Shipshaped

Kongsberg industry and innovations in deepwater technology, 1975-2007

by

Stein Bjørnstad

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Stein Bjørnstad
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Abstract

Shipshaped is a thesis on the emergence of an innovative offshore supplier industry. Multiple influences combined to the success of various techniques to extract oil and gas without fixed platforms; this thesis put particular emphasis on the relaxation of hierarchies in fostering innovation. Such disintegration occurred *within* firms in which empowered employees took on larger responsibilities and *between* firms. The pace of innovation accelerated where people were allowed to sort out things themselves rather than conforming to directions from above. Initially these conditions were more evident in offshore support services serviced by shipping companies, but practices pioneered in shipping eventually spread to the proper offshore oil industry.

Two business units at Kongsberg, Albatross and Kongsberg Offshore, serves as a vantage point for this thesis. Kongsberg Offshore pioneered production systems that help oil companies control the flow of petroleum from a valve tree on the seabed rather than on fixed platforms. Albatross pioneered dynamic positioning, a technique that helps shipping companies maintain their position using propellers rather than mooring lines and anchors. In the 1970s, dynamic positioning rapidly gained a market whereas the oil industry hesitated to introduce subsea production systems. In each case, qualities related to demand for technology as opposed to supply of technology, are central to the conclusions in the thesis.

Eventually, oil companies went through a number of changes that aligned the practices of shipping and the practices of oil. These changes in procurement practices, management and institutional framework helped develop an innovative Norwegian supplier industry. The effects showed in profitability, global expansion and the development of advanced capabilities. As of 2007, this thesis argues, supplier industries can combine to handle most tasks associated with an oil company. Their growing capabilities permit innovative and entrepreneurial ways of exploiting oil offshore.

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I am fortunate to have a patient and supportive wife in Dagmar. You must have wished for a speedier process, but I could not have asked for a kinder way of urging me on.

Oslo, 1 April 2009

Stein Bjørnstad

1 Introduction

In the 1970s, when Norwegians first encountered petroleum, large oil companies knew how to exploit the fields. They hired help to execute plans, they built huge islands of concrete, and they extracted oil and gas in a manner that resembled how oil companies operated onshore. Thirty years later, supplier industries had acquired capabilities that rivalled the oil companies. They were instrumental in changing the technological basis of the industry and helped introduce various techniques to extract oil and gas without fixed installations, from greater depths and at a lower cost than gravity platforms. I call these *deepwater technologies* and they are the subjects of this thesis. I ask how these techniques came into being, why they became successful, and why independent suppliers rather than oil companies came to master such techniques.

In order to study how deepwater technology moved from the margins of the Norwegian oil industry into the core in the course of some 35 years, I use the supplier industry at Kongsberg as a vantage point. Unless clarity requires the use of legal company names, I refer to *Albatross*[1] and *Kongsberg Offshore*. The official names have changed several times,[2] but their core business remains the same. Kongsberg Offshore pioneered subsea production systems that help oil companies control the flow of petroleum from a well based on the seabed, rather than on fixed platforms. Albatross pioneered dynamic positioning, a technique that helps shipping companies keep a vessel in position above subsea equipment using propellers rather than mooring lines and anchors.

Although the narrative centres on Kongsberg, its implications are wide enough to include a basic transformation of the Norwegian oil industry and by implication the Norwegian economy. I start out in an age of oil companies and fixed platforms, and finish in an age of outsourced knowledge and moveable equipment. It is helpful to think of the shift as *shipshaped*, partly because some of the new equipment was floating and moveable, but also because the offshore industry increasingly commissioned, managed and traded equipment and services in a fashion that

[1] To emphasise detachment from mooring lines and firm ground, the system was named *Albatross* in honour of the sea bird that never lands except for nesting. A secretary working at the KV Oil Division, Kari Paulsen, came up with the name, see Unn Kristin Daling et al., *Offshore Kongsberg: This is the story of Kongsberg offshore's first 25 years in the oil business* (Familievennen, 1999).

[2] Appendix 11.1 provides an overview of names and legal structures.

reminds one of practices in shipping. With each passing decade, the differences between the oil industry and the shipping industry became less profound. Both industries converged, but the more noticeable change was the oil industry's adoption of practices from shipping. The title of this thesis, *Shipshaped*, reflects the direction of the shift, at times the inspiration that triggered the shift, and frequently its neat consequences.

One broad change affected *industry architecture*. In the 1970s, the oil industry relied on extensive vertical integration. The parts of the industry that operated offshore sourced more equipment and services from independent suppliers than was the case in the onshore oil industry, but oil companies were very much in command.[3] In Norway, the division between suppliers and oil companies was blurred. Statoil ventured into exploration, production, refining and retailing, but mostly stopped short of direct control of the supplier industry. The state oil company orchestrated a supplier industry, however. We shall return to this division of labour in chapter 2. Shipping companies, by contrast, rarely attempted extensive vertical integration but rather relied on specialization. One specialist might focus on fleet ownership, another on operations; a third brokered the terms of cargo while a forth insured that cargo. Ship owners also relied heavily on third parties for design and manufacturing of vessels and equipment. Initially, that is, the world of shipping differed considerably from the world of oil.

Starting in the 1980s, oil companies on the Norwegian shelf increasingly asked their suppliers to deliver turnkey systems rather than fabrication according to specifications. Oil companies supplied functional descriptions rather than blueprints and began trusting their suppliers in the same fashion that shipping companies trusted their yards. In the process, oil companies became somewhat less attached to a business model of vertical integration and somewhat more attracted to specialization. Several sections in this thesis track developments in industry architecture, most notably chapter 5. This gradual shift towards vertical specialization gathered pace as the supplier industry enhanced its capabilities (cf. chapter 7 and 8).

A second shift affected the *principles for allocating resources*. In the mid-1970s, Statoil and the Norwegian authorities preferred to manage the emerging oil economy in quite minute detail. In due course, more aspects of capitalism took hold. The 1986 oil price fall and a liberal shift in the general economy crippled most dirigiste ambitions and forced a businesslike attitude to earnings and transactions – much like the sentiments that were

[3] Hans Veldman and George Lagers, *50 years offshore* (Delft: Foundation for Offshore Studies, 1997).

predominant in the shipping industry. I should hasten to add that there was no direct attraction between the two in this respect. Chapter 6 in particular provides insight in aspects of the transformation. The crisis helped shape a political climate where change was possible and where cost-efficient technologies and organization gained ground.

A third shift related to *management practices* and business culture – the balance between centralized decision-making and reliance on the discretion of subordinates. The long-term trend was one away from hierarchal organization directed from the top in an army-like fashion, towards self-contained business units with goals and strategies in their own right. Everywhere, managers, owners and management thinkers started to question the logic of company bureaucracies and omnipotent management. Focus shifted onto communicating goals, motivating those that were to execute on them, and having people contribute to the common good. Such thinking emphasized buy-in from employees and the establishment of independent business units organizing employees and resources around a customer segment and a business idea, hoping to make achievements more transparent and getting increased commitment.[4] We witness the shift most evidently in the management philosophy of Albatross (chapters 4.5 and 4.6) and in the disintegration of Kongsberg Våpenfabrikk (chapter 6). Albatross emulated a culture of empowerment that they associated with (some) shipping companies – in certain contrast to the centralized decision-making practices of (some) oil companies. I imagine the picture would change depending on the manager in question, but oil companies covered in this thesis relied on more extensive central control than contemporary shipping companies.

Finally, and most basically, *technology* shifted. Initially, operators on the Norwegian shelf applied almost nothing but huge, integrated gravity platforms made of concrete. The offshore oil industry sported fixed means of production, built to last, and integral to the company in much the same manner a farmer would think the barn integral to the farm. Specifying, designing and operating a platform were core tasks seemingly inseparable from the core business of an oil company. Gradually, and particularly in the aftermath of the oil price fall in 1985-86, the field development style became

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[4] The shift is frequently associated with the works of Peter Drucker, e.g. Peter F. Drucker, *The practice of management* (New York: Harper, 1954). Drucker advocated divisionalization the way of General Motors as opposed to centralized control the way of Ford and argued the merits of managing by objectives rather than orders. Drucker's writing is extensive, but consistent in its themes; Wikipedia – a free and collaborative dictionary – contains a useful summary of concepts from his writing, see http://en.wikipedia.org/wiki/Peter_Drucker.

unsustainable and yielded to agile field developments based on deepwater technology. The new style somewhat resembled the world of shipping with movable, reusable and tradable means of production – vessels that were not necessarily owned by the company that employed them. The shipping industry kept a somewhat larger distance from the means of production and incurred experimentation and risk taking – or at least a willingness to question the appropriateness of a particular solution.

Rather like a contrast agent, dichotomies make for easy observation. I compare historic practices in the shipping industry and historic practices in the oil industry – for lack of a better term - a shipping paradigm vs. an oil paradigm. The table below highlights major differences between the two.

Figure 1) ***Schematic outline of differences between oil and shipping***

	Oil paradigm	**Shipping paradigm**
Technology	Technology integral to operations – frequently as infrastructure (e.g. fixed platforms and pipelines)	Technology external to the business – moveable, tradable and not necessarily owned by the user (e.g. ships)
Industry architecture	Vertical integration allowing control of technology development and resources	Highly specialized companies in a value chain
Coordinating principles	Corporatism, plans to ensure the different parts work in concert	Prices allocate resources in a market; volunteer cooperation and networks
Management & organization	Command to ensure the proper execution of plans; risk aversion	Empowered employees; risk tolerance

If the table above trades accuracy for simplicity, subsequent chapters in this thesis will strive to recapture the complexity of what went on. Influences were intertwined; technology rubbed off on industry architecture; institutional change affected management decisions, and so on. Besides, the distinction between oil and shipping sometimes dissolved. Some shipping magnates extended into other stages of the value chain, felt a strong attachment to their ships and held opinions about their design and operations.[5] Similarly, some oil executives encouraged suppliers to act

[5] Fred Olsen's stake in Aker (an engineering and shipbuilding company) and Sigvald Bergesen d.y.'s stake in Rosenberg mekaniske verksted are examples. Both shipping

independently. Rather like ideal types, the distinctions remain useful in discussing a wide-ranging change. Nevertheless, the main thrust of my work is holistic. In a somewhat eclectic fashion, I included those facts that seemed most relevant for a reader. Because the subject is complex, I opted for a rigorous narrative where numerous causes formed a chain of events that established new technologies and a new industry. That chain of events was specific to its time and its circumstances. In short, I apply the same approach as most historians have done.

1.1 Innovation: a history of technology and business

What a man can achieve depends on his abilities and the constraints placed upon him by his contemporaries.[6] The same basic observation goes for entrepreneurs who strived to establish deepwater technology. At KV and the various companies that replaced the engineering conglomerate, people showed great abilities, but circumstances sometimes prevented them from taking on responsibility and from reaping the rewards. Innovative technology would sometimes be slow to catch on, or fail to catch on entirely, due to the prevalence of *structures* that favored continuity. Philosophically speaking, the development and diffusion of deepwater technology is a story about agency that sought change in the face of structures that favored continuity.

The notion that structures limit or influence individuals originates with sociology, but affects history and the humanities as well.[7] A strict Marxist interpretation of history would tend to allow individuals little discretion, but rather focus on class and relations of production, while historians that adhere

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companies placed orders with ”their” yards, cf. Hans K. Mjelva, "Tre storverft i norsk industris finaste stund: Ein komparativ studie av stord verft, rosenberg mek. Verksted og fredrikstad mek. Verksted 1960-1980", (Ph.D., University of Bergen, 2005), p. 221.

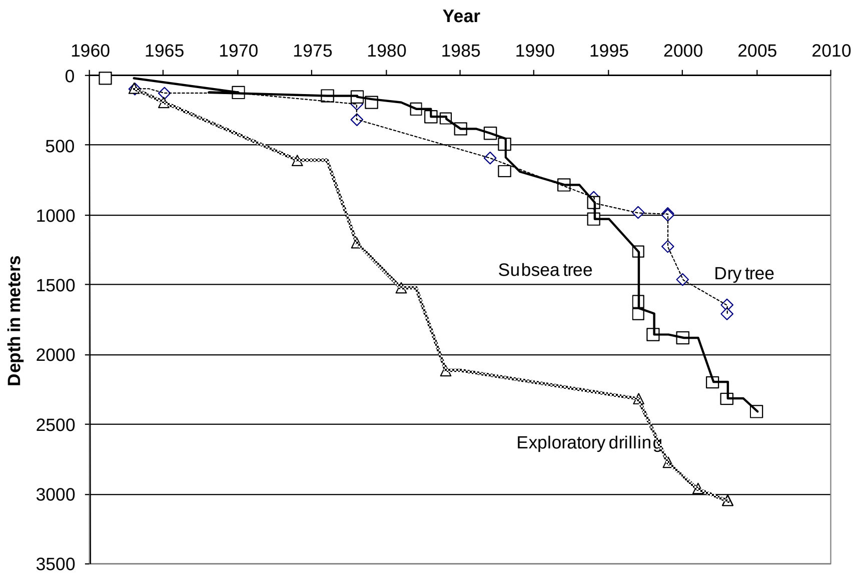
[6] The approach resembles the basic framework of competitive strategic analysis (strengths, weaknesses, opportunities and threats), but the inspiration originates with Jens Arup Seip’s philosophical introduction in his biography of Ole Jacob Broch, a technology pioneer, cf. Jens Arup Seip, *Ole jacob broch og hans samtid* (Oslo: Gyldendal, 1971).

[7] In positioning my work, I have frequently turned to Mark J. Smith, *Social science in question* (London: Sage, 1998). Mr. Smith’s instructive lecturing at the Norwegian School of Management has added further to the subject. On the relevance for history, I trust the pedagogic approach in Knut Kjeldstadli, *Fortida er ikke hva den en gang var: En innføring i historiefaget* (Oslo: Universitetsforlaget, 1992).

to methodological individualism will emphasize society as an aggregation of individual choices. Like many historians, I resist the idea that structures determine an individual’s behavior, but find it difficult to argue human agency rules supreme. I generally seek some middle ground where structure influences human behavior, and humans are capable of changing the structures they inhabit if only to a degree. Put differently, successful businesses evolved at Kongsberg not least because of favorable circumstances.

Past technology shapes present technology and forces this thesis to adhere to schemes pioneered by historians of technology. The graph depicts how exploration (drilling) progressed to deeper waters due to advances in dynamic positioning and a host of other techniques. For a while, advances in drilling outpaced the industry’s ability to set up a production facility, but eventually production techniques began to catch up. Since the mid-1990s, techniques based on subsea trees (valve trees on the seabed) and floating production improved much more rapidly than techniques based on dry trees and fixed platforms. Obviously, my account of deepwater technology would be incomplete without an account of how engineers and businesses worked to improve these techniques.

Figure 2) ***Race to the bottom: deepest recorded drilling, wet tree and dry tree, 1960-2005*[8]**



While the engineers' perspective is useful, other influences helped shape deepwater technology as well. The figure above shows the output of engineers and inventors, but it might just as well depict the oil companies' desperation. When tracing the advance of deepwater technology, I also trace sentiments in the oil industry such as agony and promise. Ultimately, the decisions to explore deep waters depended on the oil companies' calculations of risk and reward. Having explored shallow waters in stable

[8] The figure is assembled from a variety of sources, most importantly Mike Utt, *The offshore industry - middle-aged, but still learning* (Society of Petroleum Engineers, 2004 [cited April 2007]); available from http://www.spe.org/specma/binary/files/2657688MUttOffshoreIndustry.pdf. and M.W. Krall, "Keynote speech from Exxonmobil development company" (paper presented at 2002 Dynamic Positioning Conference, Houston, 17 September 2002). Some additional information appears in John Reed, "Innovative approaches to gathering systems for producing wells in deep water" in Offshore Technology Conference (Houston: 2005); Asle Solheim, "Riserless light well intervention & through tubing rotary drilling" in Subsea Technology Conference (Esbjerg: 2005); Barba Wallace, John Duberg, and James Kirkley, "Dynamics of the oil and gas industry in the gulf of Mexico: 1980-2000: Final report", *OCS Study MMS 2003-004* (New Orleans: U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, 2003).

regions, the industry moved on to rougher climates, more challenging political regimes, smaller fields – and deeper waters. In this respect, the race towards deeper waters depicts the increasing anguish of the oil industry in the absence of easily accessible reserves and the increasing willingness to tolerate risk in search of reward. Economic and business history offers an approach to such inquiries and a corrective to technological perspectives.

* * *

A new technology of economic importance is analogous to *innovation*. Always an elusive quality, innovation underpins economic development. Charles Edquist, for example, refers to an "almost universally accepted" claim that "technological change and other kinds of innovations are the most important sources of productivity growth and increased material welfare".[9] Some make the point poetically claiming that a study of economy without innovation is similar to playing Hamlet without the prince.[10] The importance of innovations for the economy was forcefully emphasised in two papers by Moses Abramowitz (1956) and Robert Solow (1957).[11] Both explored the importance of technical progress to the long-term economic growth of the American economy. Both identified an unexplained growth in resource productivity that Abramovitz dubbed a "measure of our ignorance", and found this residual to be surprisingly large. Additional labour, raw materials and capital tend to matter less than improved technology, better processes and organization.

Some apply the term innovation broadly enough to include invention or indeed acts of creativity such as design. I use the term rather narrowly in much the same fashion as Joseph Schumpeter, the Austrian economist who

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[9] Quoted from the first paragraph in Charles Edquist, "Introduction" in *Systems of innovation: Technologies, institutions and organizations* (London: Pinter, 1997).

[10] The reference to Shakespeare appears among other places in Joseph A. Schumpeter, *Capitalism, socialism & democracy* (Routledge, 1996), p. 86; Nathan Rosenberg, *Inside the black box: Technology and economics* (Cambridge: Cambridge University Press, 1982), p. 4, Kristine Bruland, "Comparative studies in European history of technology" (paper at Historiography and National Histories of Technology, Roskilde, February 1992 1993) p. 8, and in William J. Baumol, *The free-market innovation machine* (Princeton: Princeton University Press, 2002), p. 9.

[11] M Abramovitz, "Resource and output trends in the united states since 1870", *American Economic Review Papers and Proceedings* (1956); Robert Solow, "Technical change and the aggregate production function", *Review of Economics and Statistics* (1957).

identified the importance of innovations in the working of the economy and broadened the outlook of neo-classical economists.[12]

The first defining characteristic in Schumpeter's concept of innovation is disruptive novelty. In the words of Schumpeter, "innovations are changes in production functions which cannot be decomposed into infinitesimal parts. Add as many mail-coaches as you please you will never get a railway so doing".[13] Innovations may be brand-new, but frequently they originate with new combinations of existing elements. Like Schumpeter, my interest is in innovations that broke radically with practices of the past. Conservative innovations, by contrast, serve to improve and prolong existing practices.[14] For example, the use of concrete to build large gravity platforms (Condeeps) may have been innovative, not by virtue of the huge size of these platforms, but because the massive foundations withstood very harsh weather. Like a cliff or an island, they formed an immovable foundation from where oil companies could drill, process and control the flow using equipment that was first pioneered on dry land at the turn of the 19th and 20th centuries. Deepwater technology, by contrast, can do without fixed platforms.

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[12] Entrepreneurs innovating to escape hardship are encompassed in the term "creative destruction", cf. Joseph A. Schumpeter, "A process of creative destruction" in *Capitalism, socialism & democracy*, ed. Joseph A. Schumpeter (Routledge, 1996), pp. 81-86. The text inspired others, e.g. a classic study on the entrepreneurial reorientation of Norwegian industry in the wake of the 1930s depression, cf. Francis Sejersted, *Vekst gjennom krise : Studier i norsk teknologihistorie* (Oslo: Universitetsforlaget, 1982).

[13] Joseph A. Schumpeter, "The analysis of economic change", *The Review of Economic Statistics* (1935) quoted from Nathan Rosenberg, *Inside the black box: Technology and economics* (Cambridge: Cambridge University Press, 1982), p. 6.

[14] On the common division of radical vs. incremental innovation, and how this fits with Schumpeter's thoughts, cf. Jan Fagerberg, "Innovation: A guide to the litterature" in *The Oxford handbook of innovation*, ed. Jan Fagerberg, David C. Mowery, and Richard R. Nelson (Oxford: Oxford University Press, 2005). Schumpeter argued the economy progressed not by "price-cutting among harness makers"; what mattered in the end were the innovative acts of automobile manufacturers eventually abolishing harness-making as an economic activity, cf. Joseph A. Schumpeter, *Capitalism, socialism, and democracy*, 2nd ed. (New York: Harper, 1942). My account of the work of Schumpeter draws on the interpretation in Rosenberg, *Inside the black box* and the reflections of Francis Sejersted, "Schumpeterforskningen i norge" (paper at Instituttseminar, Sandvika, Norway, 2004).

Schumpeter's second defining characteristic of innovation is economic importance. He was a pioneer in analysing innovations for their economic rather than scientific importance. According to this scheme, pure research and certain advanced technologies do not count as innovations. If scientific breakthroughs, such as mapping the human genome or designing the Apollo spacecraft, consume resources in excess of what they contribute to the economy, they fail the test - whereas humble creations such as discount retailing may count as innovations, not because they stretch the scientific frontier, but because they have significant, even disruptive, effects on business. Schumpeter's approach encourages a focus on profitability – a criteria that many creative efforts at Kongsberg failed to meet. KV's ventures into industrial gas turbines and jet engines were certainly advanced, but not innovative since these businesses have generated historic losses that far exceed revenues despite a return to profitability in the two decades since 1987. [15] Although this thesis frequently quantifies savings made from deepwater technology, I do not include any effort to calculate total benefits for the oil industry. It is more straightforward to show how deepwater technology affected Kongsberg – cf. chapter 9.3.

Schumpeter employed the term innovation in a broad term and included any "new form of organization such as a merger, of the opening up of new markets, and so on". [16] In much the same fashion, we are interested in hardware improvements, but also changes in business practices, the introduction of simple cost accountability, market exposure, accountability and other changes that have affected the performance of deepwater technology.

In asking what made deepwater technology feasible, the answer should include both a workable technology *and* companies willing and able to exploit that technology. There is no need to introduce any sharp analytical divide between technical innovations and business practices. *Both* deserve attention. In this approach, I draw inspiration both from historians of technology and business historians – and indeed from those who have sought to combine such perspectives. [17] The combination allows a fuller and less

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[15] For an overview, cf. Figure 34) on page 181 and Figure 33) on page 179.

[16] Joseph A. Schumpeter, Business cycles: A theoretical historical, and statistical analysis of the capitalist process (New York: McGraw-Hill, 1964, first published 1939), quoted from Rosenberg, Inside the black box, p.6.

[17] For an example of a dual approach and the usefulness of studying business in relation to R&D, cf. Knut Sogner, "An innovative culture: Nyegaard & co, Norway and the environments of business", (PhD thesis, University of Oslo, 1996).

distorted understanding, albeit at the cost of some complexity – for example in the number of useful concepts that serve to illuminate the subject.

1.2 On theories and concepts

In the narrow interpretation, my work reads as a thesis about how innovative business evolved at Kongsberg. At first notice, what I portray was particular to Albatross and Kongsberg Offshore, their technology and the people they employed. At times, I propose a wider interpretation: the offshore oil industry as it emerged from the mid-1990s onwards was itself shipshaped because important developments seen at Kongsberg were general in their nature. Since my work does not cover any representative selection of the offshore industry, any claim to a wider interpretation rests on the nature of the cases I cover.

There are reasons to suggest what went on at Kongsberg reflected a wider industry development. We can start from the observation that deepwater technology went to the core of their customers' operations. Albatross controlled the manoeuvring of ships, a task otherwise entrusted to the captain; Kongsberg Offshore controlled the flow of oil and gas, a task that was critical to the operations of a field. Being central to their customers' operations, the businesses I study had to internalize the qualities of the industries they served. Albatross and Kongsberg Offshore adapted their customers' attitudes to outsourcing or in-sourcing, risk-taking or risk-aversion, entrepreneurship or strategic planning, etc. Where the two businesses diverged, they diverged in much the same way the shipping industry stood apart from the oil industry. The thesis strives to identify people and circumstances that were particular to my objects of study, but enough remains to suggest a common link between the shaping of industry at Kongsberg and the shaping of the Norwegian oil economy.[18]

If this thesis contributes to a wider understanding, the credit is widely shared. While a few twists are original, I have borrowed numerous useful concepts from scholars with an ability to point out the general nature of particular developments. The sections below identify the concepts I have found most useful. They cluster around four bodies of theory that deal with

[18] The approach resembles varieties of case methods as applied e.g. in anthrophology. An anthropologist studying but one family or a few families may dare suggest that his findings apply to the culture in question since the family could not but internalize the values and habits of their society. For an introduction to case study methodology, cf. Svein S. Andersen, *Case-studier og generalisering: Forskningsstrategi og design* (Bergen-Sandviken: Fagbokforlaget, 1997).

technological change, with the integration and disintegration of business, with institutional change and with management. I return to each in turn.

Historians of technology have gained significantly by applying concepts pioneered by Thomas Hughes. Hughes developed a theoretical framework to explain utilities such as electricity or telecommunications, but the framework fits reasonably well even for offshore petroleum. Like large technological systems in general, the nature of the business was systemic and involved not simply physical components but the enlisting of legislators, financiers, raw materials, etc. [19] Technological systems do not change easily. Although Hughes created a large room for people, in the shape of system-building entrepreneurs, he was equally explicit on the hard-to-change nature of mature, technological systems. When adapted to new circumstances, technological systems might acquire a distinct *style*, but their basic qualities did not change.[20] When studying stand-alone technologies, it is common to observe how early variety yields to a *dominant design*.[21] Large technological systems display a similar tendency towards technological lock-in. *Momentum* is the term used by Hughes to denote the inertia created by investments, identifiable interests – and social structures. Other historians more commonly use *path dependency* to identify the phenomenon. In this respect, social structures and technological systems seem analogues. The

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[19] Thomas Parker Hughes, "The evolution of large technological systems" in *The social construction of technological systems: New directions in the sociology and history of technology*, ed. Wiebe E. Bijker, Thomas Parker Hughes, and Trevor J. Pinch (London: MIT Press, 1987). Similar perspectives were stated in the introduction to Thomas Parker Hughes, *Networks of power: Electrification in western society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983).

[20] Hughes, "The evolution of large technological systems".

[21] The notion of dominant designs occurs frequently in the literature on *life cycles* of products and industries, cf. Richard R. Nelson, "The co-evolution of technology, industrial structure, and supporting institutions" in *Technology, organization and competitiveness: Perspectives on industrial and corporate change*, ed. Giovanni Dosi, David J. Teece, and Josef Chytry (Oxford: Oxford University Press, 1998). Nelson discusses the reasons why a design becomes dominant. It may be better or, in case of cumulative technologies, it may gain an early advantage. A version of this relates to technologies that become entrenched out of habit or user patterns, for example our dysfunctional keyboards, as explained in an entertaining article by Paul A. David, "Understanding the economics of qwerty: The necessity of history" in *Economic history and the modern economist*, ed. William N. Parker (Oxford: Blackwell, 1986).

continued presence of either is no proof of superior functional qualities, but a pointer to the past.[22]

Hughes' framework provides a way of assessing change. Like Schumpeter, Hughes points to the role of entrepreneurs – system builders that invented, managed and financed technological systems. Since the technologies in question were systemic, shortcomings in one field might obstruct progress in another. Hughes refers to these issues as *reverse salients* – a term borrowed from the military to denote a section of a front that fails to progress due to e.g. difficult terrain or hard resistance, and consequently delays or halts the overall advance of an army.[23] System-building entrepreneurs identified and overcame such reverse salients.

Portraying the advance of deepwater technology as a long effort to overcome reverse salients provides a useful perspective. Unlike notions such as "bottleneck", a reverse salient implies a constantly moving technological frontier. It emphasises the importance not of perfecting a particular component, but of working with any mundane issue that halted progress: the limited reach of divers, the shortcomings of position reference systems and computers, the limited durability of parts, or the limited ability to separate water and petroleum on the seabed, etc. Since dynamic positioning and, particularly, subsea production equipment were systemic in nature, they could not evolve in isolation. Subsea production systems relied on advanced maintenance and drilling techniques; deepwater drilling and maintenance would be less feasible without dynamic positioning – these and other deepwater techniques had to evolve in tandem and in concert with e.g. seismic technology and floating production.[24]

The reverse-salient notion has been criticised for implying a degree of consensus as to the direction and nature of technological advance.[25] As

[22] For a comparison of theory on institutions and theory on technological systems, cf. the introduction in Harald Rinde, "Kontingens og kontinuitet : Framveksten av stiavhengige organisasjonsmønstre i skandinavisk telefoni", (Ph.D., Det historisk-filosofiske fakultet Universitet i Oslo, 2004).

[23] Cf. the introduction in Hughes, Networks of power: Electrification in western society, 1880-1930.

[24] Virginia Acha and John Finch, "Paths to deepwater in the international petroleum industry" (paper given at DRUID Summer conference on creating, sharing and transferring knowledge, Copenhagen, 18 May 2003).

[25] David Hounshell, 'Hughesian History of Technology and Chandlerian Business History: Parallels, Departures and Criticis', *History and Technology*, 12 (1995) 205-224.

applied to deepwater technology, that is a fair criticism. Unlike Hughes' system-building entrepreneurs, we encounter people with limited control of their environments although at times they managed to set developments in motion. Progress was uneven, often slow, and not necessarily part of any master plan. A hobgoblin of the mind sometimes suggests radical new practices must originate with spectacular leaps and conscious plans – that big effects must have big causes. Historians frequently find that technological development may be slow and decompose into a large number of unspectacular improvements. Nathan Rosenberg, for example, makes the point rhetorically by asking who invented the ship.[26] His inquiry into technological and economical change emphasises the cumulative effect of numerous incremental improvements. Similarly, in the case of deepwater technology there were certain big advances such as the research done by Shell Oil around 1960, but these breakthroughs were followed by a series of improvements.

* * *

Technology apart, this thesis traces the shaping and organization of a supplier industry. When treating such topics, the works of Alfred Chandler are hard to ignore.[27] Even those critical of his work frequently gravitate towards his subject[28] – how the business dynamics within firms differ markedly from economists' perception of the economy, how large centralized combines achieved economics of scale and scope in 20th-century American capitalism, how hierarchies and management rather than trading

[26] Cf. Rosenberg, Inside the black box, who refers to S. Colum Gilfillan, Inventing the ship: A study of the inventions made in her history between floating log and rotorship: A self-contained but companion volume to the author's "Sociology of invention" (Chicago: Follett, 1935).

[27] The central works are Alfred D. Chandler, *The visible hand: The managerial revolution in American business* (Cambridge, Mass.: Belknap Press, 1977); Alfred D. Chandler and Takashi Hikino, *Scale and scope: The dynamics of industrial capitalism* (Cambridge, Mass.: Belknap Press, 1990); Alfred D. Chandler, *Strategy and structure: Chapters in the history of the industrial enterprise* (Cambridge, Mass.: M.I.T. Press, 1962).

[28] On the impact of Chandler and the critique, cf. Richard N. Langlois, "The vanishing hand: The changing dynamics of industrial capitalism ", *Industrial and corporate change*, 12, no. 2 (2003): 351-358. An early observation to the same effect, cf. Louis Galambos, "What have CEOs been doing?" *The Journal of Economic History*, 48, no. 2 (1988): 243-258. On how Chandler has affected Norwegian business history, cf. Knut Sogner, "Recent trends in business history", *Scandinavian economic history review* 45, no. 1 (1997): 58-69.

and contracting shaped outcomes. Chandler used the oil industry as a prominent example of vertical integration, from upstream exploration to downstream retailing.[29] According to Chandler, superior coordination made vertically integrated companies more efficient than their smaller competitors. The work of Chandler broadly corresponds with *transaction cost* economics and the work of Oliver Williamson, who emphasised the ability of integrated firms to reduce transaction costs, e.g. the costs of specifying contracts, identifying suppliers, the risks of agency and other neglected costs of market transactions.[30] Much the same argument appears in the work of David Teece on why firms that innovate may have to "secure a prior position in complimentary assets" if the nature of their innovation is systemic – where imitation is easy a competitor may well reap the benefits from the work of the innovator.[31] These and other influential scholars have provided influential theories to explain how integration made firms innovative and efficient.

Since the 1990s, scholars writing in the *Systems of Innovation* (SI) tradition have continued to explore the role of non-market coordination in the economy. Work originating with this research programme looks to alliances, networks and industrial cooperation rather than actions of individuals and stand-alone companies.[32] SI stresses that companies do not innovate in isolation but are part of a system where companies, universities, banks and

[29] The establishment of Standard Oil is a case used by Chandler, cf. Chandler, *Strategy and structure*.

[30] For Williamson's original work, cf. Oliver E. Williamson, "The economics of organisation: The transaction cost approach", *American Journal of Sociology*, 87 (1981): 548-577. For an assessment of how his work reflects on Chandler and vice versa, Charles Perrow, "Markets, hierarchies and hegemony" in *The essential Alfred Chandler: Essays toward a historical theory of big business*, ed. Thomas K. McCraw (Boston: Harvard Business School Press, 1988), 432 ff.

[31] David J. Teece, "Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy", *Research Policy*, 15 (1986): 285-305; David J. Teece, "Technological change and the nature of the firm" in *Technical change and economic theory,* ed. Giovanni Dosi, et al. (London: Pinter Publishers, 1988), 256-288.

[32] For a principled discussion of the variance that exists in business organizations, whether they are labelled hierarchy or market, cf. Gary G Hamilton and Robert C. Feenstra, "Varieties of hierarchies and markets: An introduction" in *Technology, organization and competitiveness: Perspectives on industrial and corporate change*, ed. Giovanni Dosi, David J. Teece, and Josef Chytry (Oxford: Oxford University Press, 1998).

other components interact with each other and the wider environment.[33] Innovative combinations frequently occurred, not in a given component of the system such as a firm, but where firms met to share qualitative information, not just information on price and volume. In the words of Bengt Åke Lundvall, innovating firms exchange *visual handshake*s – a paraphrase of Chandler’s visible hand and Adam Smith’s invisible hand.[34]

The works of Chandler, Lundvall and others are less helpful in explaining a *disappearing hand*.[35] The innovations traced by this thesis coincided with a shift towards more market coordination and less use of hierarchies within firms and between firms. If Chandler showed how managerial coordination could foster economic development, I am concerned with showing how the opposite could hold true, particularly how initiative migrated from governments and oil companies to the realm of independent suppliers such as Kongsberg Våpenfabrikk (KV), a weapons and engineering conglomerate. KV then disintegrated into composite parts such as Albatross AS (dynamic positioning) and Kongsberg Offshore AS (subsea systems) that focused on control systems and systems integration. Numerous improvements occurred by replacing costly or sub-standard parts made at Kongsberg with better or cheaper parts made by sub-suppliers. In the industries we follow, the main thrust favoured the vertical disintegration of production or, much better, *trading tasks*.[36] Our challenge is the opposite of Chandler’s task – to explain the favourable effects of less omnipotent management of businesses and industries.

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[33] Numerous articles attempt to summarize the essence of the systems of innovations approach, e.g. Charles Edquist, "The system of innovation approach and innovation policy: An account of the state of the art" (paper at DRUID, Aalborg, 2001); for an influential collection of works, cf. Richard R. Nelson, *National innovation systems: A comparative analysis* (Oxford: Oxford University Press, 1993).

[34] Bengt Åke Lundvall, "National innovation systems – theoretical foundations and implications for economic development" (paper presented at Globelics Academy, Lissabon, May 2004). Chandler, *The visible hand*. Strictly speaking, Adam Smith is out of context – his invisible hand did not coordinate business, but rather resolved a moral dilemma by turning selfish action into virtuous outcomes that emerged from selfish action – but the metaphor has caught on as symbol of the price-setting mechanism as well.

[35] Inspired by Langlois, "The vanishing hand".

[36] The term “trading tasks” and a broad account of increasing specialization, cf. Gene M. Grossman and Esteban Rossi-Hansberg, "The rise of offshoring: It's not wine for cloth anymore" in *The new economic geography: effects and policy implications* (Jackson Hole, Wyoming: 2006).

I have drawn some inspiration from those scholars of competitive strategy that attempt to reconcile transaction cost economics (widely defined to include the work of Chandler), with a different line of thought that centres on capabilities and competences. Business is difficult, this line of argument goes; that is why firms rarely are good at many things. In principle, a company should centre on what it does best, but if the comparative (dis)advantage is tolerable, a business may still rely on hierarchy rather than contracting. That is because transaction costs moderate the calculation. Such considerations are time specific and may change. Transaction costs may diminish or increase; internal capabilities may improve or deteriorate, and; potential suppliers may get better or worse at their task. When conditions change, so eventually will the *industry architecture*. The works of Michael Jacobides and other researchers in this emerging research programme acknowledge that new industries are often initially more integrated. New industries may suffer from a lack of competent suppliers and subsequently opt for vertical integration.[37] In due time, integrated companies may disintegrate in the face of lower transaction costs or a more capable supplier industry.

A great strength of this approach is that it does not presuppose a market – or rather another firm capable of supplying the product or service in demand – and offers a link between innovation and company structure. Unlike transaction cost economics, which takes markets as a starting point and strives to identify why businesses nevertheless create hierarchies, researchers that look into industry architecture take hierarchy as the point of departure. Similarly, the emergence of a well-functioning supplier industry allowed oil companies to source deepwater technology.

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[37] The implications are outlined in a rare field-defining article, Michael G. Jacobides and Sidney G. Winter, "The co-evolution of capability and transaction costs: Explaining the institutional structure of production", *Strategic Management Journal*, 26, no. 5 (2005): 395-413. An illuminating case is the emergence of specialist firms in banking, cf. Michael G. Jacobides, "Industry change through vertical disintegration: How and why markets emerged in mortgage banking", *Academy of Management Journal*, 48, no. 3 (2005): 465-498. Only somewhat later did the term *industry architecture* appear to define the issues in question, as outlined in Michael G. Jacobides, Thorbjørn Knudsen, and Mie Augier, "Benefiting from innovation: Value creation, value appropriation and the role of industry architectures ", *Research Policy*, 35, no. 8 (2006): 1200-1221. The quotes are drawn from Michael G. Jacobides, What does my research examine? [Faculty home pages] (London Business School, 2008 [cited January 2008]); available from http://faculty.london.edu/mjacobides/Research.htm. The authoritative starting point of transaction cost theory is Williamson, "The economics of organisation: The transaction cost approach".

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Sometimes a commercial logic is sufficient to explain the emergence of new business practices, but frequently the choices are constrained. There are rules to the game and those rules occasionally change. In discussing such changes, I rely in part on insights inspired by Douglas North and institutional historians. Not to be confused with "organizations", *institutions* are quite analogous to the formal and informal rules in competitive sports. They include property rights, codes of conduct, customs and other structures that influence economic performance. Frequently, institutions serve to rise or lower *transaction costs*, but they are equally instrumental in the distribution of resources and rewards, e.g. allowing entrepreneurs to keep their gains.[38] Institutions underpin the allocation of resources and rewards. Supported by habit and interests, institutions are a source of continuity and are not easily altered. Where institutions are shared in society at large, they create coherence in the economy, as observed in studies of *business systems* and *varieties of capitalism*.[39] Several sections in this thesis aim to explain how institutions served to conserve technological choices and how the wide adoption of deepwater technology depended on institutional change.

If shared institutions explain coherence, diverging institutions may explain variety. In Chapter 3 of this thesis I aim to show how the institutional framework differed between oil and shipping. Norwegian shipping companies provided the offshore oil industry services such as drilling, diving, construction and supply, but seemed to obey a different set of rules than oil companies. Shipping was a capitalist endeavour in the genuine

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[38] Douglass C. North, *Institutions, institutional change and economic performance* (Cambridge: Cambridge University Press, 1990). On the nature of institutions, cf. pp. 3 ff; on institutions and economic change, cf. pp. 118 ff.

