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DP and the Art of Perfect Positioning

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Abstract

How does a vessel keep its position at sea without mooring? The answer is through dynamic positioning, or DP. Advanced technology, combining position reference sensors, computers, propellers and thrusters, is used to counteract environmental forces such as wind, currents and waves to dynamically position the vessel without using anchors or mooring lines. Today, DP systems are found in every ocean region in the world. The Kongsberg DP adventure began in 1975 when Kongsberg Våpenfabrikk signed its first contract. Eighteen months later, an Albatross DP system was installed on board a Norwegian diving vessel in the North Sea. Today, dynamic positioning equipment from the inland town of Kongsberg is found onboard a myriad of ship types including supply vessels, drilling rigs, pipe and cable layers, stone-dumping and bulk vessels, shuttle tankers, crane and lifting vessels, mine hunting vessels, cruise ships, floating hotels and yachts. Dynamic positioning is not limited to keeping a vessel on a fixed location but also to controlling the motions of vessels along predetermined tracks. After over 40 years in business, Kongsberg Maritime still maintains a world-leading position within dynamic positioning. This paper is based on the book "The Jewel in the Crown: Kongsberg Dynamic Positioning Systems 1975 – 2015" (Kvaal and Østby, 2015).

Keywords: Dynamic positioning, Jens G. Balchen, Kongsberg Våpenfabrikk, Albatross, Offshore vessels

1 Introduction

When the first people began to move out of the near seas and learned to master the art of sailing and navigation, they also changed the conditions for development of human societies. Through the development of larger and safer vessels, more advanced navigation methods and improvement of navigational signs along the coast, humans have improved their possibilities of reaching distant waters and increased the chance of returning safely. Nevertheless, for a long time the seafarers only had their seamanship and the vessel's sail or engines to rely on when bad weather was coming. Anchors were the only aid they had to keep the ship at rest in bad weather and to avoid ending up in the reefs and rocks.

History is full of tragic stories about vessels that have been lost and crews that have died in battle against the violent forces of wind and waves. At the end of the 19th century, however, someone found an answer to how the ocean could be tamed, at least in theory. In the novel "L'ile à hélice" (Propeller Island), Jules Verne writes about an artificial island, Standard Island, sailing in the Pacific and keeping calm in all types of weather. The novel, published in 1895, was science fiction (Verne, 1895). However, Verne's adventurous imagination was materialized just few generations after his death. Today, we do not call it science fiction, but dynamic positioning, or DP for short.

The DP systems have an almost 60-year long history and started with an American drill ship in the Pacific in 1961. In 1977, 16 years later, the first Norwegian-produced DP system from Kongsberg Weapons Factory (Kongsberg Våpenfabrikk, KV) was installed on board a Norwegian diving vessel in the North Sea. Since then, DP systems have been used for ever-new applications, and is presently used for a wide range of

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vessel types, such as drilling rigs, supply vessels, pipe and cable layers, rock dumpers, mine hunting vessels, cruise ships, floating hotels and yachts. Dynamic positioning is also no longer just about staying in position, but additionally about e.g. following a path or staying within a restricted area. In this paper, we will describe and analyze how Kongsberg Maritime became a world-leading manufacturer of advanced DP systems.

2 Dynamic positioning

A vessel at sea is continuously exposed to wind, currents and waves that will drive it off position if the crew does nothing to counteract these forces of nature. Traditionally, the possibilities have been to anchor the vessel, or to steer it to the correct position by means of rudder and sail, or the propellers. Such was the situation for a long time. However, about sixty years ago it was possible to leave the positioning to an automatic control system, a so-called dynamic positioning system. Such an automated system holds a vessel in the same position above the seabed or in constant distance to another vessel without the use of anchors (Morgan, 1978) and (Faÿ, 1990), see Figure 1.

According to the International Maritime Organization (IMO), a DP system is defined as: "The complete installation necessary for dynamically positioning a vessel comprising the following sub-systems: Power system, thruster system, and DP control system" (IMO, 1994). The power system includes motors, generators, switchboards and a power distribution system. The thruster system includes thruster, propeller and rudder units, as well as their control electronics and cabling. Finally, the DP control system includes computer hardware and software, sensors, position references and operator interfaces. A DP system also necessitates a human DP operator (DPO). However, the term "DP system" is commonly used about the DP control system. Still, it is usually the control system most people think about when it comes to a DP system. Without it, the other two systems only constitute a traditional propulsion system. The DP system controls the vessel movements in the horizontal plane, i.e. longitudinal (surge) and lateral (sway) displacement, and rotation around the vertical axis (yaw), see Figure 1. Movements up and down (heave), rolling and pitching cannot be counteracted.

In order to keep a certain position, you must know both where you are and where you want to be. To calculate a vessel's position requires measurements from one or more position reference systems that can tell where the vessel is relative to known points of reference. On supply vessels carrying out missions close to an oil platform, it would be most important to know

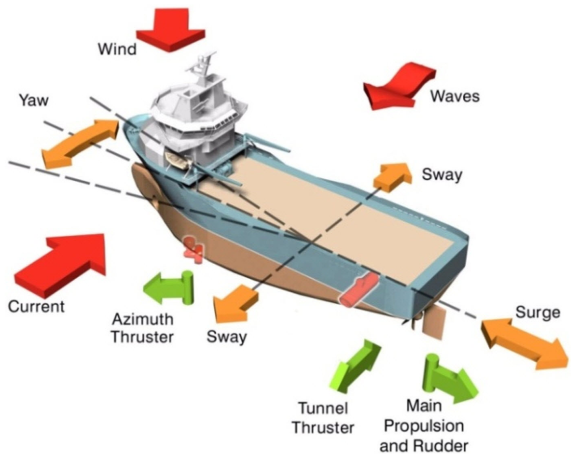


Figure 1: To stay in position, a dynamically positioned vessel must automatically counteract environmental forces and moments from wind, waves and current by active use of its thrusters. Illustration: KM.

the position relative to the platform, while on a vessel that is going to lay a pipeline, one must know where it is in relation to the route along which the pipe is to be laid. There are basically two different types of position reference systems; those that give an absolute, global position (i.e. latitude, longitude), and those that give a relative position (range, bearing) to a fixed object. The most common position reference systems of the first type are satellite-based like the Global Positioning System (GPS), which calculates the global position with a small margin of error. An example of the latter is hydro-acoustic position reference systems, which calculate the position using transducers placed on the ship's hull and transponders on the seabed. Another example is the so-called taut-wire, which is a metal wire with a weight keeping it down on the seabed.

Position reference systems based on radio signals, radar and laser are also options. These systems all have their pros and cons and are commonly used in combination to increase precision and safety. The positioning data from the reference systems are also supplemented with directional information from gyrocompasses.

When the vessel's position is known, the control problem is reduced to minimizing the difference between where you are and where you want to be, i.e., the challenge of minimizing the distance to a desired position. This is done by using propellers and thrusters, i.e. fixed or moving maneuvering propellers, to move the vessel until the deviation between the actual and desired positions has become as small as possible. In order to calculate the required power and how this power should be distributed between the various propulsion units, advanced mathematical models and calculations are required. These are part of a cybernetic control structure that constitutes the brain of a DP system.

A main component of this brain is the guidance system, which calculates a commanded motion that the vessel should follow to move to the desired position. Another main component is a model-based estimator, which uses measurements of wind, position, thruster usage and other forces, to calculate how the vessel actually moves and which forces are affecting it. The estimator continues to calculate this information even if several of the measurements disappear for a shorter or longer period. By comparing the commanded motion from the guidance system with the actual motion from the estimator, a controller then determines which forces the vessel must use to move towards the desired position. The controller sends its force commands to a thrust allocation unit, which calculates how the forces can be distributed between the different propellers and thrusters in an optimal manner. Together, the guidance, estimator, controller and thrust allocation units make up the most important components of the DP system's brain.

A vessel can be moved both by means of the main propellers and one or more thrusters. Thrusters can be both directionally-fixed as the tunnel thruster, which is located laterally in the hull, or steerable like the azimuth thruster, which is attached below the hull and can be rotated in all directions. These devices require a lot of power. Modern DP vessels are mainly based on diesel-electric propulsion, which means that diesel engines are used to drive generators that produce electric power for electric motors that are connected to the thrusters. Hence, such vessels do not only have a traditional engine but also a separate power station with an associated power distribution system on board. The size and design of the vessel affect how the natural forces work. Therefore, there are large variations in the various vessels' thruster equipment and power systems. Some vessels may also have special needs because they will carry very heavy loads such as anchor chains while moving an anchored drilling rig or controlling the tension in large pipes laid out on the seabed.

A modern supply ship is usually equipped with four to five thrusters with a total power requirement in the order of 5 megawatt (MW). This is approximately the same as the corresponding power of fifty ordinary cars. Over a year, these thrusters will consume several million liters of diesel, equivalent to the energy consumption of thousands of homes. The installed capacity of a drilling rig, which typically has between four and eight giant thrusters, is usually in the order of 30 MW, and has annual energy consumption that is five to ten times higher than that of a supply vessel. This power corresponds to a medium-sized Norwegian hydropower plant, and the energy used by the thruster on such a drilling rig amounts to approximately the same as 6000 homes.

There are therefore great forces at play, and consequently also large costs associated with an operation at sea. In addition, the vessels themselves represent large investments. A modern supply ship would like to have a price tag of almost half a billion Norwegian kroner (NOK), while a drilling rig can be ten times as expensive. The daily rates for supply ships are in the order of a couple of hundred thousand NOK, while for drilling rigs they generally amount to more than one million NOK a day. In addition, the formidable fuel costs are usually paid by the client. That's why it's a lot to earn by making good use of the time. Dynamic positioning therefore is not just about precise positioning, but also about effective time usage.

