flow

25 years of multiphase subsea transport of oil and gas

– As well as improving the utilisation of resources on the continental shelf, multi-phase research led to the development of subsea technology – a field in which Norwegian industry leads the world, with an annual turnover of 12.5 million euro.

Kjell Bendiksen, *President of the Institute for Energy Technology, and one of the fathers of OLGA, the software that was the key to multiphase subsea transport of oil and gas.*

– Its total benefits have never been calculated, but if I were to guess, I would estimate that the development of multiphase transport alone has created enough value to have paid for all the Norwegian research carried out during the past 20 years.

Johannes Moe, *President of SINTEF when the Multiphase Flow Laboratory was built and came into operation.*

Unni Steinsmo
President
SINTEF

Kjell Bendiksen
President
Institute for Energy Technology

A valuable giant leap into the ocean

A quarter of a century ago, two Norwegian research institutes started to collaborate closely with Norwegian industry. From their efforts emerged a new technology that made it possible to transport oil and gas in a single pipeline over long distances on the seabed. In the language of the petroleum industry, this was "multiphase transport".

Although the multiphase installations on the continental shelf are not visible to the general public, they have produced considerable economic benefits and have made a significant contribution to the development of Norway's prosperity.

The development of multiphase technology demonstrates the importance of investing in research and development. Advances in this area have made it possible to produce oil and gas more efficiently and to develop fields that would otherwise have been impossible to operate.

The birth and adoption of multiphase technology demonstrate what a small country can achieve by setting up national technology teams. As early as the beginning of the 80s, the Institute for Energy Technology (IFE) had developed a preliminary version of its OLGA software package, which could simulate two-phase flow in pipelines. SINTEF contributed the results of its studies of multiphase flow, which were performed in the largest laboratory of its kind in the world. Combined with the expertise of the petroleum industry, this was of decisive importance for the success of the technology on the Norwegian shelf and elsewhere in the world.

The commercialisation of multiphase technology also triggered the development of a world-class Norwegian supply industry in this field.

There are few if any examples in Norway that illustrate better that it pays to do research.

A PETROLEUM NATION IS BORN: Prime Minister Trygve Bratteli surveys the Ekofisk field during the official inauguration of Norway's first offshore platform in summer 1971. Photo: Scanpix.

– I hereby declare ...

Date: June 9, 1971. A new era in the history of Norway. The country's first offshore platform is inaugurated on Ekofisk, and Norway becomes a petroleum nation.

At that time, and for several years to come, a separate platform needed to be installed on every single field wherever petroleum was being produced at sea. Norwegian multiphase research is one important reason that this is no longer the case.

New era at sea

The Multiphase Flow Laboratory in Trondheim was inaugurated on January 25, 1983 by Vidkunn Hveding, Minister of Petroleum and Energy.

In rural Tiller, on the south side of Trondheim, the guests could glimpse a network of shining pipework: 1000 metres of large-diameter steel pipe that ended in a 58 metre high concrete tower. A test facility that would help to change industrial history, as time would show, for the combination of OLGA software from IFE and SINTEF's multiphase laboratory on the banks of the river Nidelva would be the start of a new era in offshore petroleum production.

Safer and cheaper

In collaboration with Statoil, IFE had developed the first version of OLGA three years ahead of the opening of the laboratory. With data from the large-scale laboratory in Trondheim, OLGA laid the foundations of a new technology that enabled the petroleum industry to carry untreated well flow – oil, water and gas – in one and the same pipeline over long distances on the seabed. Directly from the well to existing platforms on a neighbouring field, or all the way to the shore!

This is what professionals call multiphase transport, and it is an important reason why today's petroleum industry can install an entire production facility on the seabed, leaving operating personnel ashore, where is it safer, cheaper and more environmentally friendly to work than on board platforms that depend on helicopter transport.

A major contribution to society

These new transportation arteries on the seabed have saved the petroleum sector huge outlays. Multiphase technology has also made it possible to develop oil and gas fields that would otherwise have been unprofitable.

All this means that the millions of kroner that were invested in the multiphase laboratory in Trondheim, the biggest of its kind in the world, have been paid back many times over.

The story of the building of the laboratory began when one of the world's leading oil companies contacted the Norwegian authorities one day in 1979 ...

"To Norway – with best wishes, Esso"

"We would like to finance the world's biggest laboratory of its sort, operate it on our own account for one year – and then donate it to the host institution of your choice."

SPOKE UP FOR TRONDHEIM: **Johannes Moe was President of SINTEF from 1976 until 1989. He regards the construction and operation of the Multiphase Laboratory as the most important project taken on by the research foundation during his time at the helm.** Photo: Gry Karin Stimo

This was the content of an offer that Esso laid on the Norwegian government's table in 1979. It arrived in the framework of what were known as the Technology Agreements; for an oil company to win a licence on the Norwegian continental shelf, at least half of the research carried out in connection with the field development must be done in Norway.

Geographical tug-of-war

Rogaland Research and SINTEF were quick to sign up as being interested in the offer. A powerful tug-of-war ended in 1980 with the government resolving to locate the laboratory in Trondheim. Johannes Moe was the head of SINTEF at the time, and a driving force for bringing the laboratory to the city. When he looks back today, 30 years on, he is quite certain that Esso's invitation was decisive for Norway's future as a petroleum nation.

"Golden egg" from IFE and SINTEF

"Of all the individual technologies that SINTEF has contributed to, probably none has been responsible for such a level of wealth creation for society and our customers as multiphase technology. Its total benefits have never been calculated. If I were to make a guess, I would estimate that the development of multiphase transport alone has created enough value to pay for all the Norwegian research carried out during the past 20 years," says Moe.

A national technology team

As he looks back, he sees multiphase technology as good evidence of what the oil companies gained by joining forces with SINTEF/NTNU and IFE as a national team in this field. When it was completed in 1983, the laboratory cost NOK 80 million (10 million euro). It was taken over by SINTEF in 1984. But why are in-depth multiphase studies necessary before this technology can be deployed on the seabed? And why does the laboratory need to be so large?