[39] In the work of Peter Soskice and David Hall, we learn how capitalism comes in two flavours: liberal and coordinated market economies. The liberal version is dominant in Anglo-Saxon countries, the coordinated version in e.g. Scandinavian countries, Germany and Japan. The first relies mainly on markets to allocate labour and capital, the second on negotiation, consensus and coordination among participant firms. The first kind is frequently credited with rapid response, the second with long-termism. Each generates wealth, but the strengths of one cannot easily be combined with the strengths of the other; each is supported by a set of complementary institutions that serve to reinforce each other. For example, a fluid capital market may not easily coexist with inflexible labour markets, cf. Peter Hall and David Soskice, "An introduction to varieties of capitalism" in *Varieties of capitalism: The institutional foundations of comparative advantage*, ed. Peter Hall and David Soskice (Oxford: Oxford University Press, 2001).

meaning: “an economic system characterized by private or corporate ownership of capital goods, by investments that are determined by private decision, and by prices, production, and the distribution of goods that are determined mainly by competition in a free market.”[40] Neither characteristic fitted the oil industry on the Norwegian shelf in the 1970s.

When contrasting practices in the oil industry and the shipping industry I sometimes refer to a particular subset of institutions: *mentalities* (“systems of values, ideas and beliefs”) or business *cultures* complete with myths and symbols. The approach bears a resemblance to the recipe of Kenneth Lipartito, who stresses how culture is integral to decision making and correspondingly important when studying innovation.[41] The same basic observation is central to Amar Bhidé’s theory of *venturesome consumption*.[42] It is of lesser importance, the argument goes, who invents or manufactures this or any other piece of equipment; success occurs where people are inclined to buy and implement new ideas. These “downstream” activities are essential to economic progress. If the attitude of customers affects innovation, it may help explain why dynamic positioning quickly found applications among venturesome customers while subsea production systems met with concerns and risk aversion in the 1970s and early 1980s.

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[40] The term “capitalism” seems a little awkward when applied to a sector, but accurately captures the direction of the shift. Capitalism, according to Merriam-Webster, is “an economic system characterized by private or corporate ownership of capital goods, by investments that are determined by private decision, and by prices, production, and the distribution of goods that are determined mainly by competition in a free market”.

[41] Kenneth Lipartito, "Culture and the practice of business history", *Business and economic history*, 24, no. 2 (1995).

[42] Amar Bhidé, "Venturesome consumption, innovation and globalization" (paper presented at ‘Perspectives on the performance of the continent's economies’, Venice, San Servolo, 2006).

Figure 3) ***Useful concepts – a summary***

	Oil paradigm	**Shipping paradigm**	**Useful concepts**
Technology	Technology integral to operations – frequently as infrastructure (e.g. fixed Condeep platforms and pipelines)	Technology external to the business – moveable, tradable and not necessarily owned by the user (e.g. ships and drilling rigs)	Technological style, momentum, reverse salient
Industry architecture	Vertical integration allowing control of technology development and resources	Highly specialized companies in a value chain	Industrial architecture, transaction costs, firm capabilities, trading tasks
Coordinating principles	Corporatism, plans to ensure the different parts work in concert	Prices allocate resources in a competitive market; volunteer cooperation	Institutions, capitalism, venturesome consumption,
Management & organization	Command to ensure the proper execution of plans; risk aversion	Empowered employees; risk tolerance	Management by objectives, business culture

1.3 A select historiography

If concepts sprawl, the volume of writing that in some way adds to our understanding of the oil economy is equally extensive. I have been able to rely on an extensive research literature on structural change in the economy, innovation, and developments in the oil and shipping industries. The selection referred below deals only with work that combines these three areas and how they relate to each other.

There is a substantial body of prior research into the complex relationships between Statoil, Norwegian industry and the state – and its implications for such issues as labour relations and technological style. Moreover, this research is fairly coherent, not least because of the generalizing talents of Professor Francis Sejersted, a doyen of Norwegian economic history, and his ability to unite people who have diverse reasons to dislike the *oil-industrial* *complex* – a large and powerful industry tightly connected to politics.[43] The term captures an opaque institutional framework, partially market-oriented, partially government-controlled, and in many respects a law unto itself in the 1970s and 1980s. Semantically, the notion of an industrial complex traces back to Dwight Eisenhower, who in his 1960 farewell address chose to make his compatriots aware of a close alliance between officers, politicians and industry. Eisenhower thought the military industrial complex was at odds with fundamental freedoms; it escaped control due to the magnitude of its tasks, the resourcefulness and determination of the industry, and the non-transparent conditions in which it operated. The Norwegian oil economy sported similar qualities: tight alliances between oilmen, researchers, politicians and industry in pursuit of large-scale technological projects with strategic implications.[44]

The industrial-complex school has delivered a set of useful studies of technological choices on the Norwegian shelf. Most strive to reclaim technology on behalf of the social sciences; their work shows a keen awareness of the interests that shaped technology and emphasize how technology does not appear in a fixed shape from above, nor from the laboratory, but is shaped by culture and society.[45] As for specific studies, Sejersted is a prominent contributor, as is Odd Einar Olsen. Much work pays homage to Gunnar Nerheim's detailed outline of various field developments in the 1970s. Nerheim is credited with coining the phrase "Norwegian Style" to describe a succession of large gravity platforms built in concrete, each

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[43] For an overview, cf. Francis Sejersted, Systemtvang eller politikk: Om utviklingen av det oljeindustrielle kompleks i norge (Oslo: Universitetsforlaget, 1999). This essay elaborates on work published in Oljevirksomheten som teknologiutviklingsprosjekt, ed. Odd Einar Olsen and Francis Sejersted (Oslo: Ad Notam Gyldendal, 1997). The term "oil-industrial complex" occurred in the late 1980s in debate articles, cf. Yngve Nilsen, En felles plattform? Norsk oljeindustri og klimadebatten i norge fram til 1998, Acta humaniora nr 97 (Oslo: Senter for teknologi, innovasjon og kultur Unipub, 2001).

[44] Ben Baack and E. Ray, "The Political Economy of the Origins of the U.S. Military-Industrial Complex", *Journal of Economic History* (June 1985).

[45] For a philosophical comment on technological determinism, cf. Håkon With Andersen, "Manna fra himmelen: Om teknologihistorie og teknologideterministisk historie", *Arbeidsnotat / Norsk elektronikkindustri 1945-1970; 25*, (Oslo: 1986). For a particular study, cf. Odd Einar Olsen and Ole Andreas Engen, "Et teknologisk system i endring: Fra norsk stil til internasjonale ambisjoner" in *Oljevirksomheten som teknologiutviklingsprosjekt*, ed. Francis Sejersted and Odd Einar Olsen (Oslo: ad Notam Gyldendal, 1997).

large enough to be self-contained.[46] As for the decline and fall of the Norwegian Style platform, I have learned much from Ole Andreas Engen, who provides a very useful chronicle in the introductory chapters in his Ph.D. about the 1990s NORSOK programme.[47] A sociologist by training, Engen fits in the broad tent of research that analyzes developments in the light of a Norwegian oil-industrial complex – as does the excellent work on labour relations offshore by Helge Ryggvik and others.[48]

This author shares the same liberal concern that has troubled historians of business, economy, technology and politics. The only slight discomfort originates with the remarkable coherence of findings in the literature – a unity that partly reflects a shared institutional background and collaborative work on various oil-related projects where the works of one leans on the works of another to form a compact guard. I hope to add to this literature by going beyond the focus on institutional change and pointing to a creative response among large and small companies that sought a share in the oil bonanza. I point to an innovative undercurrent that ran contrary to mainstream initiatives pioneered by the government, Statoil and large oil companies – particularly how a shipping paradigm reshaped the oil industry, not only its technology but also its mentalities and organization.

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The business-history tradition allows discretion for individuals and companies, although historians that treat oil-related business rarely fail to mention the tight institutional framework that shaped this sector of the

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[46] Gunnar Nerheim, cf. Tore Jørgen Hanisch and Gunnar Nerheim, *Fra vanntro til overmot*, vol. 1, Norsk oljehistorie (Oslo: Leseselskapet, 1992); Gunnar Nerheim, *En gassnasjon blir til*, ed. Francis Sejersted, vol. 2, Norsk oljehistorie (Oslo: Leseselskapet, 1996).

[47] The historical developments are captured in the work of a non-historian on (changing) development styles, cf. the introductory chapters in Ole Andreas Engen, "Rhetoric and realities: The norsok programme and technical and organisational change in the Norwegian petroleum industrial complex", (Dr. polit, University of Bergen : RF - Rogaland Research, 2002).

[48] With regard to labour related issues, the authoritative work is Helge Ryggvik, Else Wiker Gullvåg, and Marie Smith-Solbakken, *Blod, svette og olje* (Oslo: Ad notam Gyldendal, 1997). The subject is also covered in Marie Smith-Solbakken, "Oljearbeiderkulturen: Historien om cowboys og rabulister" (Dr.art. thesis, University of Trondheim, 1997).

economy. Alas, the official Statoil history forsakes this opportunity,[49] but there is a substitute in three volumes about Norsk Hydro. This semi-private industrial conglomerate touched most major crossroads in the development of oil and gas offshore Norway,[50] frequently questioning the policies of Statoil. Consequently, Hydro's history highlights the prevailing attitude on the Norwegian shelf.

As with Hydro, shipping companies took part in the oil business without fully conforming to the common orthodoxy. There are numerous accounts of shipping companies, but the literature provides little in terms of synthesis. Anecdotal studies of individual shipping magnates and family-owned shipping companies flourish, many pointing to the entrepreneurial nature of the founders, but few attempt scholarly analysis.[51] The best single introduction to Norwegian shipping may be the history of a classification society, *Det Norsk Veritas* (DNV), written with a keen eye on the industry's institutional framework.[52] Some memoirs provide oversight.[53] Furthermore, several useful studies from the Norwegian School of Economics and

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[49] Bjørn Vidar Lerøen, *Drops of black gold : Statoil 1972-2002* (Stavanger: Statoil, 2002).

[50] Einar Lie, *Oljerikdommer og internasjonal ekspansjon: Hydro 1977-2005*, vol. 3, Hydros historie 1905-2005 (Oslo: Pax, 2005) and Finn Erhard Johannessen, Asle Rønning, and Pål Thonstad Sandvik, *Nasjonal kontroll og industriell fornyelse: Hydro 1945-1977*, vol. 2, Hydros historie 1905-2005 (Oslo: Pax, 2005).

[51] For a review of the literature, cf. Arild Marøy Hansen and Atle Thowsen, *Sjøfartshistorie som etterkrigshistorisk forskningsfelt*, vol. 3, Etterkrigshistorisk register (Bergen: LOS Senteret, 1994). Books written after 1994 seem to concur with the established pattern with rather few thorough business histories. A recently established programme for historical research headed by Professor Even Lange at the University of Oslo aims to provide synthesizing work. For some of the better shipping histories, cf. Tore Jørgen Hanisch and Liv Jorunn Ramskjær, *Firmaet sigval bergesen, stavanger under vekslende vilkår 1887-1987* (Stavanger: Dreyer bok, 1987); Gunnar Nerheim and Bjørn Saxe Utne, *Under samme stjerne rederiet peder smedvig 1915-1990* (Stavanger: Peder Smedvig A/S, 1990).

[52] Håkon With Andersen and John Peter Collett, *Anchor and balance: Det norske veritas 1864-1989* (Oslo: Cappelen, 1989).

[53] A useful insiders' account, but hardly unbiased, is John O. Egeland, *Eventyr og virkelighet i skipsfartens tjeneste* (Oslo: Stenersen, 1984); John O. Egeland, *Vi skal videre norsk skipsfart etter den annen verdenskrig: Perioden 1945-1970* (Oslo: Aschehoug, 1971).

Business Administration in Bergen map the ups and downs of the industry from an economic perspective.[54]

As for the supplier industries, there is an uneven picking. The shipbuilding industry – much of which later shifted to building oil installations – has been the subject of thorough and inspiring studies, although the best studies do not stretch much beyond 1980 and deal mainly with traditional shipbuilding.[55] As for the industry at Kongsberg, Kongsberg Gruppen ASA has initiated a history of the Kongsberg industry.[56] The official inquiry into the troubles of Kongsberg Våpenfabrikk offers some useful information,[57] as do a few books written to celebrate anniversaries and achievements in the various companies that succeeded KV.[58] Knut Sogner has studied marine electronics in general and the activities of Simrad in particular.[59] These studies cover technological developments, but also wider changes in business, e.g. the perspectives of owners and managers respectively. As a background for Albatross and Kongsberg Offshore, these studies provide a valuable foundation.

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[54] For a useful point of departure, cf. Stig Tenold, "Skipsfartskrisen og utviklingen i norsk skipsfart 1970-91", *SNF-rapport*, 45, (Bergen: Stiftelsen for samfunns- og næringslivsforskning, 2001).

[55] Two studies that stand out, but only touch upon the issue of oil, cf. Håkon With Andersen, "Fra det britiske til det amerikanske produksjonsideal: forandringer i teknologi og arbeid ved Aker mek. verksted og i norsk skipsbyggingsindustri 1935-1970" (Ph.D., NTNU, 1986); Mjelva, "Tre storverft i norsk industris finaste stund: Ein komparativ studie av Stord Verft, Rosenberg mek. Verksted og Fredrikstad mek. Verksted 1960-1980". A history of ABB's Norwegian operations is forthcoming, authored by Harald Rinde and Sverre Christensen at the Norwegian School of Management (BI).

[56] Several volumes are expected by 2014. Knut Øyangen covers 1945-1987. He is employed at the Norwegian School of Management (BI).

[57] KV-utvalget and Andreas Arntzen, "Kongsberg våpenfabrikk", *NOU*, 2, (Oslo: Forvaltningstjenestene Statens trykningskontor, 1989).

[58] Daling et al., *Offshore kongsberg* ; Hans Christian Erlandsen, *Flygende pingviner: Historien om sjømålsraketten penguin* (Kongsberg: Kongsberg Defence & Aerospace, 2003).

[59] Knut Sogner, En liten brikke i et stort spill : den norske IT-industrien fra krise til vekst 1975-2000 (Bergen: Fagbokforl., 2002); Knut Sogner, Fra plan til marked : staten og elektronikkindustrien på 1970-tallet, TMV skriftserie; 9 (Oslo: TMV-senteret, 1994); Knut Sogner, God på bunnen: Simrad - virksomhet 1947-1997 (Oslo: Novus, 1997).

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Appendix 11.12 lists archives and other sources I have consulted in my work. Among these are several indexed libraries containing such sources as conference proceedings and articles on specific topics.

1.4 Structure of the thesis

The chapters in this thesis are chronological. A new chapter starts, roughly, where the previous one ends. At times, the chronology of two chapters may overlap to allow a comprehensive discussion of certain subjects, but nothing rivals *time* as an organizing principle. The main strength of this structure is to consider what went on at Kongsberg in the light of developments in the environment and to allow a comparison of Albatross and Kongsberg Offshore. The costs include a need for the reader to switch attention between several subjects in a single chapter and a certain unevenness in the composition. In some early sections, Albatross is covered in more detail because it quickly evolved into a complete business; in some late sections, focus shifts to subsea systems while dynamic positioning was increasingly sold as part of comprehensive offerings.

Chapter 2 (1960-1974) covers the invention of deepwater technology – in which Kongsberg played no part – and the subsequent diffusion of the technology to Norway during the early years of the Norwegian oil bonanza. I also sketch the institutional setting that covered oil and how Kongsberg Våpenfabrikk and Statoil shared values and key personnel.

Chapter 3 (1974-1976) explains why Albatross quickly found a market while Kongsberg Offshore struggled to find outlets. I link the asymmetry, not to technology and factors internal to Kongsberg, but to the different nature of the recipients: shipping customers and oil companies respectively.

Chapter 4 (1976-1984) shows how wider industry sentiments spilt across to business at Kongsberg and how Albatross evolved into a distinct business. Its flat and responsive organization contributed considerably to Albatross's rapid success.

Chapter 5 (1979-1985) traces developments at Kongsberg Offshore, and particularly a shift in procurement practices. The use of Engineering Procurement Construction contracts strengthened the role of supplier industry and paved the way for innovative practices.

Chapter 6 (1984-1987) covers a collapse in oil prices and a collapse at Kongsberg Våpenfabrikk. The Norwegian oil industry changed in ways that annulled some of Kongsberg Våpenfabrikk's previous advantages, but also created a market for innovative, cost-efficient deepwater technology.

Chapter 7 (1987-1991) covers a set of technological refinements that paved the way for our subjects' return to profitability in the 1990s.

Chapter 8 (1991-1996) shows how deepwater technology succeeded on the Norwegian market when Norwegian style platforms became impossibly uneconomical.

Chapter 9 (1997-2007) explains how the conditions that made Albatross and Kongsberg Offshore innovative in the first place (cf. chapters 5 and 7) also paved the way for international expansion – particularly when procurement practices pioneered on the Norwegian shelf became global.

Chapter 10 recapitulates the transformation that took place with a particular eye on innovations.

2 Birth of an offshore supplier industry, -1974

By 1974, deepwater technology had become part of Kongsberg Våpenfabrikk's offerings. The decision emerged in part from foresight, in part from chance and in part from a set of conditions that offered Kongsberg Våpenfabrikk a decent hand and a promising opportunity.

In outlining the opportunity, some issues require discussion. If today it seems natural that oil companies source technology and services from a supplier industry, this division of labour was not self-evident around 1970. Oil companies (indeed any company) might choose to handle most tasks in-house, but the offshore industry became fairly specialized with distinct roles for such firms as drilling companies and oil tool manufacturers. When oil was discovered, KV was also able to seize upon various initiatives to secure a role for Norwegian industry – most noteworthy the procurement policy of the state oil company, Statoil. Norwegian politicians and captains of industry moved to establish control, not only of resources, but also of procurement practices. The people in charge probably foresaw an industry fully controlled by Norwegians, but intended to exploit foreign investments and expertise as far as possible while assisting and building a national supplier industry.

If deepwater technology was an opportunity, what made it an opportunity *for Kongsberg Våpenfabrikk?* I address the post-war rebirth of Kongsberg Våpenfabrikk and the weapon factory's move into advanced research-based projects. Furthermore, I point to the close connection between the people that ran KV and the people that ran the Norwegian oil establishment. Finally, I address the mindset that made people at Kongsberg think not only about contemporary needs, but also about what technology would eventually prove useful in order to exploit oil in deep waters.

2.1 Oil in Norway: rules of the game

Initially, the oil business on the Norwegian shelf was largely a business matter, not a public concern. When the extent of the riches became clear in the early 1970s, the state became heavily involved – and so did Kongsberg Våpenfabrikk. Kongsberg helps reveal the nature of the supplier business that emerged in the early 1970s.

All things equal, offshore oil exploration has been more costly than onshore production. In periods of easy supply, offshore oil exploration lagged behind, for example during the two decades from the late 1930s to the late 1950s when the Middle East provided a steady source of oil even as demand grew in the industrialized countries. Gradually, exporting countries managed to secure a larger reward, Middle Eastern supplies looked less secure, and the oil majors began to look seriously at oil offshore.[60]

In the 1960s, the offshore industry moved closer to Norway. Following the discovery of gas in Groningen in 1959, oil companies took an interest in the North Sea. Out of caution rather than expectations, the Norwegian government established an institutional framework for oil exploration, claimed any resources as public property, and negotiated a division of the continental shelf along the median line. In 1965, a few consortiums received concessions to explore parts of the Norwegian shelf. The Ministry of industry asked for, and received, assurances that the oil companies would work out of Norway and give preference to "competitive" Norwegian offers.[61] In practice, the oil companies could work with whomever they preferred in this initial stage.

In 1969, Phillips Petroleum, an American oil company, struck oil at Ekofisk, almost half way between Norway and Denmark. Amongst the beneficiaries were Norsk Hydro, a large industrial firm with ties to French industry and Elf. Hydro participated in the Petronord consortium that, in 1967, had swapped concessions with Phillips Petroleum and gained a 20 per cent share in the block that contained Ekofisk.[62] The newly discovered field was the largest known oil offshore reserve at the time and these riches helped change the political climate in favour of more assertive national control. A Labour

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[60] Possibly the most informative approach to the oil economy from a company perspective, cf. *A history of Royal Dutch Shell* (Oxford University Press, 2007); Joost Jonker and Stephen Howarth, *Powering the hydrocarbon revolution, 1939-1973* (2007). With regard to shifts in the 1950s, cf. the tome by Jonker and Howarth, *Powering the hydrocarbon revolution, 1939-1973*.

[61] In the first round of concessions (1965), the national preferences were handled through a gentlemen's agreement. Beginning with the second round of concessions (1969), preferred treatment of competitive Norwegian suppliers was listed as a condition when blocks were awarded, cf. Jan Thorsvik, "Politikk og marked: En studie av norsk leveransepolitikk for oljevirksomheten" (Ph.D. thesis, University of Bergen, 1990), p. 47. The formalized coupling between oil concessions and jobs for Norwegian industry was written into the Petroleum Law in December 1972 (§54), cf. Mjelva, "Tre storverft", pp. 214-215. Initially, the law was pursued with restraint for fear of evoking arguments about protectionism and retaliation, but following a shipping and ship-building crisis in 1975, the decisions were applied vigorously, cf. Nerheim, *En gassnasjon blir til*, pp. 81ff.

[62] On the deal, cf. Johannessen, Rønning, and Thonstad Sandvik, *Nasjonal kontroll og industriell fornyelse: Hydro 1945-1977*.

government replaced a fractured coalition in March 1971 and submitted a white paper to parliament that foresaw the creation of a public oil company (Den norske stats oljeselskap, also known as *Statoil*) with capabilities similar to the integrated, multinational oil giants.[63] The proposal faced no serious objection, partly because the sentiment was widely shared, and partly because the exact nature of the future regime was neither conceived nor communicated.

A number of developments then made the 1971 shift truly radical. First, a fresh string of discoveries raised expectations. Frigg, close to Ekofisk, contained more gas than any known offshore field at the time. The yield of these fields was excellent: a single well could produce almost as much as the best Saudi Arabian wells, the most productive in the world.[64] The 1973 oil price shock then underlined the strategic importance of the oil industry and quadrupled the spot price of crude.[65] At the same time, ideology had re-emerged to shape the political climate in Norway and to some extent globally: everywhere people held multinationals in less high regard.[66] In the autumn of 1972, Norwegian voters turned down membership in the European Economic Community and the Labour government resigned. A general election in the autumn of 1973 returned the social democrats to power with support from radical socialists and Prime Minister Trygve Bratteli moved sharply to the left and introduced a series of *dirigiste* economic policies.[67]

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[63] For the proposition, cf. Innst. S. nr. 294 (1970-71) which responded to the government white paper dated 14 June 1971. The principles set forward in the white paper (the "ten oil commandments" are available on Wikipedia, cf. http://no.wikipedia.org/wiki/De_10_oljebud.

[64] Svein A. Andersen and Øystein Noreng, "Industriell organisering i nordsjøen: Utfordringer i norsk petroleumvirksomhet", (Oslo: BI, 1997).

[65] For an excellent way of assessing nominal and inflation adjusted oil prices, cf. Tim McMahon, Historical crude oil prices (Financial Trend Forecaster, 2007 [cited April 2007]); available from http://inflationdata.com/inflation/Inflation_Rate/Historical_Oil_Prices_Table.asp.

[66] Thorsvik, "Politikk og marked: En studie av norsk leveransepolitikk for oljevirksomheten".

[67] For three comprehensive accounts, cf. Harald Espeli, Industripolitikk på avveie : Motkonjunkturpolitikken og norges industriforbunds rolle 1975-1980 (Oslo: Ad Notam Gyldendal, 1992); Per Kleppe, Kleppepakke: Meninger og minner fra et politisk liv (Oslo: Aschehoug, 2003); Francis Sejersted, Opposisjon og posisjon 1945-1981 (1984).

One of the missions of Bratteli and Statoil was to ensure a role for Norwegian industry in the North Sea. In the early 1970s, when Ekofisk and Frigg were developed, Norwegian suppliers secured few assignments. A continuous boom in shipbuilding kept the engineering industry occupied. One may argue the industry lacked relevant skills to work offshore, but Norwegian suppliers also suffered from being outsiders amongst oil companies married to established procedures. New suppliers struggled to penetrate the hierarchal and centralized decision-making processes oil companies had erected to ensure professionalism - and avoid the risks of using untested local suppliers. The oil companies tended to make procurements based on closed bidding between pre-qualified suppliers, a procedure that required a considerable effort from any prospective bidder.[68] Norwegian politicians ached to address this handicap and Statoil possessed every means necessary to implement whatever the politicians wanted or whatever Statoil wanted.

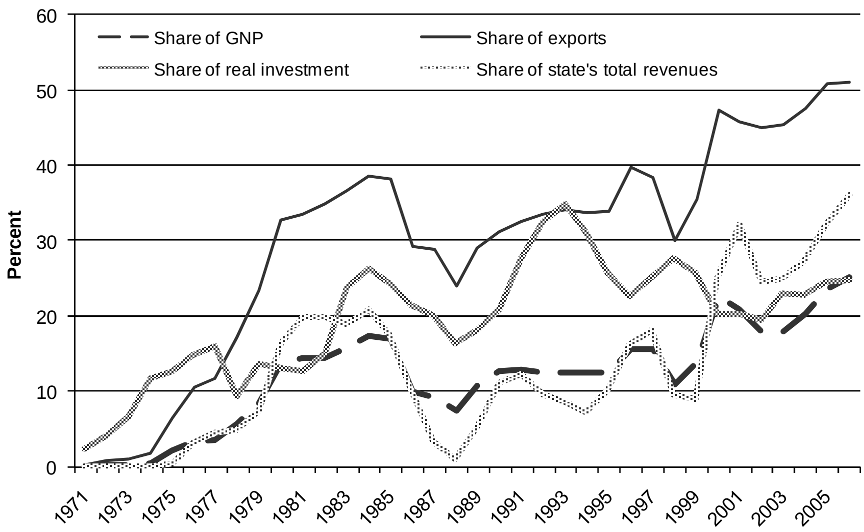
Statoil had a range of formal and arbitrary powers to orchestrate a supplier industry. The state-owned company got at least 50 per cent in every promising concession.[69] These stakes allowed Statoil to act as principal and influence acquisition policies. Meanwhile, a set of special privileges protected the company from any downside and increased its potential upside. Statoil was exempt from paying the costs of exploration and, in concessions granted from 1974 to 1985, enjoyed the right to increase its share of a field in line with increases in production. In a very rich reservoir, Statoil could increase its share of investments and returns up to 80 per cent and the company looked set eventually to control a cash flow that equalled 30-50 per cent of Norwegian exports, 20-30 per cent of Norwegian investments, a fifth of state revenues and some 10-20 per cent of GDP.[70] Besides, Statoil enjoyed excellent political connections.

[68] Smeby's private papers, Nils H. Lundberg and Tom Friedrich, "Petroleumsaktiviteter i norge: Behov for varer og tjenester", (Oslo: Industriforbundets Servicekontor, 1972), p. 12.

[69] On the power broking abilities of Statoil, see Hilmar Rommetvedt, *Butikk eller politikk? Statoils roller i norsk oljevirksomhet*, Rapport rf 24/91 (Stavanger: Rogalandsforskning, 1991).

[70] Figure 4) places the industry that Statoil looked set to control in perspective. For a contemporary observation, cf. Terje Osmundsen, *Gjøkungen: Skal statoil styre norge?* (Oslo: Dreyer, 1981).

Figure 4) ***Heartbeats: the impact of oil and gas on the Norwegian economy***[71]



2.2 Kongsberg moves into oil

Kongsberg Våpenfabrikk had little experience in offshore, but the company's manufacturing and engineering operations drew on a very wide range of skills and capabilities. The company had a certain foothold businesses as varied as machine tools, missiles, guns, automotive parts, computers and gas turbines.

Many initiatives relied on Jens Christian Hauge, a lawyer with impeccable credentials from the armed wartime resistance. He became minister of defence in 1945, at the age of 30, and helped establish KV as a legal entity separate from the army.[72] In 1952, upon leaving the Ministry of defence, Mr. Hauge joined the board of KV. He found a confidant in Bjarne Hurlen, an

[71] The data behind this graph and a wealth of useful information about the Norwegian oil economy is available from *Facts 2007 - the Norwegian petroleum sector* (Ministry of petroleum and energy, 2007 [cited April 2007]); available from http://www.npd.no/English/Produkter+og+tjenester/Publikasjoner/Faktaheftet/Faktaheftet+2007/coverpage.htm.

[72] On the general sentiments that spurred the incorporation, see Olav Wicken, "Avslutning" in *Elektronikkentreprenørene : Studier av norsk elektronikkforskning og -industri etter 1945*, ed. Olav Wicken (Oslo: Ad notam Gyldendal, 1994); on the actual incorporation, cf. KV-board, box 1.

artillery captain who rose to become head of sales in 1953 and managing director three years later.[73] In companionship with Hauge, he continued to dominate Kongsberg for more than 30 years. Hauge remained deputy chairman from 1953 to 1983 and legal council until 1987.[74] Hurlen stayed on as managing director from 1955/56 until 1975 and then as working chairman until 1985.

Turning KV into an advanced engineering firm was a momentous task. After the immediate post-war recovery, continuing production at the workshop was not an obvious choice, but Marshall Aid and the prospect of NATO assignments induced the government to invest in new equipment. The turnaround that followed relied on powerful personalities such as Hauge.

In the first post-war decades, KV became part of a conscious effort to modernize Norwegian industry and the Norwegian armed forces. Hauge and Hurlen sought projects that fitted the vision of building an advanced machine tools industry. Such businesses, Hurlen believed, explained the success of advanced industrial economies such as Sweden, Germany and the United States. Conversely, the lack of a decent machine tool industry contributed to Norway's comparative backwardness.[75] The circle of modernizers to which they belonged tended to believe private industry could not be trusted to know their best interests with regard to investments in new technologies and modernization. Experience had told them that success and progress followed from consorted development efforts.[76]

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[73] Hurlen's ascent is shown in the board minutes, cf. KV-board, box 2. On 10 September 1953, the board involved the Ministry of defence to prevent his transfer to operative duty; on 30 October 1953, the board made him head of sales – against the votes of the employees' representatives who considered sales a drain on the company's resources.

[74] Hauge's attachment to KV was evident, not only from his 30 years of service, but from his affectionate portrait of the company's managing director, Bjarne Hurlen, see Jens Chr Hauge, *Mennesker* (Oslo: Tiden, 1989).

[75] The subject appear in a number of Hurlen's speeches and articles, for example Næsset's private papers, "Perspektiver i verkstedsindustrien", speech by Bjarne Hurlen, at NTH, 30 October 1967.

[76] The sentiments of the modernizing politicians are a recurrent theme in the writings of Olav Wicken, see also Tore Grønlie, *Statsdrift: Staten som industrieier i norge 1945-1963* (Oslo: Tano, 1989). Hauge's belief in planning industries is treated briefly in Olav Njølstad, *Jens chr. Hauge: Fullt og helt* (Oslo: Aschehoug, 2008), pp. 603 and 639.

During the long Labour reign from 1945 to 1965, Hauge gained key roles in strategic industries that caught his and the government's attention - airlines, nuclear power, electronics and automotive. As minister of defence, he helped establish the Norwegian Defence Research Establishment (NDRE) and the Institute for Atomic Energy (IAE), two institutions that sought to build on the rapid advances in military technology during the Second World War.[77] At the time, the main current of economic thinking in Norway centred on labour-, capital- and resource-based industries – in some contrast to those who argued the case for building research-based industries.[78] Hauge and Bjarne Hurlen, the officer he recruited to run KV, belonged to the latter camp. So did the technologically versatile director of NDRE, Finn Lied.

Due to political privilege, and the industrial policy instigated by people close to Jens Christian Hauge, Kongsberg Våpenfabrikk built scale and scope. A number of new products arrived at KV from the United States, frequently by way of the defence research establishment, in what Njølstad and Wicken refer to as a "system of innovation".[79] *Diffusion* may be a better term for what went on in the initial search for new products. Hurlen opted for advanced projects, and the early post-war decades played to the strengths of companies with sufficient skills to act as agents of diffusion. Although we obviously risk belittling their effort – adapting American heat-seeker technology for the Penguin anti-ship missile, for example, required 600 man-years at KV and NDRE[80] – there is no denying the advantage of access to rockets, computers, inertial navigation and various oil-related technologies. At a micro level, KV displayed what economists frequently observed on a macro level: less advanced economies rapidly catching up by adopting and adapting technology and management techniques from more advanced economies. Economists believe the ability to capitalize on technology diffusion from the United States was the single most important contribution to growth in the Norwegian economy between 1950 and 1973.[81] In 1960, the

[77] Several essays by Olav Wicken cover the technology transfer, but the single best source is Olav Njølstad and Olav Wicken, *Kunnskap som våpen: Forsvarets forskningsinstitutt 1946-1975* (Oslo: Tano Aschehoug, 1997).

[78] The macro-economist, of course, had no objections to advanced industry – the contrast was one of perspective. For a brief introduction, see the concluding chapter of Andersen and Collett, *Anchor and balance: Det norske veritas 1864-1989*, pp. 253 ff.

[79] Njølstad and Wicken, *Kunnskap som våpen*.

[80] Ibid. p. 137.

[81] Sverre Knutsen, "Staten og kapitalen i det 20. Århundre: Regulering, kriser og endring i det norske finanssystemet 1900-2000" (Oslo: 2005). Knutsen refers to a.o.

Norwegian GNP per capita was but 60 per cent of American levels, and labour was correspondingly affordable.

Engineers gradually swamped KV’s organization from the late 1950s. They brought a set of values: engineering excellence became a value that “informed every single allocative decision taken within the firm. Engineering excellence was pursued strenuously, sometimes irrespective of time and cost constraints.”[82] The general attitude that radiated from Hurlen down was one of technological risk-taking. KV did not perceive problems, or rather did not see problems as a reason to stop. Nobody was paralysed when a problem arose one could not immediately solve.[83] People learned to settle everything apart from the actual novelty. When working with dynamic positioning, for example, the general thoroughness at KV helped to establish a proper running environment for the computer (back up, power supply, emergency power, cooling, etc) and an array of project management skills such as documentation routines and quality assurance routines. Besides, the engineers and technicians at KV maintained a rather generous and open attitude and there were few inhibitions to sharing information and experience.[84]

In the early 1970s, the people that moved to secure the state’s interests in oil were the exact same crew that had previously worked to establish an advanced, research-based industry founded on military procurement. In 1972, Finn Lied served as minister of industry. He chose Hauge as Statoil’s first chairman. Hauge hired Lied’s deputy, Arve Johnsen, as managing director. Everywhere, there were connections between the defence establishment and the new oil establishment. The people involved believed in similar ideals and probably drew similar conclusions as to what strategy, management and organization were suitable for the state oil company.

Anders Skonhoft, "Norsk vekst i internasjonalt lys: Etterkrigsperioden 1950-1988", *Historisk tidsskrift*, no. 2 (1994): 179-204.

[82] The quotation relates to another troubled engineering firm, the Rolls-Royce turbofan factory, but is equally fitting for KV. Olav Wicken, "Stille propell i storpolitisk storm: KV/Toshiba-saken og dens bakgrunn", Forsvarsstudier, 1, (Oslo: Institutt for forsvarsstudier, 1988).

[83] Interviews with Sælid, 12 October 2004, and Mr. Mathiesen, 13 October 2004.

[84] Interview with Corneliussen, 19 October 2004.

Figure 5) ***Liaison officers: defence figures in the oil industry***

	Role in the military industrial complex	**Role in the oil industrial complex**	**Other connection**
Jens Chr. Hauge	Minister of defence, 1945-52; KV vice chairman, 1953-82, KV legal council, 1955-87, founded NDRE and IAE	Statoil chairman, 1972-74	Numerous tasks related to industrial policy; negotiated Volvo agreement[85]
Bjarne Hurlen	KV Managing director, 1955-75, KV chairman, 1975-85	Entered into a number of businesses in the alliance between KV and Statoil	Headed effort to establish a holding company for all state-owned enterprises; Chairman ÅSV
Finn Lied	Head of NDRE, 1957-1971 and 1972-1983.	Minister of industry, March 1971 - October 1972, Statoil chairman, 1974-84	Author of various government white papers; minister of industry, 1971-72.
Arve Johnsen		Statoil managing director, 1972-87; Hydro manager before 1971	Deputy to Lied at the Ministry of industry
Henrik J. Ager-Hanssen	KV deputy chairman, 1986-87; researcher and director at IAE, 1957-71	Statoil's deputy managing director, 1977-89	
Rolf Qvenild	KV head of planning, 1969-75; KV managing director, 1979-87	Head of KV's Oil Division, 1975-79	Nephew of Finn Lied
Haakon Sandvold	First employee at IFA; KV board member, 1968-81	Hydro board member, 1977-89	Managing director at ÅSV

[85] An agreement to allow Volvo an important role on the Norwegian continental shelf in return for a stake in the car company. The Swedish shareholders rejected the agreement in January 1979. For details, cf. Olav Njølstad, *Jens chr. Hauge fullt og helt* (Oslo: Aschehoug, 2008).

In 1973, Hurlen announced his decision to seek business offshore. Other Norwegian engineering firms, most notably Aker and Kværner, made similar decisions years earlier.[86] KV had a rather large portfolio of products even without an offshore branch – something that may have delayed the decision. Besides, Labour was back in government by 1973 with an ambitious programme that offered KV and Statoil a wide range of opportunities.[87]

In the mid-1970s, there were few signs the people that governed KV and Statoil contemplated any natural limit to how extensive the state's ambitions in industry should be. The impetus was on strengthening the state's involvement as manifested in plans to establish a joint management structure for all publicly owned companies (*Statlig forvaltningsselskap for industrien*). Hurlen led the task force; Finn Lied participated and the retired Erik Brofoss (born at Kongsberg) worked behind the scenes alongside Jens Christian Hauge. Tonje Tveite, a historian who has researched the attempt, remarked on the outlook of this entourage. They saw the government as a perfectly normal industrialist. To them, state ownership and involvement was not good or evil, but natural. The question was a neutral one: what state intervention was the most efficient and rational. They did not think that state-owned companies would pursue interests and agendas of their own.[88] They did not think that national preferences might reduce the overall value of the Norwegian resource base, but rather believed exploitation presupposed a strong national presence. The people that ran Statoil probably foresaw an oil industry and a supplier industry fully controlled by Norwegians.[89]

2.3 A peculiar industry architecture for offshore

A number of concerns served to shape the offshore industry as it emerged in the early and mid-1970s. Political power rested with people that preferred an extensive role for public industry, but state companies lacked experience and trained men. At first sight, the division of labour between oil companies and suppliers on the Norwegian shelf came to resemble the practice in other

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[86] Interview with Qvenild, 29 September 2004.

[87] The ambitions were most explicitly stated in St.meld. 25 (*Oljemeldingen*), published in February 1974.

[88] Cf. Tonje Tveite, "Løve og skinnfell : En analyse av forsøket på å etablere et statlig forvaltningsselskap for industri 1967-1981", *LOS-senter rapport*, 6, (Bergen: LOS-senteret, 1993), pp. 103-105, 119-122.

