, UK, Spain, France, Italy
- America: USA, Canada and Brazil
- Oceania: Australia
- Asia: Singapore, Vietnam, South Korea, China, Japan, India, Malaysia

In Brazil, the company is well positioned for the boom that is expected for the Brazilian market, while in the U.S., the company has been working over time to gain access. The first sale is made, and the number of requests is increasing. Yet, still remains the big breakthrough in the United States. As of today, their toughest competitor is that customers do not see themselves doing the trouble of implementing third-party verification of the software on board ships and offshore installations

Starting point: The global knowledge hub

The basis technology and competence of its employees originate from several years of research and education at NTNU, and especially from the Institute of Marine Technology, Department of Engineering Cybernetics and CeSOS. In the start-up, the founders also got a business lawyer and business developer on the owner side. 100% of the employees have today a PhD, MSc, BSc or higher maritime education. 36 employees of which:

- 11 PhD - Technology
- 20 MSc - Technology
- 1 MSc - Economics
- 1 Maritime - Captain
- 3 BSc - Technology

Where 28 of these are from NTNU, and 5 people in the company have their education from abroad:

- 1 PhD Singapore
- 1 BSc Brazil
- 2 MSc Germany
- 1 BSc Russia / Norway
- 1 PhD Italy (Italy MSc and PhD in Norway)

MC still has close cooperation with Public Research Institutions (PROs) and especially NTNU. 4 of the company's employees are professors or associate professor at NTNU. Through the professors MC also has an extensive network to leading universities in the United States, Brazil, Singapore, Denmark, Germany and Portugal.

Their main activities are today research and development, project management, sales, management and administration. The main activities take place in their headquarter located in Trondheim, Norway. *"There is no doubt that close relation between the R & D environment in Trondheim has put the company in a unique opportunity to be established, trim business plan and test out the technology and implementation. The interaction with the entire value chain is difficult, but necessary for success"*, says CEO Asgeir Sørensen. Further, he continuous, *"It's not just the knowledge from the research institution that is important for being located in Norway, but also that Norway has a world-leading cluster and global knowledge hub within the maritime, oil and gas. The company therefore yields significant valuable knowledge by the close interaction with the industry. "*

Norwegian schools, colleges and universities, ship owners, equipment makers, oil and gas operators, ICT companies, ship and offshore yards and ship designers and ship consultants are the groups of firms that MC have the strongest relations with. The company will find most of their needs of research in Norway.

A possible motive for using foreign research services in the future is to strengthen the local content and presence, networks, expertise and capacity. For MC, Singapore and Brazil seem to be most important in this respect. Share of the company's revenue that was used for R & D in 2009 and 2008 was between 20-25%. MC makes most of their R & D within their own company. This occurs mainly in relation with customers and DNV.

Competent Risk Capital (CRC)

Incubator: The company obtained a grant from the Norwegian Research Council (NFR) and established itself at the Innovation Center Gløshaugen (IG) at NTNU in 2002. After this the company got an incubator grant from Innovation Norway. Innovation Norway (IN) has been crucial for the financing of the company in the early years. Today, the company diligently uses IN for assistance in their internationalization process, especially in Singapore, India and Brazil. The establishment of the IG was very important for the company. From then on it was serious and the company gained access to the necessary Research and Development Infrastructure (RDI) for a reasonable price. In addition, the IG gave the establishment of the company credibility and secured maintenance of their good relation with NTNU.

Venture: Statoil I & K was crucial in this phase. The company received a LUP / IRD (supplier development fund and funding from Innovation Norway) project with IN, Statoil, DNV and selected shipping companies and Kongsberg Group. This contributed to the development of core technology and the first reference installation. After successful demonstration of the pilot installation Statoil became an owner trough an equity issue.

Growth Phase: The company is now in late stage venture-growth phase. In autumn 2008 the company entered into an agreement with the Jebsen Asset Management (Private Equity company located in Oslo, Norway) who become shareholders. This has strengthened MC financially and added strong financial expertise for international market development and growth for the company. See table 3 for a summary of the different stages Marine Cybernetics has gone trough since its start in 2002.

Success Criteria	Arrange holder
Incubator phase: • Technology (Research and Development) • Business Development • Reference Sales (pilot 1)	IG NTNU Innovation Norway Statoil LUP, DNV Skattefunn
Commercialization phase: • Technology (Research and Development) • Business Development • Organization Building • Reference Sales (2 pilots, 3, 4 ....)	Innovation Norway Statoil I & K Skattefunn DNV
Growth phase (the next step for MC): • Technology (Research and Development) • Trimming of products / services • Mass production • Organization Building • International start-ups • Partnership / agents • Acquisition	DNV Innovation Norway Statoil I & K Jebsen Asset Management .... New investors.......

Table 3: Establishment and growth for Marine Cybernetics

Things have moved fast for MC, and the company is currently in a strong growth phase. Below in table 4 are some key figures from 2005 to 2008.

1000 NOK	2008	2007	2006	2005
Employees	33	29	19	7
Total Income	33 027	23 894	10 569	1 952
Costs	39 317	30 421	18 267	6 871
EBIT	-6 290	-6 527	-7 698	-4 919
EBIT %	-19 %	-27 %	-73 %	-252 %
Order Backlog per 31. Dec.	**24 625**	**20 000**	**7 000**	**950**
Order Booking per year	**37 466**	**29 600**	**8 400**	**1 900**

Table 4: Key figures from 2005 to 2008

A small niche company with great ambitions and global success

Below you can see how revenues are sorted out by ship owner location in 2006 versus 2008 and similarly how revenue sorted by yard location is in 2006 compared to 2008. We can see from the figures and maps in Figure 23 and 24 that the company is slowly becoming a global player.