Computer simulations to deal with dangerous slugs

Without in-depth research into the long-distance transportation of oil and gas in the same pipe, the receivers at the end of multiphase pipelines would risk finding long slugs of liquid in their laps.

If we don't know what we are doing when oil and gas are sent on long trips together across the seabed, long slugs of liquid can come rushing through the pipeline on the final uphill stretch to the platform or onshore facility. In the worst case, they may overflow into the processing plant.

Only studies can help

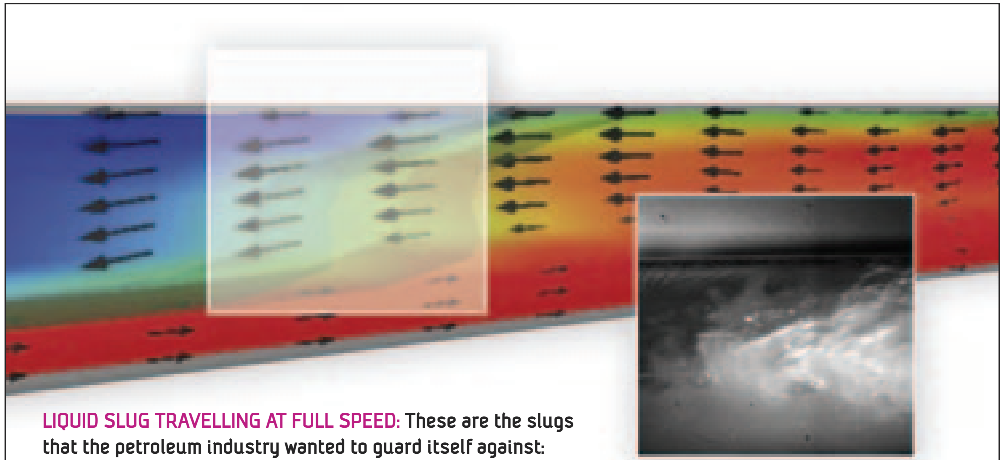
The engineers realised that it would be expensive to build process equipment at the reception end that was sufficiently strong to be capable of handling such slugs. For safety reasons, they needed to be able to estimate how much liquid would remain in the pipeline when production was shut down. They also needed to know how often they would need to deploy "pigs" (equipment sent through the pipeline) to scrape wax and other deposits off the pipe wall.

All this meant that in-depth studies were needed before the dimensions of multiphase pipelines could be calculated. The aim was to develop a computer model that could be used to design and operate multiphase facilities on the seabed. In order to be sure that the model's calculations would be adequate, the development team needed the results of large-scale tests, for when small-scale experiments are carried out in a laboratory it can be questioned whether the results can be transferred to large-diameter pipelines. For this reason, the pipelines in the laboratory in Trondheim were of a diameter that was very close to what the industry would need on the continental shelf.

Trondheim-Kjeller cooperation

At the Institute for Energy Technology (IFE) in Kjeller near Oslo, the scientists possessed both the theoretical expertise and the advanced models that meant that the laboratory results from Trondheim could be used to develop epoch-making computer tools.

On the basis of data from the Multiphase Flow Laboratory, the IFE scientists refined their OLGA model and improved its accuracy. And as it turned out, the market would show a great deal of interest ...



LIQUID SLUG TRAVELLING AT FULL SPEED: These are the slugs that the petroleum industry wanted to guard itself against: computer simulation (above), and immortalised via high-speed photography in the image on the right. Illustration: SINTEF

From Gulf of Mexico copies to North Sea technology

Clients were standing in line at the laboratory in Trondheim after the handover to SINTEF – both to participate in the research programme and gain access to the OLGA computer tool.

Nine oil companies financed a joint NOK 40 million (5 million euro) project that lasted from 1984 to 1986. When construction costs are included, the petroleum industry had invested no less than NOK 140 million (17.5 million euro) in Tiller and Kjeller by the end of 1986. Obviously, the need for multiphase transport was big in the oil industry. But why?

At the start of the petroleum era in Norway, only oil that lay close to a platform could be produced. Oil and gas began to flow to the jack-up "Gulftide" on Ekofisk, the country's first offshore platform, from four wells in short pipelines laid on the seabed. On the platform deck the oil was separated from the water and the gas, which was subsequently flared off.

SMALL TO BEGIN WITH: Norway's first offshore installation, the temporary production platform Gulftide, commenced production in summer 1971 on Ekofisk, at depths of 70–75 metres. The rig was removed as early as 1974. Photo: Scanpix

From modest ocean depths ...

The first fields that were surveyed in the North Sea lay at depths of 50 to 70 metres, and could be exploited using technology developed for shallow areas of the Gulf of Mexico. Fixed platforms were deployed in large numbers; they were relatively small, and were built of steel. In financial terms, building several such platforms on each field could be justified.

BIGGER AND BIGGER: Concrete giants like Statfjord A (which started production in 1977 at a depth of 145 m) could not be "strewn" over an oilfield in the same way as the steel platforms on shallower areas of the continental shelf. Photo: Statoil Hydro

... to deeper waters

In the course of the 70s, however, Norway began to develop fields in ever deeper waters, and huge concrete platforms began to appear. For these developments to be profitable, more of the field needed to be drained of oil and gas by each platform. The first answers to this challenge came in the form of horizontal drilling technology and the development of satellite fields with direct multiphase transport to existing platforms.

Feeding the dream

Multiphase technology makes it possible to exploit small finds where platforms would be too expensive, and carry the oil and gas in the form of untreated well flow to platforms that have spare capacity. Moreover, mixtures of natural gas and condensate (light oil fractions) can be taken ashore directly from the seabed installations on large offshore gas fields.

But OLGA had been born into an environment in which the scientists came from a quite different part of the energy world than the petroleum sector ...

OLGA is born at IFE

... and has its roots in nuclear power research

OLGA's 'FATHER': Kjell Bendiksen, president of IFE since 1995, was among those behind the OLGA model in 1979. He also played a major role in subsequent development efforts. Photo: Scanpix / Gorm Kallestad

The concept of the OLGA computer simulation package was the brainchild of two IFE scientists, Dag Malnes and Kjell Bendiksen, in 1979.