[89] On the tactical considerations, cf. Helge Ole Bergesen and Anne Kristin Sydnes, *Naive newcomer or shrewd salesman?* (Bergen: Fritjof Nansen Institute, 1990).

offshore oil provinces – one where oil companies bought services from private businesses rather than relying on extensive vertical integration for numerous upstream activities.[90] However, while the industry architecture resembled a market for offshore goods and services, the practice was blurred. From 1973 onwards, Statoil became the mechanism for allocating resources and for building a national supplier industry. Competencies and cost-effectiveness counted, but less than nationality (being Norwegian) or affiliation (being close to Statoil and KV) or deprivation (having suffered setbacks that could lead to unemployment).[91]

The large global oil companies, sometimes called the *seven sisters*, were vertically integrated businesses. They handled most tasks in-house, from exploration to the eventual retailing of gasoline. Offshore, however, the picture was more blurred. In the 1950s, oil companies working offshore shred some tasks and began buying services. An excellent study by Veldman and Lagers observes how it "became rare that an oil company would take responsibility for the construction of installations. Generally, they were merely concerned with the strategic development of know-how."[92] Oil companies retreated somewhat from construction and a new sector of industry emerged, consisting of shipyards, engineering firms, seismic surveyors, pipe-laying firms, tugs, consulting engineers, etc. *Offshore* became a term that encompassed a set of tasks from geological and geographical surveys to exploration, production, infrastructure, and support. These operations were left to (sub)contractors that rarely operated in more than one subsector. This approach, which also became the norm in Norway, was remarkable: during the 1960s, other industrial sectors saw a shift towards vertical integration, and the onshore oil business performed an extensive set of tasks in-house.[93]

The 1970s saw a reversion to more hierarchy in the offshore industry. Having come to rely excessively on external suppliers in the 1950s and 1960s, the offshore oil industry began employing extensive internal bureaucracies to plan and oversee field developments. In Norway, field developments had just begun, and there was no useful comparison with early practices; the international engineering industry, on the other hand, noticed

[90] On the established practice, cf. Veldman and Lagers, *50 years offshore*.

[91] The practice is discussed in detail both in Nerheim, *En gassnasjon blir til* and particularly in Mjelva, "Tre storverft".

[92] Veldman and Lagers, *50 years offshore*.

[93] Ibid. pp. 86-89.

how oil companies became more risk-aversive in the face of rising oil prices. After the 1973 oil price hike, oil companies could afford more expensive field developments and the cost of potential mistakes multiplied.[94] However, although oil companies working offshore reined in control in the 1970s, they continued to rely on a supplier industry for numerous tasks related to service and manufacturing.

The foundation of a specialized Norwegian supplier industry had emerged before anybody had discovered oil on the Norwegian shelf. By 1969, various nascent industries had come forward to support the oil industry. Certain shipping companies had been pursuing offshore opportunities for almost a decade. They attempted to earn money in drilling and supply even before the North Sea countries agreed on how to split the continental shelf (in 1965). Although Norwegian firms had no privileged access at the time,[95] and although oil failed to raise high expectations, the shipping industry sensed an opportunity. A shipping magnate, Fred Olsen, went into drilling in the early 1960s followed by colleagues Odfjell, Smedvig and Ugland.[96] These shipping companies, usually controlled by a magnate, had a knack for entrepreneurship. Risks and fluctuations were inherent in their business – besides, in the long post-war boom, being hesitant had been a losing proposition.[97] In the 1960s, the main thrust of the business went into drilling and various activities that supported drilling, e.g. supply bases and

[94] Concerns about increasingly centralized planning are cited in Joseph A. Pratt, Tyler Priest, and Christopher J. Castaneda, *Offshore pioneers: Brown & root and the history of offshore oil and gas* (Houston: Gulf Publishing Company, 1997), p. 88. The authors link the new practices to high oil prices.

[95] Because of the impetus of attracting risk capital rather than allocating scarce Norwegian resources to a venture with substantial perceived risks, offshore profits were initially taxed more leniently than profits from onshore industry and the concessions were offered free of charge. Sejersted invites us to think of this early model as non-discriminatory. If there was any bias, it was foreigner-friendly. Cf. the chapter on a Norwegian “Sonderweg” in Francis Sejersted, *Demokratisk kapitalisme*, Det blå bibliotek (Oslo: Universitetsforlaget, 1993).

[96] I trust the brief outline in Hanisch and Nerheim, *Fra vanntro til overmot*, pp. 231 ff.

[97] There are many historical studies of individual shipping companies, but very little decent industry-level analysis. A good starting point would be Tenold, "Skipsfartskrisen og utviklingen i norsk skipsfart 1970-91", pp. 11, 38 and 55-57. Tenold reflects on risk taking and argues that the Scandinavian (and particularly the Norwegian) shipping industry had a high appetite for risk; many preferred short-term contracts and markets with large fluctuations.

maintenance.[98] In the actual oil industry, shipping companies played a less prominent role. Shipping magnates helped establish NOCO, a consortium aiming to work alongside experienced oil companies, but the venture failed to come across a viable find. Undeterred, the NOCO partners helped establish Saga Petroleum (1972), a privately held Norwegian oil company that eventually gained a role on the Norwegian shelf. [99] The foundation for an offshore industry was in place even before anybody had drawn oil from the Norwegian continental shelf.

This specialized supplier industry gained some early successes. Aker, an engineering company in which Fred Olsen held a substantial stake, began building semi-submersible rigs according to specifications from oil companies in the early 1960s. Around 1970, the company designed a proprietary rig, the H3, with catamaran-type floaters and columns to support the drilling deck.[100] The design did not depart considerably from existing gear; the novelty was rather in the fact that this design was "being offered by a group of shipyards and available to every interested contractor," according to Veldman and Lagers.[101] In this perspective, success originated not as consequence of research and development, but as consequence of a productive division of labour between oil companies and suppliers.

When Statoil became involved, the company seemed to expand into every step in the value chain including downstream. Initially, Statoil considered involvement in the supply industry and exploration in alliance with KV. By the early 1970s, seismic surveys had greatly improved the prospects of oil exploration. By analysing the echo from an explosion (onshore) or an air gun (offshore), seismic surveys revealed possible pockets of oil and gas deep below the surface. KV had a certain computer experience useful for analyzing data. Statoil and KV proceeded to set up a seismic company, Statex, in which each held 50 per cent of the shares. This company acquired technology and assignments from Geophysical Service Incorporated, a subsidiary of Texas Instruments.[102] One problem for Statex was competition

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[98] The best documented is probably the effort of Smedvig, cf. Nerheim and Utne, *Under samme stjerne rederiet peder smedvig 1915-1990.*

[99] Egil Helle, "Saga i norsk oljehistorie" in *Sagaen om saga*, ed. Bjørn Glenne (Oslo: Saga Petroleum, 1997), p. 9 ff.

[100] The design was novel in 1971, according to Nerheim, *En gassnasjon blir til*, p. 81.

[101] Veldman and Lagers, *50 years offshore*, pp. 118-119.

[102] RA-Arntzen-Oil, Board reports dated 10 September 1973, 23 November 1973, 13 May 1974 and 1 November 1974.

from Geco, a Norwegian company established in 1972 with computing experience from *Computas* and geophysics from *Geoteam* AS.[103] Hurlen apparently decided to brush the competitor aside. In December 1973, KV wrote a letter to Geco stating that Statoil and KV, acting in the best interests of the nation, intended to create a separate seismic company and that there would be no use for the services of Geco in seismic data processing, data mapping or data storage – but Statex would be interested in hiring its seismic vessel. Geco realized its exposed position, decided to negotiate, and eventually gained a share in a merged company.[104]

For a few years, roughly from 1973 to 1975, KV enjoyed a right of first refusal when Statoil acted to establish Norwegian suppliers. The weapons factory regarded itself as a special partner of Statoil and the government – a player whose public ownership allowed a part in particularly delicate matters of great national importance. KV hoped eventually to become as instrumental to the Norwegian supplier industry as Statoil would be to the oil industry.[105] A 1974 planning procedure at KV offered some insights into the sentiments of KV's management. When contemplating opportunities in the oil business, KV mapped capabilities and deduced what products KV could supply to the offshore industry somewhat irrespective of competitors. Implicitly the planners assumed Statoil would brush aside or coerce domestic and foreign competition and invite KV to enter any markets in which its productive resources could be put to intelligent use.[106] Supply and demand of products was only an implicit consideration – probably because these were within the control of Statoil and the authorities. This is not to say KV's planning lacked any reference to what economists today call *competitive advantage*. Rolf Qvenild, the head of planning, did not intend to compete on fixed and floating structures – numerous yards were already in

[103] Andersen and Collett, *Anchor and balance: Det norske veritas 1864-1989*, pp. 32-33. Computas was the computing arm of a Norwegian classification society, *Det Norsk Veritas*.

[104] Olsen and Engen, "Et teknologisk system i endring: Fra norsk stil til internasjonale ambisjoner", pp. 37-42.

[105] KV-Cor, box 242, Qvenild (KV) and Tømmeraas (Raufoss), 1974-78 long-term plan, revision dated 13 August 1974. The Norwegian text runs: "Bedriftene kan på utstyrssiden industrielt spille en like aktiv rolle som STATOIL kan på operatør og oljeselskapssiden."

[106] KV-Cor, box 242, Qvenild (KV) and Tømmeraas (Raufoss), 1974-78 long-term plan, revision dated 13 August 1974.

this business, Kongsberg was far from the ocean, and he realized KV had a cost handicap that excluded the company from certain markets.[107]

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KV and other prospective suppliers frequently found that advisory engineers working for the oil companies made crucial decisions that affected procurement practices. The oil companies that Statoil sought to copy employed large in-house engineering departments that worked in concert with independent engineering firms acting as main contractors for specific field developments. Many strategic decisions rested with the main contractor who made detailed designs and specifications for a presumably dumb manufacturer to perform.[108]

Because the main contractor had considerable influence on procurement, Statoil and KV were intent on gaining a say. Alas, neither company had the necessary skills. Statoil's need for technical consultants became particularly acute when planning for the Statfjord field began in late 1974. In Norway, there were few engineers with relevant experience and Statoil realized it would be impossible both to establish a large in-house engineering department and find a competent external contractor.[109]

The international oil industry employed large engineering firms such as Brown & Root to devise field developments. Decisions made by these technical consultants, e.g. how to generate power, affected suppliers such as KV. Ideally, KV hoped to combine the role of supplier and technical consultant. More importantly, Hurlen loathed the thought of somebody else in this strategic position.[110] Alas, KV lacked the necessary skills and resources. KV employed fewer than ten engineers with relevant experience. Aker and Kværner had more offshore experience and employed 100 and 150 qualified engineers respectively.[111] In December 1974, Hauge, Hurlen,

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[107] RA-Arntzen-Oil, KV board minutes, 10 October 1974.

[108] On the limited role of suppliers, cf. Nerheim, *En gassnasjon blir til*.

[109] The considerations are explained in some detail in Sveinung Engeland, "Ingeniørfabrikk på norsk: Oppbygginga av norsk petroleumsrelatert engineeringkompetanse" (Hovedoppgave, Universitetet i Oslo, 1995), pp. 86, 104-115.

[110] KV-Cor 245, Qvenild, minutes from 5 December meeting with AS Raufoss ammunisjonsfabrikker and Statoil, 10 December 1974.

[111] Engeland, "Ingeniørfabrikk på norsk".

Johnsen, Qvenild and Lied met privately and decided KV would not become engineering contractor in its own right, but participate in a consortium of capable Norwegian engineering firms.[112]

Securing a role for KV meant taming the ambitions of Aker and Kværner. Both were big in shipbuilding and both became more attracted to oil and gas when a shipping crisis hit Norwegian yards in the winter of 1974-75. The two had sufficient resources to act as a main contractor, and considered establishing a consultancy. For political reasons, Aker was intent on including KV, and the three companies discussed the establishment of a technical consultancy during the winter of 1975. When they failed to agree, Statoil refocused their minds by promising to make a national engineering champion main contractor for a second platform on the Statfjord field – a task that presumably would involve three to four million hours of engineering work, handsome margins and a great deal of learning. Statoil then retreated from the scene, while KV became correspondingly active.[113]

The outcome of these deliberations was Norwegian Petroleum Consultants, a public-private partnership with ten equal partners. Half the participants were aligned with KV, including *Norsk Jernverk A/S* and *A/S Årdal og Sunndal Verk*, in which Hurlen was chairman and Norconsult, a coalition of independent advisors. Aker, Kværner and associated companies joined hesitantly, recognizing how power was allocated. This was abundantly clear at the first general meeting of shareholders on 27 November 1975, where Hauge overruled objections to the participation of Norconsult. Hauge advised the people in the room to be "practical" – KV and Aker supported Norconsult, he assured, and for the rest he did not "give a damn".[114] He then called the minister of industry, Ingvald Ulveseth, and had him come over to sign the papers.[115]

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[112] KV-Cor 245, Qvenild, minutes from 5 December meeting with AS Raufoss ammunisjonsfabrikker and Statoil, 10 December 1974.

[113] Noted by Engeland, "Ingeniørfabrikk på norsk", pp. 33-34.

[114] Ibid., p. 50, with reference to the notes of Kristian Walentin (Kværner). The objections were voiced by Høyer-Ellefsen, a construction company that had enlisted Norconsult in the planning of concrete structures for Ekofisk, Brent and Beryl, and feared Norconsult would share confidential information about Condeeps with the broader engineering community. Norconsult was a collection of independent advisors that had problems gaining business on their own and a matching interest in coordination.

[115] Interview with Bjørn Barth Jacobsen, 9 September 2004.

* * *

The control of design was important to secure a field development style that required particular deliveries. As for procurement decisions, KV gained considerably from Statoil's direct influence. Statoil repeatedly assisted KV in selling products that struggled to find applications offshore, for example the KG 2. This radial gas turbine yielded 1600-2200 horsepower, insufficient for most industrial applications, particularly large offshore platforms that required as much power as a city.[116] Usually, the platforms employed turbines with high efficacy, usually aircraft-derived turbines that burned fuel at very high temperatures and required less space than conventional gas turbines. Nevertheless, applying proper pressures, KV managed to sell 60 low efficacy KG2 gas turbines to Phillips for use chiefly at the Ekofisk field.[117] Statoil also helped KV establish a control system business with a solution named SCADA (supervisory control and data acquisition). Around 1970, KV had developed some applications for Norwegian electrical power transmission. Drawing on this experience, KV offered to develop a control system for Frigg, but Elf rejected the offer; the price for this untested product was 50 per cent above what the competition could offer.[118] On Statfjord, the operator (Mobil Petroleum Company) asked for a solution to collect key data on the platform, convey these to the control room operators, and submit status reports and statistical analysis to a headquarters onshore in real time. Siemens had the expertise, but Statoil, which owned a majority stake, pushed to split the task between KV and Siemens.[119] KV was to handle tasks in the control rooms offshore and onshore, while Siemens handled decentralized monitoring and data

[116] As of 2005, the declining production on Ekofisk and adjacent fields in the southern parts of the North Sea required 1 TWh of energy, mostly electricity generated on the platforms, while offshore oil in general required 17 TWh (Fellesrapport Oljediretkoratet-NVE, *Kraftforsyning fra land til sokkel: muligheter, kostnader og miljøvrikninger*, Oslo, November 2002). In 2005, Norwegian households and farms consumed approximately 35 TWh (NVE, *Kraftbalansen i Norge mot 2020*, Oslo, June 2005). Ekofisk, in proportion, consumed as much power as a population of 128,000.

[117] KV-Cor 245 Qvenild, minutes from 5 December meeting with AS Raufoss ammunisjonsfabrikker and Statoil, 10 December 1974.

[118] RA-Arntzen-Oil, Q3 report, 1 November 1974.

[119] On the Scada development, cf. Daling et al., *Offshore Kongsberg*, chapter 11. On the sale, see RA-Arntzen-Oil, Board report dated 7 November 1975.

gathering.[120] Both in gas turbines and control systems, KV had considerable background, but Statoil's assistance was nevertheless essential.

In some cases, KV used its political contacts to secure a presence. Maintenance was one example. Statoil was being groomed to become the field operator one day, which meant the company needed maintenance services and thus enlisted KV. In 1974, KV established a small electronics workshop at the Costal Center Base (CCB) near Bergen in which Statoil bought the majority of the shares the following year. The base already housed a maintenance operation, a small yard run by Wisbech Refsum, a Finnish company. KV thought this operation would be useful and got in touch with the Ministry of industry. The ministry duly denied Kone OY, the parent company of Wisbech Refsum, a concession to run the workshop and forced the Finns to sell the yard to KV.[121]

Although it was common for multinational oil companies in the 1970s to court trusted suppliers, Statoil's relations with KV were of a particularly close nature. With Statoil's backing, KV coerced and replaced domestic and foreign competition in fields such as maintenance, seismic surveys and engineering. On the supplier market that emerged, success and failure were not necessarily a product of price and quality. Statoil, the state oil company that took upon itself to implement a policy of national preferences, held extensive formal and arbitrary powers and a corresponding discretion in deciding which suppliers would succeed and which would fail. Particularly in the aftermath of the 1974-75 shipping crisis, Statoil and the public authorities channelled orders to Norwegian yards in need of employment. [122]

One part of the offshore industry remained largely unaffected by Statoil and public policy. The shipping companies that began supplying services such as drilling, tug boats and anchor handling in the 1960s continued their thriving business. Shipping apart, much of the nascent Norwegian supplier industry relied heavily on a political economy orchestrated by Statoil.

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[120] Smeby's private papers, SCADA brochure dated April 1977 in marketing folder dated September 1977.

[121] Interview with Leif Fjellin, 4 October 2004. Mr. Fjellin, who worked with Wisbech Refsum prior to the acquisition, stayed on as KV's local manager.

[122] The practice is discussed in detail both in Nerheim, En gassnasjon blir til and particularly in Mjelva, "Tre storverft".

2.4 *Two technological systems at odds*

When Kongsberg Våpenfabrikk entered the offshore industry, most of the initiatives originated with the company's partnership with Statoil and various attempts to leverage existing products and services. Statex and Norwegian Petroleum Consultants were examples of the former, gas turbines and SCADA of the latter. In addition, Kongsberg Våpenfabrikk made a couple of technology bets on its own account. These related to deepwater technology.

Initially, offshore oil exploration was but the continuation of onshore oil exploration. The first recorded attempt is instructive. It took place in 1887 outside California, where oil surfaced on the ocean. A wildcatter noticed the spill, built a wharf, placed a drilling rig on the pier, and struck oil. Before the age of decent seismic surveys, oil companies sunk offshore wells where an onshore field met water, for example along the shores of the Gulf of Mexico. Gradually oil exploration crept further ashore and piers gave way to fixed platforms. In 1947, Kerr-McGee built the first platforms out –of sight of dry land. Many more followed where the water was comparably shallow.[123] The offshore procedure resembled the onshore procedure with fixed installations playing a crucial role. These platforms acted as a miniature island.

Exploratory drilling was a particular challenge when working offshore. Until the 1950s, exploratory drilling required a fixed platform whether the well was dry or not. This changed in the 1940s and 1950s with the invention of floating and movable drilling rigs.[124] The reach of these rigs was limited, in part because *heave* (vertical wave-induced movements) frustrated the working of *blowout preventer* (BOP) equipment. These stacks played a critical role. If in heavy drilling mud could not keep the pressurized oil and gas from forcing their way towards the surface, the BOP would choke the stream. In worst case, the BOP could ram a plate of steel through the well like a guillotine. In the late 1950s, engineers working with Shell devised a BOP stack for use on the seabed. Using hydraulic cables, a floating rig would be capable of closing down a well regardless of waves and weather. Consequently, subsea BOPs enabled oil companies to drill at much greater depths.

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[123] Acha and Finch, "Paths to deepwater in the international petroleum industry". In the late 1960s, more than 800 platforms were deployed in the Gulf of Mexico.

[124] Floating barges with rotary rigs data back to the early 20th century, but the more capable jack-ups arrived only in the 1940s and semi-submersibles in the late 1950s; cf. Veldman and Lagers, 50 years offshore.

It took only a small step of imagination to realize that if BOPs would work on the seabed, so might a *Christmas tree*. A Christmas tree is a stack of valves that control the flow of oil and gas from a working well – somewhat like a tap on a volcano. Such pressure-containing equipment is essential to oil production. In the early 20th century, oilmen in Louisiana would occasionally place a Christmas tree in a swamp and the valves could in principle work underwater. Another early subsea development (1943) involved a gas field beneath Lake Erie where ice formation frustrated the working of fixed platforms. Rather, the field developer chose to place valve trees on the seabed ten metres below the surface and let divers open and shut the valves that governed production.[125] In 1961, Shell devised a Christmas tree that could be remotely controlled using hydraulic pressure. At about the same time some 20 subsea-completed wells were being installed offshore California as tiebacks to the Conception field platform.[126] By the early 1960s, oil companies were capable of exploring and producing oil without a fixed platform placed directly above the well.

Blowout preventers and subsea Christmas trees were important components, but oil exploration in deep waters required much more. It is probably fruitful to think of the field as a technological *system* consisting of a host of interdependent components. Within this system, Shell played a central role. Applying the language of Thomas Hughes, we might say Shell acted as a *system builder* or an *inventor-entrepreneur*.[127] The company worked in every offshore oil province apart from the Gulf of Mexico: Lake Maracaibo (Venezuela), off the Californian coast, in Cook Inlet (Alaska), outside British Borneo and Brunei, in the Gulf of Paria (between Venezuela and Trinidad), off Nigeria, and in the Persian Gulf near Qatar. Shell's engineers collected experience from numerous operations and particularly the CUSS consortium (an acronym for Continental, Union, Shell and Superior – four oil companies). Based on this experience, Shell gathered or applied for 160

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[125] Smeby's private papers, "Subsea oil well completion and production systems: a current evaluation", Dixon Associates, Houston, Texas, 31 August 1973.

[126] The single most informative text is Veldman and Lagers, 50 years offshore. Developments are also cited in various accounts of early subsea developments, e.g. Underwater wellheads (Offshore Energy Center, 2006 [cited April 2007]); available from
http://www.oceanstaroec.com/fame/1999/underwaterwellheads.htm.Fitzsimmons, Ian. Sizing up the next 25 years Atlantic Communications, 2004 [cited April 2007]. Available from
http://www.oilonline.com/news/features/oe/20040801.Sizing_u.15509.asp.

[127] Cf. footnote 19 on page 19.

patents covering basic innovations such as a semi-submersible drilling rig, a dynamic positioning system, a sea-floor wellhead and guide base, a mooring system for drilling rigs, and remotely controlled blowout preventers. Some concepts were entirely new such as an underwater "manipulator", today called a remotely operated underwater vehicle (ROV); such free-swimming robots were first used to operate connectors and override valves at the seafloor outside Santa Barbara, California.[128] Shell also introduced through-flow-line (TFL) well service – the practice of pumping tools down to the well in order to perform maintenance operations.[129] By 1961, Shell knew how to build every component of a technological system capable of draining oil and gas without the depth limitations of fixed platforms.

For a while, Shell kept its deepwater technology secret. At the time, the most promising area for deepwater development was the Gulf of Mexico. In 1962, the US government opened large tracts of the Gulf to the oil companies. Shell bid for much deepwater acreage, but Shell was frequently the only bidder, which meant the government could exercise an option not to honour these bids. This triggered a rethink in Shell. The company decided competition was necessary for future prospects; besides, the company believed real money rested with figuring out where the oil was, not figuring out how to produce it.[130] Hence, in 1963 the company changed tracks and decided there was more to earn from licensing than from attempting to maintain a monopoly on deepwater technology. Shell offered to share its insights in a three-week course. Despite an entry ticket of USD100 000, Exxon sent ten and Mobil twelve participants. According to one participant, the perspectives were "overwhelming".[131]

Subsea processing was still not in place. In some cases, as with the gas from below Lake Erie, little processing was required. Elsewhere, oil companies had to install compressors, pumps, metering systems and storage tanks to separate oil, gas, sand and water. Because such operations could not be done underwater in the 1960s, output from most subsea wells was connected (*tied back*) to a nearby platform.

[128] Veldman and Lagers, *50 years offshore*, pp. 86-89.

[129] Derrick Booth, "North Sea: Testbed for advanced subsea production", *Noroil*, June 1983, 37-49

[130] Tyler Priest, *The offshore imperative: Shell oil's search for petroleum in postwar America*, vol. 19, Kenneth e. Montague series in oil and business history (College Station: Texas A&M University Press, 2007), p. 96.

[131] Veldman and Lagers, *50 years offshore*, pp. 83-86.

Figure 6) ***Options for the offshore oil industry, 1960-75***

	Drilling (Ability to host a rotary rig)	**Production** (Ability to host a Christmas tree)	**Processing** (Ability to host separation equipment)
Fixed platforms	✓	✓	✓
Floaters (Ships, rigs, semisubs)	✓		
Subsea templates		✓	

In the 1960s and early 1970s, the fixed platform remained the natural choice for the great majority of offshore field developments. Platform technology improved and offset the need for subsea systems.[132] Their one great drawback, however, was the ability to exploit oil in very deep waters. Fully two-thirds of the Norwegian Shelf lay in depths in excess of 200 metres. By 1973, nobody had developed any field at such depths.[133] Although oil companies and their suppliers devised very large platforms to handle deepwater, there was a limit to how deep the platforms could reach – at least if economy was part of the equation. Around 1972, Shell - the company that most actively pursued new approaches offshore - accurately predicted that fixed platforms would be able to handle 1000 feet (300 metres) of water by 1980 and then level off (see figure below).[134] To explore and extract oil from beyond this limit, oil companies had to think differently. Looking thirty years ahead, Shell (again accurately) predicted oil production from below 2500 metres of water with the assistance of subsea systems.

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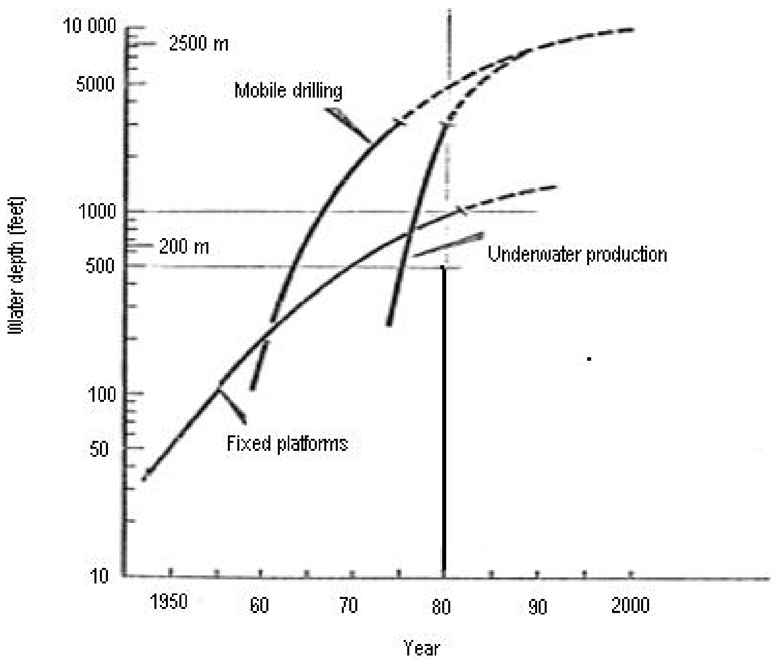
[132] Priest, The offshore imperative: Shell oil's search for petroleum in postwar America.

[133] Smeby's private papers, Smeby, "A Norwegian activity on subsea completion / deep water production systems", 11 November 1975.

[134] Smeby's private papers, Dixon Associates to KV, "Subsea oil well completion and production systems: a current evaluation", Houston, Texas, 31 August 1973. The sketch from Shell Development Company referred on the figure is drawn from this document.

Figure 7) ***Shooting stars observed in 1972: projected capability***[135]



While Shell first shared knowledge with competing oil companies, their patents and technology soon disseminated to independent suppliers. Aerospace companies were among the first to explore deepwater technology. In the 1960s, subsea systems looked set to evolve rapidly. Naïve optimism surrounded subsea oil production: man had flown to the moon, so why not conquer the deep?[136] A number of the companies that developed subsea technology around 1970 had been working on the Apollo project: Raytheon, Hughes, Boeing and Lockheed all looked into subsea systems. They were attracted to the prospect of sponsors as rich as the US government and the opportunity to apply hydraulic controls and advanced engineering in a new field.[137] The design and manufacturing of subsea Christmas trees seemed to fit their capabilities. The weapons factory at Kongsberg shared these sentiments.

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[135] Ibid.

[136] "Subsea technology into the realistic years: The contemporary era of subsea production", *Noroil*, 1981, p. 31 ff.

[137] Ibid.

2.5 *California to Kongsberg: the diffusion of deepwater technology*

At the onset of the Norwegian oil age, Kongsberg Våpenfabrikk was nowhere close to inventing radical new technology, let alone technological systems. The weapons factory was at ease with complex technology, however, and its engineers reasoned there would be multiple applications for deepwater technology. With regard to subsea systems, this realization was homegrown and pursued with insights from well-placed advisors. With regard to dynamic positioning, KV's eventual interest owed a lot to a crusading professor of cybernetics, Jens Glad Balchen.

In the early 1970s, it seemed quite likely there would be a market for subsea systems on the Norwegian shelf. The first oil to reach the market from Ekofisk flowed from four subsea wells. Phillips Petroleum had hooked these on to a jack-up rig with some processing equipment and used the subsea system to gain experience with the field and to earn badly needed cash for the forthcoming field development. The wells produced a total 28 million barrels of crude and a tidy profit. When proper platforms arrived, Phillips Petroleum shut down the subsea wells and freed the jack-up for other assignments.[138]

While the subsea system was still operating at Ekofisk, KV got in touch with Lockheed Petroleum Services. Both companies were defence contractors and had joined forces to deliver command and control systems for the Norwegian armed forces in the 1960s.[139] KV hoped to license Lockheed's technology for dry subsea systems - systems that allowed submarine-borne technicians to work in atmospheric chambers on the seabed.[140] Dry systems never gained a wide following, but raised high expectations in the early 1970s.

KV failed to reach agreement with Lockheed, but continued to investigate subsea technology. In the summer of 1973, KV commissioned a report from

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[138] T.I. Pedersen et al., "Introduction to subsea production systems" in Subsea Completion systems (Kristiansand: Norwegian Society of Chartered Engineers, 1983). The technological choice is outlined in Pratt, Priest, and Castaneda, *Offshore pioneers*, p. 226.

[139] KV-Cor 248, Qvenild to Hurlen (copy Aasland), 1 July 1976; KV-board, minutes, 23 November 1973.

[140] Smeby's private papers, Dixon Associates, "Subsea oil well completion and production systems: a current evaluation", Houston, Texas, 31 August 1973. The only operational dry well at the time was a Lockheed system operated by Shell Oil offshore Louisiana. A competitor, Subsea Equipment Associates Limited (SEAL) was about to launch another solution.

Don E. Dixon, a firm of consultants that greatly improved the Norwegians' understanding of subsea systems.[141] Dixon advised against building proprietary technology and argued in favour of working with an established supplier. Oil companies, Dixon argued, held an aversion to unproven equipment and suppliers. This conservatism stemmed partly from the dire consequences of failure and partly from an inability to make informed decisions: procurement people usually had extensive field experience, but insufficient theoretical knowledge to assess new and unproven products.[142]

Just as KV was considering Dixon's recommendations, Ole Magnus Smeby, the appointed product manager for subsea systems, received a phone fall from Cameron Iron Works Inc. In 1922, the founder of this Houston-based company had invented the blowout preventer.[143] The company expanded into valve trees and became a recognized leader with some 50 per cent of the market for pressure-containing oil equipment, critical components that fetched a high price in the market. Cameron needed more capacity to supply wellheads for new rigs during the 1973-74 building boom and considered enlisting KV as a contract manufacturer.[144] For KV, the real attraction with Cameron was not the prospect of some lucrative fabrication assignments, but the opportunity to form a partnership with a leading supplier of subsea equipment – including blowout preventers mounted on the seabed. Cameron's global market share loomed above 40 per cent.[145] Smeby travelled to Houston, visited five leading subsea providers, and eventually

[141] Smeby's private papers, "Subsea oil well completion and production systems: a current evaluation", Dixon Associates, Houston, Texas, 31 August 1973. This document also provided insights in the thinking of Shell and other forward-looking oil companies; cf. p. 57.

[142] Smeby's private papers, Smeby to KV Oil Division, "KV's oil tool equipment: activity status and future prospects", 29 June 1981; the same observation can be found in Hanisch and Nerheim, *Fra vanntro til overmot*.

[143] Shantell DeHart, "Cameron: A humble philosophy, a company growing," *Business News*, 15 December 1997, accessible at www.businessnewsonline.com.

[144] Smeby's private papers, Smeby, memorandum on 28-31 January visit to US oil equipment manufacturers, 15 March 1974.

[145] Smeby's private papers, Smeby, "A Norwegian activity on subsea completion / deep water production systems", 11 November 1975.

concluded Cameron was the best partner available.[146] Besides, Cameron was not yet committed to work with any of KV's engineering rivals.[147]

Like KV, Cameron was bureaucratic and conservative, somewhat unused to cooperation, and held its proprietary capability in high regard. Despite these similarities, or maybe because of them, the two parties signed a memorandum of understanding.[148] KV started out as a sales channel and contract manufacturer of wellhead equipment while pursuing additional opportunities. In 1976, Cameron agreed in principle to let KV serve as a "contractual partner" if Cameron sold subsea equipment to Norwegian customers or customers on the Norwegian shelf.[149]

* * *

The diffusion of dynamic positioning took a different path, but the application of basic military technology offers a link of sorts. Dynamic positioning builds on the theories of Norbert Wiener who, during the Second World War, worked on ways to let radar systems automatically aim anti-aircraft artillery. The thought struck him that these systems resembled the working of a nervous system, and he was inspired to formulate a general theory (cybernetics) on processes that interact with themselves. In effect, he broadened people's perspective on matter; prior to Wiener, engineers focused almost exclusively on solids, energy and mechanics.[150]

Dynamic positioning was invented to solve a particular problem relating to Project Mohole. In 1960, nobody had sunk a well at water depths beyond 200 feet (ca 70 metres). American scientists nevertheless proposed to drill a hole[151] in the middle of the Pacific Ocean where the Earth's crust was

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[146] Smeby's private papers, Smeby to KV Oil Division, "KV's oil tool equipment: activity status and future prospects", 29 June 1981.

[147] Interview with Qvenild, 29 September 2004.

[148] Smeby's private papers, Smeby to KV Oil Division, "KV's oil tool equipment: activity status and future prospects", 29 June 1981.

[149] RA-Arntzen-Oil, board report, 26 April 1976.

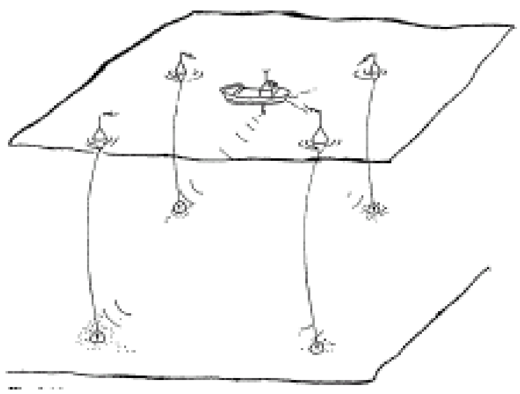
[150] For an introduction, I trust http://en.wikipedia.org/wiki/Cybernetics and another Internet based encyclopaedia: J Rosnay, *History of cybernetics and systems science* (Principia Cybernetica, 2000 [cited October 2005]); available from http://pespmc1.vub.ac.be/CYBSHIST.html.

[151] Some of the challenges are described in Pratt, Priest, and Castaneda, *Offshore pioneers*.

comparably thin. They hoped to collect a core sample from the intersection between the crust and mantle (the *Mohorovičić Discontinuity*) near Hawaii where the water was 15,000-18,000 feet deep. When the project got going, with American public funding, pundits dubbed it "geology's moon landing". [152] The attempt itself was discontinued after some years, but nevertheless succeeded in boosting offshore drilling.

One pressing challenge faced by Project Mohole was to keep its drillship (*CUSS I*) in position. Anchors would not work because the length of the mooring lines allowed for intolerable drift due to wind, current and waves. Drifting while drilling risked losing the equipment, and the Mohole team had to find a way to stay in position. Using four directional propellers (thrusters), the crew attempted to manoeuvre the *CUSS I* in relation to radio buoys and subsea beacons positioned around the drillship; each submitted signals. When the signals appeared equally strong, the *CUSS I* was in exact position. Since navigation was difficult and tedious, somebody thought of letting a computer detect the signals and guide the thrusters. Although the attempt failed, Shell Oil learned from the experience and decided to attempt computer-aided *dynamic positioning* on its *Eureka* coring vessel. In 1961, the company introduced an analogue automatic position controller able to retain a ship's position and heading. It worked, more or less.[153]

Figure 8) ***Cuss Control: how dynamic positioning works***[154]



[152] *Project Mohole, 1958-1966* (National Academy of Sciences 2005 [cited November 2005]); available from http://www.nas.edu/history/mohole/.

[153] Hubert Faÿ, Dynamic positioning systems: Principles, design and applications (Paris: Éditions Technip, 1990), pp. 7-8.

[154] Ibid., p. 52.

KV pursued subsea systems, but with regard to dynamic positioning, the company itself was *being pursued*. Jens Glad Balchen was a professor of technical cybernetics at NTH[155] (the Norwegian Institute of Technology in Trondheim), and a firm believer in dynamic positioning. His conviction dated from 1967-68. At the time, he spent his sabbatical at his Alma Mater in Santa Barbara. While teaching a class, he encountered two students involved in a project to equip the *Glomar Challenger* with dynamic positioning. The ship was being equipped to collect core samples and eventually provided substantiating proof of plate-tectonics theory. [156] Professor Balchen became convinced a similar technology could be useful in the North Sea and that the concepts for dynamic positioning could be improved upon.[157]

Professor Balchen thought he could improve upon the approach of the *Challenger*, but he also borrowed extensively. *AC Electronics*, a research branch of General Motors later known as Delco, considered using *inertial navigation* to get a position reference for the ship. First developed to guide the flight of intercontinental missiles, inertial navigation relies on spinning discs manufactured with immense accuracy to calculate the impact of forces upon an object. [158] The task resembles somewhat the effort involved in assessing the acceleration of a car by watching the surface of a coffee mug; if one were able to measure the tilt of the surface, one could decide whether the object was accelerating or decelerating, in what direction, for how long and at what speed. Knowing where one started out, one should then be able to calculate one's present position. In principle, the same approach would work on a boat. Although Balchen was no strong advocate of inertial navigation, he argued the case for Kalman filtering, a novel statistical technique for such advanced tasks as improving the navigation systems on

[155] The *Norwegian Institute of Technology* is referred to by its Norwegian acronym *NTH* (Norges Tekniske Høgskole*)* was established as an independent technical univsersity in 1910. Following a merger in 1996, the institution was renamed University of Science and Technology (Norwegian acronym NTNU).

[156] Max J. Morgan, *Dynamic positioning of offshore vessels* (Tulsa, Oklahoma: The Petroleum Publishing Company, 1978).