3 Not just technical?

Dynamic positioning is rarely mentioned without being described as a system, i.e. a dynamic positioning system, or usually a DP system. This is one way of saying that it consists of several parts that not only belong together, but each is necessary for the whole system to function. Normally, the term is used for the technical units, but a DP system not only includes technical components. A wide range of non-technical elements must also be in place for it to work. The use of the system is governed by many different safety regulations and laws that provide conditions for the equipment to be used for different types of operations. In addition, rules are contained in international standards and class companies' class notations. In order to function, the system is also dependent on standards that allow the control system and the other devices to communicate with each other and with other systems on board.

A technology must be maintained and adapted to changing demands and new opportunities. The system includes developers, service personnel and others who make adjustments and maintenance, and ensure that the different parts work well together. In addition, it is dependent on a sales and marketing staff, who ensure that users' needs are communicated to those who develop the technical parts and that the finished results become available to the users. Ultimately, it is the many operators using the system who determine whether it succeeds in doing the job it is supposed to do. It is also a prerequisite that those who use the technology possess the required competence of how to use it.

A DP system is thus dependent on the efforts of many people, who in various ways make sure that the individual parts of the system play together. It also consists of many technologies that are basically not designed for dynamic positioning. More powerful, faster, cheaper and more robust computers have had a decisive influence on the development. Similarly, several other innovations have characterized the way the DP systems have been developed, including new storage media, data communication protocols, operating systems and programming languages. GPS is another example of a technology designed for other purposes but which has become an important part of DP. With such an understanding of dynamic positioning, it is not always easy to say where one technology stops and where the other starts. Similarly, it is not obvious when the story of Kongsberg's DP systems started.

4 New challenges and theories

The DP development was the result of several lines of development in the fields of science and technological research in the 1940s and 1950s. Particularly in the United Kingdom and the United States, major advances were made in electronics and various control technologies. Knowledge about this new technology also reached Norway. This knowledge and the technology transfer were not just about products and production processes. It was also about people moving around and taking the knowledge with them. In the years after the Second World War, many Norwegian engineers took education or further education in the United States. Jens Glad Balchen was one of them. See e.g. (Kvaal, 1990), (Sejersted, 2002) and (Kvaal, 2009) for details about this development. See also (Breivik and Sand, 2009) and (Paulsen, 2019) for more details about Balchen.

After graduating from the Norwegian Institute of Technology (Norges tekniske høgskole, NTH; today the Norwegian University of Science and Technology, NTNU) in 1950, Balchen traveled to the US to further educate himself within control technology. He went to Dunham Laboratory, Yale University, where he also obtained his Master of Science in Engineering degree in 1951. Then he became involved in the prestigious Whirlwind project, developing computer technology. A spin-off of Whirlwind was the development of numerical control of machine tools at MIT (Redmond and Smith, 1990). In this way, he not only gained insight into the work with computers, but also how these could be used to control machine tools and industrial processes.

In 1953, Balchen led the construction of the analog computer DIANA and was the central driving force in the development of the cybernetics field at NTH. From 1954 to 1963, the activity took place in the Automatic Control Laboratory and its corresponding SINTEF department. Balchen was appointed professor in 1962, and the following year the Department of Automatic Control was established, which changed name to Department of Engineering Cybernetics in 1973, ref. e.g. (Østby, 1989), (Kvaal, 1990) and (Paulsen, 2019). A young soon-to-be-professor Balchen can be seen in Figure 2.

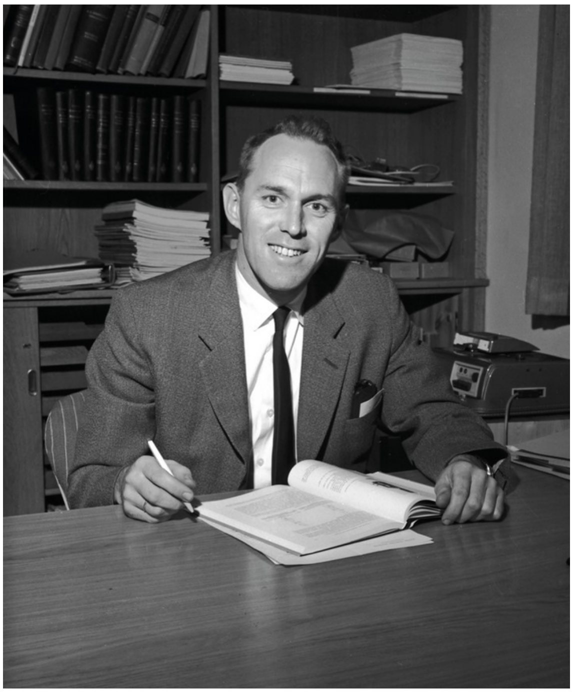


Figure 2: Jens Glad Balchen in 1961, shortly before he was appointed professor at NTH. Photo: NTNU.

When Balchen went to the United States again in the early 1960s, he met a researcher who was on his way to becoming a new star in the sky of cybernetics and automation. It was the Hungarian-born Rudolf Emil Kalman, who with his theories launched a completely new way of handling measurements for control systems, whether it was for ships, submarines or spacecraft. The Kalman filter, which is an advanced mathematical algorithm, was an essential part of the navigation system of the spacecraft in the American Apollo program, which brought humans to the moon for the first time on July 20, 1969 (Mindell, 2008) and (Bugos, 2010). The Kalman filter would be very important when Kongsberg started the development of its DP system.

Rudolf Kalman was born in Budapest in Hungary in 1930, but fled to the United States with the family during the Second World War. There he studied electrical engineering at MIT, where he was initially introduced to applied mathematics for control engineering applications. Along the way, he was introduced to a new mathematical world, including nonlinear oscillations. In 1958, he was employed as a research mathematician at the Research Institute for Advanced Studies (RIAS) in Baltimore, Maryland, where he developed the algorithm that carries his name and brought him up in the cybernetics elite division.

In 1960, Kalman published an article where he presented "a new method of linear filtering and prediction problems", later known as the Kalman filter (Kalman, 1960). Simply put, the Kalman filter provides an intelligent filtering of measurements by combining a mathematical model of a system with the actual measurements from the system. Based on the measurements' statistical properties, the model and measurements are weighted in an optimal way, so that it is possible to achieve far more accurate and stable signals than using the measurements alone.

This model-based filtering makes it possible to filter out measurement noise in a very effective way. Unlike the Wiener filter, the Kalman filter is a recursive algorithm that is particularly suitable for implementation on a computer. The algorithm therefore received a strong applied impact in a short period of time. When Balchen and his colleagues started working on solutions for a DP system, Kalman's algorithm gradually became an integral part of the development of such a system.

In 1971, Balchen, who now was a cybernetics professor at NTH, contacted the management of Kongsberg Weapons Factory (KV). He told them that international companies were selling DP systems for drilling vessels in the offshore market. He claimed that by using Kalman's theories, it was possible to make a better DP system than what the foreign companies delivered. Should KV not develop a separate DP system that the company could offer to the offshore industry (Bjørnstad, 2009)? Soon, the huge Ekofisk field in the North Sea would start production. Operations in the tough conditions of the North Sea would require advanced technological solutions. He also pointed to Norway's long history as a maritime nation. As Balchen saw it, KV had a good reputation with its high industrial ability and competence. The company therefore had a responsibility to contribute to Norwegian industrial development aimed at the potential offshore market, he claimed. However, the KV management did not see any immediate market for the product, and the professor had to leave the meeting without a deal.[1] What was the background for Balchen's visit to KV?

The development of DP began in the United States. In 1961, the drilling vessel "CUSS 1", originally a marine barge, was rebuilt for drilling into the earth crust at large ocean depths. To handle such operations, the ship had to be accurately positioned. It was therefore equipped with four azimuth thrusters in each corner. The thrusters were manually controlled by two operators who followed the ship's position visually and on a sonar screen. The "CUSS 1" drilled holes at a depth of 945 meters outside of La Jolla, California (Faÿ, 1990). Based on these technological advances, geologists succeeded in taking samples of the earth crust. Hence, geology and not oil were the goal of drilling in the first few years.

Later in 1961, the much smaller drilling vessel "Eureka" was also launched. Basically, the plan had been to equip it with the same type of instrumentation and manual control as on "CUSS 1". However, the plans were changed. This was due to the young engineer Howard Shatto, who had previous experience with automation systems for industrial processes.[2] The ship should initially be manually controlled, but Shatto developed an automated control system based on concepts and equipment from the process industry. The most important part of the control mechanism consisted of three electronic PID controllers (proportional, integral, derivative) with one controller for each horizontal degree of freedom.[3] These controllers were connected with an electromechanical device that distributed the command signals to the two azimuth thrusters of the ship. The steering device could move the boat back and forth and sideways by adjusting the thruster angles (orientation) and speed. With this, the world's first thrust allocation functionality at sea was a reality.

When KV turned the thumb down for Jens Glad Balchen's idea of developing a new dynamic positioning system in 1971, several internationally renowned companies like Honeywell (USA), Delco (USA), General Electric Company (GEC) (United Kingdom), CIT Alcatel (France) and Thomson-CSF (France) delivered DP systems in the US and Europe (Morgan, 1978). However, in 1975 there were no more than ten drilling vessels with DP in the whole world (Faÿ, 1990). In other words, it was not a big market for these systems at that time, but this would soon change.

5 Interlude

At the same time as international companies improved the capacity and precision of the DP systems they

[1] Interview with Steinar Sælid, 10.11.2004 and Eldar Mathisen, 13.10.2004.