In 1980, the first version of OLGA was already capable of simulating experiments with slugs that had been observed in sloping pipes in the USA. IFE had already been developing software for simulating the flow of water and steam in nuclear reactors for more than 20 years.

Statoil financed the development of OLGA at IFE for four years before the two partners agreed to continue the development process together with SINTEF in a major joint industry project, which was launched on January 1, 1984.

Industrial requirements

The task was divided up in such a way that IFE continued to develop OLGA, while the complementary, and quite essential, experiments were performed in Trondheim. This was the start of a close and fruitful 15-year collaboration between SINTEF and IFE, which also brought in NTNU.

"The fact that the two biggest Norwegian centres of research in this area had joined forces gave them considerable combined power. Together, we defined and prioritised the experiments in Trondheim on the basis of both industrial and technological requirements. The potential for developing OLGA was always the basis of the design of new experiments in the laboratory in Trondheim," says Kjell Bendiksen, who became president of IFE in 1995.

Practical tool

The aim of OLGA was to develop a practical industrial tool. "Industry needed a tool that could calculate important properties such as production rates, pressure and fluid content, through the entire transportation system. OLGA needed to be able to predict whether the flow would be stable, or if there was a risk of dangerous instabilities," explains Bendiksen. IFE has been continuously improving OLGA throughout the 30 years that have passed since the concept originated. In 2008, IFE was awarded Statoil's research prize for its efforts in multiphase research. The man who was Mr. Statoil himself for 15 years praises the results obtained by the Norwegian pioneers in multiphase research ...

Launch help from the father of petroleum nation Norway

Multiphase technology was soon given high priority as an area of special effort by Statoil's management, confirms Arve Johnsen, the first head of the company.

PRAISE FROM STATOIL PIONEER: Arve Johnsen, the first head of the company is in no doubt that home-grown multiphase technology deserves a place on the podium in the history of national and international petroleum production. Photo: Werner Juvik

Norway's first petroleum boss explains that the ocean depths that awaited the young Norwegian oil industry produced a growing realisation in Statoil during the 70s and early 80s: a certainty that finding a means of transporting oil and gas in the same pipeline was essential.

Huge sums set aside

"It would have been neither technically nor economically possible to separate the product at sea. The installations would have been too big and heavy, and the cost too high," says Johnsen.

It was because of this that Statoil got involved in multiphase research, according to the oil industry veteran, who explains that he and his colleagues soon realised that Statoil "would have to invest several hundred million kroner in this field."

The birth of modern Norway

Arve Johnsen is not just anybody in the story of Norwegian oil. As a state secretary and the closest colleague of Finn Lied, Minister of Industry at the time, he was one of the principal architects of the founding of the state oil company Statoil.

As the first head of the company, Johnsen was actually Statoil's sole employee when it was set up. In 1972, he installed himself in a rented office in Stavanger, with the company cash kept in a little cigar box. Fifteen years later, when he retired, Statoil was one of Norway's biggest industrial companies – and one of the world's biggest offshore oil companies.

Important interactions

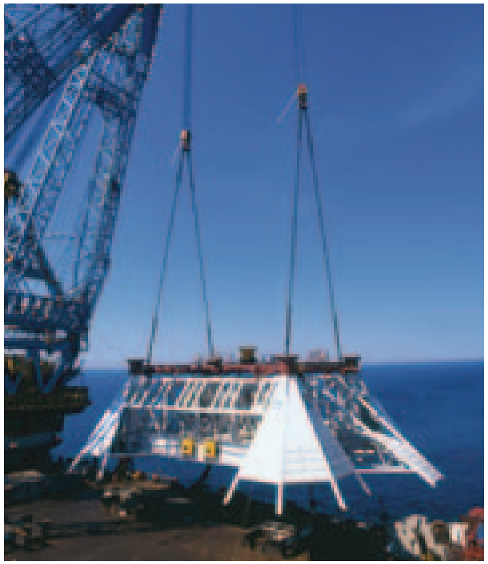
Johnsen points out that a large number of different technologies made the Norwegian oil story possible, and that it is impossible to rank them in order of importance. They are all interconnected, he points out, and mentions as an example the close interactions between technological developments in multiphase transportation and subsea production. He has no hesitation in finding room for these two fields on the podium in national and international petroleum history.

Subsea technology is a method of production "that nowadays characterises not only the Norwegian continental shelf but also the Gulf of Mexico, Angola and the Brazilian shelf," as Johnsen puts it. He regards multiphase and subsea technology as good examples of the fact that we do not need to think on a small scale in Norway, even though we are a small country.

"It is quite possible to think big, and it is always possible to see that technology, when it is appropriately developed, can be exported to all parts of the world where there is a need for it," says the "father of the petroleum nation of Norway".

Going beneath the surface

The end of the 80s: with the OLGA simulation model behind them, Phillips and Statoil inaugurate the world's first long-distance subsea multiphase transportation pipelines.



BREAKTHROUGH FOR MULTIPHASE TECHNOLOGY: The TOGI project increased oil production from the Oseberg field. For the first time in history, gas was pumped from one field to another in order to recover more oil from a reservoir. Photo: StatoilHydro

Phillips took this step on the Ekofisk field, while Statoil for its part, in 1988 started to send oil and condensate (light crude oil) together through a 12 kilometre long pipeline from Tommeliten to the Edda platform. However, the major breakthrough for multiphase transport came with the TOGI project (Troll-Oseberg Gas Injection).

By injecting gas rather than water on Oseberg, oil production on the field would be raised by seven percent, field operator Hydro told the Gemini research magazine before the project started. The rise in itself was actually more than Norway's annual petroleum consumption at the beginning of the 90s.

OLGA was also utilised in the design of the TOGI production and transportation system, which came into operation in 1991. From subsea wells on the Troll field, gas and condensate were sent 48 kilometres in the same pipeline to a remotely controlled subsea installation on Oseberg. Operation was supported by a simulator based on OLGA. For the first time in history, gas was pumped from one field to another in order to recover more oil from a reservoir.