[157] Interview with Balchen, 15 September 2004; interview with Sælid, 12 October 2004

[158] For a fascinating introduction, cf. Donald Mackenzie, *Inventing accuracy: An historical sociology of nuclear missile guidance*, Inside technology (Cambridge, Mass.: MIT Press, 1990).

board the Apollo shuttle.[159] A Kalman *filter* is an algorithm, for most practical purposes a piece of software designed to provide accurate information out of inaccurate data and update a "best" estimate for the state of a system as new, but still inaccurate, data pour in (see Appendix 11.5. on page 301).[160]

Back in Trondheim, the Californian ideas reached an unusually vibrant scientific community at the institute of technical cybernetics. Professor Balchen, who headed the institute, focused on the application of technology. In this, he differed from most European Universities in which the cybernetics faculties focused on theory,[161] but resembled the outlook of enterprising researchers, the “electronics entrepreneurs” that frequently had had their sentiments shaped by participation in British defence-related research.[162] His knowledge of cybernetics was undisputed, but there were better theoreticians around him and people more adept at coding an application. Professor Balchen’s undisputable talent, however, was his ability to inspire students and emphasise the need to get things done. In short, he was an arch-typical entrepreneur. With creativity and authority, but not necessarily a corresponding instinct for profit, his ventures were a “delightful way of losing money” according to one sympathetic follower.[163]

In the early 1970s, Balchen made repeated attempts to commercialise dynamic positioning. He got several students to write their diplomas on Kalman filtering and other issues relevant to dynamic positioning.[164] He

[159] Kalman filtering was a technique first outlined in a famous 1960 paper Rudolf E. Kalman, "A new approach to linear filtering and prediction problems", *Transaction of the ASME - Journal of Basic Engineering* (1960): 33-45. For a thorough mathematical introduction, cf. Greg Welch and Gary Bishop, "An introduction to the Kalman filter" (Chapell Hill, North Carolina: 2004). Laymen will be better off reading Peter S. Maybeck, *Stochastic models, estimation, and control*, ed. Richard Bellman, vol. 141, Mathematics in science and engineering (San Francisco: Academic Press, 1979).

[160] Barry A. Cipra, "Engineers look to Kalman filtering for guidance", *SIAM News* 26, no. 5 (1993).

[161] On the distinguishing features of cybernetics at Trondheim, cf. interview with Nils Albert Jenssen, 14 October 2004.

[162] Stig Kvaal, "-og vi var alle frelst på den nye teknikken" : Servoentusiastene og visjonen om et moderne norge, Ifim-paper ; 1994:13 (Trondheim: Sintef Ifim, 1994).

[163] Interview with Jacobsen, 9 September 2004.

[164] Arne Asphjell and Anne Kristine Børresen, *Institutt for teknisk kybernetikk: 50 år* (Trondhjem: NTNU, 2004).

visited KV with plans to manufacture dynamic positioning from 1971 on, but felt “rejected by way of committee”.[165] Not easily deterred, he came back to KV and kept marketing dynamic positioning through meetings and conferences. Somehow, eventually, a pre-project emerged, officially from January 1974.[166] At the time, the initiative was a joint effort that involved two research institutes (the institute of technical cybernetics in Trondheim and scientists from Christian Michelsen’s Institute in Bergen) and two marine electronics companies (Kongsberg Våpenfabrikk and *Simrad*, a Horten-based company where Kåre Hansen led a team that worked on a hydroacoustic position reference system). The most competent potential supplier was not part of the effort: Norcontrol in Horten. Norcontrol had delivered some 400 ship-automation projects between 1965 and 1976 and had been exploring dynamic positioning in more minute detail than KV had been. Norcontrol aimed to develop a proprietary dynamic positioning (DP) system.[167]

In September 1974, none of the parties had yet to assume ownership of dynamic positioning; the modus was one of burden sharing rather than the pursuit of opportunities. They met as equal partners in an unfunded project. They agreed to exchange information and knowledge, sketch a pre-project, and continue seeking out sources of finance from public funds. Both KV and Simrad were potential manufacturers of various pieces of hardware. Both NTH and CMI were interested in the software components of the system. KV assumed responsibility for the mapping of resources and overall project administration, but throughout the meeting, Balchen spoke of the competencies of “Norway Inc.” and on the need of the parties to make decisions and work as if they were a company.[168]

2.6 Conclusions

KV pursued products and services with Statoil, on behalf of Statoil or with the support of Statoil. By 1975, KV’s portfolio of oil-related products and services ran like a list of concessions from Statoil and public agencies. If KV and Statoil were ever concerned about the absence of a market and the danger of misallocating resources, such concerns failed to materialize in

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[165] Interview with Balchen, 15 September 2004.

[166] KV-Cor 239, KV to Utviklingsfondet, request for grants, 10 November 1975.

[167] Interview with Jenssen, 14 October 2004.

[168] KV-Cor, box 136, Jahnsen to various recipients, meeting minutes, 30 September 1974.

writing. Probably, the people in charge at Statoil and KV saw no distinction between the interests of Statoil, the interests of KV and the interests of the country. It was difficult and maybe futile to identify who acted on behalf of whom; the connections between the two were very close and the people in charge frequently held overlapping roles. Many of KV's initiatives involved advanced technology, but rarely innovative technology.

In the 1970s, the industry architecture of the Norwegian supplier industry resembled the market-based approach seen elsewhere – where offshore oil relied on independent suppliers. Procurement was tightly controlled, however. Statoil was in a position to influence procurement directly, and used this opportunity extensively. Industry building and political constituencies played a larger role in determining the allocation of tasks than technical prowess and ingenuity.

While most of KV's oil ventures originated in an alliance with Statoil, dynamic positioning and subsea systems were based on a belief that North Sea oil exploration required novel techniques. As a point of departure, it is useful to reflect on similarities between the two techniques. Neither originated at Kongsberg. Both relied on American inventions pioneered by Shell outside California in 1960-61, both were unproven in the markets and both faced competition from established technologies (mooring and fixed platforms). The young engineers at Kongsberg Våpenfabrikk who worked on these deepwater technologies had a broadly similar background and a joint management. Both technologies were attractive, from an engineer's point of view – they triggered the imagination and pointed to new ways of extracting oil from the deep oceans. Both technologies seemed to fit the capabilities of the defence industry. The two business lines originated at the same time, from the same town and the same corporate structure. Both technologies were systemic in the sense they worked not on their own but in interaction with a technological system.

The most remarkable difference related to initiative. If anything, managers at the defence and engineering conglomerate believed subsea production systems looked set to find many applications; the interest in subsea technology seemed home-grown while dynamic positioning was pushed by people outside KV. Apart from that, there is little in the early history of either initiative to indicate these two initiatives would evolve in very different directions – that is before we take into account the very different nature of the shipping and oil paradigms.

3 Slow track and fast track, 1974-1976

Deepwater technology diverged from the various products that KV pushed with Statoil's assistance: these business lines required innovative customers that applied unproven technology in search of excess revenues or cost savings.

Subsea systems looked very promising from an engineer's point of view, but functionality was not the only concern that shaped field developments. Statoil favoured concrete deepwater structures (Condeeps) that allowed the use of (comparably) conventional technology from established Norwegian suppliers. When the Condeeps had secured a following, advisory engineers, shipyards, unions, regulators and politicians worked to preserve their stake in the dominant design. The concept was copied from field to field with only slight modification. No other style of field development managed to draw attention – and subsea technology lingered. In this setting, KV's relationship with Statoil was of less assistance. Statoil pushed for Condeeps on every field, with little time to spare for subsea solutions; the 1970s went by without a single attempt at subsea completions.

Dynamic positioning, however, soon found a market. *Albatross* dynamic positioning found customers in the shipping industry among the various offshore companies that provided drilling, maintenance, service and support. These firms embraced dynamic positioning. Most suppliers originated with shipping companies whose attitude to experimentation, sourcing and risk stood apart from the oil industry. They adopted innovation quickly and embraced experimentation wholeheartedly.

The slow adoption of subsea technology and the speedy acceptance of dynamic positioning resembled the modus operandi of their respective customers.

3.1 A slow start to subsea sales

On 1 January 1975, KV set up a separate oil division.[169] Unlike other divisions at KV, the Oil Division lacked a portfolio of products. It was an almost empty shell set up to pursue emerging opportunities. Its first head was Rolf Qvenild, a calm, aloof and analytical man. He started out with nothing but a few offices in the KV headquarters and three product

[169] For an overview of KV's divisions and changes in the corporate structure, 1973-86, cf. appendix 11.3.

managers: Ole Magnus Smeby in charge of O-3 Marine Systems (subsea), Bjørn Jahnsen at O-6 Vessel Automation (dynamic positioning) and Bjørn Barth Jacobsen in a freelance position. Subsea systems seemed to have the brightest future.

KV soon got started making subsea components for drilling rigs. In this line of work, KV simply rented its production capacity to Cameron. Cameron priced its products somewhat higher than the competition, preferred quality to costs and was unconcerned about productivity at KV.[170] KV gained some research and development contracts, and Cameron was generally supportive of these, particularly when the development in question could enlarge the market for Cameron equipment.[171] In 1975, KV made 25 valve blocks and foundations for BOPs and dry trees. KV shipped these huge parts to Leeds where Cameron's British factory assembled valve trees.[172] Because many wellheads failed quality control and were discarded, KV decided to invest in a new lathe. Either way, exceptional costs swallowed the exceptional margins.[173] The main promise of this venture was to position KV for work on subsea production systems.

Industry experts believed the capabilities of the subsea production systems were set to improve rapidly. The technology to install and operate a subsea system in water depths of up to 1000 metres seemed reasonably close in 1973. If the rewards were high enough, several oil companies could pull through such developments.[174] The technology received a boost from the 1973 oil price shock, which made subsea production cost efficient under certain conditions, particularly by reducing time-to-market.

One reason to be optimistic on behalf of subsea systems was the high costs of conventional field developments in the North Sea. In the 1970s, offshore fields in the North Sea were roughly 25 times more expensive to develop

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[170] Smeby's private papers, Smeby to KV Oil Division, "KV's oil tool equipment: activity status and future prospects", 29 June 1981.

[171] Smeby's private papers, Smeby to KV Oil Division, "KV's oil tool equipment: activity status and future prospects", 29 June 1981.

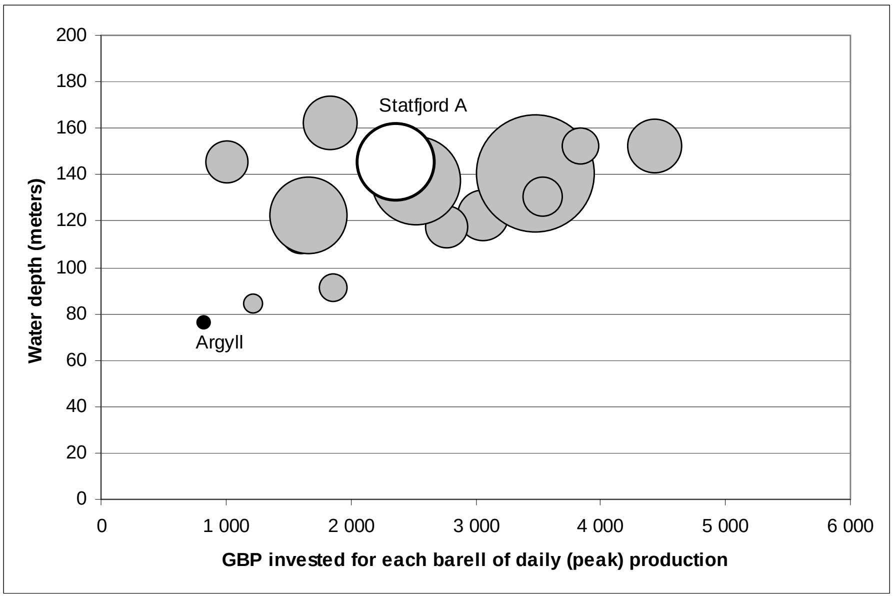
[172] Smeby's private papers, Smeby, proposal for long-term cooperation with Cameron Iron Works Inc, 5 February 1975; RA-Arntzen-Oil, board report, 9 September 1975.

[173] RA-Arntzen-Oil, board reports dated 24 April 1975, 1 March 1977, 10 May 1977, 24 February 1976, and 26 April 1976.

[174] Smeby's private papers, "Subsea oil well completion and production systems: a current evaluation", Dixon Associates, Houston, Texas, 31 August 1973.

than onshore fields in the Middle East – and the deeper the water, the more voluminous the foundation. Rather like a pyramid or a cone, the volume of a gravity platform grew exponentially in relation to its height and made fixed platforms on deep waters costly. The figure below depicts the relationship between water depth and investments based on data mostly from the British shelf. There was no correlation between the richness of the find (large bubbles) and the cost of extracting an extra barrel of oil – but there was a distinct correlation between extraction costs and water depth.

Figure 9) ***A sinking feeling: cost increase with water depth, 1975***[175]



Interestingly, the most cost-efficient field development on the British shelf was a subsea completion on the Argyll field (the small bubble in the lower left-hand corner of the figure). The subsea wells fed oil onto a semi-

[175] The figures are cited from *Economist*, July 1975, referred to in Smeby's private papers, Smeby, "A Norwegian activity on subsea completion / deep water production systems", 11 November 1975. The figure shows UK fields as of 1975 – the size of the bubbles indicate the fields' estimated peak output. Statfjord A (1979) was not in the original material, but has been added for reference – its peak capacity was estimated at 40,000 barrels a day; costs as estimated by Styringsgruppen for kostnadsanalysen - norsk kontinentalsokkel and Johannes Moe, "Rapport fra styringsgruppen oppnevnt ved kongelig resolusjon av 16. Mars 1979", *Kostnadsanalysen norsk kontinentalsokkel*, Volume 2, (Oslo: Ministry of oil and energy, 1980) All costs are investments only, not operating costs, and given in nominal currency.

submersible rig deployed in 1975 by a small oil company, Hamilton Brothers. The company used field-proven equipment that may not have been ideally suited to the local circumstances. They worried less about fine-tuning their systems, and did not attempt to circumvent divers. Mooring lines kept the rig in position above plain subsea wells with standard Christmas trees not much different from those used topside albeit with a down time of close to 20 per cent.[176] Without the excessive technology focus, their operation extracted oil far more economically than fixed platforms. The entrepreneurs, tellingly, had a background in the drilling industry rather than the oil industry proper.[177]

Some Norwegian engineering companies took notice of what went on. Probably inspired by this precedence, Aker proposed floating production on the Norwegian shelf arguing this would be particularly economical on deep water.[178] At the time, KV proposed a desktop study into subsea completions that might fit Aker's plans.[179] Norsk Hydro, a semi-private Norwegian oil company that gained a foothold in the 1960s, sponsored the study. In late 1975, KV's head of subsea systems hoped to install multiwell projects by the early 1980s and subsea satellites by 1978. Satellites were single Christmas trees that fed oil and gas to a nearby platform without manifolds.[180] Several fields could benefit from the use of satellites, including a dozen pockets around Statfjord and East Frigg.[181]
KV spent the year 1976 petitioning Statoil and Hydro to try out subsea systems.[182] When Statoil discovered Tommeliten in 1976, a smallish

[176] Ben Van Bilderbeek and L.E. Reimert, "Early subsea production systems: Advance in the state-of-the art" (paper presented at Offshore Technology Conference, Houston, 1978), 789ff.

[177] M.R. Williams et al., "Simple subsea trees for shallow water: An economical alternative" (paper presented at Offshore Technology Conference, Houston, 27-30 April 1987), 107 ff. For an investment cost comparison, turn to the figure on page 70. The Argyll field is the smallish bubble in the lower left section.

[178] Smeby's private papers, "Proposal for long term production and engineering cooperation between Cameron Iron Works Inc. and A/S Kongsberg Våpenfabrikk", 28 February 1975.

[179] RA-Artnzen-Oil, board reports, 24 February 1976 and 24 August 1976.

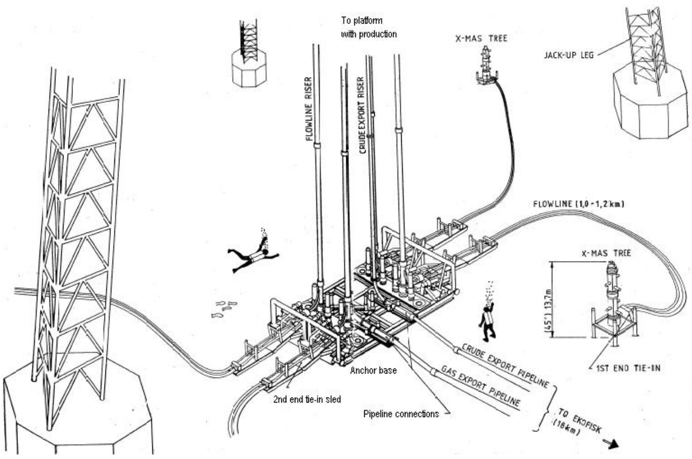
[180] Smeby's private papers, Smeby, "A Norwegian activity on subsea completion / deep water production systems", 11 November 1975.

[181] KV-Cor 248, Qvenild to Hurlen, memorandum on subsea technology, 1 July 1976.

[182] RA-Arntzen-Oil, board report on activities in 1976, 1 March 1977.

reservoir by contemporary Norwegian standards in 83 metres of water, the state oil company considered using subsea wells tied to a converted jack-up in the same fashion Phillips had done on Ekofisk.[183] In the summer of 1977, Statoil asked KV and Cameron to submit an offer for Tommeliten,[184] and the Oil Division was greatly encouraged.[185] KV and Cameron proposed four single-well satellites and a straightforward development that resembled a solution Cameron had supplied to Shell. The system included valve trees with individual controls, flowlines from the valve trees to the riser base, a pipeline from the riser base onto the deck of the jack-up, and some equipment on the jack-up to steady the oncoming pipeline. Cameron and KV offered the package for NOK 55 million, of which 85-70 per cent related to equipment supplied by Cameron.[186]

Figure 10) ***The Tommeliten proposal, 1977***[187]



Statoil continued drilling exploratory wells, but was unable to decide on the economic viability of Tommeliten.[188] The rewards could not justify a regular

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[183] KV-Cor 248, Qvenild, letter to Statoil, 10 June 1977. Phillips Petroleum was Statoil's technology partner at Tommeliten.

[184] KV-Cor 245, Qvenild to Hurlen and Aasland, minutes from meeting with Statoil (Ager-Hansen), 23 June 1977.

[185] RA-Arntzen-Oil, board report dated 25 August 1977.

[186] KV-Cor 248, KV board proposal, 12 August 1977; KV-Cor 248, Qvenild, letter to Aasland, 7 July 1977.

[187] The illustration was attached to KV-Cor 248, Aasland, proposal, 12 August 1977.

[188] RA-Arntzen-Oil, board report, 17 November 1977.

gravity platform, but Statoil was unable to assess the pros and cons of a subsea solution. Elsewhere on the continental shelf, Mobil looked into subsea satellites for Statfjord, and Elf considered subsea completions around Frigg.[189] Nevertheless, none of the oil companies asked for subsea systems. The question that comes to mind is why subsea systems progressed so slowly.

3.2 The conserving effect of field development styles

Possibly, KV had bought into a hyped technology; *subsea* was a "'glamour' phrase" in the early 1970s. Although there had been approximately 75 underwater well completions in 1973 and the number grew by a dozen each year, most systems were experimental and few had withstood the wear and tear.[190] In 1973, KV's advisors admitted there "does not appear to be enough practical field experience to allow any meaningful equipment evaluation to be made". None of the subsea systems available to the industry was reliable, and, based on progress to date and contemporary efforts, none would work in a "'normal' manner" for at least another five years.[191]

The main difficulty for those that advocated subsea systems, however, was the rapid ascendancy of a competing field development style. Oil companies on the Norwegian shelf were simply too preoccupied developing fields in the *Norwegian Style*[192] – self-contained gravity platforms with a concrete foundation to support the deck. A desire to utilize a few early experiences with gravity platforms, and the need to keep thousands of blue-collar workers occupied, formed an efficient block against more agile field development styles.

The use of concrete structures in the North Sea was not an invention of Statoil's. In 1973, Phillips Petroleum installed a storage tank built of concrete built by the construction company Høyer-Ellefsen. Phillips Petroleum thought it advantageous for political reasons to go with a Norwegian firm – besides, the income from the field was such the issue

[189] KV-Cor 248, Smeby, minutes from 5 May meeting with Cameron in Houston, 20 June 1977.

[190] Smeby's private papers, "Subsea oil well completion and production systems: a current evaluation", Dixon Associates, Houston, Texas, 31 August 1973

[191] Smeby's private papers, "Subsea oil well completion and production systems: a current evaluation", Dixon Associates, Houston, Texas, 31 August 1973.

[192] A term coined by Gunnar Nerheim, according to Francis Sejersted in Hanisch and Nerheim, *Fra vanntro til overmot*.

hardly mattered. Elf employed a similar reasoning when the company placed a Condeep on the Frigg field alongside an anchored steel structure: the technological risk seemed small compared to the political gain.[193]

In 1974, when Statoil's focus turned to the Statfjord field, Norwegian construction firms had already gained some experience of building concrete structures. Drawing on this experience seemed natural, particularly since Statoil and Mobil (the operator) felt compelled to make a rapid decision. Across the median line towards Shetland, the British had found a huge field and the geological structures at Brent seemed to continue across the median line - Statfjord looked like an extension of the Brent reservoir and the Brent development looked set to drain the adjacent blocks across the sea border. Statoil and Mobil rushed to place an order with Norwegian Petroleum Contractors for a Condeep, resembling one that Mobile had ordered for Beryl (operational 1975), only larger.[194]

The structure used on Statfjord stood apart because of its sole reliance on concrete foundations. The concrete installations at Ekofisk (from 1971 onwards), Frigg (1977) and Brent (1975 and 1976) coexisted with other installations, whereas Statfjord was made up of *self-contained* concrete platforms. Each contained living quarters, a chemical plant processing highly flammable and pressurized raw materials, a drilling rig, a power plant, a hotel with hundreds of workers, a heliport, and a small harbour. All this rested on an extensive deck 30 metres above the sea level supported by four shafts that stretched down to a gravity base. This base doubled as a storage tank.[195]

The approach at Statfjord A became the default approach elsewhere on the Norwegian shelf. The Statfjord A design was copied onto Statfjord B and then Statfjord C with few alterations. Then followed Gullfaks A, Gullfaks B, Gullfaks C, and so on. Engen observes how it was important for Statoil that "the small amount of competence they had gained with large offshore production plants could be utilised to the fullest. At that time, Statoil's only

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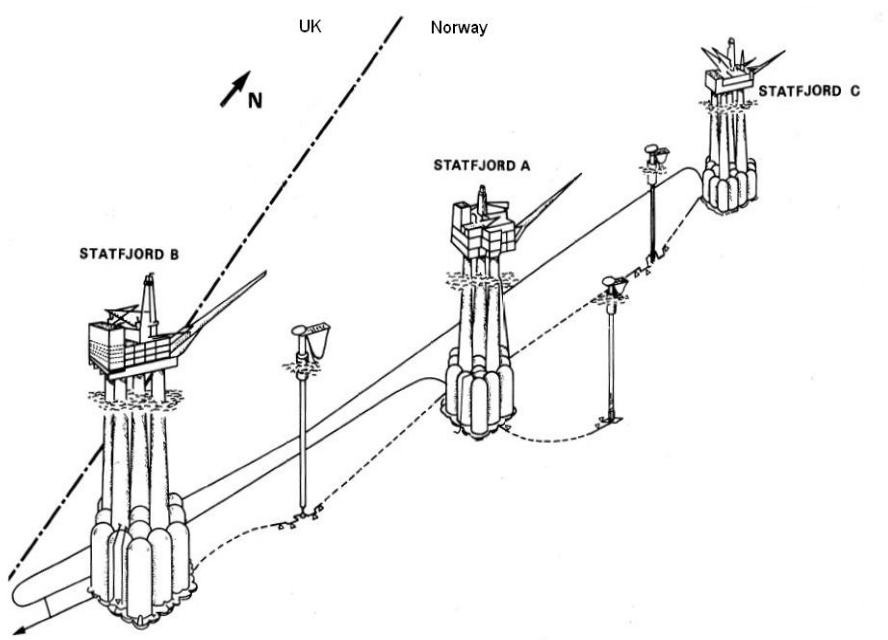
[193] Ibid.; Engen, "Rhetoric and realities", based on interviews with Phillips Petroleum Company Norway, 22 December 1994 and Elf Norway, 14 December 1994.

[194] Hanisch and Nerheim, *Fra vanntro til overmot*. Gunnar Nerheim, Det norske olje-eventyret 1965-2000 (Norsk Teknisk Museum, [cited April 2007]); available from http://www.tekniskmuseum.no/no/utstillingene/Jakten_oljen/historie.htm..

[195] Deplyment, see Nerheim, *Det norske oje-eventyret* ([cited).

experience was with that type of production design." [196] Statoil was the operator on every field where the integrated Condeep design was applied exclusively. Almost every field Statoil developed between 1979 and 1993 made use of huge concrete platforms and there were "certain divisions in Statoil which proclaimed that everything had to be constructed in concrete". [197]

Figure 11) ***Condeep installations on Statfjord***[198]



Statoil took upon itself to secure orders for Norwegian industry. When the shipbuilding industry turned from boom to bust in the winter of 1974-75, the Norwegian shipbuilding industry, possibly bloated in the first place, lost most of its traditional market and turned with some desperation to the

[196] Engen, "Rhetoric and realities".

[197] Engen, "Rhetoric and realities", chapter 6 with reference to an interview with Nils Gulnes, executive president of Amerada Hess on 24 September 1997.

[198] Drawing, slightly modified, from St.mld. 8, 1984-85, *1983 Annual report of the Norweigan Petroleum Directorate*, p. 54.

offshore market. Norwegian authorities facilitated this search for new markets with a hands-on approach, not least through Statoil.[199] A policy of national preferences, and the procurement policies of Statoil, did succeed in diminishing the role of foreign suppliers on the Norwegian shelf. Statoil channelled orders for large structures to Norwegian industry and usually supported a few suppliers in each segment. The proportion of Norwegian content rose and soon accounted for two-thirds of the volume although the industry continued to rely on Houston-based oil tool manufacturers for mission-critical drilling equipment and pressure-containing equipment.[200]

The use of Condeeps simplified the concern about Norwegian content. Huge concrete foundations had to be built in Norway almost by default; their construction required a very deep fjord. Such massive foundations allowed Statoil to fit a deck large enough to assemble several individually manufactured modules into a topside structure; the approach allowed for work to be divided among the numerous and small Norwegian engineering companies and yards. Such extensive modularisation was a brainchild of Aker, which pushed the concept with support from Statoil and the government because it allowed Norwegian engineering companies to compete for more of the tasks.[201] Indeed, spreading the supply business and localising operations became an important goal of domestic policy.

In some respects, subsea development became a victim of the concrete platforms. Although subsea satellites could work with Condeeps, the focus on building huge self-contained structures for every purpose removed attention from more agile field development - as evident in the Tommeliten case. Besides, Statoil had come across fields that were sufficiently prolific to support several Condeeps and economy allowed the company to rely on fixed platforms only.

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[199] For a detailed study, cf. Thorsvik, "Politikk og marked: En studie av norsk leveransepolitikk for oljevirksomheten", Particularly pp. 55, 84.

[200] On Statoil's policy towards competition, cf. Hanisch and Nerheim, *Fra vanntro til overmot*.

[201] Ibid., pp. 386-387; Thorsvik, "Politikk og marked: En studie av norsk leveransepolitikk for oljevirksomheten", pp. 68-69, with reference to an interview with Statoil who emphasised the choice of concept design in securing a high percentage of Norwegian content and a 1985 report by Norwegian Petroleum Consultants, cf. Norwegian Petroleum Consultants, "Vurdering av anbudstyper, innhold og vurderingspraksis ved leveranser til virksomheten på kontinentalsokkelen", 1-6, (Bergen: Ministry of oil and energy, 1983).

3.3 Meanwhile, in the sea off Brazil…

We may question whether subsea systems really were reliable at the time and appropriate for the tasks. Could the Norwegian shelf have seen field developments based on deepwater technology? Oil companies on the Norwegian shelf had their qualms. Maybe the technology was still immature, but the Brazilian example suggested otherwise.

In the early 1970s, Brazil's onshore production was declining. The country imported oil and the 1973 price hike upset the country's unbalanced external payment account forcing a shift to alcohol-powered vehicles. Then, in 1974, oil was discovered in the Campos Basin not far from Rio de Janeiro. The military government opted against foreign involvement and granted the state-owned Petróleo Brasileiro S.A. (*Petrobras*) a monopoly on upstream activities. Conventional development using fixed platforms was technically and economically feasible, but would take between four and eight years and require a lot of capital - which the company lacked.[202] Using subsea techniques and floaters, in the same fashion Hamilton Brothers had done, Petrobras cut back cash requirements and managed to get a well on stream in August 1977.

First perceived as a solution to cut development times, Petrobras discovered the subsea systems and the floating production facilities were reliable and cost-efficient. Consequently, the company employed subsea techniques on successively larger fields and deeper waters as an alternative to fixed platforms.[203] Besides, such early production systems offered clues as to the best field layout. In the late 1970s and early 1980s, seismic surveys were still crude tools and the information from early production systems correspondingly valuable in determining the best field layout.[204]

The Campos Basin became a laboratory for deepwater technology – arguably the most innovative region in offshore oil. On the Enchova field, Petrobras combined subsea trees, flexible production risers, a mono-buoy tanker facility and new techniques quickly to disconnect the semi-sub from the subsea wells in case of emergency. By 1983, three-quarters of the Brazilian offshore output (145,000 barrels per day) poured from subsea

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[202] L.P. Ribeiro, C.A.S. Paulo, and E.A. Neto, "Campos basin subsea equipment: Evolution and next steps" in Offshore Technology Conference (Houston: 2003).

[203] "Subsea technology", *Noroil*, June 1983, pp. 27-36.

[204] Salim Armando, "Petrobras experience on early production systems" (paper presented at Offshore Technology Conference, Houston, 2-5 May 1983), p. 289ff.

systems,[205] but in the shallow part of the basin, Petrobras built steel platforms and used these to host infrastructure for a wider network of subsea satellites and floating production systems.[206]

This is not to say the Brazilian experience with subsea systems was a continuous success. It was not. Some attempts, like the dry trees installed at Garoupa in 1979, clearly did not work according to plan (Petrobras installed a Lockheed system with subsea atmospheric chambers). The dry system itself worked, but intervention and maintenance were expensive and the electro-hydraulic controls failed repeatedly – it was decommissioned in 1984.[207] Regardless of such setbacks, the Brazilians continued to deploy subsea systems – preferably proven techniques and equipment.

In one respect, however, the Brazilian experience and the Norwegian experience converge. Both countries aspired to build a national offshore industry centred on state-owned oil companies, both had a narrow range of previous offshore experience, and both oil companies settled for a particular development style - which they then applied somewhat irrespective of the circumstances. Petrobras arguably chose the more innovative approach.

3.4 Shipping customers and a rapid start to DP sales

When engineers assessed the North Sea offshore market around 1973-1975, subsea systems seemed quite a promising option, whereas dynamic positioning could be a tough sell. Demand for dynamic positioning was low, but rising. In the 1960s, dynamic positioning was applied about once a year and almost exclusively on drillships. Because the likelihood of failure in a DP system was higher than with a mooring system, DP found applications mostly where one could not do without, e.g. when drilling at depths of more than 200 metres, in situations were mooring was very time consuming or where the customer had to maintain a very exact position.[208] A famous case

[205] Bilderbeek and Reimert, "Early subsea production systems: Advance in the state-of-the art", C.T. da Costa Fraga et al., "Campos basin: 25 years of production and its contribution to the oil industry" (paper presented at Offshore Technology Conference (Houston: 2003).

[206] Fraga et al., "Campos basin: 25 years of production and its contribution to the oil industry".

[207] Ibid.

[208] Svein Fagerlund, "Er dynamisk posisjoneringsutstyr interessant for norsk industri?" (paper presented at Dynamisk posisjonering, Trondheim, 3-5 January 1974).

was the *Glomar Explorer*, which spent the early 1970s trying to salvage a sunken Russian submarine from below 5000 metres of water near Hawaii under the pretext of mining minerals on the seabed.[209] In the mid-1970s, there were three or four installations each year, mainly on drillships, semi-submersible exploratory rigs and pipe-lying vessels. Few service vessels employed dynamic positioning, although the technology was quite handy for e.g. diving support - a morbid clue to the relative cost of losing drill bits and divers respectively.[210]

Considering the limited size of the market, the number of competitors in the market for dynamic positioning was quite remarkable. Eight companies had experience in the field: General Electric, General Motors (AC Electronics/Delco), Baylor Company, Edo Western, Ocean Research Equipment, Honeywell, CIT Alcatel and Thomson CSF. [211] Most of them attempted only once, and as of 1975 Honeywell enjoyed an 80 per cent market share with Thomson a distant second picking up mostly French military orders. For those able to compete, DP systems fetched a premium price. Systems sold at NOK 6-8 million (NOK 28-28 million at present day purchasing power), not counting costs of another NOK 7-11 million for extra thrusters, engines and transmission.[212]

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A large number of competitors and few areas of application made it unlikely that KV would manage to push DP technology. Surprisingly, the first order arrived without any marketing and without anything that remotely resembled a working product.

A former employee named Bjørn Bendigtsen connected KV with the shipping industry. Bendigtsen had left KV in disgust back in 1968 thinking the environment was suffocating and ignorant about ideas from anybody but *graduate* engineers, not mere engineers like himself. After business studies, he became head of sales at *Aukra Bruk*, a yard, and in 1973 went on to manage the offshore business of Stolt-Nielsen, a shipping company. In the

[209] Veldman and Lagers, *50 years offshore*, p. 87.

[210] Interview with Røkeberg, 9 May 2006. Risers are the tubes that contain the drill string and the pipes through which heavy mud is pumped into the well to remove earth and stone, cool the drill bit and prevent a blow out. During drilling, drift caused increased wear and tear on risers and they could be torn off.

[211] Fagerlund, "Er dynamisk posisjoneringsutstyr interessant for norsk industri?".

[212] Ibid.

fall of 1974, he worked on a concept for the *Seaway Falcon*, a vessel capable of maintenance, diver support and fire extinction.[213] The vessel sported dynamic positioning from Honeywell, but Bendigtsen wanted to add yet more refinement. He recalled how KV had made L-70 anti-aircraft guns. Their barrels would follow the trajectory of a passing aircraft and fire automatically guided by radar. The idea struck him his fire-extinguishing vessel could apply the same basic approach, only this time the burning target would be stationary while the water cannon surged, swayed, rolled and drifted in troubled waters.[214] Bendigtsen placed a NOK 11 million order to equip the *Falcon* with fire extinguishing technology, the most substantial task of the Oil Division during 1975.[215] Bendigtsen also learned that KV had taken an interest in dynamic positioning.

The next challenge Bendigtsen faced was a collapse in the drilling market. Starting in the early 1960s, a number of Norwegian shipping companies had invested in rigs for oil exploration. A decade later the market for drillships and drilling rigs collapsed due to excessive building. Some 16 semi-submersibles had entered the market in 1975 and 36 in 1976, but the next couple of years saw only one or two additions.[216] The slump was evidence of a dynamic industry; shipping companies had saturated the market for drilling vessels before the bulk of Norwegian industry managed to gain a foothold in oil.

One of the vessels left redundant was the *Seaway Swan*, an aging H4 drilling rig owned by Stolt-Nielsen Seaways. Bendigtsen, who had made a habit of including advanced technology to secure a competitive advantage, hoped advanced electronics could turn the old rig into an advanced maintenance & repair vessel capable of servicing pipelines and other underwater structures.[217] Such vessels were in short supply and commanded a high price. Although equipping a small support vessel might cost a hefty NOK 50 million in 1975 (four times more in current denomination), the initial investment could be recovered in a couple of years because day rates ran at NOK 100,000 on long-term contracts and substantially more on short-term contracts.

[213] Interview with Bendigtsen, 21 November 2005.

[214] Interview with Bendigtsen, 21 November 2005.

[215] RA-Arntzen-Oil, board report, 9 September 1975.

[216] KV-Cor 239, KV to Utviklingsfondet, application, 31 December 1976.

[217] Interview with Bendigtsen, 21 November 2005. The topic has also been covered in interviews with Jenssen, 14 October 2004 and Bart Jacobsen, 31 March 2005.

In the mid-1970s, there was still no consensus on what capabilities a petroleum support vessel should have. In more mature markets, standards evolve due to public regulation or simply habit and experience. In the process, solutions become *commoditized* – cheaper to build and definitely easier to procure. For an oil company in the North Sea around 1975, there was no recipe as to what constituted a fire extinguisher or a diver support vessel. It was for shipping companies to suggest a service package and ask a price - and the market conditions generally allowed the shipping companies to recoup on their gamble if they managed to deliver a working solution on time. Bendigtsen assumed the *Swan* would benefit from dynamic positioning because anchors easily damaged pipelines and other subsea structures. On a previous occasion, Bendigtsen had bought dynamic positioning from Honeywell for use on the *Seaway Falcon*, but he was unimpressed by their Automatic Station Keeping (ASK) solution. The Americans were slow to recognize the North Sea as an emerging market. Their solution was not cheap and service was done out of Seattle – a costly drawback. ASK required separate quarters for computers and equipment, which was acceptable on drillships and rigs, but impractical on smaller vessels. Dissatisfied with Honeywell, Stolt-Nielsen asked KV for a proposal. On 24 November 1975, he signed a contract for a redundant DP system from KV.

The *Swan* was one big technology gamble and a new DP system served only to raise the stakes a little. Bendingtsen had already ordered heave-compensated derricks and other novelties. In one sense, the gamble backfired. The rebuilding ran into delays and the delivery was postponed until 1978. As a replacement, Bendigtsen offered KV the opportunity to supply a non-redundant system for the *Seaway Eagle*, a support vessel scheduled for delivery in the spring of 1977. KV agreed. Whereas the *Swan* required three computers (two computers working in parallel with a third computer to survey the two), the *Eagle* could do with one computer and somewhat less complex software.[218] On the other hand, fitting but one computer into a small vessel involved a set of challenges. The KS 500 had to be installed through a torched opening in the hull; once inside it could not be removed. Because of the space constraints, Albatross had to buy memory from Intel and abandon KV's proprietary memory modules – the Kongsberg computer employed 64 kilobytes of memory composed of four kilobytes modules each the size of a beer cage.[219] Nevertheless, the change made the task of developing dynamic positioning somewhat less daunting.

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[218] Interview with Corneliussen, 19 October 2004.

[219] Interview with Mathiesen, 13 October 2004, with Corneliussen, 19 October 2004.

Possibly, Stolt-Nielsen underestimated the risk of buying something new, but KV had a reassuring image of reliability; one would think that someone capable of designing anti-ship missiles could deliver regulatory software. Correspondence between KV and Stolt-Nielsen hinted at a political reason for buying a KV product. Stolt-Nielsen hoped to employ the *Swan* in work for Statoil. Qvenild told Stolt-Nielsen the company would meet with “greater understanding” at the customer’s premises if the *Swan* employed Kongsberg’s DP; conversely, if Stolt-Nielsen bought dynamic positioning from anyone but KV, it would be “more difficult” to recommend Stolt-Nielsen – a subtle reminder about KV’s power relations with Statoil.[220]

Were Stolt-Nielsen an atypical customer, the history of Albatross would have ended some time in the 1970s. Albatross was fortunate, however, to address a market in which numerous companies were willing to take risks and experiment with new technology in search of extra profits. Many more followed. It seemed shipping customers offered a more forgiving market for new technology than oil. The difference rested not with technical prowess – oil people were as advanced – and the early customers of dynamic positioning might not even have understood what they were buying. Rather the difference rested with a reward structure that heaped money on calculated risk-takers – or those fortunate enough to initiate a successful experiment.

As a malapropos, the shipping culture was manifest even in the ideology of managers. The international and profit-conscious Norwegian shipping industry fostered some principled economic liberalists.[221] The first two people to invest in dynamically positioned vessels were both standard-bearers for economic liberalism. Odd Berg, the Tromsø-based shipping magnate who ordered DP from Honeywell in the early 1970s, founded *Libertas*, a liberalist think tank.[222] Jacob Stolt-Nielsen, the second ship-owner to order a dynamic positioning system, held similar opinions on the

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[220] KV-Cor, box 136, letter, Qvenild to Stolt-Nielsen, 22 October 1975.