[2] Interview with Howard Shatto, 04.10.2013 and Howard Shatto: "2011 – The year in which Dynamic Positioning celebrated its fiftieth anniversary!", https://dynamic-positioning.com/history-of-dp/

[3] Morten Christian Swensson: "Praktisk prosess-regulering – PID-regulatoren" in Teknisk Ukeblad 07.05.2013.

delivered, various activities were ongoing to build up expertise and experience with dynamic positioning in Norway. At NTH and SINTEF, which was an independent research organization in Trondheim, several engineers wrote their master theses related to this new technology. In 1973, Balchen therefore asked one of his doctoral students, Steinar Sælid, to intensify the development of the theoretical and practical principles of dynamic positioning. Sælid, together with Nils Albert Jenssen and Eldar Mathisen, embarked on this work. Under Balchen's guidance, these three developed the software for the first Norwegian-built DP system, see (Balchen et al., 1976), (Balchen et al., 1980) and (Jenssen, 1981). Figure 2 shows Nils Albert and his colleague Leif Palmstrøm working with the development of software for the management and control of submersible platforms in 1982.

At the same time, there was a rapid development going on in the North Sea. In the 1970s, the oil fields were like construction sites. Remotely controlled underwater robots such as ROVs (remotely operated vehicles) did not exist, so the divers were indispensable construction workers. Until the mid-1970s they operated from service boats or rigs, but as oil operations moved into deeper waters, diving ships had to be used. The depth of Ekofisk was approximately 70 meters, while at Statfjord it was about 150 meters down to the seabed. There were many accidents, often with tragic outcomes.[4] Anchoring in connection with tasks on the bottom took time and could also be difficult. Therefore, some ship owners started to be interested in specially-equipped DP vessels.

Offering diving services also became an alluring business idea for the risk-taking shipowner Jacob Stolt-Nielsen from Haugesund. The shipping company Stolt-Nielsen Seaways had a relatively large tank fleet that was sold to invest in various types of activities in the North Sea. The company's head of the North Sea initiative, Bjørn Bendigtsen, was responsible for the order of "Seaway Falcon". This vessel was the first with a DP system in the North Sea, which was provided by the American company Honeywell. The "Seaway Falcon" was intended to not only operate as a diving vessel, but also be used for fire fighting. Bendigtsen had been employed at KV before joining Stolt-Nielsen and had followed the construction of automatic control systems for the air defense cannons L/70, which were produced on license from the Swedish Bofors Group. Bendigtsen therefore asked KV to use their expertise in this field to develop a control system for the water cannons on board the "Seaway Falcon". This order was the start of an extensive cooperation between Stolt-Nielsen and KV.[5]

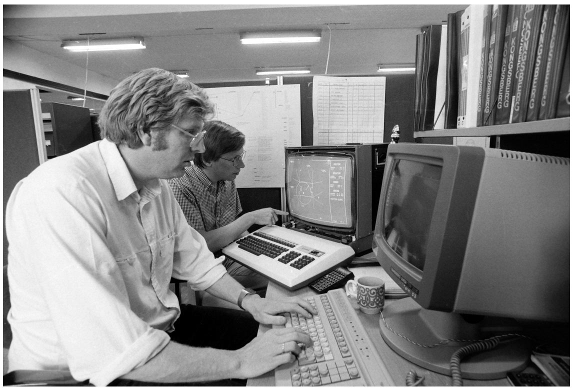


Figure 3: Nils Albert Jenssen, in the foreground, was central to the development of software for dynamic positioning. Photo: Mediafoto.

On September 23, 1974, KV invited potential partners to a meeting at their Oslo office. Here, they agreed to start the development of a DP system.[6] The Norwegian ship electronics company Simrad was tasked with designing and manufacturing the hydroacoustic position reference system, while KV would deliver the computer and other hardware. Balchen also participated in the meeting and announced that NTH and SINTEF were already well underway in the process of creating cybernetic algorithms and software for a DP system. Shortly thereafter, the development started up as the Dynpos project under KV's newly established Oil Division. A year later, the project was still an airy idea. There were sketches, specifications and dreams, but it was lacking a customer and a concrete mission to transform the idea into reality. However, the Stolt-Nielsen management had on several occasions expressed that Honeywell's DP systems were not as expected. They were too expensive, not very user-friendly and not sufficiently robust. Also, spare parts were expensive, and the service was not like they wanted. Could the company be persuaded to change its DP supplier?

In November 1975, a fire broke out at the Alpha platform on the Ekofisk field. There, Stolt-Nielsen was given an opportunity to show what his ships and crew could do. For many hours, "Seaway Falcon" stayed in position only meters from the fire. With the powerful water cannon on the stern deck, large amounts of water were sprayed onto the large platform. For a long time, the fight against the fire seemed hopeless, but after many hours of tireless extinguishing work, the flames finally died out. Since the "Seaway Falcon" had cooled

[4] NOU 2003: 5 "Pionerdykkerne i Nordsjøen".

[5] Interview with Bjørn Bendigtsen, 29.05.2014.

[6] The archive of former KV director Rolf Qvenild: Bjørn Jahnsen: Report from meeting between NTH, CMI, Simrad and KV, 30.09.1974.

the steel with water during the fire, the structure of the metal had not been weakened. The platform was saved, and the owners spared many millions not having to replace the load-bearing structure (Ilner, 2009). The event was widely discussed in the media and actualized the relationship between DP systems and the safety of those who worked in the sector.

On November 22, 1975, not long after the Ekofisk fire was extinguished, the first contract between KV and Stolt-Nielsen Seaway was signed. It was a DP system for the service rig “Seaway Swan”. For the Dynpos project, this did not happen one day too early. When the development project had started in January 1975, the Dynpos people was informed by KV’s CEO Rolf Qvenild that they were protected for six months, but after that he wanted to see a contract. They were therefore running well on overtime. When the contract was put in the safe at KV, it was not only Qvenild that breathed a sigh of relief. The Dynpos project had probably been stranded in 1975 unless KV had achieved this agreement. However, the signing of the contract was only one step on the way to a fully operating system.

6 Forgiveness, rather than permission

The “Seaway Swan” was an H-3 drill rig, a type of rig that many companies bought in the 1970s. These rigs were manufactured by the Norwegian company Aker, exemplifying that Norwegian industry was also a major supplier of equipment for the oil industry. However, after the Arabic oil embargo in 1973, there was overcapacity in the rig market, so in order to get a mission, Stolt-Nielsen Seaway had decided that “Seaway Swan” should be converted into a service, construction and diving-support platform. The rebuilding, which was to take place at the Rauma-Repola yard in Mantyluoto, Finland, also meant that a lot of new equipment had to be installed, including automatically controlled water cannons. Both the water cannon control system and the DP system were to be delivered by KV. Thus, the market leader Honeywell was challenged (Bjørnstad, 2009).

Due to the scale of the project, there were delays in the conversion of the rig. Meanwhile, KV received a new contract for one of Stolt-Nielsen Seaway’s dive-support ships, the “Seaway Eagle”. In the next two years, the Dynpos team solved a number of technical challenges with its new DP technology. The process tied the engineers closer together and when the group became more firmly organized, they took the name “Albatross”, after the bird with the huge wingspan. It is known as a very efficient flyer and can sail on the wind for hours without a single beat of its wings.

The knowledge from DP modeling at NTH/SINTEF was implemented on KV hardware. Simrad also developed a new hydroacoustic position reference (HPR) system. At this time, this represented innovations at the limit of what was technically possible. It was therefore more of a prototype than a finished system that was finally hoisted through a hole in the roof of the “Seaway Eagle”’s wheelhouse. The system, which was called ADP501 (Albatross Dynamic Positioning 501), used a KS500 computer from KV as its “brain”. The KS500 was very advanced for its time and a result of joint efforts from people at NTH and the defence division at KV in order to make a digital computer for the maritime and defence markets that could operate even under the rough conditions onboard a ship at sea.

On May 17, 1977, the installation was formally accepted by the customer. Early in the morning, the captain on the ship set out to open waters not far from Haugesund. On board were representatives from both Simrad and KV. When the skipper stopped the ship, a transducer for the HPR from Simrad was lowered into the water. Then the DP system was turned on, and it worked as it should. Hence, the 17th of May, which is Norway’s national day, became a major event in the development of a fully working Norwegian DP system.

It did not take long before Albatross got a new DP mission to solve. This time it was about a system for the Italian ship “Capalonga.” In December 1976, one of the Albatross managers Thor Skoland heard rumors that Shell and the Italian company SSOS/Talassa in Milan planned to equip a ship for missions with diving and fire-extinguishing services in the North Sea.[7] Another manager, Bjørn Barth Jacobsen, traveled to Italy together with engineer Eldar Mathisen the same day. However, when they came to the company’s office, nobody wanted to meet them. The receptionists communicated zero interest and no need for DP systems. In such a situation, many would have chosen to return home, but in line with manager Barth Jacobsen´s “world domination” doctrine, they followed quite an opposite approach. They therefore sat down at the front desk and were seated until the office closed for the day. The following two days they also came without being allowed to talk to anyone. However, their strategy proved to pay off. On the fourth day, they were invited to a meeting with the management and technical staff. The people were nice, but they were not interested in buying a DP system. However, Barth Jacobsen and Mathisen could be staying for a while if they wanted to.[8]

According to the Italian engineers, the ship had too

[7] Albatross Reference List: 1. Undated.
[8] Interview with Bjørn Barth Jacobsen, 28.08.2012.

little engine capacity for both propulsion and water cannons. They were therefore calculating how much extra turbine power the ship needed. Since Barth Jacobsen and Mathisen not only were sellers, but also engineers, they did not waste their time. They rolled up their sleeves and threw themselves over the calculation tasks. After several rounds of new results, they finally found that six extra turbines should be sufficient. The turbines could be delivered by KV, and maybe they needed a DP system as well? At this point, the hosts had shifted focus and expressed that they would like to buy turbines from KV if the conditions were good, and a DP system might be a good thing anyway?

Although colored by those who experienced it, the history of the "Capalonga" contract points to important aspects of what happened in this early phase. It was about constantly hunting for customers and assignments, with or without the knowledge of the KV management. KV was at this time an important incubator for a number of other projects and products that later became major commercial successes. It happened that the albatrosses sometimes went under the radar of the management. Personal relationships also played an important role in this innovation process. While Barth Jacobsen was a colorful and unorthodox leader who did not always follow the book, Skoland showed great technical knowledge and ability to implement these in the new systems that were sold. Nils Willy Gulhaugen, who was responsible for the economy during the first turbulent years, said about Barth Jacobsen: "He was crazy and broad minded, and completely impossible to frame. I think one of the most important things he contributed with was to make us dare do things. He showed us the possibilities and braveness in business. He talked about seeking forgiveness instead of getting permission." This was an important aspect of the Albatross culture during this period. It was a time to take chances and break rules.