Took the world by storm

As Hydro's TOGI project director Magne Boge said to Gemini in 1989: "In theTOGI project, we have utilised 100 percent of the results that emerged from the multiphase flow laboratory in Trondheim. The OLGA program, which we adapted for use in TOGI, was not the least decisive input for the development of the concept."

Value as cultural history

In 2002 the project came to an end, and the pipeline was closed down. The State Antiquary pointed out that the closure plan ought to include a study of the value of the installations' cultural value. By then, OLGA had already helped to save millions of kroner in the neighbourhood ...

Troll can be tamed

On February 9, 1996, a gigantic gas-field dominated the news in Norway. Here too, multiphase technology and OLGA played important roles.

That was the day on which production started on the Troll field west of Bergen. Norway became one of Europe's most important gas suppliers for the coming century.

With Troll, Norway inaugurated its first multiphase transportation system which carried gas and condensate from the North Sea to the shore. A stretch of 67 km that crossed the Norwegian Trench! The well-flow, less its water, which was removed on the platform, was sent directly to Kollsnes near Bergen, which meant that the offshore processing plant could be dramatically smaller than it otherwise would have been. The operators were thus able to avoid a far more expensive solution; an even larger Troll platform. Operating costs were also cut, because the needs for manpower (and thus accommodation and food) at sea were much lower.

Almost NOK 46 billion saved

At a press conference in 1989, Norske Shell, the operator, said that splitting the Troll project between offshore and onshore plants would reduce development costs by NOK 4.5 billion (570 million euro), and cut annual operating costs by NOK 330 million (40 million euro).

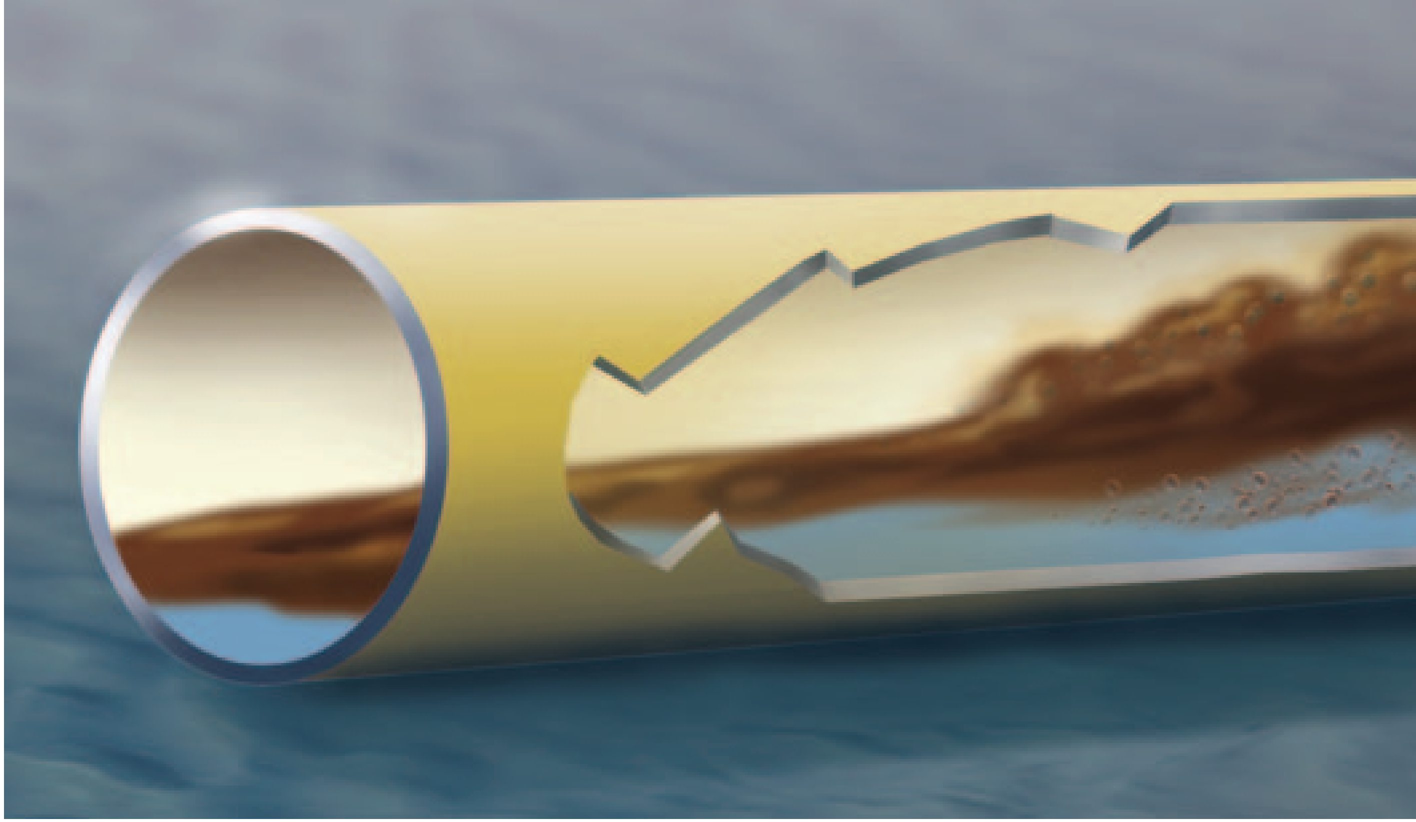
The Troll field will produce gas for 75 years. Over the lifetime of the platform, multiphase technology will thus be responsible for savings of almost 30 billion 1969-kroner (nearly NOK 46 billion (5.7 billion euro) in 2009 terms). And that is on Troll alone!

But almost at the same moment as the gas was beginning to flow in from the Troll field, dark clouds were beginning to gather over the Tiller laboratories ...

Photo: StatoilHydro

Crisis – and new potential

In 1996, the biggest multiphase laboratory in the world suddenly became too big!