0-1 million NOK

1-10 million NOK

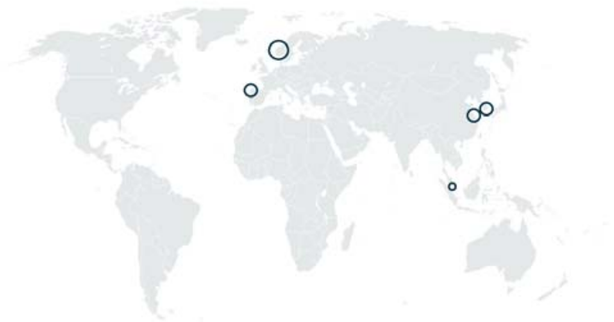
10- million NOK

2006

2008

Figure 23: Revenue sorted by ship owner location in 2006 compared to 2008

2006



2008

Figure 24: Revenue sorted by yard location in 2006 compared to 2008

The way forward for MC

A global expansion plan for 2009 – 2011 is already set. One important feature of their market plan is to be closer to decision makers (oil companies, contractors and ship owners, operation sites and yards). In table 5, the company's plans for change in distribution of market volume in different countries and regions are illustrated. Only time will tell if they will succeed with these plans. But if so, the journey from the knowledge cathedral to the stock exchange will be virtually completed.

Market volume contractors, ship owners, oil companies	2008	2012
Norway	55%	20%
UK	10%	10%
Europe	10%	10%
US	10%	20%
SEA (Singapore, Malaysia, India, Indonesia, Viet-Nam)	10%	20%
Australia	5%	5%
Brazil	-	10%
Other (Russia, Canada, Mexico, UAE,...)	-	5%

Market volume yards	2008	2012
Norway	50%	10%
South Korea	25%	30%
Singapore	15%	10%
China	5%	25%
Brazil	-	5%
Europe	5%	5%
Other (India, Indonesia, Viet Nam, US, Canada, UAE,..)	-	15%

Table 5: Market plan

THE MARITIME KNOWLEDGE-BASED COMPANY (MKF): ULSTEIN GROUP

Turning visions into reality

The X-Bow®: From a pointy nose to a round snout

Traditional ship bows are narrow and raked, and are designed to break the waves and be kept above the surface. Ulstein on the other hand started to think completely new. Instead of the traditional ship bow they gave their new ships a huge snout. Instead of breaking the waves, the X-Bow let the vessel glide through them and allow the water to go as high as up as possible to the weather deck (just below the bridge). A vessel with the X-Box design (see Figure 25) will therefore move much smoother through the waters. The main effect is that the foreship of the vessel will experience a great reduction in buoying. This will serve great benefits especially for supply ships serving in heavy waters like the North Sea. Supply ships have the bridge and the living quarters in the foreship, and not in the stern like most other ships. The foreship is the part of the vessel that moves the most in heavy waves. These movements and the continuous accelerations make it very hard for the crew to get proper restitution. As the X-Bow considerably reduces these movements, the comfort of the crew is dramatically increased. They will be much more rested and sharp when they are working. The benefit of the X-Bow exceeds the welfare of the crew. It is also an improvement of efficiency. Since the vessel is able to go through the waves instead of over them, it can hold a much higher speed in rough sea than ships with conventional design. Because the ship does not have to push up the waves and fall down on the other side, it can also hold a more steady velocity. This way the X-Bow both improves the bunker cost for the ship owner and the environmental impact of the ship. The X-Bow design also enables the ship structure to sustain rougher treatment. The only question being asked about the X-Bow is why did not anyone come up with this design earlier?

Figure 25: Ulstein X-Bow (Ullstein AX104)

From an old boathouse to a global ship innovator

The transition from sail and rowing boats in the Norwegian fishing fleet to motorized vessels in the beginning of the 1900s created a surge for mechanical competence. The fish boats needed to get motor installed and maintained. It was during this period Martin Ulstein started the path of one of the world's most complete ship building companies. Driven by his skills, determination and by the help from his friends and family, Ulstein mek. Verksted became a reality by the fall of 1917. It was located at Naustneset just west of Ulsteinvik. This property was bought from Martin's uncle, and gave him a 800 square meter real estate with enough space for a couple of boat slips and a workshop of about 50 square meters. Not a lot, but obviously enough. In 1919 Ulstein landed the first job that was more than a repair job, it was a rebuild job. This was a breakthrough, and the workshop had to be extended, and not for the last time.

Over the years the Ulstein Group came about and grew much larger than the people of Sunnmøre, and Norway for that matter, understood. This was probably because the speed Ulstein Group became internationalized and that they mainly expanded by acquisitions. By the 1990s after acquiring Bird Johnsen, Ulstein Group was one of the three largest propeller manufacturers in the world.

In the 1990s something else happened within the Ulstein Group. It was now time for the third generations of Ulsteins to have their say in the business. They were a large flock of 24 cousins, and it is an understatement to say that they didn’t have the same vision on how the company should develop. To insure that the focus were on the business, the owners decided to take the Ulstein Group public and list it on the stock exchange. On October 1997 it got listed with a price of NOK 1.05 billion. It did not last long before someone wanted to make an offer to take over Ulstein. In 1998 the British industrial company Vickers plc acquired almost the entire group, with the exception of the shipbuilding division, for NOK 3.9 billion, twice the price in the stock market. The CEO of Vickers called the acquisition a marriage made in heaven. However, this company structure was not destined to last for a long term. Only a few months after Vickers acquired Ulstein, Rolls-Rocye acquired Vickers. This was the end of the old Ulstein Group, but it was also the beginning of a new Ulstein group.