From an initially uncertain position, KV's DP initiative became a success and developed into a well-oiled money machine. This was due to several factors. The DP systems developed along a slightly different track than its major international competitors. The new systems should have a good user interface and be able to withstand the rough conditions in the North Sea. The technology was the basis for this bold attempt to succeed. The KS500 computer was not fantastic, but good enough. More important was the simple user interface and advanced software solutions. With feedforward control and a Kalman filter, the DP functionality was itself an innovation. Although the most sophisticated algorithms proved difficult to implement at first, the rumors about them became an unbeatable selling point. As computers became better, the full implementation came into place.

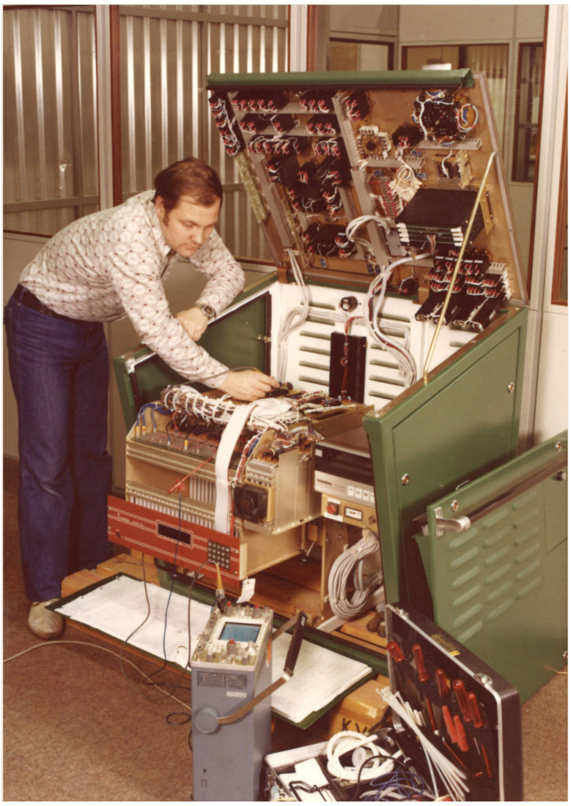
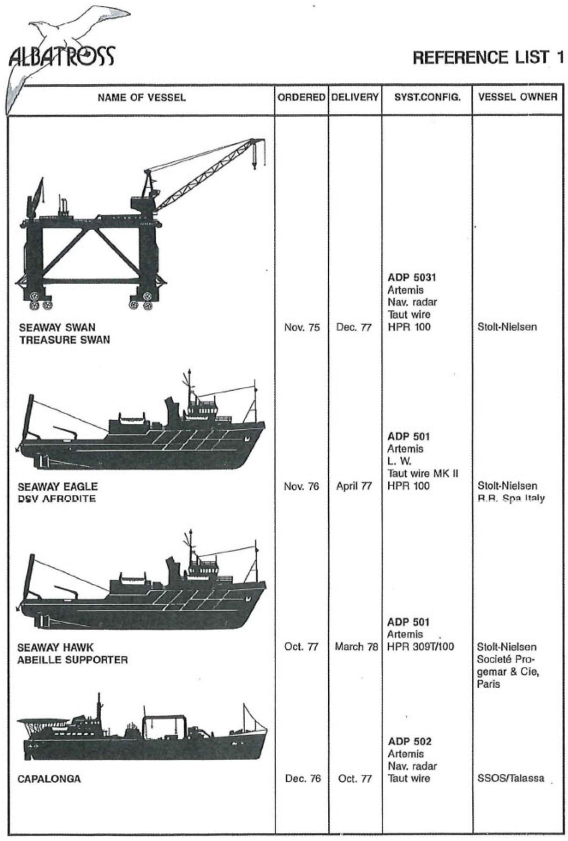


Figure 4: The ADP311 was more compact than the ADP500 series, with all electronics now collected in the console. The photo shows Odd Inge Tangen performing troubleshooting on the KS500 computer. Photo: KM.

Kongsberg Weapons Factory (KV) represented quality, solidity and delivery guarantees. The company had hardware and skilled professionals with experience with machine tools and fire control systems. This was an invaluable basic competence, but Albatross became something more. Those who started the DP initiative came from outside KV. It was Balchen's young, ambitious cyberneticists with a new kind of knowledge, who had been raised to have high ambitions and wager a lot. They also went for forgiveness rather than permission. There was room for making mistakes as long as the contracts were secured, and the customers were satisfied.

The DP systems eventually gained extended functionality. At first, it was about keeping a vessel staying still. Eventually, systems that could handle position mooring and functionality which made it possible to follow a pre-planned path, for example when laying pipes on the seabed. The technology behind the first DP systems was crucial for the bold attempt to compete with the major international companies, but smart technological innovations were insufficient. In order for dynamic positioning to be more than a good idea and an innovation in the market, a larger organization was required that could not only solve technical challenges but also handle everything from marketing and sales to training and customer support. Albatross succeeded well with this. The combination of outstanding technical expertise, a flair for the market and the ability to support its customers was a good recipe for success.

In addition, customers must be willing to pay a price that provides sufficient earnings. The second mainstay in this exciting initiative was precisely the relationship with the customers. When ship owner Jacob Stolt-Nielsen ordered the first DP system, the Dynpos project could really start. With the next contract, the project gained momentum and could continue. However, the success only came when more customers got interested and wanted the same type of DP system. The uncompromising and inventive development community was crucial. Equally important was the “wolf pack” of technologically savvy sellers who never took no for an answer and never yielded in the fight for a new contract. During this period, Albatross created a unique relationship with its customers, which has been very important not only for sales but also to be able to develop systems that the customers and the market wanted.


ALBATROSS

REFERENCE LIST 1

NAME OF VESSEL	ORDERED	DELIVERY	SYST.CONFIG.	VESSEL OWNER
SEAWAY SWAN TREASURE SWAN	Nov. 75	Dec. 77	ADP 5031 Artemis Nav. radar Taut wire HPR 100	Stolt-Nielsen
SEAWAY EAGLE DSV AFRODITE	Nov. 76	April 77	ADP 501 Artemis L. W. Taut wire MK II HPR 100	Stolt-Nielsen R.R. Spa Italy
SEAWAY HAWK ABEILLE SUPPORTER	Oct. 77	March 78	ADP 501 Artemis HPR 309T/100	Stolt-Nielsen Societé Progemar & Cie, Paris
CAPALONGA	Dec. 76	Oct. 77	ADP 502 Artemis Nav. radar Taut wire	SSOS/Talassa

Figure 5: The first page in Albatross’ reference list from 1984, showing all ships that the company had delivered equipment to up to that point. Details about delivery dates, company names and the type of DP system were also included. Illustration: KM.

7 Theory Albatross

When KV received its first order in 1975, Honeywell dominated the world market. However, in the year 1980, Albatross in fact secured all of the orders for DP systems worldwide, thereby taking over the leadership position. By the end of this year, over half of the installed DP systems in the world were an Albatross DP. This was a remarkable achievement after just five years in the market.[9] The Albatross pioneers were an untraditional and hard-working group with a strong esprit de corps and an almost extreme customer orientation.

It was in many ways a very homogenous group. A significant proportion were engineers, and most of them were men.[10] The average age was not much over 30 years. This applied to all parts of the organization. The director was 30 years old in 1981. The CFO was three years younger, while the sales manager was four years older.[11] The business culture could be confused with what they were used to from the student life, where the boundaries between work, leisure and partying were not always sharp. In many ways, they were rebels within the KV system. Since Albatross earned good money, they were exempt from strong involvement by the KV management.[12]

In 1980, the Albatross group consisted of just over 60 people. The following year, the staff increased by another 14 people, and then the growth exploded. By the end of 1982, 135 people were intensively developing, selling and building DP systems branded Albatross. [13] The rapid increase in the number of employees meant that many had to be properly educated and socialized into the Albatross culture. As already mentioned, the group’s success was not only due to good technical so-

[9] “The Kongsberg Group: Experts on Dynamic positioning. The group has delivered 42 of the 80 modern DP systems in use today”, in Scandinavian Oil-Gas Magazine no. 7/8, 1981: 70–71.

[10] Albatross board meeting documents 1986: Prospect. Report in relation with sales of stock and capital increase.

[11] Who’s who and where in Albatross. Undated, 1983.

[12] Interview with Bjørn Barth Jacobsen, 27.08.2012, Nils Willy Gulhaugen, 18.09.2012, Rolf Qvenild, 18.09.2012 and Svein Thorsen, 13.02.2014.

[13] Kongsberg Albatross A/S: “Prosjektundersøkelse mennesker i utvikling”, PM, undated, possibly 1987. Figure 1.3.1.

lutions. Much also lay in the culture, and especially in how the company related to its customers. It was important to take care of and further develop this culture. In order to do this, there was a need for a more systematic culture building. With the strong growth, the need for a more structured organization also rose. It was about maturing and a need for order and seriousness, not about streamlining and adapting to the rest of KV. The group had succeeded very well in a short period of time, and the Albatross leadership realized that it had to take care of the values that brought it wherever it was; energy, simplicity, pace and creativity.

The special Albatross culture, with a clear anarchistic touch, with great freedom for the individual and an extreme customer orientation, proved to be a good recipe for success. In the early 1980s, this culture was further refined and renamed through "Theory Albatross".