AGEING FIELDS PRODUCE WATER: **Special studies were performed using the medium-scale loops in Trondheim and Kjeller. These revealed how the increasing amounts of water that were being found in multiphase pipelines behaved in conjunction with the flows of gas and oil in the pipe.** Illustration: SINTEF

By now, the oil companies had used OLGA in many field developments; they had acquired operating experience and could compare the results of OLGA simulations with field data.

Many of these companies found that OLGA was good enough to deal with the challenges they faced, and they claimed that it would be too expensive to continue tests on such a large scale as that offered by SINTEF. After 13 years of full order books, the kilometre-long pipe-loop was decommissioned.

From large- to medium-scale

For OLGA to become even better, other types of experiments were needed. The necessity for more detailed studies of flow also required more advanced instrumentation.

In 1985, in parallel with the tests carried out at Tiller, IFE built a medium-scale experimental facility that was aimed at improving our understanding of multiphase flow phenomena. In collaboration with SINTEF and Statoil, IFE built a medium-sized multiphase rig in 1994 to improve OLGA's ability to simulate flows in deviation wells, and in 1996, SINTEF upgraded a younger brother of the large-scale loop.

The increasing amounts of water that were being produced by ageing oil fields were at the focus of the medium-scale experiments.

Large volumes of water flowing through a pipeline can bring in their wake a number of problems, including corrosion. Internal corrosion can occur suddenly and may have very serious consequences, in the worst cases leading to leaks. IFE's response to this problem was to spend years developing methods and chemicals, known as inhibitors, to counteract corrosion.

More water in pipelines may also cause ice-like crystals called hydrates to form in the oil and gas flow. IFE and SINTEF also tackled this problem. The risk of hydrate formation is greatest when production on a field is shut down, for example for maintenance.

Without countermeasures such as using anti-freeze, heating or other solutions, hydrate plugs can lead to expensive operating shutdowns or, in the worst case, permanent blockage.

And while the industry was equipping itself for the conditions awaiting it in these pitch-dark waters, a new report brightened up the lives of OLGA's parents ...

Flattering testimony from giant oil company

In 1999, Conoco stated that OLGA was one of the greatest successes with which the company had been involved in Norwegian research.

SATISFIED CUSTOMER: Ole Lindefjeld, currently director of research and development in ConocoPhillips Norge, was behind the 1999 report that identified OLGA as one of the greatest successes on the research front in the history of Conoco Norge. Photo: Rune Petter Ness, Adresseavisen

The report "Value Creation through Technology" was drawn up by Conoco Norge. Between its covers, the company described how it had calculated the value created by a selection of R & D projects performed between 1979 and -99.

OLGA was one of four projects chosen as "The Greatest Success Stories", and the report received wide coverage in the business and industry press. In current kroner, Conoco had put NOK 900 million into Norwegian research and development (NOK 1.3 billion 1999 kroner - 160 million euro), which went to 318 projects. Part of that sum went into the research that eventually materialised in the shape of OLGA. Conoco was one of several oil companies that financed these efforts.

Good business

For its calculations, Conoco Norge selected 64 of the 318 projects. The company's conclusion was that these projects alone had saved it some NOK 3.6 billion (450 million euro), or four times the amount the company had invested in all its R & D in the course of 20 years.

The report also estimated that the savings made by other companies came to NOK 12.3 billion (1.5 billion euro).

A cautious estimate

"We looked at what projects can offer in terms of pure cost reductions, without counting the gains in increased oil and gas production, so the total value created by these projects has been even greater," said research director Ole Lindefjeld at the launch of the report.

New challenges ahead

Meanwhile, IFE and SINTEF were going full speed ahead with refining multiphase technology for a challenging new millennium ...

WITH GAZE FIXED ON THE SEABED: **Senior scientist Peter Andersson observes well flow in IFE's multiphase rig.**
Photo: Mick Tulley, Image Communication

On course for wilder waters

In the future, oil and gas will be brought ashore from subsea systems laid at depths of several thousand metres. The well flow will have to travel several hundred kilometres in the same pipeline!

This was the challenge that awaited the multiphase engineers at the turn of the century. The coming of the 21st century announced a need for new technology on the continental shelf.

Shtokman gas and heavy oils

Future multiphase pipelines will be designed to stretch from great depths across long distances to shore and up steep slopes on the seabed. Many of these systems will carry heavy oils, and several will probably be laid in the Arctic.

The giant Shtokman gas field, 550 kilometres north of Russia, and several other developments, place heavy demands on multiphase systems, which require more accurate simulation models. This is why the petroleum sector now has launched several major new research projects.

Celebrated "lady" meets a challenger

At the beginning of the new century, OLGA had long been a celebrated "lady", with a share of almost 90 percent of the global market for design and operating software for offshore multiphase systems. Mindful of the challenges that were queuing up on the seabed, SINTEF took an initiative that will provide OLGA with a challenger.

In 2002, in collaboration with ConocoPhillips Norge and Total Norge, SINTEF started to develop LEDA, a computer simulation tool that will offer detailed images of flow conditions in parts of the pipeline that users can zoom in on.

As part of the LEDA project, the large-scale laboratory was reopened in 2001. The Tiller laboratory was also enlarged with a hall for medium-scale experiments and an explosion proof bunker in autumn 2009.

These new facilities will be used to study interactions between flow regimes and the surface chemistry of oil droplets, an important topic when heavy oils are to be transported in multiphase pipelines.

Together with STP Group, Statoil, Chevron, ExxonMobil, ENI and Shell, IFE launched a project that will completely renew OLGA via a new generation of multiphase models that depended on basic physical principles.

While OLGA is based exclusively on relationships that had been observed in the course of laboratory experiments, HORIZON is developing a detailed mathematical model that reproduces the physical world more accurately than OLGA.

Multidisciplinary team

The aim of the LEDA and HORIZON projects was to develop pipeline systems with greater transport capacity and reduced risks of breaks in operation. Norwegian research institutes put large multidisciplinary teams on the job.

While LEDA was gradually being fleshed out, OLGA was adopted by the two development projects that formed Norway's most important arenas of innovation at the turn of the century ...