[221] Two books provide an insider’s account of the shipping milieu and the outlook of the ship-owners, including the Libertas involvement, cf. Egeland, *Vi skal videre norsk skipsfart etter den annen verdenskrig: Perioden 1945-1970*, particularly p. 238. Egeland, *Eventyr og virkelighet i skipsfartens tjeneste*.

[222] On shipping’s almost complete adherence to economic liberalism, cf. Sejersted, *Opposisjon og posisjon 1945-1981*, pp. 52-53.

role of government in the economy.[223] In contrast, Statoil initially drew its top management from circles close to the Labour Party. In each case, managers probably saw the way they did business as natural, right and just.

3.5 Conclusions

Unlike KV's traditional customers in defence, automotive and oil, shipping companies were prepared to gamble on technology, particularly in the aftermath of the 1975 shipping crisis. Whether or not shipping companies like Stolt-Nielsen knew the risks they were running, we may at least notice a marked difference between the shipping companies and the more conservative oil industry in terms of risk taking. In the 1970s, oil companies working out of Norway (and possibly everywhere) were part of an "elite offshore club" with large budgets and elaborate decision-making designed to reduce risk.[224] Smaller companies might sport more entrepreneurial flair, particularly when faced with a crisis such as the one that hit the shipping and drilling companies around 1974-75.

Mostly, the planned developments offshore suited KV well, but in one area the company seemed to be getting nowhere: despite repeated efforts, subsea systems failed to find customers on the Norwegian shelf. Arguably, subsea systems were somewhat hyped in the early 1970s, and both technological and psychological issues served to undermine their wider application. We have argued the dominant development style, the ever-present Condeeps, obstructed more agile field development styles. In contrasting Norway with Brazil, one gets an impression the slow ascent of subsea systems on was not inevitable. At a time when only Condeeps seemed permissible on the Norwegian shelf, innovative oil companies began experimenting with floating production and subsea systems. A hint to the entrepreneurial effects of deprivation, small and less wealthy operators went ahead and experimented with floating production and subsea production systems. Below the horizon, maverick companies developed offshore oil using subsea systems. Petrobras was a case in point. In 1975, Hamilton Brothers, an

[223] On the political outlook of Stolt-Nielsen, cf. interview with Qvenild, 29 September 2004; with Barth Jacobsen, 31 March 2005. For a sense of the family's unapologetic right-wing sentiments, cf. the anecdotal Tor Inge Vormedal, *B. Stolt-nielsen : Den glemte pioneren* (Haugesund: T.I. Vormedal, 2001).

[224] A comment on the slow emergence of subsea technologies, cf. Booth, "North Sea: Testbed for advanced subsea production". Derrick Booth was a veteran observer and founder of the most comprehensive subsea industry database, cf. *Quest offshore resources* (Quest Offshore, 2007 [cited November 2006]); available from http://www.questoffshore.com/Home/.

independent oil company, developed the Argyll on the British Shelf using a semi-submersible drilling rig with refitted processing equipment.

Shipping companies asked for dynamic positioning while the oil companies on the Norwegian shelf seemed to think subsea production was unreliable. Subsea production *was* unreliable, but that is beside the point. Albatross dynamic positioning was hardly reliable either. Hence, when one was sold and the other struggled to find applications, the single most important reason originated with the willingness of the shipping industry to accept technological risks and the speed in which the industry exploited business opportunities. The venturesome approach of the shipping companies contrasted with the careful, risk-averse approach of the big oil companies. The two industries at times seemed diametrically opposed. In the next stage, the differing business environments of customers spilt across to the suppliers at Kongsberg.

4 Venturesome consumption and company culture, 1976-84

In the second half of the 1970s, Kongsberg Albatross developed a particular culture distinct from that of KV proper. There is a maxim with few exceptions that people define their culture in relation to *others*. Strong cultures need distinct others. Being Canadian, I understand, is partly about not being a citizen of the United States. Belonging to Albatross was about denying the ways of KV and particularly the structured, long-term, sure-footed Defence Division.

I suggest company culture made Albatross innovative. Kenneth Lipartito remarks on how culture serves as a “mental apparatus for grasping reality […] limiting and organizing concepts that determine what is real or rational for management […]. When firms project beyond what is known, as they must when innovating, they inevitably encroach on the boundaries of rationality.”[225] To no small extent, the success of its dynamic positioning rested on a business culture that fostered entrepreneurial energy. The *albatrosses* developed a peculiar company culture with wide-ranging freedom of action for its engineers and salespeople. This helped the company innovate.

Apart from being a mere reflection of shared attitudes in an industry, this chapter also encounters culture as a management technique. At Albatross, for example, culture was part of a conscious effort to set expectations and guide behaviour. Bjørn Barth Jacobsen and later managers at Albatross turned the product group into a believing, zealous and very productive organization. Through institutionalization, the peculiar culture survived a period of rapid expansion.

While Albatross contributed by making dynamic positioning a fun and reliable product, a certain standardization also served to cut transaction costs and simplify the ordering of dynamic positioning. Institutions such as *Lloyd’s Register*, *American Bureau of Shipping* and *Det Norske Veritas* (DNV) took upon themselves to articulate technical standards for the design and construction of vessels and list vessels that complied with the standards. Once classification societies had spelt out a desirable standard, oil companies tended to opt for this – if for no other reason then as an additional insurance against bad publicity. The introduction of a DP class regime in the

225 Lipartito, "Culture and the practice of business history".

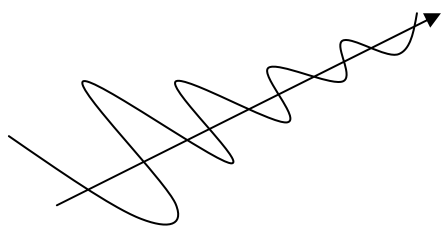
late 1970s simplified the process of ordering dynamic positioning and spurred sales of advanced systems.

4.1 Dynamic positioning in theory

Initially, nothing much separated dynamic positioning from any number of technology-centric projects at KV. The Oil Division had no proprietary development resources. Rather Olav Berdal, who headed R&D in the Defence Division, assembled a development team headed by Thor Skoland. Together with a dozen engineers, he mapped whatever knowledge was available. He looked at Honeywell's system on board the *Falcon*, established some grasp of what to do, helped sketch a hardware solution, and hired two young scientists from Trondheim to transform Professor Balchen's concepts into a high-level software model.[226] That task fell on Steinar Sælid and Nils Albert Jenssen, two young researchers at the Norwegian Institute of Technology (NTH).

Albatross dynamic positioning employed a few novelties. KV planned to use Kalman filtering, an advanced statistical technique to update a "best" estimate in the face of new, but still inaccurate, data (cf. appendix 11.5). More fundamentally, the system relied on *forward coupling*, a predictive rather than responsive regulatory strategy. Existing DP systems detected a drift, and manoeuvred the vessel back to the desired position (measure, calculate gap from desired state, adjust). Like a hotel guest in an unfamiliar shower, who suffers successive eruptions of hot and cold water before eventually finding a balance, old dynamic positioning systems required time to find equilibrium. When the impact of wind or stream changed, the ship would experience bursts of thruster action.

Figure 12) ***Schematic draft of the behaviour of a retrospective DP system***



[226] Interview with Sælid, 12 October 2004, with Jenssen, 14 October 2004, and Mathiesen, 13 October 2004.

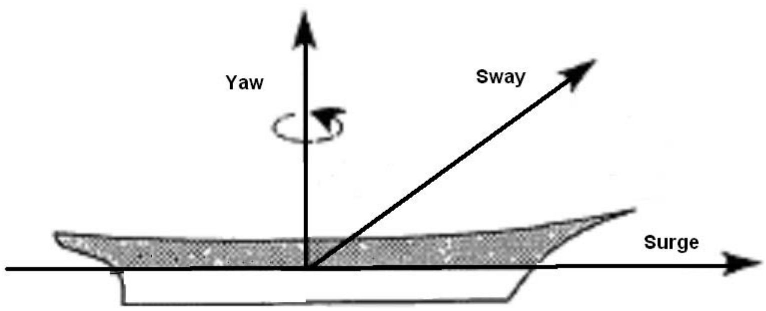
The strength of forward coupling, and the weakness of retrospective regulation, is stability. Forward coupling attempts to predict a disturbance in advance by modelling how a change in input will affect the outcome of a process. In principle, the procedure resembles what a person goes through when learning to ride a bike. A youngster without such a model rides into the gutter before abruptly turning towards the opposite gutter. A trained cyclist foresees how the bike will behave, pre-emptively changes his balance and rides straight.[227] Dynamic positioning without forward coupling, Professor Balchen insisted, was like steering a car by watching the mid-line through a hole in the floor.[228]

To accomplish forward coupling, the Albatross dynamic positioning employed four basic models: a *wind force model*, a *surge model*, a *sway model* and a *yaw model*. These algorithms mimicked the calculations of a sea captain trying to manoeuvre a ship against wind, waves and stream. The calculation depends not only on the strength of the wind, but also on the vessel's bulk (the area exposed to wind) and inertia. Inertia depends on load (weight) and drag, the quality that makes a one-tonne canoe more agile than a one-tonne raft. With such a model in place, a DP system could measure the strength and direction of the wind and counteract these forces with a burst of the thrusters before the vessel started drifting.

[227] For a general introduction to regulatory strategies, see Jens G. Balchen, Trond Andresen, and Bjarne A. Foss, *Reguleringsteknikk*, 5. utg. ed. (Trondheim: Institutt for teknisk kybernetikk, Norges teknisk-naturvitenskapelige universitet, 2003).

[228] Balchen is quoted from Daling et al., *Offshore Kongsberg*, p. 23; for the biking example, interview with Steinar Sælid, 12 October 2004.

Figure 13) ***The terminology of seasickness***[229]

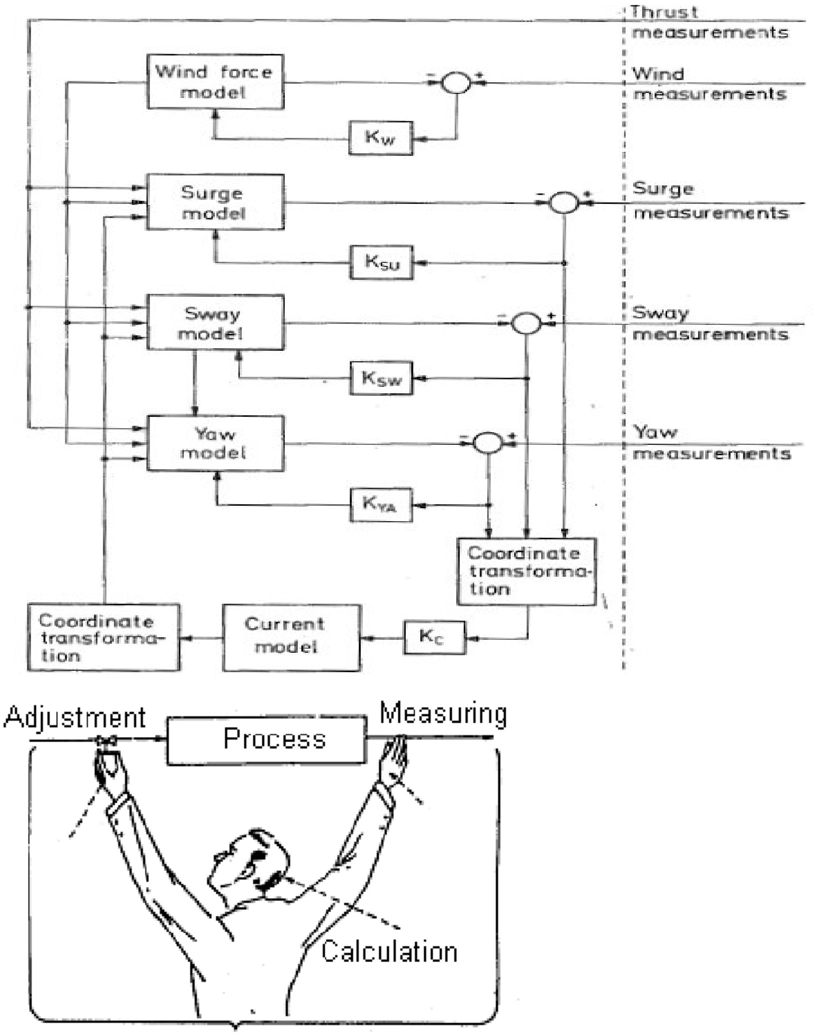


To see how the Albatross software worked, consider the sketch above. Put simply, the software checked the location of the vessel, measured what forces affected the vessel, and calculated a new present position. The algorithm that handled surge (the *Surge model*) estimated forwards and backwards movements. This algorithm received four inputs: a) the previous best estimate or *Coordinate transformation*, b) the strength and angle of the wind from the *Wind force model*, c) information about which thrusters were working in what directions, i.e. *Thrust measurements*, and d) actual observations about movements, i.e. *Surge measurements* from a position reference systems fed through a Kalman filter (K_{SU}).[230]

[229] Copied from Faÿ, *Dynamic positioning systems: Principles, design and applications*, p. 27. Roll, heave and pitch are irrelevant to dynamic positioning since the vessel's position and heading remain unchanged.

[230] The principle remains unchanged from the 1970s until today, cf. Jens G. Balchen et al., "A dynamic positioning system based on Kalman filtering and optimal control", *Modeling, identification and control* 1, no. 3 (1980): pp. 135-163 and Jon Holvik, "Basics of dynamic positioning" in Dynamic positioning conference (Houston: 1998).

Figure 14) ***Schematic cybernetics: The DP filter structure***[231]

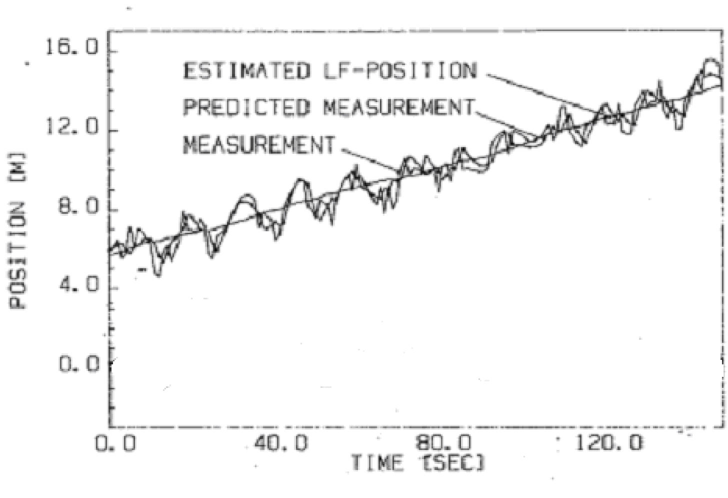


The point in distinguishing between these various expressions of movement was a quest for an optimal regulatory strategy. It is futile to fight wave-induced movements (they are too strong and nevertheless cancel each other

[231] Balchen et al., "A dynamic positioning system based on Kalman filtering and optimal control", p. 142. The conceptual drawing to the right was made by Balchen for a 1956 paper – I have modified a reprint in Stig Kvaal, *Drømmen om det moderne norge : Automasjon som visjon og virkelighet i etterkrigstiden*, Sts-rapport ; 13 (Trondheim: Universitetet i Trondheim Senter for teknologi og samfunn, 1992).

out). Rather, a DP system should identify the underlying pattern of drift. The systems provided by Honeywell, ASI Electronics and others in the 1960s and 1970s used a wave filter that removed high frequency movements (rapid oscillations) for the same reason a Dolby filter removes noise. Balchen's solution was more elegant. The DP software played around with three opinions about how far the vessel had truly surged: the *estimate* provided by the surge model, the *measurement* provided by navigation equipment, and the *prediction* of the Kalman filter that took both of the above into account along with previous best estimates. The *estimate* of the model (the one built for forward coupling) revealed the slow forces. Turning the thrusters against the estimate provided the smoothest and most economic way to stay in position. The chart below compares these three "opinions". Whichever way, the vessel moved from being roughly six metres ahead at 0 seconds to being roughly 12 metres ahead at 120 seconds. As shown by the *predicted* and the *measured* position, the vessel oscillated back and forth throughout the journey – probably because of waves: the ship moved two steps forward, one step back, etc.[232] The estimate (the straightest of the lines) indicates the strength and direction of slow forces such as wind and stream.

Figure 15) ***Straight behaviour: DP filter outputs***[233]



[232] Balchen et al., "A dynamic positioning system based on Kalman filtering and optimal control".

[233] Ibid.

From the point of view of a cybernetics expert, dynamic positioning was a textbook case – a matter of applying science to provide an optimal solution to a problem. Alas, reality conspired against science.

4.2 Dynamic positioning in reality

On 17 May 1977, the Albatross prototype was in place. Bjørn Barth Jacobsen, head of the product group, sent flowers to his team. Having worked continuously for 36 hours, people collapsed believing the worst part of the job was done.[234] Alas, there was "uncertainty and unreliability in every link" and little time for rest.[235] The errors that kept appearing were not theoretical, but very real.

Despite an elegant high-level software design, many issues surfaced when science met reality. To make the code work onboard vessels, the young engineers had to make a number of modifications. In the process, they dumped most - some think all - attempts to maintain an optimal regulatory strategy and simplified the software lest none but scientists would be able to maintain the code. The people at Kongsberg who implemented the high-level code from Trondheim abandoned dynamic Kalman filtering, that is the ability to recognize improving or deteriorating performance of an instrument and weight the information accordingly. Such tuning was too demanding for KV's proprietary KS 500 computer. KV also had to compromise on the ability of Albatross to manoeuvre smoothly. Although the system in principle identified the optimal counterforce vector, the calculations involved were too complex for practical purposes. Thus, both in the ability to identify the correct position and in the ability to manoeuvre the vessel back to the desired position, Albatross ended up with solutions whose performance hardly differed dramatically from the tried and tested approach of Honeywell.[236]

Another set of concerns originated with hardware. Once, using DP in the dead calm waters of Horten harbour, the *Eagle* suddenly speeded ahead on full throttle. Eldar Mathiesen, a young engineer in charge, set up a tracking routine and identified the unlikely problem. As planned, the Albatross software zeroed out any historic data after three hours without detectable wind. However, the KS 500's micro program (its computer-specific hard-coded software) mistook the instruction – a bug in the micro program

[234] Interview with Mathiesen, 13 October 2004, with Corneliussen, 19 October 2004.

[235] Interview with Mathiesen, 13 October 2004.

[236] Interview with Skoland, 4 January 2006, with Mathiesen, 13 October 2004.

confused plus and minus and uploaded the largest number its cache could hold. Albatross consequently believed it had encountered a wind of unfathomable proportions, and roused all thrusters against the imaginary tornado. Such mistakes showed how computers designed for presumably demanding military applications sometimes failed in other settings; they had proved themselves in guiding specific tasks of shorter duration like the aiming of a gun or the guiding of a machine tool, but not for continuous operations.[237]

The weakest link in the new system was arguably the hydro-acoustic position reference system (HPR system) that Albatross sourced from Simrad. The system worked by emitting a sound wave in the direction of a transponder on the seabed. Having detected the signal, the transponder emitted an artificial echo; the direction of this signal, and the lapse from query to response, revealed the vessel's position relative to the transponder. Depending on the ability to measure angles accurately, one or more transponders were required to establish an exact position. Simrad was in the process of developing a system that worked with one receiver and one transponder,[238] which improved ease of use at the expense of accuracy.[239] In 1977, Albatross relied on Simrad's HPR prototype – it was as unreliable as the DP. On one occasion when the *Eagle* was involved in sandbagging a pipeline from Ekofisk, the vessel repeatedly drifted off position. After 48 hours of emergency repair work, the team discovered the novel HPR would occasionally misread the input because some sound waves had multiple interpretations.[240]

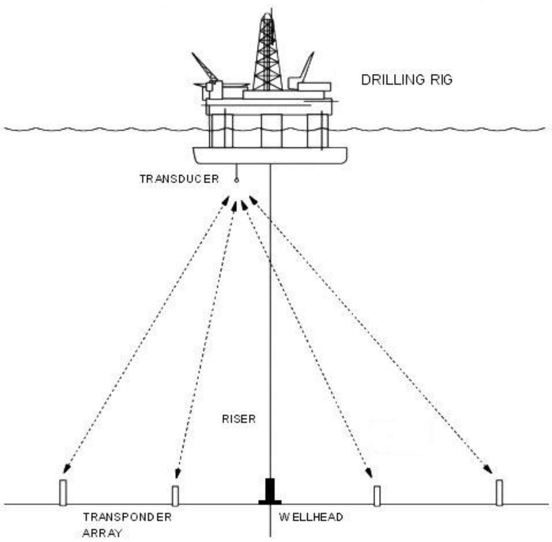
[237] Interview with Mathiesen, 13 October 2004.

[238] For an in-depth account of the development, see Knut Sogner, *God på bunnen: Simrad - virksomhet 1947-1997* (Oslo: Novus, 1997), pp. 107-109.

[239] R. Bond, "Dynamic positioning control systems and operational experience" (paper presented at Conference on Ship Dynamic Positioning & Mooring Systems Electrical Aspects, Thursday, 22 February 1979, London, 22 February 1979) p. 55.

[240] Interview with Corneliussen, 19 October 2004.

Figure 16) ***Artificial echo: Hydro-acoustic position reference system***



Albatross's various problems were not confined to the first prototype. Every one of the early deliveries experienced problems. The Capalonga project (1976-77) ran into problems because the vessel had insufficient engine power to withstand rough weather, regardless of its redundant DP system. Albatross could hardly be blamed for this mishap. In 1977-78, Albatross installed dynamic positioning on three dredging barges, and this time the Kongsberg people were responsible for underestimating the power requirements. The Seaway Sandpiper assignment (1977-78) was deeply frustrating as well, allegedly because a subsystem from Norcontrol malfunctioned.[241] A final and particularly damaging incident occurred with the *Seaway Swan*. On 27 September 1978, the *Swan* was in position some 15 metres from a platform in the UK sector – both anchors, dynamic positioning and a tugboat worked in concert to keep the *Swan* in safe distance from the platform. Shortly after midnight, the *Swan* began turning. A lookout became aware of the danger, switched to manual control, managed to move the rig away, but too late to prevent a derrick on board the *Swan* from hitting a platform rail. None blamed the DP system, but none could acquit it either. Most likely, the error was human, for example an inadvertent manoeuvre by the tugboat. Such errors were hard to pinpoint because operators resisted

[241] Interview with Skoland, 24 January 2006.

"Judas systems", tracking software similar to an airplane's flight recorder.[242] Maybe Albatross would have survived a few more hiccups, but the bugs that did occur were sufficiently serious as to have killed the project. Stolt-Nielsen was neither happy nor content. On one occasion the project looked particularly flawed, Mathiesen had the discomforting experience of being the subject of Jacob Stolt-Nielsen's abuse at Fornebu. On another occasion, he was picked up by helicopter on 45 minutes notice because the DP did not work and the *Eagle* lost USD 25,000 a day.[243]

Was Albatross more reliable or more accurate than Honeywell's solution? Opinions differ somewhat as to functional superiority. Sælid clearly believes the Norwegian solution was the better one. Mathiesen believes the first application was no improvement on Honeywell's solution. Maybe both in a sense were right. The code Sælid wrote was superior to Honeywell's; the code Mathiesen ended up implementing was not such a big improvement.[244]

4.3 Jacobsen's escape from the weapons factory

In 1975-76, Honeywell supplied four out of five dynamic positioning systems with Thomson a distant second picking up mostly French military orders. A few years later, the picture had changed. In 1981, there were 80 operational DP systems globally, half of them supplied by Albatross.[245] Interestingly, Albatross gained market leadership between 1976 and 1979 during a period when the product was hardly reliable. So how did Albatross relegate Honeywell to a marginal position? Any full explanation would need to consider the peculiar culture that evolved at Albatross.

To understand what Albatross became, it is useful to look at the parent from which it departed. Probably, every attempt to capture the attitudes that governed KV in the 1970s would produce a different answer. Emphasis is a matter of perspective. The outline in this section is obviously no exception,

[242] On the *Capalonga*: interview with Corneliussen, 19 October 2004. On the barges: interview with Skoland, 4 January 2006. On the *Swan*: KV-Cor 239, Henriksen, memo to Aasland, 9 October 1978.

[243] Interview with Mathiesen, 13 October 2004

[244] Interview with Mathiesen, 13 October 2004, with Sælid, 12 October 2004.

[245] "The Kongsberg group: Experts on dynamic positioning", *Scandinavian oil-gas magazine*, 1981, pp. 70-71.

but it is uncontroversial to claim that much lot rested with the influence of Bjarne Hurlen and the legacy of KV as an army workshop.[246]

By most accounts, Kongsberg was a run-down workshop by the end of the Second World War. The factory lacked a proper sales office; its task was limited to the proper processing of incoming orders from the army and various companies using KV as a contract manufacturer. There was no proper finance function. Until 1948, KV had simply been an entity on the defence budget and the transformation into a separate legal entity was less than abrupt. Funds tended to arrive once a year; following the passing of a defence budget, the company purchased inputs and refined them until the funds were depleted. Each budget year composed a business cycle.[247] KV looked increasingly outdated, uncompetitive and not very businesslike.[248] This was the factory that Hurlen set out to manage.

Like Hauge, Hurlen had a formidable presence – the term *patriarchal* springs to mind. He upheld hierarchy and rank with earthly symbols such as a corporate mansion and two chauffeured limousines. He was caring and affectionate – not one to trade his loyalties – but expected subordination and demanded results with unquestionable authority and a matching temper. He was capable of "stamping results out of the ground".[249] He had unleashed these qualities on the rather moribund weapons factory from the mid-1950s. Within a decade he had installed a sense of direction in KV. With military training and precedence from the American armaments industry, it may come as no surprise that Hurlen embraced *Taylorism*. During his first years at the helm, with tremendous energy, he unleashed scientific management on the organization and was able to achieve much simply by introducing new machinery and copying techniques and practices from more advanced engineering industries. Hurlen studied in detail the time-motion analysis that

[246] During two dozen interviews with former employees during the autumn of 2004, I asked open-ended questions about sentiments at KV and about the role of Hurlen. The following paragraphs rely extensively on this material – a collective recollection, although individuals are credited with supplying particular details.

[247] Interview with Næsset, 11 October 2004.

[248] For the most depressing assessment I have seen of any business, cf. Yulke Company's review of the "defeatist" attitude, "substandard" quality and "laughable" sales and marketing at KV, cf. Kongsberg Våpenfabrikk, Korrespondanse, C1 Direktørkorrespondanse, Rekke III, 111, I.G. Yulke Company, rapport 1 - 16, 1954 - 1955, Progress Orientation Report No. 1, Meeting held October 30, 1954.

[249] Interview with John Evensen, 23 June 2004.

Volvo applied, and strived to copy these at the factory.[250] In the late 1950s, he travelled extensively in the United States, visited large defence contractors and wrote admiringly of their efficiency in execution.[251] If modernization was Hurlen's end, scientific management was his means.

Despite Hurlen's best efforts, however, KV never became a customer-centric company. Some observers, like Jens Glad Balchen, linked the lack of commercial instincts with a continued entanglement with the armed forces.[252] Defence procurements mauled the work ethics of KV proper. Norwegian military customers usually had no option but to place orders at KV and the standard contracts specified cost-plus payment. KV covered its costs and a profit specified as a percentage of the costs. Consequently, a drawn-out and costly project was more profitable than a speedy delivery on budget. It could almost be assumed that the work would be expensive and late and none would assume responsibility. The attitude was particularly damaging for Albatross and other business lines that faced competitive markets. Sverre Corneliussen, the principal hardware engineer at Albatross, would occasionally claim this or the other part was needed for personal reasons – even a hobby – in order to speed up the delivery and avoid the Defence Division's unspoken policy of not being stressed by a customer. Skoland caused friction by placing metalwork orders with a small mechanical engineering company rather than risking the usual KV delays that so alienated customers.[253] Such incidents caused strains.

Bjarne Hurlen had begun his term at a company that lagged behind the leading engineering companies of the world, but retired from a proud and immensely capable company. His most impressive performance, however, belonged to the 1950s and 1960s when the young Hurlen had been an agent of change. He "aged early", an old acquaintance observed,[254] and the older Hurlen was hard pushed to dismantle some less productive practices at KV. His engineering conglomerate was not economically prudent and rather bureaucratic. Meanwhile, despite Hurlen's best efforts, his company failed to develop a customer-centric and entrepreneurial approach. This was the setting when KV set out to manufacture dynamic positioning.

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[250] Interview with Tveit, 26 October 2004, with Næsset, 11 October 2004.

[251] KV-operations, box 7, memo, Hurlen to board of directors, 10 June 1958.

[252] Interview with Balchen, 15 September 2004.

[253] Disagreement on the taut wire is evident e.g. in KV-Cor box 239, minutes from the heads of divisions meeting 2/80 with reference to development work initiated 30 November 1978. KV Cor 142, 24 Juni 1980, AD til Maritim div og Olje Div.

[254] Interview with Tveit, 26 October 2004.

* * *

In understanding how a distinct Albatross culture could emerge in opposition to the dominant sentiments at KV, we should consider the role of Bjørn Barth Jacobsen. He was educated at NTH where he met Qvenild who agreed to become his mentor and invited him to join the KV planning department in 1970. At the time, there was simply no spare housing in Kongsberg and Jacobsen rather spent a few years working for Shell out of den Haag and Singapore. In 1973, he returned to Norway. Due to his oil experience, he had any number of job options, but eventually opted for Kongsberg. KV appeared a lot less structured than e.g. Kværner, but Kongsberg sported cheap housing and Jacobsen moved his family from the 11th floor of an Oslo complex to a detached house not far from the factory.[255] Upon starting in May 1974, he was the only KV employee with any experience from the oil industry.

No slave to public convention, Jacobsen was an asset and a liability. In 1973, before moving to Kongsberg, he had worked as chief engineer in Sønnico, an electrical engineering company, where he clashed with the hierarchy and moved on.[256] At Kongsberg, he became product manager of supervisory control and data acquisition (SCADA) and argued its case so insistently that Statoil's head of procurement, Hans M. Daastøl, called Qvenild and asked for Jacobsen's removal.[257] Jacobsen then worked on establishing an engineering business. He acquired a run-down factory in Lier, refurbished the place, and made Kongsberg Engineering look respectable despite employing only four people. However, when the business started to grow as part of Norwegian Petroleum Consultants, Bjørn Husemoen was appointed managing director, rather than Jacobsen.

Three times passed over, three times bereft of the opportunity to head a business, Jacobsen was in line for promotion. Qvenild asked him to look after dynamic positioning. Plans were already in place. The head of development (Berdal) and the head of the oil division (Qvenild) intended to see through but one project: first develop it for 18-24 months, then market it, sell it, and aim for profits by 1980.[258] Prior to delivery, the product group

[255] Interview with Jacobsen, 9 September 2004.

[256] Jacobsen, e-mail to the author, 18 April 2005.

[257] On the Scada development, cf. Daling et al., *Offshore Kongsberg*, chapter 11. On the conflict with Statoil: interview with Jacobsen, 9 September 2004.

[258] KV-Cor 239, KV, application to Utviklingsfondet, 31 December 1976.

was not supposed to do much in terms of sales and marketing. Although the niche was interesting, it had no strategic importance and Jacobsen felt deep down he was destined for something better. Nevertheless, deprived of a major business line, he set out determined to turn his project into something big.[259]

Jacobsen had the ability to think in sufficiently radical terms and insisted KV should achieve world dominance in dynamic positioning. He detested the idea of "another hobby workshop" and insisted his product area had to deliver three or four systems a year immediately in order to conquer the market and avoid becoming a "subsistence business" of the kind he thought multiplied at KV.[260] The real risk was letting Honeywell get entrenched or, worse, allowing Norcontrol a foothold. We enjoy a "tailwind" he explained – it would be "wrong not to exploit" the market.[261]Jacobsen, the son of a small businessman, was annoyed by any reluctance to pursue earnings. He was insistent Albatross should make money and help customers make money.[262] The young and inexperienced people on his team found the thought of being up against a Goliath "very exciting" and they set out to dethrone Honeywell, irrespective of the fact that KV's solution hardly worked.[263]

Almost immediately upon assuming responsibility for the dynamic positioning project, Jacobsen began his sales efforts. He went to see Odd Berg, a shipping company in Tromsø that planned to equip a vessel capable of diving support, subsea completion and surveillance of pipe-laying operations. For such tasks, the *Arctic Seal* needed dynamic positioning and - because several ships would arrive for the 1978 season - Odd Berg needed dynamic positioning by the summer of 1977. Jacobsen offered to submit a tender. "Short deadlines", he wrote to his superiors, were "positive incentives". His superiors turned him down, however, because one failure could be more easily overlooked than two failures and because the research department would be hard pressed to reallocate people.[264]

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[259] Interviews with Jacobsen, 9 September 2004 and 31 March 2005.

[260] KV-Cor 239, Jacobsen, letter to Odd Bergh (Klingenberg), 16 January 1976.

[261] KV-Cor 239, Jacobsen, memorandum to Qvenild, 18 January 1976.

[262] Interview with Jacobsen, 29 November 2005.

[263] Interview with Mathiesen, 13 October 2004.

[264] KV-Cor 239, Qvenild, memorandum to Aasland, 16 January 1976.

Undeterred, Jacobsen just kept trying to grow his business, routinely encountering scorn.[265] The first time the public saw Albatross was during the 1976 Offshore Technology Conference in Houston. Jacobsen had a local carpenter manufacture a plywood box. With the proper coating, it could resemble something digital. He put a Simrad sonar screen in front and an ordinary light bulb in the back.[266]

Jacobsen had a knack of extremes, and rarely mastered modesty. Raising the subject of Jacobsen among those who knew him at Albatross three decades ago unfailingly provokes smiles, sometimes even embarrassed smiles, and stories. He could be all things, a devil and a sympathetic man. For him, there was good and bad, right and wrong, hot and cold. When he clashed with people, he did so irredeemably. He heaped scorn on the people he did not get along with, and fell out of favour with many people.[267] An alumnus of Shell, with some 200,000 employees, he failed to be humble when faced with a few thousand people in Kongsberg without industry experience. An Albatross legend says he smashed a window to get the attention of Qvenild who was passing outside (this was not true, though he did jump through a first floor window to continue a discussion with assistant managing director Odd Løkholm).[268] None doubted, however, that Jacobsen would have been capable of smashing a window. He was ignorant of conventions and his energies were hard to control.

Jacobsen received any number of rebuffs. When, nevertheless, he was allowed to continue, or felt able to ignore the advice he was offered, it was because Albatross made money. Sometime during late 1976, the former caution was put aside. Because the *Seaway Swan* had been delayed and been supplemented by an order for the *Eagle*, Albatross nevertheless had to work on two prototypes in parallel. Then, in November 1976, Jacobsen secured a DP order for the *Capalonga*, an old tanker that Shell planned to convert into a support vessel. Jacobsen's superiors would have preferred to reject the

[265] Evident e.g. in KV-Cor 239, Hurlen, memorandum to Qvenild, 13 February 1976. Hurlen complained about repeated unprofessional behaviour; Jacobsen had printed KV advertisements featuring the *Seaway Swan* without the consent of the angry owner, Jacob Stolt-Nielsen.

[266] Interview with Jacobsen, 29 November 2005.

[267] The author's conclusions from interviews with half a dozen former Albatross employees during the autumn of 2004.

[268] The incident is referred in Daling et al., *Offshore Kongsberg* p. 23, and corrected by Jacobsen, e-mail to the author, 18 April 2006.

order, but needed the money, and Shell asked for both a redundant DP system (double everything) and six KG2 gas turbines. The project would net NOK 10 million and Shell offered to provide working capital.[269] KV at the time struggled to make a profit; the civilian product lines lost money on a large scale. Consultants were at the gate telling management what to do and contributing to a siege mentality. In this setting, KV management had a hard time insisting that Albatross should play by the rules. Had KV been a commercially viable, decently run factory, the autonomy and business practices of Albatross would never have been tolerated.[270]

One reason why Jacobsen's energies proved productive was the qualities of his head of development, Skoland. He proved eminently capable of bridging the gap between the conservative and thorough KV culture and the "craziness" associated with Jacobsen. In understanding why they managed to get along so fabulously, it is probably helpful to leave the purely rational. Skoland *liked* and *respected* Jacobsen, even *trusted* him to do right, and Jacobsen loved him in return. He thought Thor could do no wrong and accepted his guidance and judgement – he behaved. Jacobsen could be his own worst enemy, prone to excesses. An extrovert, and a bit of a clown, he nevertheless remains very aware of his weaknesses, almost shameful, and became eager to confess. A child lost in the cradle in 1971, he interpreted as divine punishment, and almost lost ground, only to find salvation in Christ. Later in life, when repentance hit upon him, Thor Skoland was there to receive his confession and offer spiritual guidance.[271] Since they were both religious in the evangelical way, there was euphoria to what they did: both attacked problems with belief and dedication. Their *modus operandi* differed, however: whereas Jacobsen hacked through the jungle, Skoland paved the road beneath and "carried the burden". The pair influenced the wider Albatross culture, which came to resemble the attitude of born-again Christians.[272]

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[269] Conversation with Jacobsen, 1 December 2005. Mr. Jacobsen interpreted the generosity as a form of showing off.

[270] This opinion was held by many contemporaries. Torfinn Kildal quoted an STK manager saying such a venture would have been impossible at STK (a Norwegian subsidiary of Alcatel), interview with Kildal, 29 October 2004.

[271] On the basics of their relationship, both Skoland and Jacobsen are in agreement, cf. interview with Skoland, 4 January 2006, with Jacobsen, 31 March 2005 and 9 September 2004.

[272] Interview with Skoland, 4 January 2006, with Mathiesen, 13 October 2004, and with Jacobsen on various occasions.

Towards the end of 1977, Skoland took his small team away from the Defence Division and united with Jacobsen and his assistant, Nils Willy Gulhaugen. On the floor of the huge KV turbine factory, they settled on some 200-300 square metres. They laughed and worked. Sometimes, someone would run out to buy a bottle of red wine and celebrate inside the parameter surrounded by decent and serious Kongsberg employees sputtering turbine parts. The KV employees began to notice this circus, and the Albatross began telling stories about their distinctness. Thus was born a meta-culture of sorts, quite distinct from anything else in the weapons factory. Jacobsen spoke of a “gypsy” culture: merry, unrestrained, globetrotting. People were told to bring their passport to work every day.[273] At times, Albatross people became excessively self-conscious and self-righteous to the point they would tear apart company policies and contradict the Defence Division on purpose. Albatross probably had an urge to rebel, but rebelling against the defence division resulted in spectacular work ethics and a high degree of responsiveness to customers.

The work spirit at Albatross was exceptional. Mathiesen recalls a Saturday evening when his close associate, Olav Ropstad, and wife had come to the Mathiesens for dinner. During dinner, the two DP engineers talked business and technology relentlessly, and by 10 at night became so captivated by work they left for the factory a few kilometres away leaving behind two bored wives.[274] The same obsessive energy that ruined Mrs. Mathiesen’s dinner could not but impress the early Albatross customers. The team showed extreme flexibility in correcting errors and managed to stay on course. They became fabulous ambassadors for the company. This was probably what made Stolt-Nielsen not only refrain from throwing KV out as his DP system continued to malfunction, but also keep buying Albatross products. Albatross’s customer-centric approach and nimble-footed culture was the most important explanation as to why the company came to dominate the dynamic positioning market towards the closing years of the 1970s, rather than its technical excellence. Around 1980, however, Albatross also gained a technological lead – albeit not for the reasons that Balchen had proposed.