In 1982, "Theory of Albatross" was presented to the staff through a small red leaflet[14], see Figure 6. Here, the group's visions and values were presented to employees through simple line drawings and short slogan postulates such as: "We help people improve their position" and "We live for, together with and by our customers." The essence of the "Little Red" was strong customer orientation and great personal responsibility with loyalty to common goals.

The slightly anarchistic attitude at the relatively small Albatross differed from the more traditional and stout culture of the large KV. The contrasts could occasionally be perceived as big. The albatrosses perceived themselves as special and were likewise considered by many of their KV colleagues as such. KV was however not only stout. Its management could also be brave. The company had large and heavy divisions, but at the same time there was room for small Albatross, which was allowed to experiment. In this way, KV was a good nest to grow up in. However, it required some "guerrilla tactics" from the albatrosses. They more often requested forgiveness than permission.[15]

Albatross had a market understanding and a sales organization that not only KV, but many companies, could envy them. As in KV, most Albatross employees were engineers. Nevertheless, several people have pointed at Albatross as being more economically driven than KV, which has been described as distinctly technologically driven.[16] It is believed that Albatross oriented itself more to the opportunities in the market, while KV was more concerned with developing new technology. KV was criticized for lacking enough attention to the market and profitability aspects, and

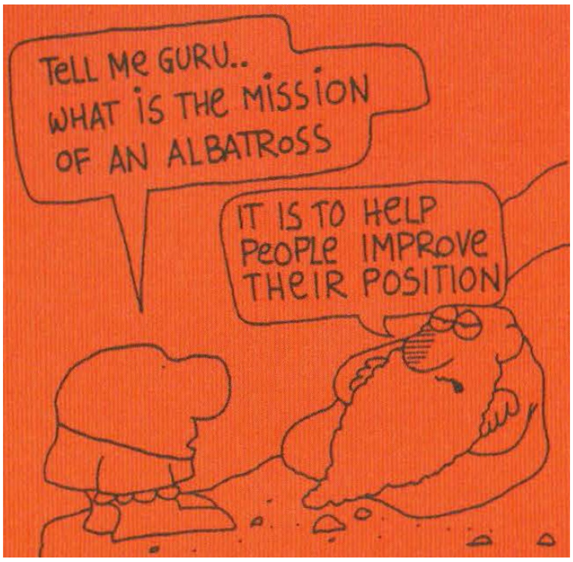


Figure 6: Excerpt from a small leaflet explaining the "Theory Albatross" culture, inspired by the comic figure "Ziggy" by Tom Wilson. Illustration: KM.

for a lack of international business and marketing expertise.[17] The same could not be said about Albatross. Metaphorically speaking, Albatross never shot the bear before the skin was sold, while KV did the opposite. Steinar Sælid, who was one of the pioneers, afterwards described the Albatross culture as follows (Sælid, 1999):

"Albatross in the 80s was a creative community, with director Nils Willy Gulhaugen in the lead. The community was very self-conscious in a positive sense. It was not a single thing you could not achieve. Often, we operated in slight conflict with the KV management. (...) Albatross also had a unique touch for marketing and sales. It was a pack of smiling wolves with Svein Thorsen in the lead. It could be stressful for a developer when one of the super sellers came home with tens of millions in sales contracts of unfinished products. (...) The Albatross community had the money, boldness and will to take initiatives, technical knowledge, skilled marketers, unlimited self-esteem and a portion of madness."

The strength of Albatross was in the combination of good technical solutions and intense sales work, and both required strong customer orientation. Without the one, the other would not have been possible. The Kalman filter was a technical solution Albatross was alone to have. However, someone needed to convince customers that such a filter was necessary and made the Albatross systems better than the DP systems from

[14] Albatross: "Lederutvikling 82–83", PM.
[15] Interview with Rolf Qvenild, 18.09.2012.
[16] Interview with Rolf Qvenild, 18.09.2012 and Svein Thorsen, 13.02.2014.
[17] NOU 1989: 2 Kongsberg Våpenfabrikk.

their competitors. Albatross had sellers who managed this. They managed not only to offer machines with different technical specifications, but also to sell something that is not easily described with words, numbers or figures. They sold safety and trust, and something undefined with a touch of magic - and it was in the Kalman filter that the magic lay. Therefore, the filter was not only important to keep the customers' vessels in position. It became equally important for Albatross' position.

8 New Times

When Albatross celebrated its tenth anniversary in 1985, it was as an independent company under KV, and the prospects for the future seemed bright. The DP systems sold well and the number of installations had increased for each year. So did the profit. A lot of new technology was also forthcoming.

However, a significant drop in the oil price meant that a good period of steady growth was replaced by meagre times of failed sales and red numbers. The problems did not improve when KV experienced financial difficulties and became technically bankrupt in late 1986. In the spring of 1987, the ties to KV were completely cut and Albatross was sold to Simrad Subsea in Horten. The red numbers disappeared quickly, but it was not until 1990 that the company could again deliver an annual result with a two-digit number of millions of NOK (Sælid, 1999). Albatross had recovered from the recession, and again became the money machine the company had once been. Still, not everything was as it had been.

The changes after the acquisition appeared in several more ways than the name change to Simrad Albatross. The Simrad culture was also beginning to form the way the albatrosses thought. The time for a bold attitude towards costs and loose financial management was over.[18] Something had happened to the Albatross culture. What had been an untraditional and slightly anarchistic group was becoming a disciplined and streamlined organization. Now it was more common to ask for permission than for forgiveness. A far tighter regime had been established with a focus on keeping costs down. Through more sober spending of money, technology development and more efficient production and testing of the systems, Albatross managed to keep the profit margins up even though the price of DP systems went down. Also, the technology was more streamlined, not only through a more elegant design, but also with a new ADP700 series that included systems for three levels of redundancy.

[18]Interview with Roy Larsen, 14.02.2014.

9 A Technological Generational Change - ADP703

In 1985, Albatross decided to launch a project to develop a new DP generation. Early in the 1980s, Sverre Corneliussen had stayed at Carnegie Mellon University in Pittsburgh. There he had gained useful knowledge of, among other things, the system used in NASA's space shuttles. NASA not only used redundancy by duplication, as was common in DP systems. Five independent computers were set to work in parallel. To select the control signal that was most correct, so-called majority voting was used. The redundancy concept originally developed by NASA was called SIFT (Software Implemented Fault Tolerance). This solution inspired the redundancy concept that Albatross based its new system on, called Triple Modular Redundancy (TMR).[19]

The Albatross TMR hardware solution was based on eight SBC1000 (Single Board Computer) computers coupled with a redundant Ethernet local area network. There were two clusters of three computers each, one for the estimator and controller software and one for the thruster allocation module. In addition, there was a cluster of two SBC1000s for the human-machine-interface software. The results of the calculations were compared, and the majority, or the machine that gave the median value, got to decide.[20] This principle was also used to find and weed out errors in the reference systems and sensors, and represented a small revolution in the DP software.[21]

The ADP703 was triple redundant, and as such a very robust system. It also had what was called “hot repair”, which meant that it was possible to replace one component while the system was still running. This helped to increase safety and availability. As a curiosity, it can be said that a “coming of age” was introduced for when a new computer could participate in the voting. The machine had to accumulate experience in terms of integrated values and time series in order for the outcome of the majority voting to be as correct as possible.[22]

In addition to implementing the redundancy principles and the majority voting principles, the complete control software, including the estimator, controller, thruster allocation and measurement handling modules

[19]Interview with Roy Larsen, 14.02.2014.

[20]Thor Hukkelås: “Om Redundans, ADP 703 og troen på flertallets diktatur”. Undated PM, 2013 and interview with Nils Albert Jenssen, 14.02.2014.

[21]Kongsberg Albatross: “ADP 703 Voting”. Undated PM, 1987.

[22]Thor Hukkelås: “Om Redundans, ADP 703 og troen på flertallets diktatur”. Undated PM, 2013 and Thor Hukkelås: Conference presentation, DP history seminar, Kongsberg, 07.05.2013.

were re-structured and re-written in the C programming language. Every DP system consists of a set of standard SW modules that are the same for every delivery and a set of customer-specific adaptations. A completely new system for SW production was developed and used for a large number of deliveries.

In 1983, Albatross had launched the ADP100 console. Compared to its predecessors, it was cheaper and had a simpler layout. It was the first Albatross DP system with their own-made computer, the aforementioned SBC1000. ADP100 was designed with a more user-friendly interface than the first models. As with the design of the ADP100 console, Albatross also used professional designers this time. The result was not only a purposeful design, but also received a design price. In 1987, the Norwegian Design Council awarded the "Good Design Award" to ADP703 in the "Industrial Design" class. The company had used the British-born designer John R. Houghton and his Norwegian design company Anglo Nordic Design. In the jury's evaluation, it was emphasized that ergonomic considerations were "very well taken care of by this thorough concept".[23]

In February 1986, the first two ADP703 systems were sold to the Dutch shipping company Smit Tak. The semi-submersible rigs "Semi 1" and "Semi 2" were both equipped with ADP703 with an HPR from Simrad and two taut-wire position reference systems.[24] There was a drive-off situation for Semi 1 during the summer of 1987, where one of the SBCs in the Thruster Allocation triade had stopped listing to the two others, but still continued "talking", i.e., still sent out commands to the thruster that were different than the two other SBCs. According to the software job leader Thor Hukkelås, the concept of "senile" computers was then introduced, and software was written to detect and handle similar situations in the future.

In addition, Albatross launched a new AIM (Albatross Integrated Multifunction) system that opened new market opportunities. The oil companies had begun to demand systems that could also handle the increasing automation complexity on board. Hence, the customers were no longer just shipowners. Now there were also oil companies on the customer list. The AIM multifunction system became a very valuable contribution to the product portfolio, but its significance did not stop with this. The complexity of the installations and the enormous need for computing power meant that AIM became an engine for the development of new hardware, especially the in-house developed SBC computer.[25] This also had consequences for the DP systems.