At the top on the bottom

With OLGA playing a supporting role, the Ormen Lange and Snøhvit gas fields came on-stream in 2007. These were the first major field developments on the Norwegian shelf that were based on neither production vessels nor platforms.

From the two huge gas fields, natural gas and condensate flow directly from the seabed installations to their onshore terminals.

Snøhvit, the pioneer

The multiphase pipeline that links the fields in the Snøhvit project with the island of Melkøya near Hammerfest is 143 kilometres in length, a record distance for pipeline transportation of untreated well-flow! The Snøhvit terminal on Melkøya is Europe's first export plant for liquefied natural gas (LNG).

"Long-term strategic efforts on the development of multiphase technology were an important prerequisite for Snøhvit, the first field development in the Barents Sea," says information manager Sverre Kojedal in StatoilHydro.

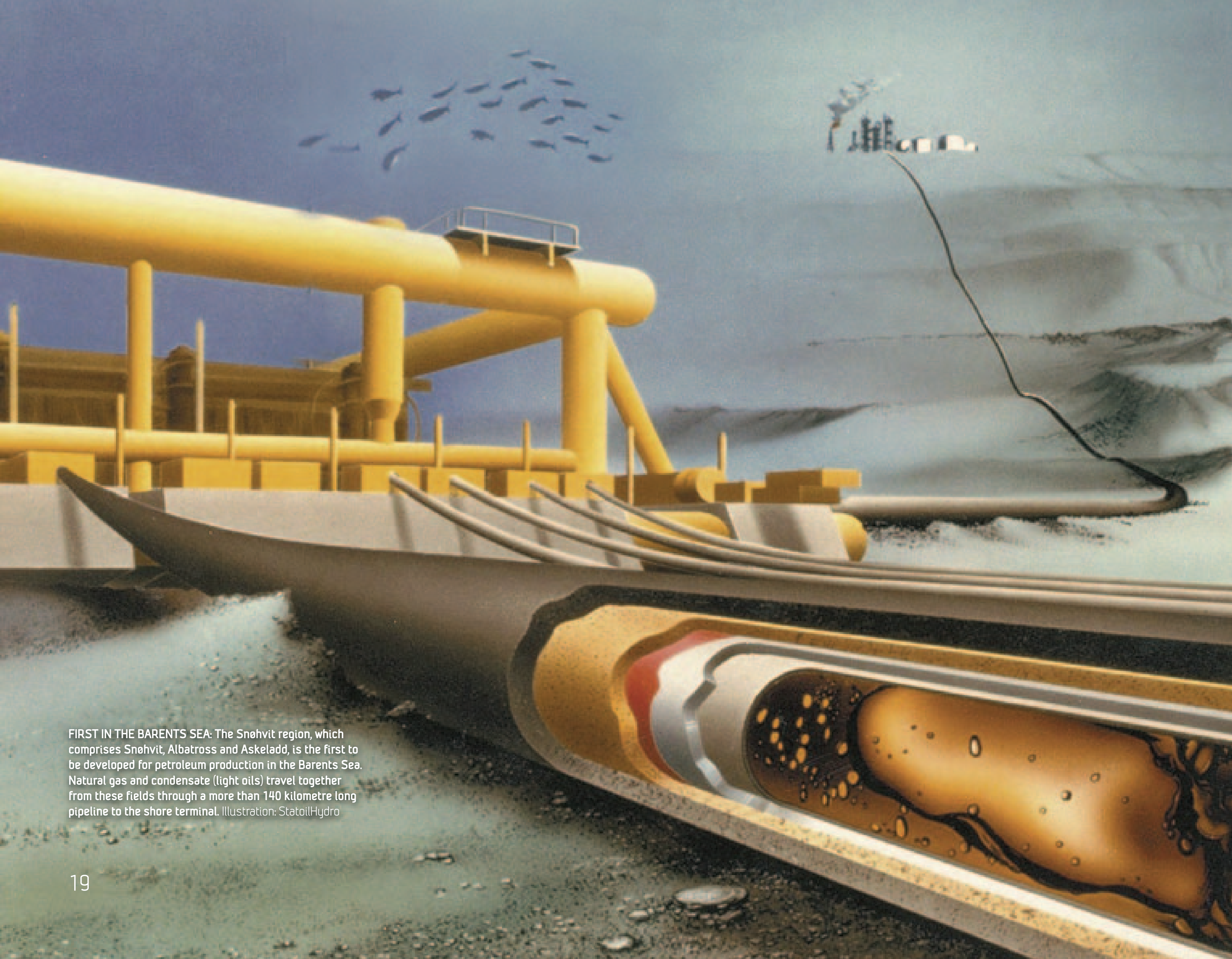
Ormen Lange, the giant

Ormen Lange, which lies 120 kilometres north of Kristiansund, is the third largest gas-field in Europe and Norway's first deepwater project (850–1100 metres). Hydro, which was the development operator, told Gemini that the company studied two potential solutions – and that a floating production platform and subsea installations were more or less identical in terms of cost.

According to Hydro, a contributory factor to the final choice was a genuine fear that approval of a platform solution might delay the project. This would lead to serious losses due to price rises and lost cash flow.

At the same time as the gas was flowing to the coasts of Finnmark and Møre og Romsdal, scientists in Kjeller and Tiller were working out how to guarantee free flow in the multiphase pipelines of the future ...

ALL ASHORE: **The well flow from Ormen Lange is separated at Nyhamna in Aukra municipality in the County of Møre og Romsdal. The natural gas is sent on to the UK through Langeled, the longest subsea gas pipeline in the world.** Foto: StatoilHydro



FIRST IN THE BARENTS SEA: The Snøhvit region, which comprises Snøhvit, Albatross and Askeladd, is the first to be developed for petroleum production in the Barents Sea. Natural gas and condensate (light oils) travel together from these fields through a more than 140 kilometre long pipeline to the shore terminal. Illustration: StatoilHydro

Special efforts to overcome production barriers

The aggressive conditions on the outside of the multiphase pipelines of the future have led SINTEF/NTNU and IFE to tread new ground in order to prevent complications inside the pipes.