[273] Interview with Skoland, 4 January 2006, with Jacobsen, 31 March 2005 and 9 September 2004, with Sælid, 12 October 2004 and with Jenssen, 14 October 2004. RA-Arntzen-Oil, quarterly board report, 17 November 1977.

[274] Interview with Mathiesen, 13 October 2004, with Jenssen, 14 October 2004.

4.4 World leader in dynamic positioning

Every DP system installed during 1980 was made by Albatross.[275] The Kongsberg supplier was responsive and customer-centric, and its product was probably superior. This technological advantage rested with an unintentional twist in Balchen's invention. Whereas Professor Balchen had planned for a smoother regulatory strategy, he ended up devising an approach that was somewhat better capable of handling mishaps and unreliability.

As for reliability and accuracy, the main concern around 1980 was faulty inputs from position reference systems. Precise navigation involved measuring the distance to some nearby beacon at a fixed, known location. Alas, radio beacons on the seabed would not work because electromagnetic energy fails to propagate through water. However, what radio waves can accomplish above the surface, sound can accomplish subsea, and most DP systems relied on acoustic position reference systems. These emitted sound waves and measured the time elapsed before receiving a response from one or more underwater transponders. The approach resembled sonar technology, the core business of Honeywell Marine System in Seattle.[276] Honeywell developed a hydro-acoustic position reference system for use mainly with deep-water drilling and eventually provided dynamic positioning as an add-on.[277]

Judging from the reference book published by Honeywell in 1978, the company's leading expert believed acoustic reference systems would continue to be the mainstay of dynamic positioning and admitted only to the desirability of some fine-tuning.[278] In reality, the approach was inherently unreliable. A shoal of fish might cross between ship and transponder, bubbles from a propeller might pass underneath, or salinity and temperature might change in ways that hampered sound waves. In the late 1970s, Albatross experienced some sort of disturbance half the time: sometimes the

[275] "The Kongsberg group: Experts on dynamic positioning".

[276] Interview with Skoland, 4 January 2006.

[277] KV-Cor 238, Albatross [internal] board papers on marketing strategy, 23 September 1983.

[278] Morgan, Dynamic positioning of offshore vessels, chapter 10.

signal shifted and reappeared from a new and unexplainable angle, sometimes the signal would disappear for minutes.[279]

Albatross gained from its willingness to incorporate numerous position reference techniques apart from hydro-acoustics. While working on the *Seaway Swan* in 1978, for example, the team just could not get a proper reference from Simrad's new acoustic position reference system and scrambled to have a local workshop build a taut-wire system on specification. A taut-wire system relies on the inclination of a line lowered onto the seabed by a heavy weight; the angle of the line reveals how the vessel has moved since the taut wire was unlashed. It was clumsy and space consuming, and not without faults, but provided a desperately needed a correction to the acoustics.[280] In other deliveries, Albatross came to rely heavily on the Artemis microwave-based reference system.[281] The system worked by measuring the angle and the distance between a receiver and a microwave beacon in the vicinity, typically on a production platform. Of the 57 deliveries that Albatross supplied between 1977 and 1983, 45 employed HPR, 43 employed taut wire and 30 employed Artemis. About a dozen used inputs from radio navigation systems while half a dozen attempted satellite navigation.[282] A few systems employed TV-tracking, radar or other experimental approaches. The variety of techniques involved shows Albatross had distanced itself from any given supplier or a specific position reference system.[283]

Most DP suppliers used multiple position reference systems even in the 1960s, but Albatross was unique in its early ability to combine inputs from various systems into a useful equation. The competitors let the operator determine which system to be trusted. When the most reliable inputs failed, the next in line came on stream according to a queuing procedure. Such DP systems took into account only the best available position reference system and discarded the remainder. Albatross pioneered a *pooling* procedure where

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[279] Nils A. Jenssen and Eldar Mathisen, "Når naturkreftene trekker i andre retninger: Dynamisk posisjonering av fartøy med "Intelligent" Datamaskin", *Teknisk Ukeblad*, 2 May 1977, pp. 10-14, chapter 10.

[280] Interview with Mathiesen, 13 October 2004.

[281] KV-ex 9, minutes from a meeting between Royal Boskalis Group and Albatross, 9 October 1984.

[282] CA-KM-hist, Reference list 1983.

[283] For an overview of available position reference systems, their accuracy, reliability, reach and limitations, cf. Appendix 11.8

every available measurement contributed data to a pool from which a “best estimate” of position was determined. Kalman filtering was an advanced approach to gain a best estimate, and the early incorporation of Kalman filtering meant Albatross could draw on all available position reference systems.[284]

Furthermore, Albatross’s core regulatory strategy was better suited for the identification of failing position reference systems and handling signal failures. We recall how the new systems included a software model of the ship and its surroundings to perform forward coupling.[285] This strategy had been included on the insistence of Professor Balchen to smoothen the manoeuvring of automatically positioned vessels: the model predicted where the vessel was heading in order to counteract drift pre-emptively. A mathematical model trying to guess where the ship was heading had an inherent ability to recognize faulty navigation inputs - at least to the extent they violate the constraints of the physical world. With starboard wind and no tide, for example, a sudden shift to the right would be unlikely. Besides, the mathematical model contributed an emergency strategy. In the unlikely situation all reference systems would fail, the mathematical model would continue to provide an idea of where the ship was heading based on the strength and direction of the wind and historical data about the stream. Such usage of the model was not what Balchen had foreseen. He wanted to include a model in order to smoothen the manoeuvring, but ended up inventing a guard against faulty data from the peculiar behaviour of sound in water.[286]

Albatross’s approach proved superior in incorporating inputs from various position reference systems of dubious accuracy. With only one measurement system running and stable noise, i.e. without unpleasant surprises, Honeywell’s solution was just as accurate and stable as the one provided by Albatross.[287] Put differently, if a reliable and accurate navigation system such as the global positioning system (GPS) had been operational in the 1970s, Honeywell would have had a better chance of withstanding the onslaught. Conversely, if position reference systems had not been so unreliable, Albatross would have had a harder time establishing itself in competitive markets. This is not to downplay the importance of good

[284] For the principles of Kalman filtering, cf. appendix 11.5.

[285] Cf. p. 88.

[286] Interview with Mathiesen, 13 October 2004.

[287] Interview with Mathiesen, 13 October 2004.

customer relations. By late 1983, Albatross management believed Honeywell and General Electric Corporation Ltd. had regained a technological equilibrium with Albatross.[288] The business skills of Albatross, however, were harder to match, and Albatross retained a very high market share.

Success came, not only from building sophisticated systems, but also from making sophisticated systems simple. Honeywell designed DP systems for semi-submersibles and large drillships, floating factories in effect, where a dedicated operator could work in a control room set-aside for station keeping. In these surroundings, it mattered less if ASK was bulky and the user interface non-intuitive. When the drilling market collapsed and petroleum support vessels began applying dynamic positioning, the operating environment gave a higher premium for compact and nimble solutions. Simrad and KV knew how to design a user interface for sea captains. Drawing on Simrad's experience in visualizing sonar signals, the Albatross screen used simple graphics to show coordinates and drift. The interface was partly derived from KV's MSI 70U submarine fire-control system and the control panel was intuitive: one button, one function. The solution could hardly be simple enough; an Albatross employee on a vessel recalled how he once saw a control panel littered with reminder stickers with helpful advice such as "call to check the engine is running before pushing this button".[289]

Figure 17) ***DP for dummies: the Albatross control panel***

[288] KV-Cor 238, Albatross [internal] board minutes, 29 September 1983. On the qualities of the updated ASK 3000."Latest dp system from Honeywell", *North Sea observer*, 1982, p. 51.

[289] Interview with Jenssen, 14 October 2004.

4.5 A company culture reinforced by customers

At Albatross, each consecutive success made the team more self-assured. The self-image, immodest in the first place, improved even further as sales orders piled up. The quite substantial orders that Albatross secured reinforced the team and deepened the division between Albatross and the rest of the company and Jacobsen gained the standing and money to run a freewheeling organization. While Albatross impressed its customers, the inexperienced engineers learned a lot from the shipping industry.

Once Albatross became a trusted supplier, customers began involving the dynamic positioning group in early stages of planning and the shipping community provided Albatross with feedback on existing products and inputs for new applications. The customers' awareness of North Sea challenges helped Albatross expand its product portfolio and stretch the notion of how a DP system could be useful.

Some market feedback helped to improve the dynamic positioning product, for example improving the tactics for getting back to where one wanted to be. *Thrusters allocation strategy* is the industry term for that operation. Initially, Albatross attempted to aim straight back to the target position. Once on a bridge, Terje Løkling of Albatross realized sea captains, who perform such manoeuvres regularly, do it differently. In a counter-intuitive manner, the captain set out in the wrong direction and gradually straightening up the curve in a ?-shaped manoeuvre much like a truck driver backing a semi-trailer. A little zigzagging turned out to be a simpler and more robust strategy than hitting and maintaining a perfectly straight line.[290]

Other user inputs resulted in entirely new products. In 1977, Stolt-Nielsen Seaways involved Albatross in a bid to cover Statoil's pipeline between the Ekofisk field and Emden in Germany. The exposed pipeline crossed Danish waters and Danish authorities objected to the environmental hazard and threatened to close it down. Because a shutdown would strangle gas production at Ekofisk, burying or covering the pipeline became a critical issue and Statoil asked construction companies to help solve the problem. Stolt-Nielsen Seaways proposed to dump sandbags on top of the pipeline and challenged Albatross to design an accurate autopilot capable of guiding the *Seaway Sandpiper* along the course of the pipeline. The best available autopilots had error margins of 10 or 100 metres; a dynamically positioned vessel might deviate no more than one metre from the track. Such accuracy would allow a barge to dump stones or sandbags on top of a subsea pipeline

[290] Interview with Løkling, 29 October 2004.

with little mass wasted on the surrounding seabed. Part of the solution involved designing a dedicated tracking device to supplement the position reference systems: a carriage on the seabed followed the pipeline like a blind person's white stick.[291] With the assistance of Albatross, Stolt-Nielsen won the tender.

Having switched from maintaining a position to following a course, new applications followed. Albatross built an application for surveillance ships that allowed a vessel to escort a remotely operated underwater vehicle equipped with a transponder. Without such software, the surveillance ships had to redeploy frequently when their ROVs did exploratory tasks such as pipeline inspection.[292]

A major new product line from Albatross assisted shuttle tankers. In 1979, *Ugland Management*, a shipping company, brought KV to a meeting with Arve Johnsen at Statoil.[293] Ugland owned a fleet of shuttle tankers carrying oil from fields with no pipeline. During such operations, a tanker would pick up a hose and a hawser (mooring line) and attach itself to a torrent where the huge ship would stay connected for between 24 and 36 hours. In order to avoid unnecessary strain on the hawser, the tanker manoeuvred back and force in phase with the oscillating torrent to reduce the strains that caused frequent and expensive hawser refitting and occasional delays. Keeping the hawser reasonably slack was difficult, but difficult in a predictable way. Like a pendulum, the oscillation of the torrent would have a degree of regularity. Using forward coupling, Albatross designed a guidance system that employed computers, measurement systems and propellers to speed or reverse the tanker and maintain a desirable distance to the torrent.[294] KV supplied the first offshore landing application to the *Anders Wilhelmsen* shipping company in 1981. It performed the job much more accurately than any captain had ever done in part because of a *horizontal taut wire* and the Artemis system that measured the distance between tanker and the torrent.[295]

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[291] Interview with Skoland, 24 January 2006, with Sælid, 12 October 2004, and with Jenssen, 14 October 2004.

[292] KV-Cor 238, Albatross [internal] board papers on marketing strategy, 23 September 1983.

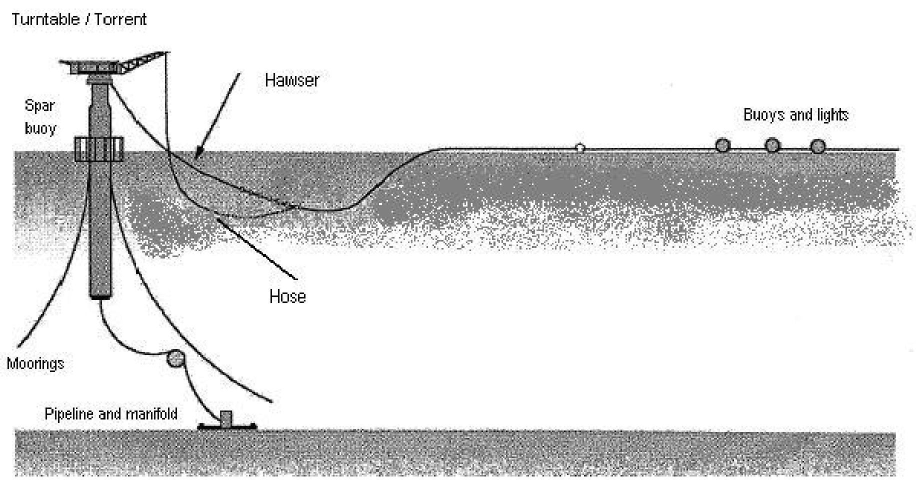
[293] KV-Cor 142, Skoland, memorandum to Qvenild, 15 May 1979; KV-Cor 142, letter from Qvenild to A.K.L. Ugland, May 1979.

[294] Interview with Dølsplass, 24 January 2006.

[295] For a review of Artemis, taut wires and other position reference systems, cf. Appendix 11.8.

Unlike regular dynamic positioning, the shuttle tanker application did not do away with mooring hawsers (the shuttle tankers had insufficient engine power to maintain position with engines only), but rather supplemented the operation of a moored vessel.

Figure 18) ***Typical offshore loading connection***[296]



Albatross also managed to apply the principles of dynamic positioning for drilling rigs. In 1983, the company introduced *dynamic mooring* - systems that combined mooring and dynamic positioning. This technology addressed usages where mooring was the norm, but where operations could be somewhat improved using dynamic positioning techniques. Despite numerous anchors, drilling rigs would experience drift due to wind and tide and risk losing risers or a gangway across to the living quarter (*floatel*). Using winches, the vessel would strive to maintain its position,[297] bit when the weather was rough, drilling operations would come to a halt and the drilling company would lose money. Position mooring reduced the time a rig spent idle and let rigs operate in otherwise forbidding waters. The system surveyed the mooring lines continuously, detected possible dangers and warned the crew when to quit operations or call for tugboat assistance. With this greater ability to detect and respond to dangers, the operator could hope

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[296] David Bray, *Dynamic positioning*, 2nd ed., Oilfield seamanship; vol. 9 (Ledbury: Oilfield Publications Limited, 2003), p. 205.

[297] KV-Cor 238, board minutes, 29 September 1983. CA-KM-sup, folder “Nostalgi”, product brochure on position mooring, ca 1985 (undated).

to get away with less engine power and fewer mooring lines. Furthermore, the operator could use Albatross *PosMoor* systems to automatically tighten and relax the mooring lines, manoeuvre more smoothly, and reduce fuel consumption and strain. Besides, if for some reason an anchor line would nevertheless break, the PosMoor system would act like a DP system, immediately employing the thrusters to prevent or limit the damage of drift.[298]

The examples above show the beneficial effect of being close to dynamic customers and gaining insight into their technological challenges. In addition, Albatross attempted to replicate some successful business practices from their shipping customers.

In no small part, Bendigtsen continued to act as a link between Albatross and the shipping industry. Upon leaving Stolt-Nielsen in 1976, he set up a trading company, acted as general agent, and secured several contracts. More importantly, he helped explain the shipping business to Albatross and transfer a customer-centric approach.[299] He insisted Albatross should always keep the customer's perspective in mind. Bendigtsen and Jacobsen knew that sales depended on more than technical merits. One story has Jacobsen insist the DP system should have brass buttons at an estimated extra cost of NOK 50,000, a request denied by more earthbound colleagues. Another story related to a Dutch sales agent who suggested a "show pin-up" function for bored crews on three dynamically positioned dredging barges intended for harbour work in Dubai.[300] Possibly, some of the attempts to please were misguided, but they were evidence of an omnipresent customer-centric culture where travelling technicians on board a customer's ship would flatter the captain shamelessly and seriously consider his preference for brass buttons. It also reflected customers who readily bought into novel technology.

To some extent, employees at Albatross developed commercial instincts, but the business unit also attracted commercially minded people. There was Bjørn Trosthoel, son of a businessman who bought surplus flowers in Oslo

[298] CA-KM-sup, folder "Nostalgi", product brochure on position mooring, ca 1985 (undated).

[299] Interview with Bendigtsen, 21 November 2005, with Jacobsen, 29 November 2005.

[300] On the brass buttons: interview with Sælid, 12 October 2004. On the "nude button": interview with Jacobsen, 31 March 2005 and e-mail, Jacobsen to the author, 11 April 2006.

on Saturday and supplied undertakers in Vestfold for the Sunday funerals. Like his colleagues at Albatross, he maximized revenues in a way unheard of at Kongsberg and maybe not in shipping either.[301] Taut-wire position reference systems required a line, some instrument to measure the inclination of the line, and a heavy weight to anchor the line. The weight was nothing but a piece of scrap metal painted white for esthetical reasons; it cost NOK 2000 to manufacture, but Albatross charged NOK 50,000. There are abundant stories of various sales tricks, the outcome of a friendly competition to sell the most.[302]

A final quality of the Albatross culture was the sweeping responsibilities granted to the employees. Both Bendigtsen and Jacobsen appreciated this value. Bendigtsen marvelled at the trust Jacob Stolt-Nielsen had granted him in running Stolt-Nilelsen Seaways, and he firmly believed empowerment inspired people to achieve. Jacobsen was a fan of Douglas McGregor - a management theorist who emphasised management based on trust and motivation.[303] He divided management philosophies into *Theory X* (people need control) and *Theory Y* (people are capable of self-management).[304] McGregor's work was descriptive, not a prescription to let go of control, but his work made managers and scholars aware of the forcefulness of soft management techniques – in this respect he was instrumental in a general shift away from hierarchies and command towards something much less rigid.

At Albatross, business success fed and underpinned the peculiar culture and work ethics that served the company well – it was probably irrelevant or misleading to talk of business practices and culture as separate issues. The Albatross culture transcended business success and, indeed, part of the Albatross culture was to pursue business success. Gradually, these sentiments became engraved on the business.

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[301] A shipping magnate responded with curses upon learning the price of a replacement interface card; interview with Sælid, 12 October 2004.

[302] On the interface card: interview with Sælid, 12 October 2004. On Throsthoel's background: interview with Jacobsen, 9 September 2004.

[303] Jacobsen, e-mails to the author, 11 April and 18 April 2006. For a brief introduction to McGregor, cf. "The new organization: A survey of the company", *Economist*, 21 January 2006, p. 20.

[304] For the original work, see Douglas McGregor, *The human side of enterprise* (New York: McGraw-Hill, 1960). For a digest, cf. http://en.wikipedia.org/wiki/Theory_X_and_theory_Y.

4.6 Theory Albatross: institutionalising company culture

If initially the company culture at Albatross rested with individuals, the culture gradually became part of a practice. Culture building was part of a conscious process to make the company capable of rapid growth and less dependent on individuals.

One night in 1979, Jacobsen felt awkward. His wife had virtually collapsed when their fourth child arrived; he had been bypassed as head of division when KV included Albatross in a new Maritime Division, and he was lonely drinking beer and watching television at a hotel in Calgary, Canada. Then Jim Bakker, the televangelist, appeared on screen. “You!” the reverend preached, “… who sit alone in the night with a beer watching television…” He spoke of empty lives, prayer and salvation – and hit the Albatross manager’s nerve. Jacobsen decided to quit. He mailed the Reverend Bakker a hundred-dollar check and visited the ministry upon leaving Albatross. Years later, when Bakker resigned, Jacobsen failed to join in the popular scorn and ridicule. Apparently, the reverend was guilty of sexual improprieties with a secretary, fraud involving a Christian theme park, and the bad judgement of installing air conditioning in a dog’s house at his parishioners’ expense.[305] What Jacobsen nevertheless appreciated was a the preaching of a raw belief that bordered on irrationality, but inspired ambition, energy and optimism much like Jacobsen himself had done.[306]

The natural heir to Jacobsen was his close associate, Thor Skoland. In the summer of 1980, however, KV placed Skoland in charge of Norcontrol AS, a troubled ship automation company KV had acquired back in 1978. The job of managing Albatross passed on to Nils Willy Gulhaugen. He was probably the first ever general manager at KV who was neither an officer nor an engineer, but a salesman at heart. Before joining the Oil Division in 1975, he studied applied economics at *Bedriftsøkonomisk Institutt*, Norway, and gained an MBA from the University of Wisconsin.[307] He went on to head Albatross’s marketing effort from 1978. He was inspirational, but something

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[305] Interview with Jacobsen, 5 March 2005; for details on the Bakker scandal, there are Internet sources galore, see e.g. http://en.wikipedia.org/wiki/Jim_Bakker#Scandals.

[306] On the establishment of the division, KV-Cor 142, Qvenild to board of directors, proposal for 2 May meeting, 27 April 1979.

[307] Interview with Gulhaugen, Kildal and Løkling, 29 October 2004. Bedriftsøkonomisk Institutt is nowadays referred to as BI Norwegian School of Management.

of a thinker, and relied on his Financial Manager Torfinn Kildal for execution and spelling out details.

By the time Jacobsen left, most resented his faults and his guerrilla tactics. The business had matured somewhat by 1980 and a certain order was required, a degree of seriousness, but not a return to Kongsberg normality. The fact Jacobsen could leave of his own choosing despite any number of serious clashes with superiors was evidence of what he had helped to achieve. The counterculture at Albatross had been very productive and the Albatross management realized they should retain energy, simplicity, speed and creativity while making a growing number of people work in concert. The task was branded *Theory Albatross*.

Theory Albatross was not without precedent. For centuries, certain organizations had prided themselves on a strong *esprit de corps,* the Catholic Church or the Prussian army for example. What went on at Albatross was similar in effect but quite opposite in approach – excessive discipline was not part of the package. In contemporary academic journals, there were a few attempts to link company culture with management and strategy.[308] In 1982, a couple of McKinsey consultants published *In search of excellence*, a bestseller that touched on the subject.[309] People everywhere seemed increasingly aware of the fact some organizations were held in low esteem and their timid employees behaved accordingly. Leif Juster, a contemporary Norwegian comedian, made people laugh simply by bending his neck in apparent shame and confessing to work for the national telecom monopoly. Conversely, commentators pointed to morale when explaining the persistent good performance of German football teams in the 1970s. The culture builders at Kongsberg were aware of all these contemporary developments, but most of all they knew well what *not* to do; for this they looked to the weapons factory next door.

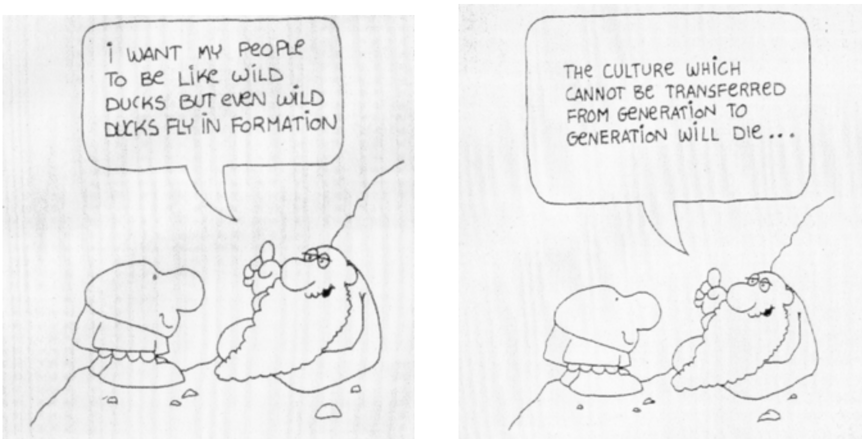
Theory Albatross was imposed upon new Albatross employees in a conscious and comprehensive effort. Knowing what attitudes to encourage, Gulhaugen and Kildal began a process of cultivation. They manifested the message in well-prepared documents and stressed repeatedly the wide

[308] Mats Alvesson and Per Olof Berg, "Why is organizational culture so popular?" in *Corporate culture and organizational symbolism: An overview*, De gruyter studies in organization, 34 (New York: W. de Gruyter, 1992), XII, p. 258.

[309] One contemporary bestseller that touched the subject was Tom Peters and Robert H. Waterman, *In search of excellence: Lessons from America's best-run companies* (New York: Harper & Row, 1982).

responsibilities that rested on each individual; people were “brainwashed” into being individuals with a common goal and they “were very happy about it”. [310] They used propaganda, compensation, organization, motivation, management and whatever means at their disposal to underpin behaviour. A present-day reader examining their catchy materials might mistakenly dismiss them as the output of some human relations consultancy or a marketing campaign. Not so: the effort was heartfelt.

Figure 19) ***Wild ducks in formation: excerpts from Albatross internal communication, ca. 1983***[311]



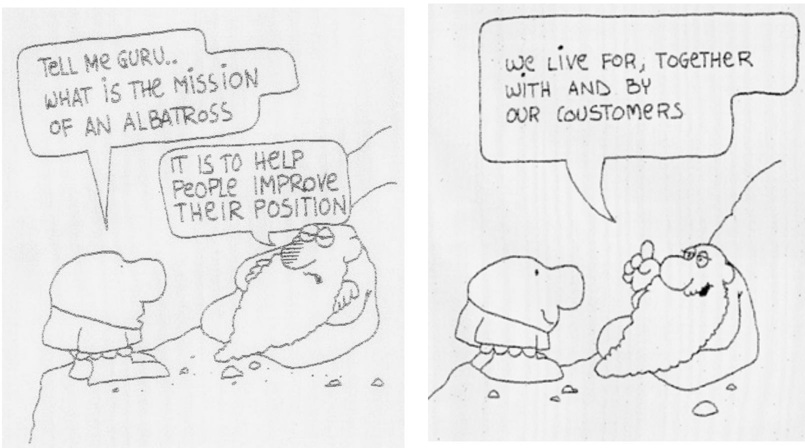
In the early 1980s, the company called staff meetings, shared information, celebrated achievements loudly, and allowed customers to take part in the fun. There were budget kick-offs and customer seminars with wining and dining - the techniques may be obvious and widespread today, but at the time these were innovative practices at least in Norway, not to mention in Kongsberg where fraternizing with customers was considered slightly strange. Company slogans urged employees to “live for, together with and by” their customers. Gulhaugen told his people they should always be available at the request of customers, assist in ways that created

[310] Interview with Jenssen, 14 October 2004.

[311] Jenssen’s private papers; the illustrations are reproduced from an undated booklet “Teori Albatross” handed to each employee in 1982-1983; similar materials were in circulation earlier, too. The above left drawing invokes a management metaphor (I want my people to be like wild, wild ducks, but even wild ducks fly in formation) that probably originated with Thomas J. Watson, President of IBM from the 1920s to the 1950s.

interdependence and display empathy.[312] "We help people improve their position" became the slogan, not 'we build the best technology in the world'. Management was very explicit customers had priority ahead of routines and rules. The best people went to see the customers and then immediately turned around to do the patching.[313]

Figure 20) ***The double meaning of positioning***



Customers at home and abroad tended to like the style. The company built such strong relations with Russian drillship operators that Soviet authorities kept open a border crossing at Kirkenes for Albatross service people; Norwegian diplomats and executives visiting the Kola peninsula had to make a 2500-kilometre detour by way of Moscow.[314]

Theory Albatross served to make the product group an attractive employer. In a virtuous cycle merry, entrepreneurial people attracted more merry and entrepreneurial people. The number of employees would typically increase by a third each year and the new hires quickly assumed operational duties, not least because of Theory Albatross and other attempts to set expectations

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[312] Citation translated from KV-ex 9, Albatross market philosophy, 29 September 1983.

[313] Interview with Gulhaugen, Kildal and Løkling, 29 October 2004, confirmed by interview with Jenssen, 14 October 2004.

[314] KV-ex10, Gulhaugen to Rolfsen on the marketing of products in Eastern Europe, 8 January 1985.

right. Among those who joined Albatross in 1982 were the two scientists that wrote the high level Albatross code back in 1975-76: Jenssen and Sælid.

* * *

Albatross was a pioneer of sorts in spelling out the importance of *human relations*. The term had not entered the Norwegian language and Gulhaugen referred to the effort as “personalomsorgen” (the *staff caring*). Upon learning her husband would not make it home on a Friday evening because of work, a wife might receive an apologetic gift of flowers. These were small signs of compassion, neither strange nor outlandish, but none had ever done such things at Kongsberg previously and the effect was profound. Gulhaugen had uncovered the beauty of motivation: “I felt like putting money into a machine and immediately receiving double the amount,” he would recall. In 1985, Albatross established a corporate kindergarten – not the first such endeavour, they were pioneered at hospitals - but quite early for an almost all-male engineering community and definitely the first kindergarten at corporate Kongsberg.[315]

There was a gulf between the manifestations at Albatross and the staid ways of Kongsberg Våpenfabrikk. Gulhaugen recalled being rebuked by a KV trade union official for celebrating people with five years of employment; one should wait 25 years and then receive the ritual gold watch, the official argued. Sometimes, when people from Albatross and KV sat down with every intention to cooperate, they still failed to communicate; the fact their team was so closely knit tended to alienate outsiders.[316] Such clashes of mentalities bothered the Albatross management who tried to come clean of their anarchist past and earn themselves a proper company.[317]

4.7 DP class certificates and their effect on innovation

Technologies that might improve health and safety received more emphasis following accidents and mishaps in the 1970s, most evidently the blowout at

[315] Interview with Gulhaugen, Kildal and Løkling, 29 October 2004

[316] On the coherence of the Albatross team, cf. KV-Cor 238, Thorbjørn Gjelstad on miscommunication between Albatross and KV management, Albatross [internal] board minutes, 22 December 1983.

[317] On the concern of KV’s management, cf. KV-Cor 238, “Albatross – Quo vadis”, assistant managing director Rolf E. Rolfsen to Albatross management, 9 February 1984; on the attempts in Albatross to behave properly, cf. interview with Gulhaugen, 29 October 2004.

Ekofisk Bravo in 1977. While a fountain of oil and gas emerged from Bravo, the *Seaway Falcon* used dynamic positioning from Honeywell to remain in place and robotic, heave-compensated, water cannons from KV to bombard the platform and prevented fire.[318] The incident provided a sales argument for anyone with a technology capable of improving offshore safety, but also an increased interest in health and safety standards. In this climate, DNV authored standards for dynamically positioned vessels. The first ship to sport a DP class certificate from Veritas was the *Tender Comet*, a diving support ship with dynamic positioning from Honeywell that entered operations in 1979.[319]

As with classification standards in general, DP classification reflected the foremost concern at the time of its creation. In the late 1970s, computers were likely to crash and computer redundancy correspondingly important. The table (below) outlines the concept of the class regime as conceived in the 1970s - and as remains today. Class 1 signified a working solution that had no redundancy. Class 2 signified a redundant system. Redundancy in this respect implied not only extra computers and position reference systems, but an approach to detect which of the installed systems was malfunctioning. This required computers capable of checking each other's configuration. Frequently, a Class 2 system employed three computers: the first online to run operations, the second off-line as a backup, and the third to continually monitoring the online computer and check for malfunction. The most robust approach, however, was for three operational computers to perform exactly the same job. This allowed a *voting logic*: if two out of three systems agreed on the position, chances were the third was erroneous.[320]

The main effect of the classification regime was to simplify the process of acquiring technology and lower the cost of a transaction. Ordering a dynamically positioned vessel became less difficult when oil companies could rely on the classification societies to specify what they needed and ensure that the delivery was according to specifications. The shipping companies *de facto* outsourced the task of specifying requirements and assuring the quality of the suppliers.

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[318] On the growing importance of safety issues, cf. Ryggvik, Gullvåg, and Smith-Solbakken, *Blod, svette og olje*. On the marketing impact of the Bravo incident, interview with Bendigtsen, 21 November 2005.

[319] Kongsberg Maritime, "Interview: Holger Røgeberg", *The full picture* 2004. DNV got extensive assistance from Albatross in outlining its DP standard.

[320] Bray, Dynamic positioning.

Figure 21) ***Touch of class: main properties of the DP classification regime***[321]

Class	**Requirements**	**Typical application**[322]	**Hardware implications**
Class 1	No redundancy, meaning loss of position may occur in the event of a single fault.	For operations where loss of position would not endanger human lives, cause significant damage or pollution.	One computer will suffice.
Class 2	Operations can continue despite any single fault in any active system component (generators, thrusters, switchboards, valves.)	Used during operations where loss of position could cause personnel injury, pollution or damage.	Requires two independent computer systems, independent reference systems, etc.
Class 3	Operations can continue despite the failure of a static component (cables, pipes, manual valves etc.) This means the system had to withstand flood or fire in any compartment.	Used during operations where loss of position could cause fatal accidents, severe pollution or damage with major economic consequences	Requires at least two independent computer systems and a backup system located in a separate compartment.

Secondly, the classification regime made customers aware of a gold standard in dynamic positioning and in effect marketed expensive systems with

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[321] Composed using information from David Bray, *Dynamic positioning*, Oilfield seamanship, vol. 9 (Ledbury: Oilfield Publications Limited, 1998) and Wikipedia's entity on dynamic positioning, cf. http://en.wikipedia.org/wiki/Dynamic_positioning.

[322] Only on the Norwegian Shelf were there legal requirements for what class to be applied in what circumstances; this column refers these demands as summarized in Maritime, "Interview: Holger Røgeberg".

multiple computers. By 1997, a triplex computer console could run for 192 years on average without a fault.[323] Ten years later, the chances of a computer failure have diminished to the point where they are miniscule compared to the risk of an engine failure or human failure – nevertheless, the classification societies impose stricter provisions on computers than on such items as fuses or diesel engines – or indeed training.[324]

In Norway, the classification regime offered the Maritime Directorate a tool to make dynamic positioning mandatory and expand the market. In Figure 21), the second column recapitulates the criteria for applying a particular class of dynamic positioning. In other oil provinces, dynamic positioning may not be mandatory, but the guidance of the classification societies may nevertheless act as a semi-official regulation. Shipping companies and oil companies tended to heed the recommendations of classification societies, if for no other reason than to escape blame if something did go wrong.

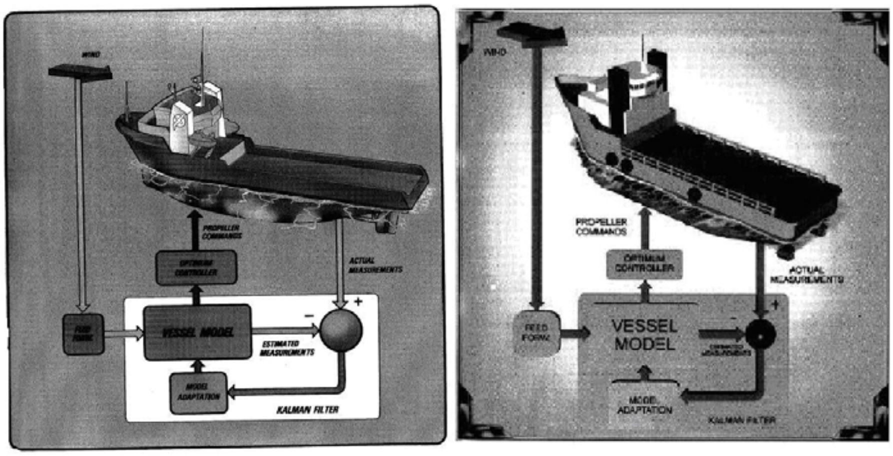
A final effect of the classification regime was less benign: Albatross lost a source of inputs. When oil companies began asking for vessels by reference to a class certificate, customers and suppliers no longer had to search for the ideal solutions, but relied on the classification societies to specify what technology was right. Because the shipping companies could rely on semi-officially sanctioned presuppositions as to what they needed, it became more difficult for Albatross and other technology providers to suggest alternations and tailor solutions to specific challenges.[325] The practice of issuing DP class certificates absolved suppliers and customers from the time-consuming, but highly creative, process of mapping requirements and specifying solutions. Such interaction had helped Kongsberg Albatross develop its solution, and the lack of such interaction did nothing to advance product development. This lack of inputs was one of several conditions that help explain why the basic principles of a DP system settled on a specific design and remained stable. The illustration below (excerpts from product brochures dated 1985 and 1998) is circumstantial evidence of this. On a conceptual level, little distinguished one from the other. It was a rare feat for a high-tech company to retain the basics of its product brochure over the course of 13 years (or indeed 22 years).

[323] Howard Shatto, "Reliability and risk analysis" (paper at Dynamic Positioning Conference, Houston, 1997), p. 26.

[324] Maritime, "Interview: Holger Røgeberg".

[325] Interview with Jenssen, 14 October 2004.

Figure 22) ***Splitting image: Product brochures of Kongsberg Albatross (1985) and Kongsberg Simrad (1998)***



The main conserving effect of the classification regime was to ensure dynamic positioning remained a stand-alone product, not to be swallowed up e.g. by advanced autopilots or general vessel automation. Dynamic positioning remains as a stand-alone solution in part because it is unfeasible to triple *every* piece of electronics on board a vessel. However, such protection from competition also served as a barrier to the further development of the technology: because classification societies tightly prescribed the requirements of a DP system, it became somewhat awkward to integrate new functionality. Albatross, thus, was entrenched in a double sense: its market position was hard to assail, but the bulwark prevented an advance into new areas of application.

4.8 Conclusions

Initially, nothing much distinguished the people that worked with marine systems from the people at Albatross. In both lines of business, KV put trust in young engineers who responded by putting down an extraordinary effort. The young Albatross engineers who left their wives behind at a dinner party one Saturday night in the late 1970s had a parallel in Ole Magnus Smeby, the famously hard-working head of the subsea group.[326] In 2004, this author had great difficulty finding a time to interview the then 74-year old subsea engineer because he travelled extensively doing what he had been done for

[326] For extensive anecdotal evidence of Smeby's work ethics, cf. Daling et al., *Offshore Kongsberg*.

31 years: subsea engineering out of Kongsberg. In each group, people will work at night, if need be, with a firm conviction one must always deliver.

There were dedicated people everywhere, but Albatross matched dedication with business sentiments. The mentalities at work reflected the outlook of some key people who began celebrating their successes and insisting they were special. There was Bjørn Barth Jacobsen, who installed in people the attitude required to succeed without a superior and patentable product. There was Thor Skoland, who made sure things did not get out of hand. Besides, there was a handful of people whose departure would have delayed and set back Albatross, but possibly not to an extent where the project would have been irredeemably derailed. The resulting business culture was very productive.

What people achieve depend not only on their abilities, but also on the age in which they live and their environment - Albatross faced market conditions that boosted the achievements of hard work. In the second half of the 1970s and early 1980s, the dynamism of the shipping industry reinforced an entrepreneurial culture in the Albatross product group and shaped a business that differed sharply from KV. Their customers were innovative and businesslike, provided ideas and rewarded effort; the young engineers worked with customers that allowed and appreciated extensive initiative. Put differently, the shipping industry reinforced the culture that originated at Albatross.

Emerging technologies frequently display diversity before a *dominant design* eventually emerges, typically due to trials, failures, habits and economics of scale.[327] In the case of dynamic positioning, classification societies acted as agents for standardization. Det Norske Veritas wrote the first recommendation, and in the process helped cement dynamic positioning as a stand-alone product subject to certain standards. This advantage came at a cost. Where Albatross had previously shaped the choice of its customers through discussions and negotiations, classification societies increasingly shaped procurement decisions; to a certain degree, they bypassed or abridged the productive dialogue between Albatross and its customers. Secondary uses of DP technology, however, continued to emerge as Albatross got in touch with customers that hoped to apply the basic approach of dynamic positioning to a new setting – navigating a narrow course, for example, or reducing the strain on hawsers while loading crude onto a tanker.