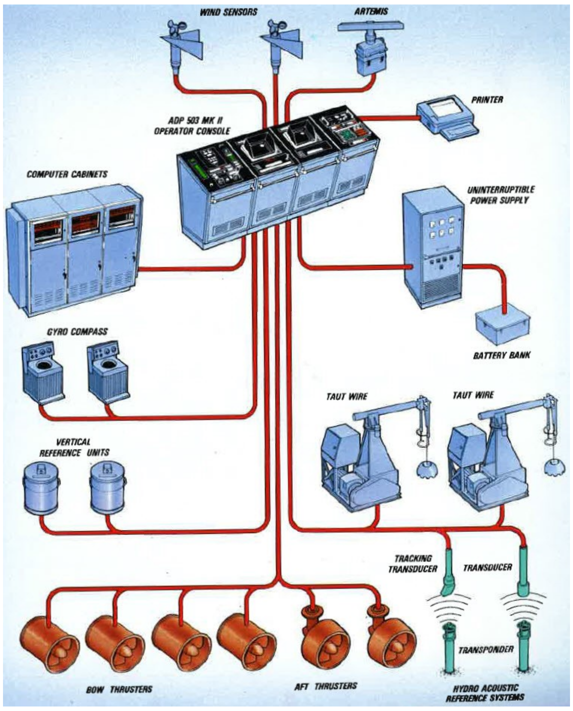


Figure 7: The ADP configuration for the diving support vessel Wilchief. Illustration: KM.

After KV became technically bankrupt in 1987, the Norwegian government sold out all civilian activities, and established a new company under the name Norwegian Defense Technology (Norsk Forsvarsteknologi, NFT) on the remains of the old state-owned KV. The new company should initially continue the military-related business, but at the end of the Cold War, it began to orient itself to other business areas. Early in the 1990s, both Simrad and NFT had ambitions to become the leading Norwegian maritime technology company. Both pursued this strategy by expanding the business through acquisitions of other companies. Simrad was by far the biggest and strongest of these two. In May 1995, what would become a drama in two acts started, ending with Simrad being acquired by the competitor from Kongsberg the following year.[26] NFT subsequently changed its name to the Kongsberg Group (Kongsberg Gruppen, KOG). The name change was partly due to the fact that the business was expanding beyond the defense-technological focus and was therefore no longer adequate for what the company did. Another important factor was that the company wanted

[23] Norsk designråd. Merket for god design, industridesign. "Posisjonering- og kontrollsystem ADP 703".

[24] Simrad: Reference list Positioning & Control Systems. Issue 20: 39 and Simrad Albatross: Positioning and Control Systems 1988: 74–75.

[25] Ingolv Olsen: "HW benyttet i DP/AIM-systemer". Undated PM, 2013 and Ingolv Olsen: Conference presentation, DP history seminar, Kongsberg, 07.05.2013.

[26] "Kongsberg tar over Simrad" i Aftenposten, 13.05.1996.

to achieve increased recognition by using the Kongsberg name and KV's old crown logo in the profiling of its products. By taking back the name and logo, the company tied the threads back to the industry and technology business that had been run on the banks of the Numedalslågen river since 1814.[27]

For those who had their daily work connected to the DP business, and especially for those who had been employed since the Albatross era, the acquisition was considered as a "homecoming".[28] The DP business was once again part of a state-owned company based in Kongsberg. When the company used the old KV logo, in a slightly modernized edition, it symbolized continuity.

The new company was operational from New Year 1997 under the name of Kongsberg Maritime (KM), being the maritime part of KOG. KOG had thus become a group with two strong main business areas. The second area was the defense activity of Kongsberg Defense & Aerospace AS.[29] Kongsberg Maritime AS was established as a wholly-owned subsidiary under the corporate management, with four divisions. For the day-to-day business, the change of ownership did not mean much. Most of the time, it continued as before. What once was the Albatross community was still located at the premises at a remote location in Kongsberg called Industritunet. The management was also located here, although the official company address was still in Horten. However, the Albatross name now got lost along the road. The systems, which were previously sold with the blue Simrad wave, could now be crowned with a large K and a royal headdress.

10 From tailor made to commodity

In May 1994, the IMO adopted the "Guidelines for Vessels with Dynamic Positioning Systems" (IMO, 1994). Initially, four so-called consequence classes were designed, which spanned from the completely consequence-less to the catastrophic. In this IMO standard, the four classes were reduced to three, and the consequence classes were changed to equipment classes. The larger the consequence of a position loss, the greater the requirements for the DP system's reliability. Equipment classes were defined based on their worst-case failure modes, i.e. the single fault which would give the greatest consequence. The three classes DP1, DP2 and DP3 had the following specifications:

- Class 1 equipment (DP1) has no redundancy. Loss of position can occur in case of a single error.
- Class 2 equipment (DP2) has redundancy such that no single fault in an active component will cause the system to fail. Loss of position should not occur from a single fault in an active component or system such as generators, thrusters, switchboards, remote-controlled valves, etc., but may occur after failure of a static component such as cables, pipes, manual valves, etc.
- Class 3 equipment (DP3) should also withstand fire or flooding in a zone without the system failing. Loss of position should not occur from any single fault, including a completely burned-out fire zone, or a flooded waterproof bulkhead.

The IMO rules meant that Class 2 equipment had to have redundancy in all active components, including the DP control system. The components of a Class 3 system also had to have a DP control system that was physically separated from the main system. The vessel also had to be equipped with two engine room shields that could withstand smoke and open fire for one hour without the temperature exceeding 180 °C.

While the old class requirements had mostly concerned only the control system, redundancy was now required everywhere. This meant a strengthening of safety, but also contributed to a significant increase in costs. With this, the DP systems became more closely embedded with the vessel's propulsion system, and the classes thus gave a better picture of the level of safety a DP vessel could operate under. IMO equipment classes became a standard that class companies quickly adapted to by developing new classes and requirements for dynamically positioned vessels. For example, DNV's response to IMO's new equipment classes 1, 2 and 3 came in the form of DYNPOS-AUT, DYNPOS-AUTR, DYNPOS-AUTRO, respectively.[30]

The IMO standard clarified and expanded the understanding of what a DP system encompasses. In the past, it was common to use the term about the control system. Now, also the units that the control system interacts with were included in the definition. This meant that a DP system should be understood as a system consisting of the following three main elements as previously described; the power system (usually diesel engines, generators and electrical power distribution), the thruster system and the DP control system including position reference systems and sensors. However, in the daily tongue it was still common to use the term DP system for the DP control system.

[27] Kongsberg Gruppen: Årsrapport 1995: 6 and Kongsberg Gruppen: Årsrapport 1996: 14, 34.

[28] Interview with Nils Albert Jenssen and Rolf Arne Klepaker, 26.06.2013.

[29] Kongsberg Gruppen: Årsrapport 1997: 2–3, 15 and 32.

[30] DNV: Rules for classification of ships. Newbuildings. Special equipment and systems. Additional class. Part 6, chapter 7. Dynamic positioning systems, January 2004: 5.

The IMO introduced the concept of equipment class, but said nothing about which classes were required under which conditions. It was left to the vessel owners, operators or national authorities to evaluate this. However, oil companies preferred the highest standard. They wanted to minimize the risk of losing money and reputation, and preferred standards that could simplify their orders. On the Norwegian continental shelf, this was further pressed by requirements from the authorities.

The Norwegian Maritime Directorate's regulations regulated the equipment classes to be used in different situations and were based on the consequences of loss of position. Class 1 equipment should be used in operations where the loss of position could cause harm or pollution with minimal consequences (Røkeberg, 1997). Class 2 equipment should be used in operations where loss of position could cause injury, pollution or damage with major financial consequences, while Class 3 equipment was required in operations where loss of position could lead to fatalities, serious pollution or damage with major economic consequences.

The Norwegian Maritime Directorate did not compile a detailed requirement specification for different operations on the Norwegian continental shelf, but was aware that Class 3 equipment had to be used for drilling operations and handling of oil wells (Røkeberg, 1997). This meant that many shipowners equipped their vessels with Class 3 equipment in order to be able to compete for contracts in the North Sea. The requirements for DP systems were also affected by the NORSOK standards.[31] These were the result of a cooperation between the players in the oil industry, Norwegian industry and the authorities in order to reduce the completion time and costs of building and operating petroleum installations on the Norwegian continental shelf. The new industry standards replaced most of the internal specifications with the oil companies operating on the Norwegian continental shelf and several parts of the Norwegian Petroleum Directorate's regulations. They also contributed to the standardization of the oil companies' requirements for DP systems.[32]

11 Deeper and higher

Sales of DP systems must be seen in conjunction with developments in the petroleum sector. The North Sea was for a long time the dominant focus area, but the KM business also grew in other areas, especially in the Gulf of Mexico. The sea outside of Brazil was another

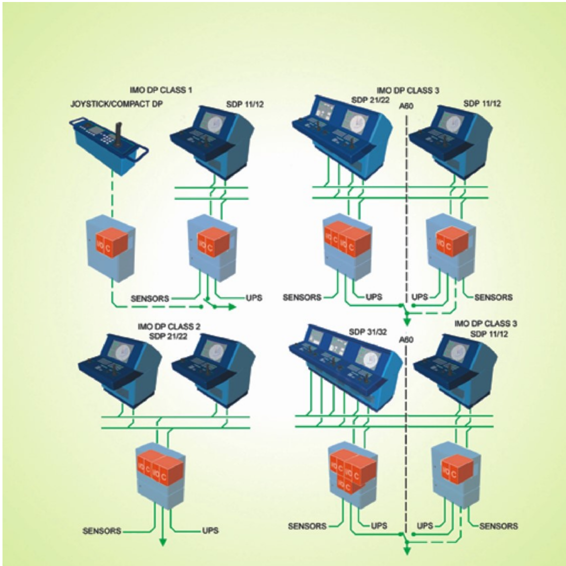


Figure 8: Various configurations of Simrad DP (SDP) systems required to satisfy the demands of different DP classes according to IMO regulations. Illustration: KM.

area of great potential. In 1996, a new service station was established in Rio de Janeiro.[33] Existing stations were found in Aberdeen, Houston, Singapore and Halifax. The company was thus established in all the most important offshore centers in the world.[34]

In the mid-1990s, the oil and gas industry moved to increasingly large ocean depths. When Albatross was established in the mid-1970s, it was often talked about drilling operations down to 100 meters depth. Twenty years later, the oil companies operated at 2000 meters, and it was expected that it would soon be drilled down to 3000 meters. The activity was also moved to other geographic areas. The period of major field developments in the North Sea seemed to be over. Towards the end of the 1990s, the activity on the Norwegian continental shelf was slowing down, while it was more stable in the waters of West Africa, Brazil and the Gulf of Mexico.[35] The oil companies therefore increasingly focused on simple and flexible solutions. With increasing depth, it was rapidly becoming impossible to place platforms on the seabed, and as the depth increased further, in practice it was also impossible to anchor platforms or ships with chains or ropes. The large ocean depths posed new and larger requirements to vessels operating on DP. The biggest challenge was to get good enough position references.