After the takeover of most of the group, the shipbuilding division was what was left of the Ulstein heritage. It was called Ulstein Mekaniske Verksted Holding ASA and consisted of Ulstein Verft, Ulstein Elektro, Ulstein Flextransport, Castor, several real estate companies and a shipping company. As Ustein Group was acquired, all it stockholders got an offer to buy a stake of the new company. Though, while the original family held 98% of the shares, the new Ulstein Group had 600 shareholders. The years after the forming of the new group was some tough ones, but the company stayed put. In 2002 they opened their new dock, a bold NOK 260 million decision in a pessimistic market, but a necessary one. A few years later the market started to pick up again, and Ulstein group was well prepared for it.

A major difference between Ulstein and its competitors is that Ulstein is a complete shipbuilding company. Ulstein does everything from design, construction and productions of ships, to the development of electronic and control systems, and is even involved in shipping. This provides Ulstein with a broad technical expertise and the ability to integrate systems to meet the needs of the ship-owners in a satisfactory manner. This broad range of experience and involvement in every aspect of the ship creation might also be why it was Ulstein Design and not any other company that came up with the revolutionary design of the X-Bow.

Built by a high skilled labor force

The Ulstein Group currently has over 800 employees working to repair, build and create ships and vessels that can prevail in the roughest corners of the seven seas. This is a highly competent labor force where 95% has an education within their craftsmanship or further higher education. Many of their best employees are graduates from NTNU or in some other sense sprung out of the Trondheim maritime community. The Ulstein Groups acknowledge that the community with NTNU and SINTEF as the spearhead is one of the best in the field of maritime technical education. The group would like to support and participate in projects that can promote the important knowledge and expertise and believe that this in turn can support further development for Ulstein Group's internationally.

The group spends about 1-2% of the company’s turn over on pure research activities and more than four times than that on research and development on products and services. The company does around 97% of the research in-house. However, the Ulstein Group does not only draw on the Trondheim environment for skilled labour. They also use the testing facilities in their design development. MARINTEK was heavily involved in testing the functionality of the X-Bow. However, they do need to use international expertise and laboratories as well. This is mainly due to low capacity when it comes to some services in Trondheim, but also price vs. value and delivery time compared to international competitors. As a result Ulstein group would like to see more interdisciplinary research and knowledge at the centres in Trondheim and more cost effective services in the future. See table 6 for some key figures.

1000 NOK	2008	2007	2006	2005
Operating income	3 215 913	1 974 451	1 786 631	1 555 382
Profit before tax	431 085	240 822	201 287	67 453

Table 6: Key figures from 2005-2008

Keeping a steady pace in global waves

The Ulstein Group has for a long time been an international company. Today, the company has offices in nine countries around the world, and they are selling their ships and ship designs to companies practically anywhere on the globe. Their strong market position is widely known, but most recognized in Western Europe and among the North Sea operation. But they are operating in a competitive landscape with strong rivals as STX Offshore and Rolls-Royce Marine, and a market that is in continuous change with fluctuations and ever-evolving new demands. Thus the company has shown that it is adaptable to new market situations in the past, and believes that it will prevail in the future. Its research and development is easily applicable to other markets and even new industries.

THE MARITIME KNOWLEDGE-BASED COMPANY (MKF): SWAY

High tech – Deep sea

Deep-sea floating wind power

6 years of intensive advanced dynamic simulations and engineering has enabled Sway to discover nature's own secrets of how to make floating towers feasible both technically and economically.

The system is based on a floating tower which extends far below the water surface. The tower consists of a floating pole with ballast in the lower end, similar to a floating bottle. The tower, which is filled with ballast, has its center of gravity located far below the center of buoyancy of the tower. This gives the tower sufficient stability to resist the large loads produced by the wind turbine mounted on top of it.

The floating tower is anchored to the seabed with a single pipe and a suction anchor. When the wind hits the rotor, the tower is tilting some 5-8 degrees. By tilting the rotor the opposite way, which is made possible by placing the rotor downwind of the tower, the rotor is kept perfectly aligned with the wind. When the wind changes direction, the entire tower turns around a subsea swivel. This, in turn, makes it possible to reinforce the tower with a tension rod system similar to wire stays on a sailboat mast. Due to the resulting reduction of stresses in the tower, the tower is capable of carrying a much larger turbine, which greatly enhances the total economy. See figure 26.