"ICE" THAT BURNS: **No, this is not ice, but hydrates, ice-like crystals that can form when oil, gas and water are transported in the same pipeline. If countermeasures are not taken, hydrates can at worst block the pipeline.** Photo: Gry Karin Stimo

When untreated well flow is transported over long distances at great depths, a number of problems can occur. Ice-like hydrates can plug pipelines, wax may be deposited on the inside wall of the pipe, reducing its capacity, and the pipe may rust.

"Cold Flow"

In SINTEF, "Cold Flow" became a well-known concept early in the new century, a new way of thinking in the war against hydrates in multiphase pipelines. The philosophy is based on tolerating hydrates instead of removing them. The recipe is to create conditions within the pipeline that make the hydrates resemble dry snow instead of slush.

"If we succeed, we will be able to dramatically increase transport distances for seabed multiphase pipelines," says chief scientist Roar Larsen, one of the inventors of the new method.

Water droplets are normally enclosed within the hydrate crystals that form in multiphase pipelines, and this causes the crystals to resemble slush, so that they stick together and may form large plugs unless we adopt countermeasures.

And so far, preventive medicine has been very expensive.

With the Cold Flow method, water and gas molecules grow into tiny round snow particles without the water becoming enclosed within the crystals. As a result, the hydrates resemble powdery snow. And as all Norwegians know, dry snow never turns into snowballs.

An "eye" for hydrates

Independently of SINTEF's work on Cold Flow, IFE and the SPT Group continued to develop OLGA in their HORIZON project, which aims to calculate where hydrate particles occur and where they then move within the pipeline. Do they attach themselves to the pipe wall, or do they aggregate themselves with other particles and grow larger? Do they follow along with the water or the oil?

Problems of this sort form part of the background for the Multiphase Flow Assurance Innovation Centre (FACE), a national centre for research-based innovation, which is hosted by IFE, in cooperation with SINTEF and NTNU.

Suppliers to the depths

When multiphase systems moved the oil story under water, they paved the way for an industry in which Norway became a great power.

BIG ON THE SEABED: **Tore Halvorsen leads the "subsea empire" of the global corporation FMC Technologies. The Norwegian part of the group plays a central role in its work in subsea technology, and in 2008, its turnover was USD 1.4 billion, equivalent to NOK 8.3 billion.** Photo: Tor Aas-Haug, Mediafoto

The world's biggest supplier of subsea technology, the global corporation FMC Technologies, has more than 3000 employees in Norway. Tore Halvorsen, the head of FMC's subsea division, has his office in Kongsberg; the company's subsea technology departments in four corners of the world report to the Norwegian.

Subsea – in the middle of Norway!

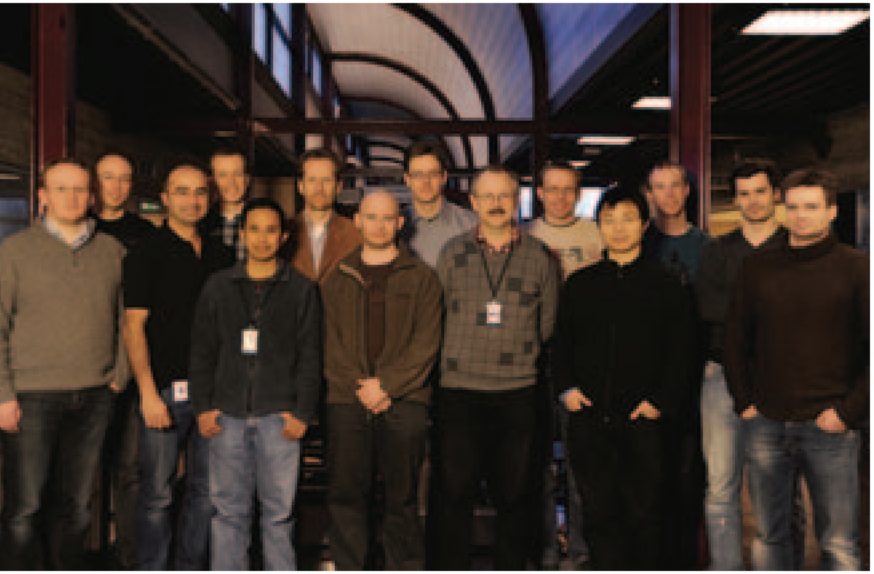
The subsea epoch in the inland city of Kongsberg started with Kongsberg Våpenfabrikk. Out of the former state-owned company, which had been wound up, arose Kongsberg Offshore AS, which is now part of FMC. The Houston-based group develops technology for both surface and subsea field developments. In the Norwegian part of the company, however, everything has to do with seabed technology. And FMC's subsea boss is quite certain that the subsea industry's operations are based on breakthroughs in multiphase technology.

"Two aspects explain why the subsea sector has grown as much as it has done. One is that we have developed robust, reliable products that are already placed on the seabed. The other is that we understand how unprocessed hydrocarbons are capable of flowing over long distances; in other words, we have a good understanding of multiphase technology," says Halvorsen.

In the wake of these subsea projects, OLGA, subsea technology's simulation tool, became a commercial product in great demand. The Scandpower software house, now the SPT Group, has brought the "lady" out to a market that she has now dominated for many years, with a market share of around 90 percent. IFE gave birth to Scandpower by a spinoff operation, and continues to collaborate closely with the SPT Group.