Simrad's HPR system had been a core component of

[31] NORSOK is an abbreviation for Norsk sokkels konkurranseposisjon (Norwegian shelf's competitive position).

[32] Nils Gundersen: "Norsok". Store norske leksikon. https://snl.no/Norsok (17.09.2014).

[33] Kongsberg Gruppen: Årsrapport 1997: 34.

[34] Kongsberg Gruppen: Årsrapport 1996: 44.

[35] Kongsberg Gruppen: Årsrapport 1999: 42.

Albatross' DP systems from the start. Both "Seaway Eagle" and "Seaway Swan" were equipped with the HPR100 product. This system was further developed and in the mid-1990s, the HPR400 family, with LBL and SSBL variants, was used[36], see Figure 9. With Simrad's acquisition of Albatross, DP and HPR activities became more closely aligned. When Simrad Albatross and Simrad Subsea were merged with Simrad Norge AS in 1995, the development of DP and HPR systems was coordinated under the same leadership. Kongsberg's subsequent acquisition did not change this.

The development had for a long time been in the direction of better precision in depth. In the 1990s, it also went to greater accuracy in height. The starting point for what is currently known as GPS was developed by the American military in the 1970s and 1980s. The positioning system, initially called Navstar, is a network that requires 24 satellites orbiting the Earth to provide global coverage. The first satellite was launched in 1978, but it would take 16 years before the system was operational with full satellite coverage.

Today, GPS makes it possible to determine a global position with a very high accuracy. However, this was not the situation at the beginning. Then the system was not particularly suitable for DP applications due to a low number of satellites. Dynamic positioning needs reference systems with continuous coverage, 24 hours a day, seven days a week. However, day-to-day coverage was possible before the GPS system was fully developed, but since it was developed for military use, restrictions on the accuracy of civilian use, so-called selective availability, were imposed. This reduced the precision by the order of tens of meters. However, the availability of satellite signals, and differential corrections by comparison with the location of known terrestrial points, GPS started to become useful as a reference system for DP from the mid-1990s. Using the satellite signals alone, it was only possible to achieve an accuracy of 40-50 meters, but by means of correction signals from land-based reference stations, known as DGPS (Differential GPS), the accuracy could be improved ten times or more.[37] Thus, the system could also be used for DP systems. By orienting both down to the seabed and upwards to the satellites, and combining hydro-acoustic systems with GPS, Kongsberg Simrad could achieve a very accurate position reference for its DP systems, with error margins of less than one meter.[38]

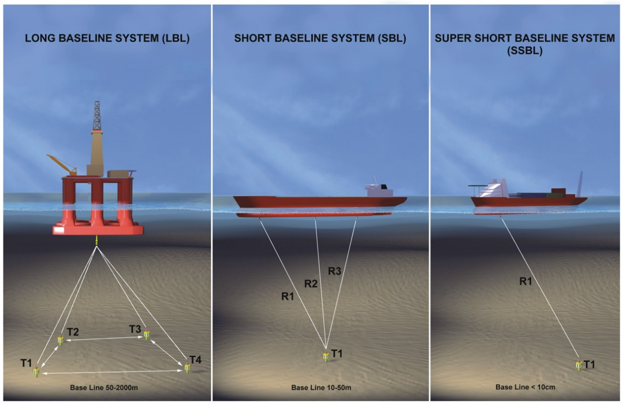


Figure 9: The acoustic positioning principles that have been used. LBL has advantages in very deep water, since its accuracy is independent of water depth. Illustration: KM.

In addition to improving HPR systems, the Simrad engineers in Horten also developed a new type of positioning system. In 1995, the HiPAP system was launched. The name, which Simrad got protected as a trademark, is an acronym for High Precision Acoustic Positioning System. Although this was a more advanced system than the HPRs, it was easier to operate. Since the system was based on the SSBL principle, only one transducer was needed under the vessel hull and one transponder on the seabed. An LBL system would have needed more transponders on the bottom, while an SBL facility would have required more transducers under the vessel.[39] With its distinctive signal-red, submersible ball of 241 transmitters and receivers, the system could measure in the entire water volume, thus giving a picture of what was under the vessel in three dimensions.

Basically, HiPAP was specified with a range of 2000 meters, but tests showed that it could operate well within a 2500-meter radius. With more powerful transponders, the limit could be stretched up to 3500 meters. This high-definition system provided very accurate measurements that were three to five times more precise than the most powerful HPR system.[40]

While the industry experienced concentration, DP technology went against integration. The oil and off-

[36] Kongsberg Simrad: Offshore and Ocean Survey products, February 1998: UI8. See also: Rolf Arne Klepaker. "Hydroakustisk Posisjonsreferanse System (HPR). Teknisk historie, per 22. oktober 2013", PM.

[37] Simrad: Albatross. Positioning and Control Systems 1990: 30–37.

[38] "Kunsten å ligge i ro", interview with Trygve Myrland og Ole Gunnar Hvamb in Cicerone, February 2002: 14.

[39] "Kunsten å ligge i ro", interview with Trygve Myrland og Ole Gunnar Hvamb in Cicerone, February 2002: 14.

[40] Lars Ove Strat and Jan Erik Faugstadmo: "Stabile og nøyaktige målinger med HiPAP" in Pinget, no. 1 1997: 4–5, Kongsberg Simrad: Offshore and Ocean Survey products, February 1998: UI10–11 and interview with Karstein Vestgård and Rolf Arne Klepaker, 17.09.2012.

shore industry had increasingly begun to request integrated systems. In 1994, the work thus began to develop the fourth DP generation. The system's user interface appeared as outdated and inflexible compared to its competitors. If Simrad were to maintain its leading market position, it was necessary to develop a user interface based on modern window-based graphics. The development community had good experience with Unix. Many other companies had already invested in this platform, but was it sufficiently forward-looking? The Windows 3.1 operating system, which was the closest option, was unsuitable to handle the tasks a required by a DP system. However, Microsoft had recently released an NT version for the corporate market which looked promising.[41] The new DP generation was launched in April 1996 as Simrad Dynamic Positioning (SDP), and included the SDP01, 11, 12, 21, 22, 31 and 32 systems. The first digit (0/1/2/3) represented "compact single", "single", "dual redundant" and "triple redundant", while the second digit (1/2) indicated whether it was a standalone or integrated DP system.

The new DP generation was designed for easy integration with other systems on board. The DP systems could also be combined with anchoring functions through SPM (Simrad Position Mooring), which was an improved version of the old Albatross position mooring system. In addition, a new thruster control system (Simrad Thruster Control, STC) was developed. The "premium" DP in the portfolio was the SVC (Simrad Vessel Control), which was a distributed automation and monitoring system based on the AIM technology. In SVC, DP and other Simrad systems, such as mooring and thruster control, could be integrated and operated through a common user interface. It did not take long before the first systems were sold. In January 1996, the partly Norwegian-owned cruise shipowner Royal Caribbean Cruise Lines ordered two SDP11 plants to be installed on board the "Rhapsody of the Seas" and "Vision of the Seas" in August of the following year.[42] In the annual report for 1996, it was noted that the product renewal seemed to "do well in the market".[43] The SDP series became a major sales success. The last plant was installed in 2007.

The AIM system was a solid platform for the company, and with the new SDP family, it also had a technology that was both flexible and that accommodated new class specifications and the customers' desire for integration on board. The IMO 1994 regulatory framework established a standard for what a DP system should be, and soon became an important premise for both class companies, government and customer requirements. This had a stabilizing effect on the DP technology. The new IMO standard's high redundancy requirements also meant that DP systems were not going to disappear into major automation systems, but remained an independent technology which was instead integrated with other systems on board.

Oil activities moved increasingly further away from land to deeper waters. This posed new requirements for the DP system, primarily for the position reference systems. Through the so-called Deep Water Project starting in 1995, the company developed new knowledge and technology that enabled vessels to be positioned using signals from both great depths and high altitudes by using HiPAP and GPS. The development of dynamic positioning had started with a goal of staying still, and also further developed into performing various marine operations. An innovation called "GreenDP" emerged in 2001, which was a new DP functionality that made it possible to stay within a given operations area with as low energy consumption as possible.

12 From Kongsberg to Copacabana

In the summer of 2010, Torfinn Kildal resigned as CEO of KM after having been part of the Albatross adventure since the 1980s.[44] He was replaced by Geir Håøy, who had led KM's global customer support in Singapore and South Korea. Håøy's experience from Asia was no disadvantage for a leader who would be in front of KM during this period. During the time Kildal had led KM, from 1999 to 2010, it had developed from being a national unit in KOG with great international success, to become a globally oriented unit where both the number of tasks and the number of employees abroad had increased rapidly. In 2010, there were 3100 employees in Kongsberg Maritime, of which a total of 1400 worked outside of Norway. Offices abroad and subsidiaries accounted for much of the value creation.