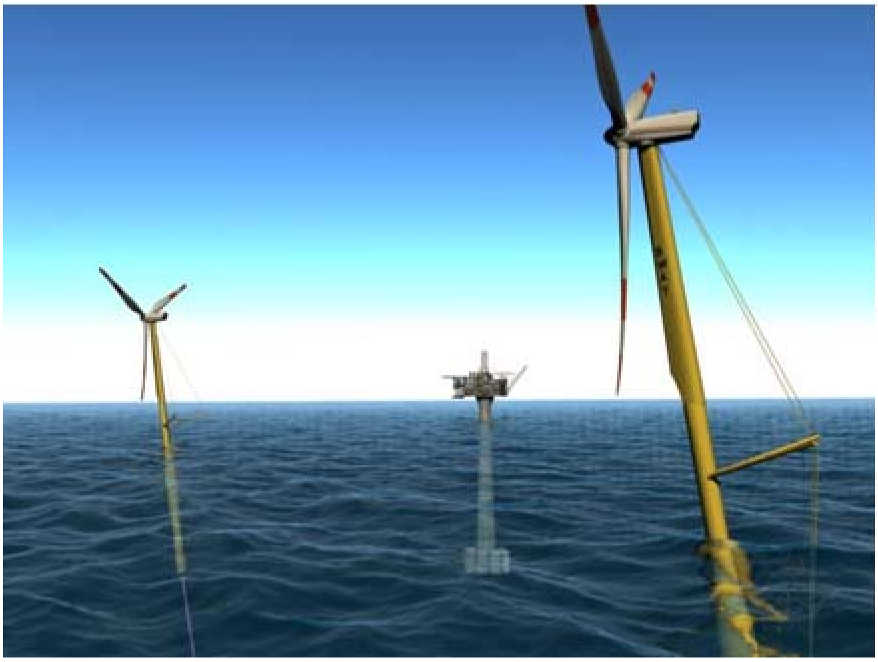


Figure 26: Deep-sea floating wind power

The Sway system will be operating in some of the worlds roughest offshore locations, and it has been designed to satisfy the strictest regulations for offshore wind turbines and installations. E.g., it has been designed to withstand impact with a once in a 100-year wave of over 30 m and have a fatigue lifespan of over 20 years. Sway has, together with its engineering partners, developed advanced calculation software to simulate the loads and dynamics of the entire floating system.

Sway's history

Sway was founded in 2001 under the name of Inocean Construction A/S. While carrying out dynamic simulations for the oil and gas industry they conceived the idea of deep water offshore wind power. The following year the first patent application for the Sway system was submitted, and in 2003 the first detailed study of a large-scale Sway wind park was carried out at a North Sea location.

In 2004 they conducted a study investigating the possibility to utilize the Sway technology to electrify an oil platform in the Norwegian Sea; the study was done on behalf of Shell Technology Norway. In the same year, Inocean Construction A/S changed its name and became Sway A/S.

In 2005 Sway received a 10MNOK budget for a 3 year development project for the SWAY concept. The project was initiated primo 2005 and supported by the Norwegian Research Council, Statkraft, Shell Technology Norway and Lyse. The following year was spent to further develop the original idea, with extensive dynamic simulations of the concept.

In 2007 a milestone was reached as Sway prepared a full scale prototype project, and equity of 150 million NOK was raised. See table 7 for some key figures from 2005 to 2008.

1000 NOK	2008	2007	2006	2005
Operating income	65	75	2 228	1 287
Annual result	-830	-6184	868	398

Table 7: Key figures from 2005-2008

Sway kept expanding the organization through 2008 as it applied for a concession from NVE (Norwegian Water Resources and Energy Directorate). A year later in 2009, Sway was granted a license from NVE for building a floating wind turbine plant for offshore wind power. The test site is located approximately 7 km outside Karmøy, on the west coast of Norway.

In August of 2009 Sway announced a partnership with German based AREVA-Multibrid for delivery of an offshore test field on the coast of Germany. AREVA-Multibrid will supply the turbine and Sway the tower solution.

In September of 2009 Sway has applied for a test concession from NVE for constructing a test turbine in Naturgassparken at Øygarden outside Bergen. The construction of the prototype will be conditional on financial support from Enova. The wind turbine will have a capacity of 10 MW and a rotor diameter of 145 meters. Along with testing their own turbine, Sway will use a turbine provided by their partner AREVA-Multibrid.

Knowledge applied

The connection to the research environment and innovations at NTNU has been vital to the creation and development of Sway. Another important influence for the development in Sway has been the competences available at the Danish Technical University (DTU) in Copenhagen, Denmark.

Sway is developing, producing and delivering deep-sea floating wind power, aimed at the global market. The product Sway has developed consists of a foundation/tower with an anchor system and a 10MW wind turbine. The market for such deep sea solutions is in its initial stage of emerging, and Sway has a very promising potential to capture a large market share as sea based wind parks move further offshore.

For Sway, there has been a discernment that research from the Trondheim research community on system solutions and new concepts are perceived to be in direct competition with the industry. They therefore wish that the research environments would focus more on basic research and parts solutions.

Sway has a very competent workforce, in which 95% of the companies employees are trained professionals or hold a university degree. Out of these 95%, 15% of the employees have their education from NTNU. Sway also employs a fair amount of skilled labor that have been educated abroad, an estimated 25% of the employees hold degrees from foreign institutions.

As Sway is quite early in the process of developing and market their system, the scope of their international operation is currently limited to Spain and USA where they sell pilot installations of their system (German partnership has been announced). The fiercest rivals as identified by Sway are Blue H and Hywind.

The R&D effort of Sway is substantial, roughly 90% of their annual turnover is put to use in R&D activities, with about 50% being done internally. This must however be seen in contrast of the Sway position in the firm’s life cycle.

Sway is confident that they are well positioned to respond to future opportunities and potential changes in their market. And the firm strongly believes that there are possibilities for their technology to find alternative uses.