[327] Although not the starting point for studies of dominant designs, the logic is described with superior overview in Nelson, "The co-evolution of technology, industrial structure, and supporting institutions".

A class certificate was a means to lower transaction costs – a way of simplifying the order process. In this respect, the classification societies underpinned the division of labour between the users and manufacturers of marine electronics and strengthened an established pattern. In next chapter, I return to transaction costs and changing procurement practises in the offshore oil industry, where the division of labour was less elaborate.

5 Changing industry architecture, 1979-1985

Around 1980, the subsea group lacked the kind of strategic overview that Albatross enjoyed. Unlike shipping suppliers, those who supplied equipment to the Norwegian oil industry relied on extensive guidance from their customers, who in effect made every important decision on what technology to employ in order to solve a particular problem. In the early 1980s, this picture began to change and the subsea group acquired tasks that previously belonged exclusively in the realm of oil companies.

In the late 1970s, the subsea group struggled to get across to an industry that preferred to make design decisions in-house and stuck with established procedures. Eventually, KV managed to secure an assignment by exploiting the concessions regime. Oil companies received concessions free of charge, not through auctions, in return for paying taxes, sourcing equipment from Norwegian suppliers and granting favours to Norwegian industry and research institutions. KV got a well-paid apprenticeship with Elf at North East Frigg. In return for this and other favours, Elf secured a concession to exploit the block where Snorre was found. A similar arrangement secured KV an advanced research assignment with Shell – which in return received concessions on the block where Troll was found.

In the mid-1980s, the picture changed somewhat. The subsea group gained something to sell: not primarily the equipment Hurlen had set out to fabricate, but the systems expertise, services and know-how that made Kongsberg Offshore a valuable player in its own right, and less dependent on political favours.

Apart from the slow accumulation of skills and experience, what particularly helped Kongsberg Offshore improve was a change in procurement practices on the Norwegian shelf. The early 1980s witnessed the introduction of *Engineering Procurement Construction* (EPC) contracts that shifted responsibilities onto suppliers. Elsewhere, oil companies employed large in-house engineering departments with firm opinions on how things should be done, or they employed advisory engineers that spelt out in detail how things should be done. The Norwegian oil companies lacked large in-house engineering departments, and the national engineering champion that Statoil hoped to nurture, NPC, had begun to disintegrate. Rather, they absolved themselves of detailed engineering and began purchasing equipment based on comparably simple specifications and functional descriptions of the end result. It was for the main contractor to build the equipment, buy it, invent it, or solve the task in whichever way they saw fit. The role and stature of suppliers grew in response to this shift in procurement practices – the industry architecture changed. The subsea group increasingly influenced the choice of its customers and allowed the concerns of customers to influence designs.

5.1 Lobbying for a role alongside oil companies

Around 1980, oil companies rather than engineering companies possessed the most useful experience in devising subsea solutions. KV's first proper subsea assignments arrived courtesy of oil companies that needed to please the authorities with which KV enjoyed close relations.

Like shipping companies, oil companies rarely manufactured tools, but preferred to acquire technology from suppliers. Unlike shipping customers, however, oil companies tended to specify what solution to apply in order to solve a particular problem and sometimes designed equipment in quite minute detail. Besides, oil companies frequently took upon themselves to integrate equipment into working technological systems. In short, *oil companies* continued to possess key technology.

Apart from oil companies, only their advisory engineers retained an overview. The advisors were large consulting companies, such as Brown & Root, which sketched every aspect of a platform. In the 1970s, oil companies everywhere bought their services. When developing an offshore field, oil companies or their engineering management contractor (e.g. Norwegian Petroleum Consultants) selected components or sub-systems from various manufacturers.[328] All planning, projecting and engineering was done before selecting suppliers, of whom little was expected except the proper execution according to drawings – whether they worked or not. This procedure limited the suppliers' responsibility and their capacity to innovate – and their room for making errors. Statoil adopted the same procedure, the issuing of *fabrication contracts*.

In the field of deepwater technology, the division of labour that marked the 1970s allowed suppliers of technology rather less room than was the case in the 1960s. In part, the suppliers were themselves to blame Lockheed and other aerospace companies had developed equipment that was too sophisticated. "Blowout preventers and Christmas trees became towering monuments of steel with a towering price-tag to match", one industry

[328] Smeby's private papers, Dixon Associates, "Subsea oil well completion and production systems: a current evaluation", Houston, Texas, 31 August 1973.

observer remarked.[329] Put simply, the aerospace companies disappointed their customers with unreliable products and high prices. Most aerospace companies then disappeared from the market and oil companies took charge of technology development; costs levelled off, and a new realism arrived in the industry. By 1980, specialist suppliers continued to play a significant role, but they rarely attempted independent technology development and mostly took their cue from oil companies. KV and Cameron played to this script.

Because oil companies retained control of their technological systems, they could accommodate special concerns – and they could be called upon to accommodate special concerns. In the highly political nature of the oil economy, KV could leverage its excellent connections to gain subsea assignments.

Since 1965, the Norwegian authorities had granted licenses to explore and develop oil fields on the Norwegian Shelf. Concessions were nominally free, but the receiver accepted a set of terms collectively known as *Technology Agreements*, i.e. various commitments to develop Norwegian industry. Initially, the receiver of a concession was expected only to support Norwegian oil-related industry, but when the fourth round of concessions was announced in April 1978, the scope broadened. The Norwegian authorities placed emphasis on the oil companies' wider cooperation with Norwegian industry.[330] KV managed to turn the procedure into a tool for the company's subsea strategy.

Technology development received more attention in the late 1970s. The costs of building the Statfjord platforms were much higher than expected, particularly Statfjord A. Conceived as an up-scaled version of Mobil's Beryl platform, it ended up costing three times as much.[331] Inflation and capacity problems in the supplier industry explained part of the cost overrun. In addition, a substantial extra charge occurred from hasty and inadequate initial planning fully equipped, the platform would have been too heavy for a tow and certain modules had to be retrofitted in the field causing delays and substantial extra costs. The operator, Mobil, had been constrained in its choice of suppliers and consultants and substantial costs went into

[329] Booth, "North Sea: Testbed for advanced subsea production".

[330] Jostein Dahl Karlsen, "Forhandling og tilpasning under usikkerhet: En studie av industrisamarbeidsordningen 1978-1986", (Diploma, BI Norwegian School of Management, 1988), pp. 15 and 27.

[331] Cf. footnote 175.

transferring competencies to Statoil and Norwegian suppliers.[332] The Moe Commission, which investigated the cost overruns, did not comment on the technological style that Statoil and Mobil had chosen, but people in the industry began questioning the economic viability of the huge platforms. "Have the giant concrete production platforms outplayed their role?" ran one introduction in *Scandinavian Oil and Gas Magazine*. The article referred to the progress of Shell Petroleum in finding new and cost-efficient approaches to extract oil from great depths including the *Spar* platforms that resembled giant buoys.[333] In the mid-1970s, establishing a production capacity capable of one barrel per day cost less than GBP 100 in the Saudi desert, about 400 offshore Nigeria and 900 in the Gulf of Mexico.[334] Statfjord A, by comparison, required GBP 2000 in investments for each barrel of capacity.[335] Hence, the cost overruns served to raise the interest in alternatives to the Norwegian Style gravity platform.

The fourth round of concessions followed in the aftermath of a failed gambit aimed at trading oil concessions for industrial prowess. During 1978, Hauge had negotiated a deal granting a Swedish automotive company, Volvo, substantial ownership on the Norwegian shelf in return for offering 40 per cent of the company's stock to Norwegians. The negotiations touched upon how to apply Volvo's broad industrial expertise to subsea developments. When Swedish shareholders rejected the gambit in January 1979, Statoil became generally more interested in the supplier industry and generally more receptive to KV's concerns about subsea systems.[336]

Hurlen was deft at exploiting opportunities offered by the technology agreements. When the government linked the concession regime with industrial policy, Hurlen shared his thoughts with the Ministry of oil and

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[332] Johannes Moe et al., "Rapport fra styringsgruppen oppnevnt ved kongelig resolusjon av 16. Mars 1979", *Kostnadsanalysen norsk kontinentalsokkel*, Volume 2, (Oslo: Ministry of oil and energy, 1980).

[333] "Shell raises the veil: How to produce petroleum from great water depths", *Scandinavian oil-gas magazine*, 1978, 43 ff. On the SPAR design, cf. Figure 41) on p. 149.

[334] Smeby's private papers, Smeby, "A Norwegian activity on subsea completion / deep water production systems", 11 November 1975.

[335] Cf. footnote 175.

[336] KV-Cor 248, Qvenild, memo from 14 December meeting with Statoil, 19 December 1979: "Vi har jo bl.a. tidligere diskutert samarbeid på undervannssystemsiden med Volvo. Dette var i Volvo-avtalens heteste dager – og når Volvo ikke fikk konsesjon, døde diskusjonen bort."

energy on how the authorities could assist KV. Primarily, KV wanted first-hand experience with a comparably simple subsea development. Secondly, a research assignment on advanced components: risers for greater depths, manifolds, valves, process equipment, control systems or maintenance techniques.[337] Hurlen identified Shell as a leading company in the field.[338] In the autumn of 1978, as if to strengthen KV's hand, the ministry asked oil companies what concrete plans they had to cooperate with Norwegian industry and research institutes on "deep-water technology".[339]

The ministry's letter established a separate category of favours that Norwegian authorities expected from the oil companies, *tilbudsavtalene* (hereinafter referred to as "arranged proposals"). The arranged proposals invited oil companies to do specific work with a specific partner; the remaining technology agreements placed general obligations on the oil companies, namely a commitment to do as much research and development as possible in Norway and no less than 50 per cent of the research and development related to the block on offer.[340]

In the autumn of 1978, KV made 14 oil companies aware of the match between what KV needed and what the ministry asked them to contribute.[341] Elf was of particular interest. The company had done pioneer work on subsea development in Grondin outside West Africa. In the second round of concessions, Elf got hold of the blocks that contained huge amounts of gas: *Heimdal* (1972), *Frigg* (1971), and several minor adjacent gas reservoirs, *East Frigg* (1973), *Lille Frigg* (1975) and *North East Frigg* (1974). The

[337] KV-Cor 242, Qvenild to Ministry of industry (Hernes), 4 January 1979.

[338] KV-Cor 248, Hurlen to Ministry of oil and energy (Tamburstuen) with copy to Statoil and Shell, 3 July 1978.

[339] The communication between the Ministry of oil and energy and the oil companies is cited in KV-Cor 242, Qvenild to Herns (industridept), 4 January 1979. The government's policy was later stated in a White Paper, St.meld nr. 63 (1978-79).

[340] The various arrangements are recapitulated in Karlsen, "Forhandling og tilpasning under usikkerhet: En studie av industrisamarbeidsordningen 1978-1986", and Heidi Wiig and Svein Olav Nås, "Teknologiavtalene som insentiv i norsk forskningspolitikk", *Notat / NTNF programmet Fremtidsrettet teknologipolitikk ; 14/92*, (Oslo: Norges teknisk-naturvitenskapelige forskningsråd, 1992).

[341] RA-Arntzen-Oil, board report dated 26 October 1978; KV-Cor 242, Qvenild to Ministry of industry (Hernes), 4 January 1979.

adjacent fields were suitable for subsea satellite developments.[342] Elf had an office in Oslo to deal with government relations, in effect seeking out what would be a good political move. In 1979, someone hinted it might be a good move if the French government made SNECMA, a French jet engine manufacturer, cooperate with KV and straighten out a certain problem with 25 per cent spare capacity at Kongsberg.[343] In the modus operandi of gentlemen, Elf was advised to look into KV's subsea interests. Headquarters in Paris then issued instructions to Elf Norway, which made a deal with KV.[344] Qvenild, who spoke fluent French and had a degree from INSEAD, was a valuable facilitator.

In early 1979, Elf offered KV a subsea assignment at North East Frigg, a pocket of gas 17 kilometres from the Frigg complex. Next, the two parties formalized this into an arranged proposal (*tilbudsavtale*). Elf sent a letter to the ministry offering to share its knowledge with KV and other Norwegian partners. KV countered with a letter stating the company wanted to become a subsea expert, but had no useful experience. The *lack of competencies* became a sales argument for hiring KV. Elf was to assist KV in the implementation and grant KV freedom to resell the intellectual property that originated from the cooperation.[345] The purpose of the letter exchange was to establish a set of conditions, not legally binding in the strictest sense, but that hardly mattered: the government not only acted as arbitrator, but also occasionally granted concessions free of charge in a rich oil province. The prospect of future grants obviously inclined Elf to withhold any second thought about KV's ability as a main contractor or any misgivings about letting KV exploit its intellectual property.

Elf was a valuable partner, but Shell had an even more extensive and valuable subsea experience. In the autumn of 1978, KV discussed how Shell

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[342] *Historien til elf petroleum norge 1965 - 2001* (Total E&P Norge, [cited April 2007]); available from http://www.total.no/no/About+TOTAL+NORGE/History/Elf/index.aspx.

[343] The deal is referred in KV-Cor 248, Qvenild, letter to Ministry of oil and energy (Himle), 4 May 1982.

[344] Interview with Steenstrup, 14 October 2004.

[345] KV-Cor 248, Qvenild, telex to Hauge with Elf's draft of letter to the Ministry of oil and energy, 7 February 1979. The vetted letter was sent from Elf to the Ministry, cf. KV-Cor 248, Elf Aquitaine Norway (Isoard) to KV, copy of letter to Ministry of oil and energy, 14 February 1979. KV approved, cf. KV-Cor 242, Qvenild to Ministry of oil and energy (Wattne) with copies to Elf, Statoil and the Ministry of industry, 14 February 1979.

could specify and finance a subsea project for KV to deliver. KV wanted proprietary rights to any technology developed during the project[346] and involved Statoil in the negotiations to add *gravitas* - but also complications. Shell was concerned about giving Statoil, a competitor, access to technology.[347] Nevertheless, KV managed to forge an agreement with Shell, although an agreement more vague than the one with Elf and one that primarily offered KV a role in assessing components in future research and development projects.[348]

Having secured deals with Elf and Shell, KV enlisted Statoil to ensure these two companies received a pay-off in the fourth round of concessions. In March 1979, Statoil co-authored a letter to the Ministry of oil and energy to confirm that both Statoil and KV needed the kind of experience offered by Elf and Shell.[349] When concessions were offered in April 1979, most blocks went to Norwegian companies: Hydro, Saga and Statoil. Only two multinationals had reasons to be satisfied: Elf and Shell. The French got parts of the block where Oseberg was found; Shell got a large share of the block where Troll, at that time the world's largest offshore gas reservoir, was found.[350] If the industrial ambitions of KV played any part in the awards, being friends with KV provided spectacular payback.

5.2 KV as a subsea apprentice

Having received the hoped-for concessions in 1979, Elf duly employed KV and Cameron in the development of a subsea solution for North East Frigg. Cameron was to supply parts, and KV was to become the main contractor. This division of labour was the result of a drawn-out dispute.

Both Cameron and Kongsberg Våpenfabrikk sported a manufacturing bias. Their business was *product* ownership, *product* fabrication and *product* sales. When Cameron and KV began to collaborate on subsea technology in the mid-1970s, the shared emphasis on products and manufacturing

[346] RA-Arntzen-Oil, board report, 26 October 1978.

[347] KV-Cor 248, Qvenild to Hurlen and Aasland, memo from meeting with Shell, 16 October 1978.

[348] RA-Arntzen-Oil, board reports dated 13 August 1979 and 6 November 1979.

[349] Drafts of letters from the Ministry to Elf and Shell were initially written at Kongsberg, cf. KV-Cor 248, KV (Qvenild) and Statoil (Ager-Hanssen) to Ministry of oil and energy (Wattne), 2 March 1979.

[350] For a brief overview, cf. Nerheim, *Det norske oje-eventyret* ([cited).

hampered their cooperation. Specifying a meaningful division of labour between the two was difficult since both wanted ownership and manufacturing assignments. KV hoped to manufacture advanced BOP stacks on behalf of Cameron, but following the rig bust in 1975, the market for blowout preventers and offshore drilling equipment diminished to the point where Cameron Iron Works could meet demand with existing capacity. This suited Cameron, which preferred in-house manufacturing.[351] KV, furthermore, hoped to develop new products in partnership with Cameron, but Cameron was anxious to protect its core competencies from a partner that hoped one day to manufacture proprietary oil tools in a factory at Kongsberg or by the sea.[352]

Denied its familiar role as a manufacturer by a protectionist partner, KV negotiated a different role, that of a "*contractor* in Norwegian waters and for systems sold to Norwegian clients" [my emphasis]. The role KV secured for itself involved tasks that Cameron either did not want or considered to be within the realms of oil companies: "system layout, design of special parts to integrate standard Cameron components, design components and subsystems where Cameron has no presence, design electronic equipment, instrumentation and control system packaging" and to "assemble and test the systems".[353] KV got the presumably less important task of making the nuts and bolts that surrounded Cameron's equipment. This included system integration, a task that, at the time, rested with oil companies and sometimes with their main contractors – no loss for Cameron. Cameron was confident that its command of the valve tree was what mattered. Cameron abandoned its control system business in 1978 despite having bought a supplier a few years earlier. The company believed it earned less from the sale of systems than from the sale of individual components and focused narrowly on Christmas trees and certain other parts. Besides, Cameron *Iron Works* had few competitive advantages in control systems.[354]

[351] Husemoen's private papers, Leif Husemoen, memorandum on the history of Kongsberg Offshore Systems, 22 September 1998. Smeby's private papers, Smeby to Oil Division, "KV's oil tool equipment: activity status and future prospects", 29 June 1981.

[352] Smeby's private papers, Smeby to Oil Division, "KV's oil tool equipment: activity status and future prospects, 29 June 1981.

[353] KV-Cor 243, memorandum of understanding between KV and Cameron Iron Works regarding engineering, marketing & production cooperation on subsea completion and control systems, 26 March 1976.

[354] KV-Cor 248, Smeby, agenda for meeting with Cameron dated 2 November 1977 and memorandum on meeting with Cameron about control systems dated 9 January 1978.

At North-East Frigg, KV became the official "main contractor". Actual management and experience, however, resided with Elf's engineers who had built subsea systems at Grondin off Gabon in West Africa, and with Cameron, which had supplied valve trees for numerous developments including the one at Grondin. Somewhat counter-intuitively, the "main contractor" handled straightforward tasks such as designing a template (the steel structure to encompass the system) and refining the hydraulics on the experimental electro-hydraulic (*multiplex*) control systems that Elf bought from Matra.[355] Cameron agreed to perform the assembly and testing in Norway, which offered KV some useful experience, but Cameron's quality demands strained the economics of the assignment.[356] Developing North East Frigg cost NOK 1.9 billion, of which KV supplied services worth five per cent, and most of this small share (70 per cent) originated from the reselling of Cameron equipment.[357] No task rested solely on KV.

Figure 23) ***Big hat – no cattle: KV's assignments on North East Frigg***[358]

Task	**Supplier**
Main contractor for subsea station	KV (with guidance from Elf and assistance from Comex and Cameron)
Valve tree	Cameron
Templates	KV/Comex
Control system	Cameron
Installation	Comex / Stolt-Nielsen
Articulated tower	Kværner and French partner
Experimental electro hydraulic control	KV and Matra
Wellheads and maintenance	KV and ACB
Installation	Herema

[355] RA-Arntzen-Oil, board reports dated 8 May 1980 and 7 May 1981.

[356] RA-Arntzen-Oil, board reports dated 8 May 1980 and 30 October 1980.

[357] The costs of North East Frigg appear in the annual report of the Norwegian Petroleum Directorate, cf. St.mld. 8, 1984-85. KV's turnover from the project are stated in various communications, using various figures within the same general ballpark (NOK 100-110 million in 1986 denomination), cf. KV-Cor 244, Kongsberg Offshore Systems information memorandum, 14 January 1986; RA-Arntzen-Oil, board reports dated 6 November 1979 and 8 May 1980.

[358] KV-Cor 248, Qvenild, letter to Statoil (Johnsen et. al.) in preparation of 18 January meeting, 15 January 1980.

The pretence to leadership backfired on KV when Elf disapproved of the quality of the valve trees and demanded a replacement. Cameron pointed to KV. As main contractor, KV was responsible, but hardly in a position to foresee or counteract the problem. People at Kongsberg suspected Cameron's new production facility in Leeds was not up to the task and that their partner neglected the project to demonstrate KV's lack of competence.[359] The incident strained KV's relationship with Cameron and revealed a standing conflict. Cameron valued KV's connections, not its technological prowess, and kept pushing its Norwegian partner to focus on sales and lobbying.[360] KV, on the other hand, found its partner complacent.[361] The more KV strived to master technology, the more difficult its relationship with Cameron became.

* * *

North East Frigg was but the first of a string of subsea related assignments that Kongsberg Offshore (the subsea group) secured during the early 1980s. The team began to assemble useful knowledge, but assignment generally originated from a political intervention, for example through provisions in the technology agreements that required foreign oil companies to spend money on Norwegian research and development. Between 1980 and 1985, the subsea group secured assignments worth NOK 387 million (see list below) – far more than the company could have hoped for in a competitive market. Each of these assignments brought not only revenues but also technology transfer.[362] KV probably received half of all funds spent on subsea research in Norway including what oil companies did in-house before 1985 and maybe 90 per cent of what was spent actually building solutions.[363]

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[359] RA-Arntzen-Oil, board report, 20 October 1981.

[360] Various incidents are referred e.g. in Daling et al., *Offshore Kongsberg*, or KV-Cor 248, Smeby, minutes from 5 May meeting with Cameron in Houston, 20 June 1977.

[361] KV-Cor 245, Smeby, memo from meeting with Norsk Hydro (Tuxen), 17 March 1976.

[362] RA-Arntzen-Oil, board report, 8 May 1980. The list does not include paid studies such as those commissioned by Deminex and Statoil, only projects that involved a technology transfer from the party that commissioned the project to KV.

[363] There are no official accounts on total research in this niche, but some numbers figure in Tore Andvig, "Undervannskonstruksjoner" (paper presented at NTNF-seminar: Norsk oljeforskning - 80 årenes petroleumsindustri: Oljeforskningen og næringslivets plass i fremtidig petroleumsvirksomhet, NTH, Trondheim, 11-12 June

However, the various subsea assignments that KV secured in the early 1980s were not so much proof the company possessed valuable competencies, but rather an important step in building such competencies.

Figure 24) ***Learning experiences, 1980-1986***[364]

Year	**Project**	**Sponsor**	**Value mNOK**
1980-83	North East Frigg	Elf	110
1982-86	Acoustic subsea control system	AGIP & Shell	45
1982-84	Connector test and design	Shell	10
1983-85	Cold tapping for repair of pipelines	Total	30
1983-85	Skuld system	Elf	80
1980-83	Riser program	Shell	4
1984	Leek monitoring	Shell	20
1982	Troll technology studies	Shell	25
1984	Dimos manifold for 600 metres depth	Shell	40
1985-86	Tie-in, etc.	Total / Statoil	15
1985	Downhole BOP	Statoil / Smedvig	6
1984-85	Offshore loading system	Statoil / Mobil	2
	TOTAL		387

5.3 EPC contracts and their effect on innovation

At North East Frigg, Kongsberg Offshore secured a somewhat hollow role as "main contractor". In practice, the important decisions rested with Elf. Like in previous decades, no oil company seriously considered purchasing a total subsea system from one supplier .[365] A set of developments in the early

1985), p. 51 ff. For turnover from the various research assignments KV received, cf. Figure 24) on p. 88.

[364] KV-Cor 244, KV to Aker, background for company presentation, 5 March 1986.

[365] Dixon Associates, ”Subsea oil well completion and production systems: a current evaluation”, Houston, Texas, 31 August 1973.

1980s turned this situation around and gave substance to KV's superfluous role as main contractor. The main contractor worked to fulfil Engineering Procurement Construction (EPC) contracts.

The use of EPC contracts for offshore deliveries was a novelty that was pioneered on the Norwegian shelf. When such procedures gained ground in the 1980s, they served to shift more responsibility from oil companies onto the supplier industry. Because EPC contracts usually would cover a rather complex product, a system or a module, the supplier industry shifted focus from being suppliers of parts to becoming providers of solutions. We will argue that greater discretion helped foster innovation. Furthermore, by simplifying the process of ordering subsea systems and lowering the cost of doing transactions, EPC contracts strengthened the role of independent suppliers in relation to the integrated oil companies.

The established procedure for ordering offshore equipment was expensive. In Norway, the combination of bureaucratic central engineering, the use of huge gravity platforms and the involvement of a protected, local supplier industry became a recipe for cost overruns. Statfjord A was always something of a special case, but the cost overruns continued on the almost identical Statfjord B; despite their close resemblance, NPC and Brown & Root spent 400-500 man-years on detailed specification.[366] Frequently, the planners had to adjust drawings to fit the competencies of individual suppliers. The oil companies added yet more costs by establishing shadow organisations to monitor the engineering and manufacturing firms they had hired. Some areas of work and responsibility tended to overlap and to secure cooperation and guard against litigation, the bureaucracy sprawled further still.[367] In the process, the shortage of skilled engineers worsened and wages skyrocketed.

In establishing NPC back in 1975, Statoil and KV had consciously circumscribed the role of Aker and Kværner in specifying designs, but neither Statoil nor KV had any interest in suffocating creativity. The issue was contentious because the fabrication contracts tended to specify in excessive detail what the suppliers should provide.[368] Big Norwegian

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[366] KV-Cor 245, Qvenild to Hurlen and Aasland, minutes from meeting with Statoil (Ager-Hansen), 23 June 1977.

[367] Engeland, "Ingeniørfabrikk på norsk", p. 138 with reference to interview with Olav Lappegaard, 3 June 1998.

[368] Cf. p. 28. KV-Cor 245, Qvenild to Hurlen and Aasland, minutes from meeting with Statoil (Ager-Hansen), 23 June 1977.

engineering companies, particularly Aker and Kværner, argued that such procurement procedures locked the industry out of the creative phase of offshore projects and constrained their opportunity to develop capabilities.[369] In their capacity as ship builders, large construction companies such as Aker and Kværner were used to taking on rather extensive responsibility in the delivery of ships including the integration of equipment and a considerable amount of the engineering. Shipping companies provided mainly functional requirements, and the yards themselves had a certain freedom to solve tasks.

Meanwhile, on the Murchison field that bordered both Norwegian and British territory, Conoco delivered an integrated production platform without cost overruns. In part, Conoco simplified the job by placing fewer orders with larger suppliers. The platform that came into production in 1980 employed only 14 modules compared with the 37 modules that spawned the extensive deck of Statfjord B. Conoco, furthermore, handled most of the conceptual design in-house and allowed the supplier industry itself to design more solutions. This approach halved the resources spent on third-party engineering compared with the approach used e.g. on Statfjord B.[370]

The success of such less intrusive planning, along with dissatisfaction amongst the biggest suppliers and a lack of skilled Norwegian engineers, made Statoil reconsider the use of engineering management contractors. From 1981, the company hired project service contractors (PCS) for less extensive support tasks in the same fashion Conoco had done on Murchison. The practice of employing a large firm of technical consultants to plan and execute field developments withered. In Norway, the attraction of large independent engineering firms diminished further because Aker and Kværner withdrew from NPC in 1982. NPC had few engineers among its staff, but drew on the employees and resources of its participating companies.[371]

Unlike its international competitors, Statoil lacked sufficient in-house capabilities to replace third-party engineers. Statoil had refrained from building a large engineering department in-house, and preferred to rely on Norwegian Petroleum Consultants in which KV and companies associated with Hurlen played a major part. Bereft of a strong partner capable of running huge centralized development projects, Statoil opted for a new

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369 Engen, "Rhetoric and realities", p. 133, drawing on an interview with Tore Bergersen, 19 September 1997.

370 Engeland, "Ingeniørfabrikk på norsk".

371 Ibid., p. 39.

procedure: *Engineering Procurement Construction* (EPC) contracts. Rather than assuming responsibilities themselves, oil companies operating in Norway adopted the approach of shipping / shipbuilding. When issuing EPC contracts, oil companies provided the supplier (the *main contractor*) with functional requirements and conceptual sketches, while the suppliers took upon themselves to plan the work, acquire supplies and assemble the equipment. After the bureaucratic excess of Statfjord, it became more common to place EPC contracts with Norwegian yard, not for complete platforms, but for straightforward modules such as living quarters, buoys for loading and various steel structures – these were tasks where the yards routinely took on full responsibility when building ships. [372] In effect, a considerable planning procedure was shifted from the oil company to the supplier company.

At the time the old approach to fabrication contracts began to unravel, Statoil was planning its first assignment as field development operator. The field in question, Gullfaks, would host three giant Condeeps just like Statfjord, only this time Statoil would add some subsea satellites to drain distant parts of the reservoir. Although the subsea wells would be well within the reach of divers, KV suggested a diverless system to gain useful knowledge for future assignments. Due to excellent relations and appeals to Statoil’s need for a future subsea supplier, KV got the assignment. [373] A breakthrough with significance beyond the technological arena, Statoil used the EPC procedure to procure the subsea system. This was the first time ever an oil company bought a subsea package consisting of engineering, procurement and construction. The contract offered only a brief summary of what Statoil wanted, and it was for KV to plan the details.[374] Statoil hired more suppliers to perform adjacent tasks such as testing, installation and the delivery of umbilicals (a hose for the supply of hydraulic power, chemicals and particularly electric signals subsea).

Although KV was in charge for the Gullfaks delivery, the task of building and assembling the system went to various subcontractors. Cameron supplied wellheads and valve trees and Ferranti supplied the control system. Ideally, the main contractor (KV) was to use a proprietary control system

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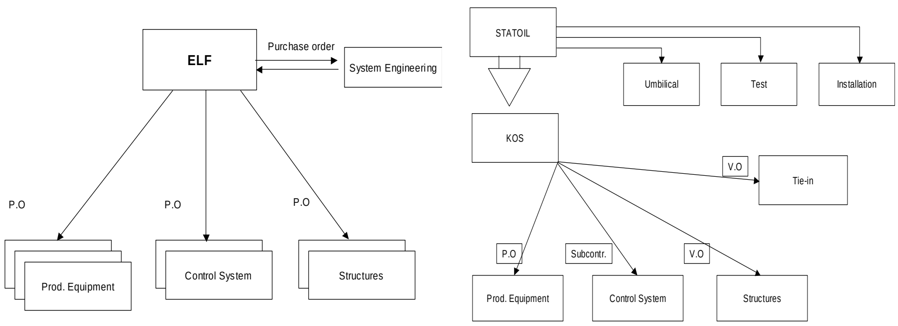
[372] SINTEF and Asbjørn Habberstad A/S, "Norsk offshoreindustris konkurranseevne", (Trondhjem: SINTEF, 1985).

[373] KV-Cor 243, Qvenild to Statoil (Johnsen et. al.), memo in preparation of 18 January meeting, 15 January 1980; KV-Cor 243, Qvenild, memo in preparation for Statoil meeting, 6 June 1983; Interview with Steenstrup, 14 October 2004.

[374] Interview with Smeby, 20 September 2004.

since guidance was integral to the system, but Statoil preferred a tried and tested solution and bought a system from Ferranti before KV got its EPC contract. In the aftermath, Statoil arranged for the contract to be transferred to a new company, Kongsberg Subsea Controls A/S, in which KV owned 51 per cent and Ferranti 49 per cent of the stocks.[375] Regardless of who supplied any subsystem in question, the Oil Division now had undisputed overall responsibility.[376]

Figure 25) ***Now you fix! Contract strategies at North East Frigg (1980) and Gullfaks A (1984)***[377]



At a fixed price of NOK 270 millions, the Gullfaks contract was probably lucrative, but it involved risks and responsibilities. Previously, KV's Oil Division mostly got reimbursements for whatever work was done or package contracts where each supplier delivered a part and the oil company assumed the risk for every interface.[378] KV had usually been able to shift whatever costs occurred onto the customer. In a publication written for the 25th anniversary of the Oil Division, one of the pioneers recalled with joy how the team "got to romp around without a thought for money". KV was paid by the hour and earned money regardless of any technical problems that might arise. The EPC contract, however, forced KV to take responsibility for every

375 KV-Cor 242 includes much material on the subject, e.g. KV board paper, 20 March 1985.

376 KV-Cor 243, Weibye to Qvenild, 15 December 1982.

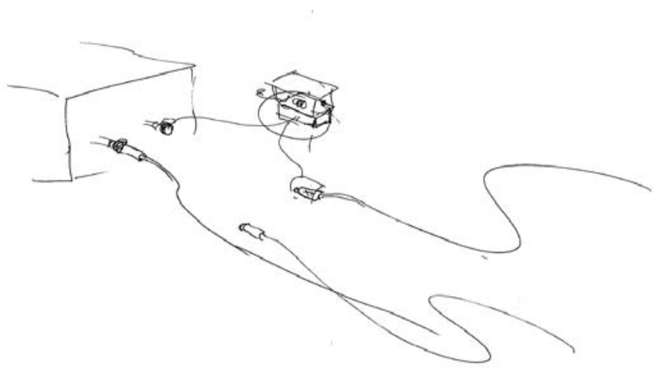
377 Steenstrup's private papers, Carl J. Steenstrup, "The changing philosophy of contracting: An international perspective" in *Contract Risk Management for Upstream Oil & Gas* (Calgary: FMC Energy Systems, 2004).

378 Interview with Steenstrup, 14 October 2004.

incorrectly bent hydraulic pipe and each incorrect fit. Since there was nobody to shield the contractor from mistakes, the impact of trial and error was strongly felt and lessons readily drawn. A number of engineers recalled the terrific experience of being relied upon to punch above one's weight. [379]

For the supplier industry, the practice of handling EPC contracts spurred innovations. Previously, when oil companies handled technology development through centralized planning, just a few people from their central staff attained a full overview: according to one Statoil manager, it "was an industry where nobody had a very large - a general overview - and there was nobody that was responsible for the totality".[380] The practice of handing out EPC contracts changed the picture by assigning responsibility for the totality onto a specialist supplier. This supplier, in turn, lavished attention on weak links and critical issues – the reverse salients that held back the advance of subsea petroleum production. Previously, when the industry relied on fabrication contracts, suppliers focused on delivering flawless components – ever better valve trees or pipes. It appeared some of the greatest shortcomings rested not with given components, but rather in the area of system integration: ways of assembling, fitting and refitting the system. KV, for example, placed much emphasis on tie-in systems to connect equipment under water. The subsea systems at Gullfaks required novel ways to fit equipment to avoid the use of divers.

Figure 26) ***Diverless tie-in***[381]



[379] Daling et al., *Offshore Kongsberg*.

[380] Quoted from Engen, "Rhetoric and realities", based on interview with Jostein Ravndal (Statoil), 15 October 1997.

[381] A freehand drawing by Halvorsen, interview with Halvorsen, 4 October 2004.

Apart from technical expertise, Kongsberg Offshore learned how to collaborate closely with customers. Some 20 Statoil people came to Kongsberg to follow the Gullfaks project.[382] Because Statoil had refrained from specifying every detail, the people involved had to sort out ambiguous details and did so with a degree of flexibility that surprised the non-Norwegians involved. [383] In the course of the project, the Oil Division improved its project management skills and pioneered internal control and computer-assisted project management with the assistance of Statoil.[384]

Furthermore, the practice of handling EPC contracts had strategic implications – it realigned the *industry architecture*. Forward-looking people at the oil division, Jørgen Haslestad among others, eyed an opportunity to gain the upper hand, not only through the control of products and product rights, but by assuming responsibility for the performance of the complete system. They managed to do so partly because of a lack of response on behalf of the industry leader, Cameron Iron Works. In Cameron's perception (and mostly in the opinion of Norwegian engineers too), he who controlled the valve tree controlled the subsea development. The Americans thought it odd to order a whole system and assign responsibility for the delivery through an EPC contract. The practice did not fit the philosophy of the Texans; they failed to understand the logic – possibly, they did not *want* to understand the logic, as it relegated the status of the product experts and elevated the status of a new kind of supplier that acted as a go-between for the oil companies.[385]

In isolation, the EPC contracts paved the way for a little less hierarchy and a bit more decentralized decision-making in the Norwegian offshore industry. It strengthened the role of a supplier industry separate from the oil companies and created a new sort of company: a main contractor capable of influencing designs and sourcing supplies.

5.4 Regulation conserving the industry architecture

In isolation, the EPC procedure allowed supplier companies an increased role in relation to oil companies. There were other issues, however, that

[382] Arne Eide, "Kv senter for undervannsteknologi?", *Drammens Tidende Buskeruds Blad*, 1985.

[383] Daling et al., *Offshore Kongsberg*.

[384] Interview with Smeby, 20 September 2004.

[385] Interview with Steenstrup, 14 October 2004; with Halvorsen, 4 October 2004.

worked to constrain the role of suppliers in relation to oil companies. The legal framework on the Norwegian shelf worked to preserve a dominant role for integrated oil companies, and reduce the scope of tasks that suppliers could handle. Due to regulation, oil companies working in the North Sea had to handle more tasks internally, and rely less on suppliers, than oil companies in the Gulf of Mexico. The first attempts to introduce floating production facilities demonstrated the conserving effects of regulation.

Companies that sought to provide production equipment *and* services faced a set of difficulties. An interesting example related to floating production facilities. While Condeeps continued to dominate the Norwegian shelf, floating production systems began to appear in other oil provinces. British Petroleum introduced floating production on the Buchan field in 1981 and began work on an experimental *single well oil production system* (SWOP) that received a lot of attention in the mid 1980s. A SWOP was a tanker, 250 metres long, equipped to extract and process oil from a single well before heading towards a terminal to unload the crude.[386]

In Norway, alternative ways of extracting oil met with resistance. In the mid-1980s, Hydro began questioning the widespread use of Condeeps. The company was operator on the Silver Block (Oseberg) in which Statoil owned a majority stake. Statoil pushed for a field development similar to Statfjord whereas Hydro wanted to combine an integrated platform with a separate production platform made of steel. Hydro's approach was somewhat more complex and possibly more expensive, but offered a number of advantages. Most importantly, when employing a steel platform, a rig could drill and complete the wells in advance allowing Hydro to retrofit the platform on top of a completed well and cut time-to production. Furthermore, the steel production platform could offload the concrete platform and possibly increase its ability to process oil and gas from satellite developments. Statoil's traditional field developments did not allow early production from pre-drilled wells and imposed space constraints that made the platforms ill fitted for additional tasks. Statfjord, for example, lacked room for engines and pumps to support a pipeline and had no spare capacity to process oil from subsea satellites. In 1984, the Ministry of energy sided with Hydro and Statoil had to give in.[387]

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[386] Inge Lorange, "Ny vending i offshoreindustrien", Norges Handels og Sjøfartstidende 1984, 11. On the attempt to supply dynamic positioning to this vessel, cf. p. 136.

[387] Engen, "Rhetoric and realities", pp. 118ff.

In cooperation with a shipping company, Hydro pioneered the use of floating production. The ship *Petrojarl* was conceived in 1983 by *Nordenfjeldske Dampskibsselskap*, a shipping company. They intended to build, own and operate the production ship through a subsidiary (*Golar-Nor Offshore*) and rent the vessel to Hydro for use at Oseberg. The *Petrojarl* would secure early production – it was capable of producing, storing and offloading oil until fixed platforms were in place. Unlike every prior development project on the Norwegian shelf, Hydro hoped to outsource oil production to a third party. This challenged a modus operandi in which integrated oil companies tightly controlled the core tasks involved in oil production.
From the conception of the *Petrojarl* initiative in 1983, the Norwegian regulatory framework frustrated the parties involved. Unlike a ship - where a class certificate could be granted irrespective of who designed, built, owned and operated the vessel – the Norwegian Petroleum Directorate refused to deal with anybody except the operator that was to hire the production ship. The directorates insisted the end-user (Hydro) should handle quality assurance, decide on design options and know the rationale behind minute technical designs. When approached by Golar-Nor, the directorate declined to comment on the design of the *Petrojarl* or comment on the requirements it would have to meet. Golan-Nor had to communicate through Hydro, which was forced to guarantee the viability of a technology designed, owned and operated by a third party.[388] The legal framework recognized only the role of the operators and assumed the oil companies themselves designed and operated every piece of equipment. In effect, the law protected the vertical integration of oil companies.