While "tearing down the pyramids" had been a keyword for many businesses in the 1980s, it was visible and strong brands that became important to many international companies after 1990. Businesses that wanted success had to appear credible and with a clear and consistent link between products, business and profile towards its customers. In 2000, the profiling of the Kongsberg Group (KOG, also denoted KONGSBERG) started, which at this time consisted of two units; Kongsberg Maritime and Kongsberg Defense & Aerospace. The processes that followed were interesting. However, the KONGSBERG brand was already clear and credible. Because a brand is not created by

[41] Amund Tinderholt: "De første årene". Undated PM, 2013.
[42] Simrad: Reference list Positioning & Control Systems. Issue 21: 14.
[43] Kongsberg Gruppen: Årsrapport 1996: 15.
[44] "Kildal slutter i Kongsberg Maritime" i Dagens Næringsliv, 03.07.2010.

itself or once and for all, any internal frictions were reason enough to be on guard, and an argument for continuing the consolidation process. Together with the employees, the KM and KOG managements developed the strategies that the group were to build on.

The North Sea was for a long time the most important market for Albatross. In 1985, as much as two thirds of its activities were related to the petroleum activities in the North Sea. The company established itself early in 1982 with the first office in Aberdeen. In the United States, the DP-related activity started in 1984 in the oil city of Houston. After 1990, the balance of activities in the North Sea and abroad changed sharply. The new Simrad Albatross gained significant impact in the US market and delivered an increasing number of DP systems to rigs and vessels operating in the Gulf of Mexico. The first offices in Asia came in Singapore in 1981. After 1990, Asian yards became world-dominant in the construction of ships and rigs. At the same time as increasingly larger parts of the newbuilding took place there, the oil companies shifted their exploration and production businesses to new areas.

It was no longer only in the North Sea and the shallow parts of the Gulf of Mexico that exploration and production fields for oil and gas were established. Also in the sea beyond Brazil and along the coast of West Africa, sales, production and services were organized in new ways. Service happened where the operations happened, sales where the shipyards that were building and equipping the vessels were located, and both sales and service where the shipowners had their headquarters. A potential project in Singapore could have a Brazilian owner, an American consultant, a Norwegian operator, while the yard was located in Singapore. This fractioning meant that Kongsberg Maritime's activities had to be coordinated and managed differently than before. A common identity and brand building went hand in hand with the homogenization of values and strategies.

In 2009, the spectacular K-Master was launched. It was a further development of Kongsberg Maritime's solutions for the stern bridge on anchor handling and supply ships, located in and around one or two operator chairs. The installation was an optimized system that had almost all functions for the ship's bridge, automation and DP control integrated in the chairs. A basic idea of the "chair" was the so-called 80-20 principle, based on the fact that 20 percent of the functions were used 80 percent of the time.[45] This laid the foundation for a very distinctive piece of furniture, tailored to satisfy general ergonomic requirements as well as new bridge design requirements. Thus, the K-Master got a unique "look" that created expectations for the user experience of the product. The next challenge was to meet these expectations by developing a simplified user interface that included all of the subsystems.

Figure 10: Through the years, DP operator stations have changed significantly, being adapted for different vessel types. Illustration: KM.

The choice fell on a concept called the "split interaction principle", where touch-sensitive screens mounted on the armrests offered simplified user panels, and where operation-related information could be observed on larger screens located in front of the chair. This concept was chosen because the task of operating menus or inserting numbers on screens located a few meters away from the operator in heavy seas is impossible, thus delegating the workload such that the operator interacts via the touch screens while information is received on the larger screens. In 2010, Kongsberg Maritime, together with the company Hareide Design, was awarded the "Good Design Award" for the K-Master.[46] Thus, Kongsberg Maritime would consolidate its position as a supplier of sophisticated systems in the upper parts of the market.

[45] "Fra informasjonsflom til oversikt" in Teknisk Ukeblad, 14.04.2011: 55.

[46] "Maritime Design Day" in K-Magazine, 01.02.2012: 23.

When K-Master was presented for the first time, it was done under the designation "Integrated reality". The term says something about how automation, monitoring, DP and navigation systems were linked together, but also how the company's activities in the global world were tied together to meet the challenges of the future. Finally, it indicated that KM was aiming for the future and participated in the creation of this future's business community.

13 More than 40 years, and solidly positioned

What was initially called Albatross dynamic positioning system was formed in the span between new research ideas, modern high-tech industrial visions and old maritime traditions, and was birthed by the opportunities that opened up when oil was found in the North Sea on the day before Christmas Eve in 1969. Nevertheless, it was not given that it would be possible for a state-owned company in a small Norwegian inland town to establish itself in this market, and in any case not to dominate it.

Today, most offshore operations are dependent on dynamic positioning. Just as it is almost impossible to imagine modern oil and gas production at sea without DP functionality, it is hard to imagine the development of DP systems without petroleum activities. There are also many other factors that have had an impact on the technology development in one way or another, but no other has had nearly as much importance. The extent of the activity, where it has taken place and how the oil and gas have been extracted and transported to land, have made strong impacts on how the DP systems have been formed and changed.

Even though external framework conditions and developments have been of great importance, it is not those that have created the DP systems. Technology is not created by framework conditions, but by initiatives and efforts from entrepreneurial personalities. The Kongsberg DP system has been made possible by all the individuals who in various ways have contributed with their skills and experience to take advantage of the chances that have emerged. They have created something where others did not see opportunities. Without them, the first Albatross system or its many successors would not have existed.

It is admirable enough in itself that the DP pioneers managed to develop an advanced dynamic positioning system. What is more impressive is that they succeeded in establishing a company that soon became a market leader and subsequently managed to hold this position. This not only requires solid technology, as well as the will and ability to develop and improve it over time, but also that the company manages to pick up signals from its customers and has the power to position itself in the market by setting a standard for what such a system should be able to do and what the customers should expect.

It all started with someone who decided to master the art of maintaining position. This apparently simple goal has grown to what is today the Kongsberg DP.

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References

Balchen, J. G., Jenssen, N. A., Mathisen, E., and Sælid, S. A dynamic positioning system based on Kalman filtering and optimal control. *Modeling, Identification and Control*, 1980. 1(3):135–163. doi:10.4173/mic.1980.3.1.

Balchen, J. G., Jenssen, N. A., and Sælid, S. Dynamic positioning using Kalman filtering and optimal control theory. In *Proceedings of the IFAC/IFIP Symposium on Automation in Offshore Oilfield Operations, Bergen, Norway.* 1976.

Bjørnstad, S. *Shipshaped. Kongsberg industry and innovations in deepwater technology, 1975–2007.* Ph.D. thesis, BI Norwegian School of Management, Norway, 2009.

Breivik, M., Kvaal, S., and Østby, P. From Eureka to K-Pos: Dynamic positioning as a highly successful and important marine control technology. In *Proceedings of the 10th IFAC Conference on Manoeuvring and Control of Marine Craft (MCMC 2015), Copenhagen, Denmark.* 2015. doi:10.1016/j.ifacol.2016.01.001.

Breivik, M. and Sand, G. Jens Glad Balchen: A Norwegian pioneer in engineering cybernetics. *Modeling, Identification and Control*, 2009. 30(3):101–125. doi:10.4173/mic.2009.3.2.

Bugos, G. E. *Atmosphere of Freedom: 70 years at the NASA AMES Research Center*. NASA History Office, Washington D.C., 2010.

Faÿ, H. *Dynamic Positioning Systems. Principles, Design and Applications*. Éditions Technip, Paris, 1990.

Ilner, K. *Jacob Stolt-Nielsen: En gründer*. Vigmostad & Bjørke, Bergen, 2009.

IMO. MSC/Circ. 645, Guidelines for vessels with dynamic positioning systems. 1994.

Jenssen, N. A. *Estimation and control in dynamic positioning of vessels*. Ph.D. thesis, Norwegian Institute of Technology, Trondheim, Norway, 1981.

Kalman, R. E. A new approach to linear filtering and prediction problems. *Journal of Basic Engineering (ASME Transactions, Part D)*, 1960. pages 35—45. doi:10.1115/1.3662552.

Kvaal, S. *Drømmen om det moderne Norge: Automasjon som visjon og virkelighet i etterkrigstiden*. Universitetet i Trondheim, Trondheim, 1990.

Kvaal, S. Hooked on a new technology: The automation pioneers in post-war Norway. *Modeling, Identification and Control*, 2009. 30(3):87–100. doi:10.4173/mic.2009.3.1.

Kvaal, S. and Østby, P. *The Jewel in the Crown: Kongsberg Dynamic Positioning Systems 1975–2015*. Pax forlag, Oslo, 2015.

Mindell, D. A. *Digital Apollo: Human and Machine in Spaceflight*. MIT Press, Cambridge, Massachusetts, 2008.

Morgan, M. J. *Dynamic Positioning of Offshore Vessels*. PPC Books, Tulsa, 1978.

Paulsen, G. *Alltid rabiat: Jens Glad Balchen og den kybernetiske tenkemåten*. Fagbokforlaget, Bergen, 2019.

Redmond, K. C. and Smith, T. M. *Project Whirlwind: The History of a Pioneer Computer*. Digital Press, Bedford, MA, 1990.

Røkeberg, H. Presentation of DP Class 2 and Class 3. In *Proceedings of the Marine Technology Society (MTS) Dynamic Positioning Conference, Houston, Texas, USA*. 1997.

Sejersted, F. *Demokratisk kapitalisme*. Pax Forlag, Oslo, 2002.

Sælid, S. AIM blir til. In B. Dybing, editor, *NFA 40 år 1958–1998*, pages 90–91. Norsk Forening for Automatisering, Oslo, 1999.

Verne, J. *L'ile à hélice*. Pierre-Jules Hetzel, Paris, 1895.

Østby, P. Tilfellet Comtec. 1989. STS-rapport nr. 8, Universitetet i Trondheim.