THE MARITIME KNOWLEDGE-BASED COMPANY (MKF): FUGRO OCEANOR

Watching Poseidon

SeaWatch: From observation to systematization

The main activity of Fugro OCEANOR is the oceanographic monitoring system, SEAWATCH. SEAWATCH systems span from single wave monitoring buoys to large regional networks monitoring a large number of oceanographic, meteorological, chemical and biological parameters. The system consists of three main parts:

- Real time observations from oceanographic buoys (see figure 27)
- Data from other sources (e.g. coastal stations, research ships, satellites) and numerical models. Data management and forecasting services
- Data and information distribution

Figure 27: Some of Fugro OCEANORs oceanic buoys and sensors

The purpose of the SEAWATCH system is to give its clients a oceanographic information system that is based on real time data for use in oceanographic forecasts, monitoring of offshore conditions, algae bloom information, pollution and oil spill monitoring. Fugro OCEANOR also provides similar systems for river, soil and ground water monitoring, but the activity in Norway in mainly concerned with SEAWATCH.

In the beginning, when OCEANOR broke away from a Norwegian research institutions, it enjoyed a market with little competition. Today, on the other hand, they are operating in a highly competitive environment with steady flow of new competitors.

Fugro OCEANOR estimates that they hold a market leader position in the SEAWATCH segment with a 60% market share on the commercialized part of the market. They have identified AXYS Technologies Inc., a Canadian company, as their main rival, but emphasize that the market is still developing, and that there are many other companies that pose as potential rivals. Either way, Fugro OCEANOR's biggest rival is the non-commercial market mainly driven by US governmental institutions and to some extent also the Japanese. They view this as one of the drivers that has led to the slow maturing rate of the market.

Starting point: The global knowledge hub

Fugro OCEANOR is a pure result of the R&D environment in Trondheim. They started up using technology and competent people from SINTEF. The ocean wave competence that through its entire existence has been important to OCEANOR is mainly drawn from the marine community in Trondheim. In particular from SINTEF, the Ship and Ocean Laboratory, NTNU, the Institute of Marine Technology, Center of Ships and Ocean Structures (CeSOS), the Institute of Mathematical Sciences and Kongsvoll Biological Station. OCEANOR also has strong relations with research communities outside of Trondheim like Chr. Michelsen Institute (CMI), Bergen, Geophysical Institute at the University of Bergen, Institute of Marine Research and the Norwegian Meteorological Institute.

Close to a 100% of their employees have today higher education and about 40% have graduated from NTNU.

OCEANOR was created when a department of SINTEF broke free and established itself as an independent company in the field of oceanographic monitoring. As the activity on the Norwegian continental shelf increased, they stared out by offering analysis for the oil and gas companies. OCEANOR became one of the leading providers of scientific data (meteorology, ocean wave movements, and oceanic currents) for offshore oil rig concept developers. Later also design criteria for offshore oil rigs.

In the late 1980s OCEANOR began to make a shift of focus from oceanographic surveying to focus more on information. They soon started to deliver products and systems and became a more commercial actor in the business. It was in this period that they merged with Continental Shelf Institute, Norway (IKU), which also started as a division of SINTEF. With the merger with IKU, OCEANOR gained an important numerical competence. This merger laid the foundation for OCEANOR's participation in a large EU project, where eleven countries contributed with on different research areas. From this project sprung one of the key activities of Fugro OCEANOR, SEAWATCH. SEAWATCH started up in 1990 as a five year research and development project with a budget of NOK 120 million. Although there was many different international research communities' participating on this project, the competence from the Trondheim research community was critical for OCEANOR. Without the Trondheim community and especially MARINTEK, it would have been much harder for OCEANOR to gain access to the international communities and competences.

Although OCEANOR had shifted its focus away from monitoring it was still a big part of their operations in the late 1990s. At this point, OCEANOR was one of the three main players in oceanographic surveying in the international market. The Dutch company Fugro was also player in this market, and bought and merged all the three biggest players. This merger led to more professionalization of the market.

A global leader

Fugro OCEANOR is a global player and possesses the leadership role in the SEAWATCH market. They have had SEAWATH deliveries to approximately 25 countries around the world.

- Europe: Norway, Iceland, Sweden, Finland, England, Ireland, Spain, Portugal, Italy, Greece and Monaco.
- Oceania: Australia.
- Asia: Oman, Qatar, Kuwait, Bahrain, Iran, Syria, India, Thailand, Malaysia, Indonesia, China and Vietnam.
- Africa: South Africa.

Most of these deliveries have been instrument buoys, but in Greece they delivered a complete version of the SEAWATCH system to the national POSEIDON system. The Greek POSEIDON system is one of the most ambitious maritime data collection and forecast systems in the world. See table 8 for some key figures from 2005-2008.

1000 NOK	2008	2007	2006	2005
Operating income	110 116	109 345	126 001	89 440
Profit before tax	2 417	5 123	3 703	-12 668

Table 8: Key figures from 2005-2008

Competent Risk Capital (CRC)

SINTEF has been crucial for the existence of Fugro OCEANOR. When OCEANOR broke out as an independent company, SINTEF continued to hold a stake of the company together with its employees.

Venture: OCEANOR got venture capital at a pretty early stage. The venture capital came from Scandinavian based venture capitalists based in Oslo. Venture capital was important for OCEANOR as it pushed the company to carry out their ambitions.

Growth Phase: After an intense period of venture ownership, the company was sold to a Stavanger based private owner which continued the development of the company. After this OCEANOR was acquired by the Dutch competitor, Fugro, that have evolved the companies to where it is today.

The road ahead

Fugro OCEANOR observes that there is a quite clear generation shift in the industry. Men in their 50s and 60s are on their way out of the industry, and have to be replaced by new, younger people. They see this generation change as potentially difficult because the education in the field has changed radically. Fugro OCEANOR underlines the importance of strong clusters and networks in such a changing environment. A research center like CeSOS helps the company to adapt and provides early insights into new market trends, demands and developments.