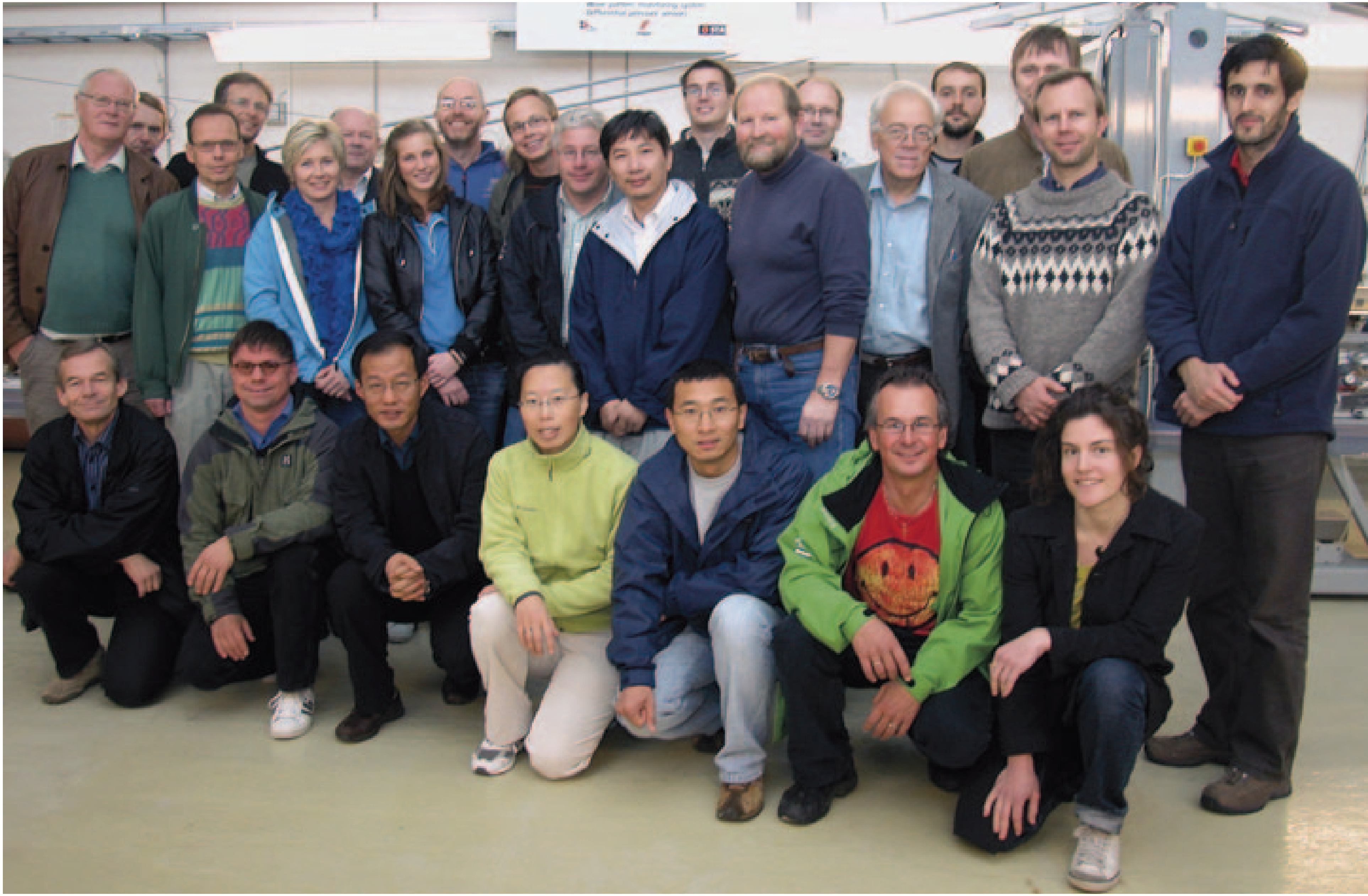
The LEDA simulation software, which SINTEF developed in collaboration with two oil majors, is about to be commercialised. LEDA's way to the market goes via a licensing agreement with Kongsberg Maritime.

NTNU students have been regularly attached to the Multiphase Flow Laboratory in Trondheim up through the years. With their studies completed, they have brought their knowledge out to industry – one important reason that multiphase technology was able to establish itself so rapidly in the petroleum world.



THE LEDAFLOW DEVELOPMENT TEAM: Front row from the left: **Ernst Meese, Alireza Ashrafian, Dadan Darmana, Jørn Kjølås, Stein Tore Johansen, Rixin Yu, Runar Holdahl.** Back row from the left: **Bård Solvang, Wouter Dijkhuizen, Øyvind Hellan, Espen Krogh, Sjur Mo, Bjørn Tore Løvfall, Guy Depay.** Not present: **John Morud, Thomas Hagelien, Thomas Janke, Vincent Pauchard and Angela de Leebeeck.** Photo: SINTEF

SINTEF'S MULTIPHASE LABORATORY STAFF: Front row from the left: **Gisle Onsrud, Tor Erling Unander, David Arla, Franklin Krampa, Roar Larsen, Jan David Ytrehus, Christian Brekken, Cecilie Sneeggen, Hilde Wanvik, Jon Harald Kaspersen, Ivar Eskerud Smith and Rolf Erik Malones Larsen.** On the ladder: **Bjørnar Lund.** Back row from the left: **Terje Øyangen, Martin Fossen, Erlend Straume and Karl Gustav Gustavsen.** Not present: **Arne Erik Rekkebo, Eva Habetinova, Marita Wolden, Sylvi Høiland and Anna Borgund.** Photo: Thor Nielsen



THE STAFF OF IFE'S DEPARTMENT OF PROCESS AND FLOW TECHNOLOGY: Front row from the left: **Peter Borg, Jan Nossen, Linzhong Li, Lan Liu, Bin Hu, Erik J. Holm and Karin Hald.** Second row, from the left: **Terje Sira, Guttorm Endrestøl, Anne Lise B. Moen, Heidi Lystad, Magne Rudshaug, Jinsong Hua, Morten Langsholt, Sven Nuland, Olaf Skjæraasen and Kalli Furtado.** Back row from the left: **Halvard G. Fjær, Einar Sørheim, Arild Ek, Chris Lawrence, Kristian Holmås, Alf Grini, Dag Lindholm, Gustavo Zarruk and Olav Senstad.** Not present: **Roar Skartlien, Steinar Groland, Peter Andersson, Paul Meakin, Dag Mortensen, Espen Sollum and Jan Sagen.** Photo: Mona Lunde Ramstad, IFE

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