Fugro OCEANOR is pointing out that having a complete maritime cluster and a strong maritime knowledge hub in Norway, is critically important for them to justify their continued localizations in the Trondheim area. As Fugro is a global corporation, it stresses the importance of locating their operations in the most value-adding localizations. Today, that is still in Trondheim.

THE MARITIME KNOWLEDGE-BASED COMPANY (MKF): KONGSBERG MARITIME

The landlocked maritime company

Anchored without an anchor

Dynamic positioning (DP) is generally a way to keep ships and semi submersible rigs in the same position over the seabed without the use of anchors, but by using the vessel's own propulsion. DP requires a separate computer that collects data about the wave’s effect on the hull, the wind, which direction the ship is pointing in, and the current position. The computer sends the command signals to the vessel's propeller and rudder. To ensure a subtle operation, the system needs to pre-compensate for changes in the environment around the vessel. It requires very advanced cybernetics to predict the changes before they actually happen. To regulate the hull and propellers is a demanding job, and if this phasing is made badly, the vessel will not be able to hold the position. See figure 28 for an illustration of a Dynamic Positioning system.

Figure 28: Dynamic Positioning system

To get the exact position of the vessel one or more navigation signals are combined. These may be radio navigation systems, differential GPS, hydro-acoustic signals on the seabed, or a steel wire attached to the seabed. The system for dynamic positioning combines information about the exact position with information about the compass direction, wind and how the vessel moves in waves. The system calculates the amount of engine power to be installed on different propellers and thrusters. To calculate this, the system has mathematical models of how propellers and thrusters affects the vessel, how the wind will take hold of the vessel, etc. The better the models are designed, the better and more economical the system will be. If the propeller counteracted effect a gust of wind before the wind has given the vessel sufficient acceleration away from the position, the vessel would require much less energy to hold its position. Management of an industrial robot is often attributed to the common expression "motion control" because there is a common theoretical foundation for the management of complex motion processes, whether these are robots or vehicles. Therefore, it is a close professional interaction between robotics and the field of navigation and vessel control.

Lately, dynamic positioning has been made applicable for precise movements. It is in particular the offshore industry that requires vessels with DP. Diving boats, shuttle tankers, supply ships, cable laying ships, pipe-laying vessels, stone dumpers, crane vessels, drilling rigs and drilling ships etc are all examples of areas of use for DP. Also the cruise industry sees the value of DP, when instead of throwing an anchor on a coral reef the cruise ship can lie still with the help of propellers and DP.

All about the control

The Kongsberg Group is an internationally oriented knowledge-based corporation. The majority of the group's activities are aimed at international markets, with solid and increasing geographic spread of revenues. The group has two business areas; Kongsberg Maritime and Kongsberg Defense & Aerospace. Though, in different markets, both divisions are working within the same technological areas. They both have their main expertise in signal processing, control theory (cybernetics), software development and system integration.

Although a maritime environment is not what strikes one when visiting the company’s offices far up in the Norwegian mainland, the company has a large market share in management systems for offshore vessels worldwide. Kongsberg Maritime delivers products and systems for positioning, navigation and automation to merchant vessels and offshore installations, as well as products and systems for seabed surveying and monitoring. They also deliver these services to fishing vessels and fisheries research. Kongsberg Maritime is among the market leaders within these business areas. Countries with large offshore operations and shipbuilding industries are naturally important markets. Kongsberg Maritime has more than 3,000 employees in 25 countries around the world. About 75 percent of the sales are generated outside of Norway. See table 9 for some key figures from 2005 to 2008.

1000 NOK	2008	2007	2006	2005
Operating income	5 072 576	3 922 053	2 756 882	2 320 992
Profit before tax	305 954	410 004	149 195	142 446

Table 9: Key figures from 2005-2008

A spin-off from the Trondheim community

The technology behind dynamic positioning and Simrad Albatross, what make up Kongsberg Maritime today, are spin-offs from the Department of Engineering Cybernetics at NTNU. In Norway, there is a long tradition of development and adaptation of new technologies for the management of ships and other marine craft. Department of Engineering Cybernetics at NTH, now NTNU, was early on with the development already in the 1950s. In the 1960s and 1970s a rapid and strong expansion in computer-based automation of commercial vessels began. Norwegian companies have taken a dominant position in this area worldwide. 1970s and 1980s were characterized by a hectic and demanding development for a new application of cybernetic systems, namely the dynamic positioning. The department played a crucial role in the fundamental development of the new technological solutions, which in a short time allowed Norwegian systems development companies, to become supreme in the world market. In 1995 the department got a special professorship in Navigation and vessel management.

Opportunity and courage

It was a golden opportunity in the mid-1970s that formed the backdrop for the development of Dynamic Positioning. The oil industry was initiated and a courageous Norwegian shipping company took a chance on the new Norwegian technology. Today, Kongsberg Maritime is a leading player in the global offshore market, but the company cannot rest on past successes.

The market evolves and continues to demand new ideas, thus research and innovation play a key role in Kongsberg Maritime.

The present trend in this market is that the customers want a complete supplier for all control systems on board. Because of this, the company delivers systems for full automation of the ship. It includes control of engines, cargo, ballast, security systems and so on, in addition to dynamic positioning. Another trend is that more and more of the work that the vessels are supposed to perform, requires it to move along a fixed course, not just stand still over a fixed point. These might be operations like cable laying, dredging, or laying pipelines. In addition, the development of the GPS system made it possible with cheaper positioning. It allows for even more customer groups to take advantage of dynamic positioning.

SUMMARY

This case study has focused on how the R & D environment in Trondheim has contributed to innovation and increased the competitiveness of the maritime industry in Norway. The study has tried to show that some of the most important technological innovations in the maritime and offshore industry largely have their roots in R&D conducted at NTNU and MARINTEK in Trondheim. The study also serves as an illustration of the various key players in the global maritime knowledge hub located in Norway (Reve 2009).

The case study started with a description of Public Research Organizations (PROs) that form the core of the global maritime knowledge hub. We took a closer look at the main Public Research Organizations for the maritime industry in Trondheim, NTNU and SINTEF, and the cooperation between the two, and gave examples of research and innovation they had produced, as well as discussing some of the important prerequisites for successful innovation. We also included a brief case study of the Norske Veritas (DNV), focusing on the close links between DNV and the R & D environment in Trondheim. A separate case study of Statoil showed that also a global corporation can serve as public research organization in the maritime and offshore industry. The Statoil case study included the development of the world's first full scale floating wind turbine, Hywind.

The next chapters in the report included brief case studies of different Maritime Knowledge Firms (MKFs) in the global maritime knowledge hub. Innovation that had been made in collaboration with Public Research Organisations (PROs), drawing heavily on the advanced R & D infrastructure (RDI) in Trondheim was the main focus. The following MKFs were presented: Sevan Marine, Marine Cybernetics, Ulstein Group, Sway, Fugro Oceanor and Kongsberg Maritime.

The Sevan Marine case study illustrated the importance of having advanced infrastructure for R & D (RDI) to facilitate innovation. The Marine Cybernetics case showed the development of knowledge-intensive services, named independent HIL testing. The testing helps to strengthen the certification of computer-based systems at sea. The company was started by four professors, and in addition the Marine Cybernetics case illustrates the importance of having access to Competent Risk Capital (CRC) in order to

realize the business plan for a maritime knowledge company. The Sway case study described a different solution for floating wind power that has not come as far as its competitor, Hywind, but it is a good illustration of how knowledge within oil and gas can be used in other areas. The newly awarded contract for offshore wind development to Statkraft and Statoil in the UK, illustrates the new business opportunities in renewable energy based on maritime know how. The Ulstein case showed the transition from a traditional shipyard to a global innovator in maritime technology. Finally, the Fugro Oceanor and Kongsberg Maritime case study illustrated how a spin-off from Public Research Organizations in Trondheim can create products and companies that are competitive on the global arena.

SAMMENDRAG

Denne case studien fokuserer på hvordan FoU-miljøet i Trondheim har bidratt til innovasjon og dermed økt konkurransekraften for den maritime næringen i Norge. Studien prøver å vise at noen av de viktigste teknologiske nyvinningene innen maritim og offshore industri i stor grad har sine røtter i FoU utført ved NTNU og MARINTEK/SINTEF i Trondheim. Studien er i tillegg en eksemplifisering av ulike sentrale aktører i det globale maritime kunnskapsnavet. (Reve 2009)

Case studinen starter med en beskrivelse av forskningsinstitusjonene (PROs) som er selve kjernen i det globale maritime kunnskapsnavet. Vi ser på de viktigste forskningsorganisasjonene for den maritime industrien i Trondheim, NTNU og MARINTEK/SINTEF og hvordan samarbeid dem imellom har vært en viktig premiss for å lykkes med industriell innovasjon. Eksempler på slikt forskning- og innovasjonssamarbeid omtales. Dagens Marinteknisk Senter har spilt en svært sentral rolle i eksemplene som trekkes frem.

En egen casestudie av Det Norske Veritas (DNV) viser de tette båndene mellom DNV og FoU-miljøet i Trondheim. Videre viser en casestudie at større organisasjoner som Statoil også har en viktig rolle som forskningsinstitusjon innen maritim og offshore industri. Statoil caset viser utviklingen av verdens første fullskala flytende vindmølle, Hywind.

Neste del av studien omhandler kortfattede casestudier av ulike selskaper som representerer maritime kunnskapsbedrifter i det globale maritime kunnskapsnavet i Norge. Innovasjon som har blitt til gjennom samarbeid med forskningsinstitusjoner og ved bruk av avansert FoU-infrastruktur, er i fokus. Følgende casestudier av maritime kunnskaps bedrifter (MKF)s er gjennomført: Sevan Marine, Marine Cybernetics, Ulsteinkonsernet, Sway, Fugro Oceanor og Kongsberg Maritime.

Sevan Marine caset illustrerer viktigheten av å ha avansert infrastruktur for FoU (RDI) for å legge til rette for innovasjon. Marine Cybernetics caset illustrerer en meget kunnskapsintensiv tjeneste som uavhengig HIL (Hardware in the loop) testing. Testingen bidrar til å styrke sertifiseringen av databaserte systemer til sjøs. Selskapet ble startet av 4 professorer og

illustrerer i tillegg betydningen av å ha kompetent risikokapital for å kunne realisere forretningsplanen. Sway caset beskriver en annen løsning for flytende vindkraft som ikke har kommet så langt i forhold til en av sine konkurrenter Hywind, men er en god illustrasjon på hvordan kunnskap innen olje og gass kan brukes innenfor nye områder. Ulstein caset viser overgangen, fra et gammelt båthus til en global skips innovatør. Til slutt, Fugro Oceanor og Kongsberg Maritime caset illustrerer hvordan en ren fisjon fra forskningsinstitusjonene i Trondheim over tid kan skape et selskap som er konkurransedyktig på den internasjonale arena.

DATA AND METHODOLOGY

The data for this report has been generated through interviews with representatives of the different companies and institutions that are being described in the case study, from the websites of these organizations, through archival data and existing case studies.

Below is a list of the data sources for each case study included.

NTNU, SINTEF and MARINTEK

The description of NTNU and MARINTEK has been based on archival data and previous case studies. No evaluation of the R&D environment in Trondheim has been performed.

Further information about NTNU and MARINTEK was retrieved through interviews (8 October 2009) with Eivind Dale, Head of Science at MARINTEK and Egil Rensvik, Head of Strategy at MARINTEK and General Manager of MARUT).

In addition, information was obtained from the following websites:

<u>www.ntnu.no</u>:

NTNU 2009. *Research Facilities*
< [Online]. http://www.cesos.ntnu.no/research/research-facilities
>. [Accessed December 15th, 2009].

CeCos 2009. *A world leadin centre*
< http://www.cesos.ntnu.no/>. [Accessed December 15th, 2009].

<u>www.sintef.no</u>:

SINTEF 2009. *Ship and Ocean Laboratory*
[Online]. < http://www.sintef.no/Home/Marine/MARINTEK/Ship-and-Ocean-Laboratory/
>. [Accessed December 15th, 2009].

SINTEF 2009. *About MARINTEK*
[Online]. < http://www.sintef.no/Home/Marine/MARINTEK/About-MARINTEK/>. [Accessed December 15th, 2009].

Det Norske Veritas (DNV):

Questionnaire, answered by Kirsten Martin Ulvester, Manager department systems and components, DNV.

Website: www.dnv.no:

DNV 2009. *tjenesteområder*
[Online]. Available from URL:
< http://www.dnv.no/din_industri/maritime/tjenesteomrader/
>. [Accessed December 15th, 2009].

DNV 2009. *Maritime*
[Online]. Available from URL:
< http://www.dnv.com/industry/maritime/
>. [Accessed December 15th, 2009].

Sway:

Questionnaire answered by Eystein Borgen, Former CEO and Co-founder, still connected to the project.

Website: www. sway.no:

Sway 2009. *Principles of the Sway system*
[Online]. Available from URL:
< http://sway.no/index.php?id=16
>. [Accessed November 15th, 2009].

Statoil (Hywind):

- Telephone interview (24 November 2009) with Stein Olav Drange, Program Manager, R & D New Development Solutions.

Websiste: www.statoil.com:

Statoil. 2009. *Hywind-putting wind power to test:*
[Online]. Available from URL:
<http://www.statoil.com/en/TechnologyInnovation/NewEnergy/RenewablePowerProduction/Offshore/Hywind/Pages/HywindPuttingWindPowerToTheTest.aspx
>. [Accessed November 15th, 2009].

Sevan Marine:

Interview (15 October 2009) with Kåre Syvertsen, Board member and Group Manager Technology, Sevan Marine and Jan Hammer (Lorentzen & Stemco). Questionnaire answered by Kåre Syvertsen.

Website: www.sevanmarine.com:

Sevan Marine2009. *Annual report 2008:*
[Online]. Available from URL:
<http://www.sevanmarine.com/images/stories/Reports/Annual/2008_annual_report.pdf>. [Accessed October December 26th, 2009].

Sevan Marine2009. *Contract status FPSOS:*
[Online]. Available from URL:
<http://www.sevanmarine.com/index.php?option=com_content&task=view&id=258&Itemid=268
>. [Accessed October December 26th, 2009].

Sevan Marine 2009. *Business:*
[Online]. Available from URL:
<http://www.sevanmarine.com/index.php?option=com_content&task=view&id=24&Itemid=131>. [Accessed October December 26th, 2009].

Marine Cybernetics:

Interview (9 October 2009) with Asgeir Sørensen at MARINTEK and questionarie answered by Asgeir Sørensen , CEO and Founder of Marine Cybernetics.

Marine Cybernetics. 2009. *HIL testing:*
[Online]. Available from URL:
< http://www.marinecybernetics.com/products.htm
>. [Accessed October 20th, 2009].

Ulstein Group:

Questionnaire answered by Øyvind G. Kamsvåg, Ulstein Design, one of the innovators of X-Bow, and Trond Berg, Training Manager, Ulstein Group.

Website: www.ulsteingroup.no:

ulsteingroup. 2009. *Ulstein Group:*
[Online]. Available from URL:
<http://www.ulsteingroup.com/Kunder/ulstein/cms66.nsf/$all/DF4E1FA5AD94658BC125715C0066B68A?open&ql=AboutLayout&qm=wcm_2,4,1,0
>. [Accessed October 20th, 2009].

Fugro OCEANOR:

Interview (10 November 2009) with Frode Berg ,CEO Fugro OCEANOR

Website: http://oceanor.no/:

OCEANOR. 2009. *Seawatch system overview:*
[Online]. Available from URL:
< http://oceanor.no/datasheets/seawatch_system.pdf
>. [Accessed October 20th, 2009].

Kongsberg Maritime:

Previous case study by Erik Jakobsen (2007)

Website: http://www.kongsberg.com

Kongsberg Maritime. 2009. *Kongsberg maritime in brief:*
[Online]. Available from URL:
< http://www.marinecybernetics.com/products.htm
>. [Accessed November 16th, 2009].