The inflexibility of Norwegian petroleum law was not only a way of writing the status quo into the legal code, but also a conscious choice. The directorate believed subcontracting could hamper security; the security assurance programme they foresaw presumed a hierarchal organization as employed by large, integrated oil companies. Helge Ryggvik, who has written extensively on the issue, has shown how labour unions influenced the health and environmental policies and insisted on extensive, non-transferable responsibilities for the operator. The unions, obviously, recognized the operators could afford paying higher wages and grant more favourable working conditions than independent suppliers could.[389] The resulting legal code hampered the evolution of specialized suppliers.

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[388] Ibid.

[389] Helge Ryggvik, "Norsk oljevirksomhet mellom det nasjonale og det internasjonale", (Dr. philol, University of Oslo, 2000).

The *Petrojarl* experience, or rather the frustrations Hydro went through when attempting early production, was evidence of the inflexible *industry architecture* offshore. Furthermore, *Petrojarl* exemplified the potential of new technology. The ship began producing oil in 1985 with 93 per cent regularity.[390] Low oil prices in 1985 and 1986 probably strained the economics of the operation, but the ship moved on. As of 2008, *Petrojarl I* had been through several refittings and served on seven oil fields in the North Sea. In the early years, the ship mostly did trial production, but in later years it drained marginal fields.[391]

5.5 Reliability as a reverse salient

In the early 1980s, most technology development related to subsea systems took part within oil companies. KV was invited to take part in a number of such studies (cf. Figure 24). A particular concern of these projects was the reliability and maintenance of systems in increasingly deep waters.

Around 1980, there was a conservative revision in relation to subsea systems. Several field developments abandoned advanced and experimental techniques and installed basic systems. The conservative reversion in the second half of the 1970s was evident in technological choices. North East Frigg was a case in point. Contemporary Norwegian magazines celebrated the North East Frigg development as innovative – but that was an exaggeration.[392] Elf wanted its installation to be foolproof, not innovative, and opted for low-tech solutions. The aerospace industry had favoured advanced electro-hydraulic control systems; they were large, cumbersome and rumoured to be unreliable because a minor breach in the insulation would short-circuit the electronics. Reflecting the sombre mood, Elf relied on direct hydraulic control at North East Frigg. This approach implied some problems; hydraulic pressure travels at a much slower speed than electric signals – too slow to allow remote control directly from Frigg 17 kilometres

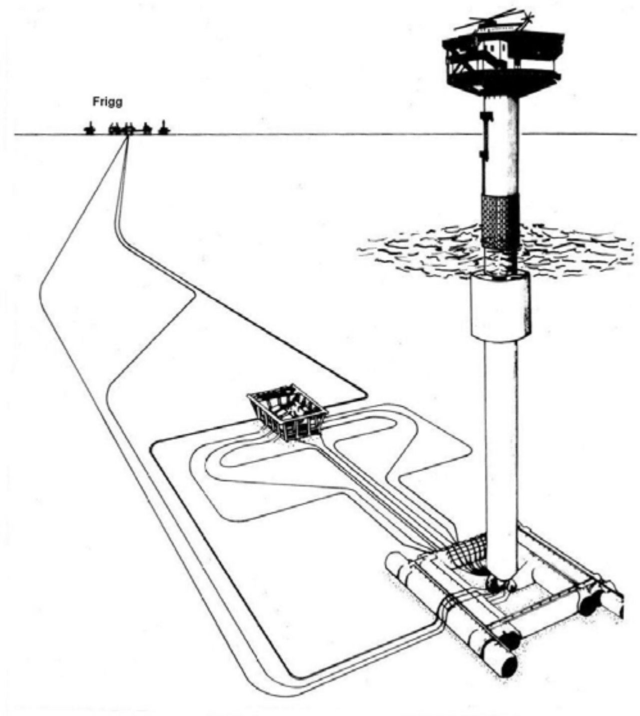
[390] Kaare M. Gisvold, "Pts petrojarl i: Eiernes erfaringer" in Feltutbygging på kontinentalsokkelen: Hvordan møte nye oljepriser? (Golsfjellet: Norske Sivilingeniørers Forening, 1987).

[391] A-tekst (a newspaper database) contains 149 articles on the ship refering to service on Oseberg (N) Fulmar (UK), Balder (N), Troll (N), Angus (UK), Hudson (UK), Foinaven-Blendhim (UK) and Glitne (N).

[392] Stein Bekkevold, "Innovatory subsea technology makes ne frigg economic", *Teknisk Ukeblad*, 19 August 1982.

away.[393] To circumvent this problem, Elf relied on a radio link between Frigg and a steel tower erected above the subsea installations. The tower contained a control system and a hydraulic pump that regulated the pressure in 22 hydraulic hoses stretching from the tower down to valves on the Christmas trees below. [394] The sixth well was equipped with an experimental multiplex system; this well required only one hydraulic hose and one electric cable.[395]

Figure 27) ***Foolproof: North East Frigg field layout***[396]



[393] Smeby's private papers, Smeby to Oil Division, "KV's oil tool equipment: activity status and future prospects", 29 June 1981.

[394] Tore Andvig, "Undervanns produksjon- og kontrollutsyr kritisk", *Teknisk Ukeblad*, 1984, pp. 26-28

[395] "Subsea technology into the realistic years: The contemporary era of subsea production".

[396] Drawing slightly modified from St.mld. 8, 1984-85, *1983 Annual report of the Norwegian Petroleum Directorate*, p. 54.

Although tried and tested solutions offered a solution, large international oil companies continued to invest in deepwater technology. Some of the development that took place on the Norwegian shelf added little to what had been attempted elsewhere, [397] but technology agreements required investments in research and development and tax deductions would offset much of the costs.

KV was involved in every major subsea trial on the Norwegian shelf. Ahead of the fifth round of concessions (1980), Elf offered to involve KV in a research programme.[398] When the formalities were in place, Elf's deputy project manager, Carl Johan Steenstrup, went to Karmøy in 1981 and enlisted KV to help assemble a test system devised at the company's research department in Pau, France. None of the parties involved had much experience, but Elf brought some people with subsea practice from West Africa: like the proverbial "one-eyed leading the blind", they guided a few people from Statoil, Hydro, Sintef and KV.[399] KV's people handled supplies (metalwork, food, hot water, etc.) and did most of the testing on the experimental system. The project was named *Skuld*, a female being from Norse mythology whose name translates into "future" but also "necessity".[400]

Skuld demonstrated a new approach to the maintenance challenge: modularity. Elf's people clustered the least reliable components (control system and wing valves) in a central module. During replacement or repair, the operator could de-couple this module, like a cork drawn from a bottle, and haul it to the surface. Other modules such as the lower parts of the valve

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[397] The considerable investments Shell made in subsea developments on the Norwegian shelf in the early 1980s did not imply any major technological leaps compared e.g. to what Shell was doing on the British Shelf. Around 1980, Shell spent considerable sums on a sophisticated, experimental *Underwater Manifold Centre* for the British Cormorant platform whose features included a track-bound robot for maintenance and repair. "Subsea Technology," *Noroil*, June 1983, pp. 27-36; M.M. Brady and D. Henery, "Subsea production systems and the umc experience", *Journal of Petroleum Technology*, 35, no. 8 (1980), pp. 1231-1238; Booth, "North sea: Testbed for advanced subsea production".

[398] "Skuld kan revolusjonere norsk offshore-fremtid", *Offshore i Vest*, 1984, p. 12; Interview with Steenstrup, 14 October 2004.

[399] For quote and background, interview with Steenstrup, 14 October 2004.

[400] "Skuld kan revolusjonere norsk offshore-fremtid", Interview with Steenstrup, 14 October 2004. Skuld was a *norne*, one of the female beings who sat by *Ygdrasil*, the tree at the centre of the cosmos, and governed fate.

tree could not be removed without killing the well, but these parts were less exposed to wear and tear.[401] While working on Skuld, KV gained important pockets of knowledge. The modular architecture of the system placed extra demands on jumpers (cables, pipes) and *connectors* (the locks that seal pipes and cables to secure the flow of oil, hydraulic fluids, chemicals and electric signals between components). Insulating the parts that carried electric current tended to be the hardest part in making decent connectors, and the Kongsberg people gained first-hand experience in the difficulties of keeping water out of electrical systems, e.g. how pressurized water and salt reacted with residual materials forming ionic pathways that failed to insulate.[402] The assignment produced some tangible results; where American firms made functional connectors that worked, KV analysed why they worked and drew up guidelines for the design of connectors that became an industry standard.[403] Due to this experience, KV secured a research contract with Shell in 1982. This was possibly the first contract that arrived without some application of political connections. Shell, of course, was committed to carrying out as much R&D as possible in Norway, but the company was not committed to placing this order at *Kongsberg*.

Many of the activities that oil companies undertook in Norway in the early 1980s centred on Troll. Shell discovered this huge gas field in 1979. Block 31/2 and adjacent blocks contained a reservoir large enough to provide *all* of Europe (including Russia) with gas from 2003 to 2007 and all of Europe with oil for three months.[404] At 340 metres of water, the reservoir was much less accessible than e.g. Statfjord and gravity platforms for such depths would be very expensive. Subsea systems were an economic alternative, but divers would struggle to work at such depths. Humans in protective suits could not easily operate below 300 metres. Besides, the profession was dangerous. In November 1983, five divers died while working on the

[401] "Subsea technology into the realistic years: The contemporary era of subsea production"; Interview with Steenstrup, 14 October 2004. On modular designs, cf. Tore Halvorsen, "Havbunnsinstallasjoner" in Flytende produksjonssystemer for olje og gass (Gol: Norske Sivilingeniøreres Forening, 1986).

[402] Daling et al., *Offshore Kongsberg*.

[403] Interview with Halvorsen, 4 October 2004.

[404] On Troll's resource base, cf. Troll (Norsk Teknisk Museum, 2005 [cited April 2007]); available from http://www.histos.no/oljemuseet/vis.php?kat=1&id=44. These are contrasted with information on natural gas consumption, cf. Natural gas consumption (BP, [cited April 2007]); available from http://www.bp.com/sectiongenericarticle.do?categoryId=9010960&contentId=7021580.

subsea systems at North East Frigg. In the early 1980s, the impetus of the technology development that took place was on reliability, maintenance and techniques that would work without divers.

Maintenance was a particular reverse salient. Although subsea systems as such would work, oil companies worried about the challenge involved in handling wear, tear and mishaps. Such challenges intensified in line with the depth of the systems. For example, the common way of shipping equipment down to a subsea system involved guidelines serving as funiculars between a maintenance vessel and specific posts on the subsea template. At close to 500 metres, however, installation vessels could no longer hold a wire taut and oil companies could no longer rely on guidelines for maintenance and repair. Rather, Shell looked into the use of remotely operated underwater vehicles in combination with cranes.[405] A crane lowered the equipment onto the seabed where a ROV could make the fit.[406]

Divers and ROVs mimicked the procedures used to maintain a dry tree. Alas, this approach had drawbacks. The remotely operated vehicles were not entirely trustworthy and required costly templates large enough for a ROV to penetrate.[407] An alternative technique involved wirelines for remedial action. In essence, a maintenance rig would first attach a heavy riser (a hose) to the well and then ship equipment down to the well with wires, not ROVs. Although the subsea gondola could carry tools for logging, gauging, plugging, re-perforation and other downhole operations, wireline operations were not ideal. The well had to be shut down with heavy mud before the intervention and maintenance rigs were expensive. The costs triggered a search for alternative methods of maintaining subsea wells.

Oil companies such as Shell had been experimenting with through-flowline (TFL) maintenance techniques. In the same fashion that antiquated pipe systems delivered internal mail in large office buildings, TFL techniques worked by pumping a piston-actuated tool from a production platform (not a maintenance rig) down the tube where oil and gas usually flowed.[408] After the tool had performed this or the other operation, the pump was reversed

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[405] "One step further for Shell's Dimos project", *North Sea Observer*, 22 April 1985, pp. 10ff.

[406] Daling et al., *Offshore Kongsberg*.

[407] Interview with Halvorsen, 4 October 2004.

[408] Booth, "North Sea: Testbed for advanced subsea production", on the evolution of competing maintenance techniques.

and the tool returned. Although suited only for half the workover operations (e.g. paraffin scraping), TFL was faster and cheaper than wireline techniques because there was no need to mobilize a maintenance rig.[409] Alas, TFL techniques added to the complexity of the wells and restricted the dimensions of the tubing.

Manifolding was another promising technique around 1980. Manifolding techniques evolved during the 1980s. A manifold pooled the output from several wells into a single riser; without a manifold, each well would require a separate flowline to the location where processing took place. When the output from several wells mixed, variations in pressure had to be cancelled out, lest the output from one well would force its way down another. Hence, a manifold needed choke valves to align the pressure and a control system to tune the valves. These controls might require manifolds of their own. Electro-hydraulic control systems used *hydraulic manifolds* to distribute power from one hydraulic pipe to the various valves on a subsea system. Additional manifolds could handle injection fluids such as corrosion inhibitors (anti-rust), scale inhibitors (anti-infarct) and hydrate inhibitor (anti-freeze). *Manifolding* was a key to reduce the number of hoses, lines and pipes that passed through the riser onto the surface; on DIMOS (diverless, installable and maintainable oil production system) manifolding cut the number of communication lines from 56 to 10.[410]

5.6 Project Thor – striving for a larger portfolio

Although KV gained a lot from being the main contractor, and from participating in various paid research efforts, the company had not forsaken its ambitions regarding product ownership.

Almost from the very onset, in the 1970s, KV had considered ways of gaining a proprietary product range, but the factory lacked resources and capabilities. An independent analysis carried out in 1983 credited KV with “a reasonably good subsea systems knowledge”, but “a virtual absence” of knowledge on how to design the core components in the system.[411] The in-house product range was small. By 1986, an informal quantification

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[409] O.J.S. Ribeiro, L.A.G. Costra, and Petrobras, "Deepwater subsea completions: State of the art and future trends" (paper presented at Offshore Technology Conference, Houston, 3-6 May 1993), p. 335ff.

[410] Ibid.

[411] KV-Cor 248, H.O. Mohr & associates, “Assessment: Kongsberg as an Independent Subsea Production Equipment Supplier”, January 1983.

indicated KV could supply one fifth of the hardware in a system, compared with 90 per cent for Cameron and Vetco and 70 per cent for McEvoy.[412] The Oil Division was rather more knowledgeable about the bits and pieces that combined production equipment into multiwell systems, e.g. templates, production risers, manifolds and control systems. In addition, KV sported knowledge about tie-in technology and diverless designs: advanced areas that many Houston-based companies failed to master or considered irrelevant because systems delivery was not in fashion in the Gulf of Mexico. Judging from its products portfolio, KV was better placed to supplement a valve tree manufacturer than to become one:[413] hence the quest to buy a valve-tree supplier. The codename for this effort was *Project Thor*.[414] The candidates for takeover were all American: *Vetco Gray* and *Cameron* were market leaders; *National* and *Reagan* (*Hughes Offshore*) had smaller market shares, but advanced technology; and McEvoy and FMC were "sporadic performers" having been in and out of the market.[415]

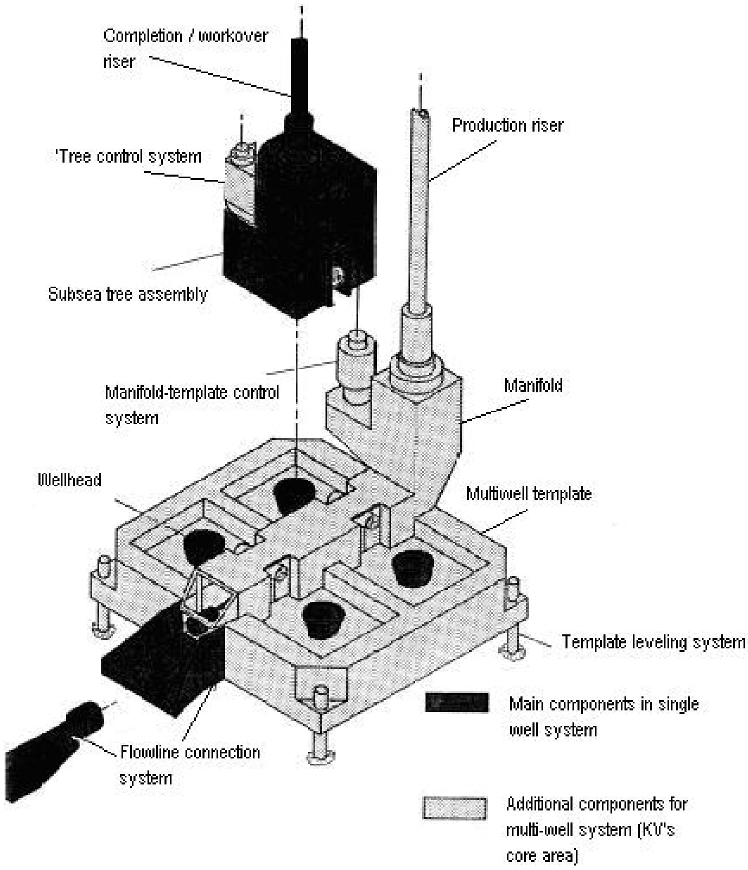
[412] KV-Cor 244, Qvenild, presentation, 14 January 1986.

[413] KV-Cor 248, Assessment: Kongsberg as an Independent Subsea Production Equipment Supplier, H.O. Mohr & associates, January 1983. On the arguments against proprietary product development, cf. Smeby's private papers, Smeby to Oil Division, "KV's oil tool equipment: activity status and future prospects", 29 June 1981.

[414] Not the first communication, but elaborate on the motives: KV-Cor 244, proposal to KV board to create Kongsberg Subsea Systems AS (KSS), 17 April 1986 (withdrawn due to Elkem's rejection).

[415] KV-Cor 248, Assessment: Kongsberg as an Independent Subsea Production Equipment Supplier, H.O. Mohr & associates, January 1983.

Figure 28) ***Dark matter: core system and adjacent manifold***



In early 1986, KV had reasons to believe both Vetco and McEvoy were for sale.[416] KV and *Mosvold*, a holding company that controlled diverse offshore and shipping interests including *Farsund-gruppen*, agreed in principle to combine forces and buy one of the American companies. KV would turn its Oil Division into a limited liability company and sell 50 per cent of the shares to Mosvold for NOK 225 million.[417] The new company would align itself with Hughes Offshore and combine resources to buy the market leader,

[416] KV-Cor 244, board proposal, 14 January 1986; KV-Cor 244, minutes of meeting with Smith International (owners of McEvoy), 3 January 1986.

[417] KV-Cor 244, proposal to the KV board, 27 February 1986 suggesting KV 32%, Mosvold through its Gambit subsidiary 32%, Norcem 32%, employees ca 5%.

Vetco Gray (with a book value of NOK 2.5 billion).[418] KV and Mosvold worked to enlist another Norwegian company in order for the Norwegians to control 55 per cent of the shares in the proposed giant. They negotiated in parallel with Aker and Elkem. Since Aker might deny KV a lead role in the new venture, KV preferred working with Elkem.[419] In April 1986 the board of Elkem rejected the deal, possibly in preparation for a forthcoming attempted to acquire Kværner,[420] and the deal unravelled. By that time, KV itself was unravelling too. That is the subject of chapter 6.

5.7 Conclusions

Where this chapter started out, Albatross was about to become a world leader in dynamic positioning. We traced the success to a consumer-centric approach to business, but also to a somewhat unforeseen effect of its model-based software: Albatross was somewhat better then the competition in handling fundamentally unreliable position reference systems.

Kongsberg Offshore was improving too. Due to the beneficiary effects of the technology agreements, the subsea group gained a number of assignments and improved its understanding. Because volumes were uneven, and because Cameron protected its technology, KV assumed a somewhat superfluous and symbolic role as *main contractor*. Bereft of a proper manufacturing assignment, the subsea group stretched the traditional responsibilities of suppliers and aspired to tasks that traditionally belonged to the oil companies. Such experience as an overseer and integrator of equipment proved to be of strategic importance when oil companies began asking their suppliers to arrange almost every aspect of a subsea completion.

A couple of changes in the way shipping companies and oil companies procured technology proved to have profound effects on suppliers of deepwater technology. EPC contracts and class certificates simplified the process and cut the costs involved in ordering technology from independent suppliers. The supplier industry gained accordingly, but there were differences as well as similarities in the changes that took place. With regard

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[418] KV-Cor 244, Morgan Stanley Project Thor LBO, Morgan Stanley, Project Thor LBO: Heads of Agreement, undated. The book value is calculated using an exchange rate of 7.4 (USD/NOK) as suggested by the National Bureau of Statistics, *Historisk statistikk*.

[419] KV-Cor 244, board proposal, 14 January 1986.

[420] Kjell Aaserud, ”Mikal H. Grønner synger ut: Har ikke tillit til Elkem”, *Aftenposten*, 17 November 1986.

to dynamic positioning, classification societies took some of the responsibility from buyers and suppliers. With regard to EPC contracts, suppliers assumed some of the responsibility of the oil industry. The latter approach spurred innovation and creativity.

Albatross had always gained from being close to its customers, learning from their concerns and taking full responsibility for eventual solutions. In the early 1980s, the subsea group gained a similar opportunity with the introduction of EPC contracts. Kongsberg Offshore changed from an (passive) executioner of fabrication orders to a contractor in charge of integrating the products of various sub-suppliers. The contractors gained a corresponding freedom to innovate, and the oversight required to handle reverse salients. The innovations that did occur centred, not so much on the individual components of subsea systems, but on better ways of making the components work together in a proper system. The most crucial search was not for a more reliable valve tree, but for ways to install and service that valve tree.

6 Creative destruction, 1984-1987

In the mid-1980s, the rules of the offshore game shifted in ways that favoured capitalism and competition. The change was much amplified at Kongsberg, where shifts in the Norwegian political economy, a collapse in the price of crude, and rapidly escalating losses at Kongsberg Våpenfabrikk caused turmoil in the deepwater business.

Despite Hurlen’s energetic efforts to build an excellent manufacturer, KV struggled to make a profit. The defence business carried little risk and some of the oil-related business thrived, but once successful product lines faced problems when exposed to competition. The difficulties became all the more critical due to KV’s response. Management rarely chose withdrawal, but rather redoubled research and development to reclaim ground. Like a speed skater about to fall, the company threw its weight around to regain balance; the eventual fall was somewhat delayed but uncontrolled and very painful.

For a while, KV’s offshore-related businesses did well enough to postpone the factory’s eventual collapse. Decent returns at Geco and Albatross, and growth in the area of subsea systems, offered KV an opportunity to float these businesses or offset their increased book value against losses elsewhere. Then, in 1985 and 1986, an outpouring of cheap Saudi oil depressed the price of crude and rapidly destroyed the economics of exploring deposits outside easily accessible reservoirs in the Middle East. Investors lost appetite for oil-related stocks and doused KV’s hope of raising funds. Furthermore, falling oil prices and diminishing public revenues reduced the government’s appetite for funding. In 1987, KV succumbed under a mountain of debt. Its various divisions and business units were sold off, including Albatross and Kongsberg Offshore Systems (KOS), the incorporated subsea group.

Although KV failed to change with sufficiently speed, a transformation had begun well before 1987 and continued well beyond 1987. Much inspiration stemmed from a wide international change in sentiments that favoured de-merging conglomerates. Albatross was arch-typical of this new philosophy. Despite not being a legal entity (not being incorporated), Albatross managed to secure considerable freedom of operations. In 1980, the business unit moved from KV’s premises in a fenced factory down to an abandoned ski factory by the river Lågen. From this location, the team continued with little interference and little assistance from KV. The remaining parts of KV moved broadly in the same direction, and by the time the arms factory ran out of funds in 1986-87, management had gone some way towards splitting the conglomerate into self-contained businesses capable of navigating their environment.

6.1 Institutional change

All around Kongsberg, the landscape was shifting in a neo-liberal direction. In Norway, Liberal politicians made gains in the polls by denouncing collectivism and demanding better service from the government. In 1981, a conservative election victory made KV's relations with the Ministry of industry less predictable. The new government discontinued the practice of awarding concessions to foreign oil companies based on their contributions to the well-being of individual companies (tilbudsavtalene). KV had been the prime recipient of favours in return for concessions.[421] Statoil became a slightly more normal company, less intent on forging a relationship with KV. Other oil companies, most notably Hydro, were able to ignore Statoil's field development strategies and supplier policies. In a new and more competitive business environment, Kongsberg Offshore initially lost ground.

In the early 1980s, the ties between KV and Statoil were very strong. In meetings, the two state-owned companies exchanged notes on the division of labour on the Norwegian shelf – what areas KV should dominate and where to allow supplements.[422] KV relied on Statoil and on Johnsen, Statoil's managing director, to convey an "industrial understanding" to his subordinates. Because Statoil acted "sensibly" and refrained from competitive tenders, KV enjoyed a strong growth in turnover from the North Sea.[423]

Something had begun to change, however, and by the mid-1980s, KV could no longer sideline its competitors at will. The shift was particularly strong compared with practices in 1973-1976, when Statoil's favouritism was unabashed and complaints from competitors had little impact on the national

[421] Before being discontinued, five arranged proposals were signed, for a total of NOK 270 million, mostly related to French subsea technology. Wiig and Nås, "Teknologiavtalene som insentiv i norsk forskningspolitikk".

[422] KV-Cor 248, Qvenild to Statoil (Johnsen et. al.), memo in preparation of 18 January meeting, 15 January 1980.

[423] KV-Cor 243, letter, Qvenild to Statoil (Johnsen), 22 April 1983. The number roughly corresponds with the calculations of this author. Roughly half of this turnover originated with gas turbines.

oil company.[424] Around 1976, the special partnerships that KV and Statoil had formed began to change. Most visibly, the two state-owned companies stopped building businesses together. Possibly, KV had more businesses running than the company could handle, but the shift also coincided with Jens Chr. Hauge's retirement as Statoil chairman – his successor Finn Lied, although no adversary of KV, valued meritocracy and disapproved of favouritism.[425]

The conservative election victory in 1981 undermined Statoil's position somewhat. The new government disliked the business practice of Statoil and its dominant position; Statoil's cash flow in relation to the Norwegian economy defied comparison with any company in any democratic country.[426] Although Statoil mostly managed to retain its privileges, the new government succeeded in handing the semi-private Hydro enough concessions to create a rival of sorts.[427] Hydro had been working on the Norwegian shelf since 1965.

The KV management was particularly concerned when the government withdrew a proposal to make Statoil the operator on the eastern part of Troll – ostensibly to make room for Hydro. The size of the reservoir and the water depth (below 300 metres) indicated there would be many opportunities for subsea developments. Block 31/2, the western part where Shell was the operator, contained about a quarter of the gas reservoir and might on its own make room for 80 subsea units worth 1.6 billion – an assignment large

[424] On the general perception that KV was a favourite of Statoil's, cf. Nerheim, *En gassnasjon blir til*, p. 96. On Statoil's attitude, cf. KV-Cor 245, Qvenild, minutes from 5 December meeting with AS Raufoss ammunisjonsfabrikker and Statoil, 10 December 1974: "I forbindelse med STATOIL's påvirkning av utenlandske oljeselskaper med sikte på kjøp av KV-utstyr var det noen selskaper som hadde klaget til Industridepartementet. For STATOIL vil ikke disse klagene ha noen praktiske konsekvenser."

[425] On Hauge acting as an advocate for his favoured causes, see for example the Norwegian Petroleum Consultants incident on p. 29. On the attitude of Lied, cf. Interview with Lied and Knut Sogner, 6 December 2005. As director of the defence research establishment, Lied seemed equally supportive of private and government defence contractors, cf. Njølstad and Wicken, *Kunnskap som våpen*.

[426] With at least 50 per cent ownership in any substantial field, Statoil looked set to control a cash flow equalling maybe ten per cent of GDP and 25 per cent of all investments in Norway, cf. Figure 4) on page 21. On the sentiments of some conservative politicians, cf. Osmundsen, *Gjøkungen: Skal statoil styre norge?*

[427] On the offshore activities of Hydro, cf. Lie, Oljerikdommer og internasjonal ekspansjon: Hydro 1977-2005.

enough to justify the development of proprietary valve trees (almost) from scratch.[428]

KV worried that Hydro's ownership structure would discourage the company from taking the "interests of the nation" into account.[429] The "interests of the nation" translated into avoiding competition. KV thought Hydro more likely than Statoil to buy subsea services from others.[430] In communication with Statoil, KV argued there was no need for alternatives since KV had been looking into the subsea field since 1973.[431] When Statoil in 1982 considered giving some research and study assignments to Seanor, a start-up with defectors from Kongsberg, the head of KV's subsea business branded Statoil as irresponsible – a "serious" company such as Statoil should know better than encourage "fragmentation" of the field.[432] Qvenild argued a single supplier should be allowed to dominate its niche to avoid "unnecessary competition" and duplication of competencies and resources - since the task of developing Troll was so formidable, and the domestic resources so meagre, the nation could not afford competition. The subsea niche should belong to KV, Qvenild argued.[433]

Whatever the policies of Statoil, Hydro had no intention of making Kongsberg Offshore its sole supplier of subsea technology. When Hydro decided to use subsea satellites on the southern part of its Oseberg reservoir, the company invited several Norwegian companies to compete for an EPC contract: KV, Kværner and Frank Mohn. At the time, the people at Kongsberg felt confident in their abilities and believed they could "maintain

[428] KV-Cor 243, Weibye to Qvenild, input to a briefing for Statoil, 12 November 1982; KV-Cor 248, memo in preparation of meeting on 18 January, Qvenild to Statoil (Johnsen et. al.), 15 January 1980; KV-Cor 243, Troll memorandum, Qvenild to Statoil (Johnsen), 17 November 1982.

[429] KV-Cor 243, Qvenild to Statoil (Johnsen), Troll memorandum, 17 November 1982. RA-Arntzen-Oil, department of public companies in the Ministry of industry, minutes from meeting with Qvenild, 11February 1983: "Qvenild mente at Hydro med sin eierstruktur ikke ville kunne ta nasjonale hensyn på samme måte."

[430] KV-Cor 243, Qvenild to Statoil (Johnsen), Troll memorandum, 17 November 1982.

[431] KV-Cor 243, Weibye to Qvenild, Troll memo, 12 November 1982.

[432] KV-Cor 243, Weibye to Qvenild, 15 December 1982.

[433] KV-Cor 243, Qvenild to Statoil (Johnsen), Troll memorandum, 17 November 1982.

a lead”. [434] Although Kongsberg Offshore had more experience, having secured every major subsea contract on offer on the Norwegian shelf, Hydro nevertheless chose Frank Mohn - a Bergen-based engineering company whose main product was hydraulic pumps. Frank Mohn had no prior experience with subsea production systems, but offered to do the job for some NOK 50 million less than KV. Apart from the price, Hydro credited Frank Mohn’s ability to work with suppliers. Thorleif Enger, Hydro’s project manager, was aware of the extent to which his Norwegian suppliers had to draw on American expertise, [435] and Frank Mohn enjoyed a close rapport with McEvoy - in some contrast to Kværner, which struggled to get along with Vetco Gray[436] and in stark contrast to KV, which was about to fall out with Cameron. For the Oil Division, losing a single contract to Frank Mohn in December 1985 was no crisis. Bidding was expensive, Husemoen admitted, but the company was busy completing orders for Gullfaks – and there were other contracts approaching.

It appeared Kongsberg Offshore was in for more losses. In the winter of 1985/1986, Elf Aquitaine decided to refit parts of the control system on North East Frigg and develop a small gas reservoir (East Frigg) using diverless technology along the lines of the Skuld project.[437] The French oil company bought valve trees (NOK 60 million) and assembly (22 million) from Vetco AS and a manifold centre (NOK 20 million) from Kværner Rosenborg. Meanwhile, Liaaen Helitron and ACB, a French company, got the order to redesign the leaky electro-hydraulics on North East Frigg.[438] KV claimed Elf sidestepped an agreement offering KV exclusive use of Skuld technology in Norway and asked the Norwegian government to annul the contract. [439] Either because of this pressure, or because KV had done innovative work in related fields, Elf hired KV to develop a clamp connector

[434] RA-Arntzen-Oil, board report on first six months, 1984; Smeby’s private papers, “Presentation to Cameron management”, 14 September 1985.

[435] Morten Wang, ”Undervannsoppdrag på Oseberg: Gjennombrudd for Frank Mohn”, *Aftenposten,* 12 December 1985.

[436] Smeby’s private papers, “Presentation to Cameron management”, 14 September 1985.

[437] KV-Cor 243, Qvenild, letter to Elf Aquitaine Norge (Godec), 22 November 1985.

[438] ”Elf-oppdrag til Rosenberg”, NTB, 27 August 1986.

[439] KV-Cor 244, Qvenild, letter to Ministry of oil and energy (Himle), 9 January 1986. Although the Norwegian government was not part of the agreement, it had been signed in the presence of Minister Kåre Kristiansen, not least in order to bestow goodwill on Elf with the granting of later concessions in mind.

that helped Elf fit flowlines without using divers. Albeit KV did secure some work for Elf, Kongsberg Offshore had lost much of its ability to gain assignments irrespective of competing offers.

6.2 Attempts to become more nimble

The institutional shift that occurred in the 1980s affected KV's ability to secure orders in the offshore market, but also the company's choices of how to organize its operations.

The conservative government began to alter the composition of KV's board. Johan H. Andresen, a conservative-leaning businessman, joined the board in 1982. In 1983, the government refrained from reappointing Hauge, and in late 1985, Andresen replaced Hurlen as chairman. More importantly, a new set of sentiments took hold. In the 1980s, investors increasingly held conglomerates to account for their profitability and – if failing to show any – expected an explanation as to how their component pieces contributed to the creation of value. Such ideas were particular to the late 1970s and early 1980s, but also evident in the drawn-out shift away from hierarchal organization with emphasis on scale and centralized oversight towards self-contained business units with goals and strategies in their own right.[440]

Hurlen's approach to management had been somewhat inconsistent. On one hand, he expected and encouraged people to take responsibility and display initiative; he rather enjoyed being around entrepreneurial people with optimism and ambition. On the other hand, he rarely relinquished the ultimate say and his tolerance of deviation may have been diminishing. In the early 1960s, he relaxed the hierarchies at the arms factory and introduced project management: a manager would bargain for resources from KV's functional departments (sales, electronics, welding, etc.) and use these resources for a project, typically product development. In the 1970s, Hurlen pursued a one-firm policy. At the board's urging, he established a divisional structure in 1973, but whereas divisions in other large companies employed the resources necessary to engage in independent pursuits on par with a limited liability company, Hurlen's divisions relied heavily on support from the Defence Division and central staff. Tasks such as purchasing and recruitment remained centralized and the divisions would typically employ but one or two people with a business or economics background.[441] Besides,

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[440] The single most influential advocate, and chronicler, of the change was probably Peter Drucker, whose main concepts are referred to in footnote 4.

[441] Eli Hoan, "Personalfunksjonen i a/s kongsberg våpenfabrikk", (Course paper [seminaroppgave], Norges Handelshøyskole, 1977).

Hurlen "liked the old style"; he and Hauge collaborated with project managers as they saw fit regardless of who headed the various divisions.[442] The naming and organization of divisions and departments continued to resemble an army bureaucracy where people and functions were assigned fixed tasks and corresponding letters and numbers: F4 was a research and development team at the defence division; O6 was the Oil Division's vessel automation group, also known as Albatross. The business units at Kongsberg remained within an unquestionable chain of command. Upon retiring in 1975, he moved upstairs and stayed on as working chairman for another ten years. The new managing director, Jacob Aasland, never gained any useful room for manoeuvre.[443] Rolf Qvenild, who became managing director in early 1979, was rather relaxed about letting subordinates actually run businesses – particularly businesses like Albatross that generated substantial revenues.[444]

Although privatizing KV was never on the agenda, the issue loomed. A conservative ideologue, Jan P. Syse, had helped coin the term *selveierdemokrati*, which is the notion that proprietary (private) ownership has civilizing, empowering and industrious effects. As minister of industry from 1983, he acted at KV's general meeting of shareholders. KV's management preferred the perceived stability of public ownership and feared any new petition for equity capital might have triggered a partial privatisation of the weapons factory. Qvenild ducked the issue by inviting investors to finance non-core activities. In 1982, KV incorporated its map drawing business and set up *Sysscan AS* in cooperation with *Messerschmitt-Bölkow-Blohm*, a German maker of drawing tools and other advanced machinery. Sysscan was listed on Oslo Stock Exchange and did well for a while. The approach was a de-facto reversal of Hurlen's policies. Whenever Hurlen had acquired a new business line, the business became a part of the sprawling portfolio of the arms factory. None of KV's businesses worked as limited liability companies except Geco/Statex and the old guard refrained from cooperative ventures they could not ultimately control.

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[442] On Hurlen's reluctance to delegate authority, see e.g. the recapitulation of the disagreement in Berdal's private papers, Qvenild's speech at the dinner in the honour of Bjarne Hurlen, Kongsberg, 29 September 1994; the same subject in KV-Cor, box 44, Binder Dijker Otte & Co, Memorandum from executive seminar 30 June – 1 July 1983, 16 August 1983.

[443] Interview with Næsset, 10 October 2004.

[444] Interview with Jenssen, 14 October 2004, and conversation with Gulhaugen, Kildal and Løkling, 29 October 2004.

Some of KV's peers went further in disintegrating composite businesses and establishing focused businesses. Simrad, for example, implemented the new thinking in full. Around 1980, the company failed to compete in the market for echo sounders and sonar, mature products sold mainly to the fishing industry. One part of the company thrived, however: the business line that provided hydro-acoustics technology for the offshore industry, most importantly as a supplier of position reference systems to Albatross dynamic positioning.[445] Offshore revenues could not offset the collapse in traditional markets, but Simrad's chief financial officer, Harald Ellefsen, floated *Simrad Subsea* and turned to the stock exchange for funds.[446] Investors believed in the company and funded it generously through several emissions. The high capitalization then enabled Simrad Subsea to acquire its sibling, Simrad Marine, the company that made sonar and echo sounders.[447]

In Horten, KV attempted something similar with Norcontrol, a supplier of ship-automation that KV had acquired in 1977. The traditional product line - monitoring machine rooms and supplying remote propulsion control – suffered in the aftermath of the 1975 shipping crisis and the continuous shift of shipbuilding from Europe to Japan and Korea in the late 1970s and early 1980s. KV decided to split the business in four: a company to focus on shared manufacturing; another to handle the ship automation (Norcontrol Automation AS); a third to supply systems for collision control, e.g. in harbours (Norcontrol Surveillance AS), and a fourth to train harbour controllers and platform operators in the same fashion a flight simulator trained pilots (Norcontrol Simulations AS). Initially, KV did not attempt to float any of these businesses.

KV drew much comfort from a success in seismic surveying. This business originated with Statex, the company that KV and Statoil founded in the early 1970s. Initially, Statex lost money. Statoil's participation was politically

[445] Knut Sogner's private papers, Simrad accounting department, historical figures, 1996 (undated).

[446] Albatross had accounted for more than two-thirds of Simrad's offshore sales in the late 1970s declining to about fifty per cent in 1981-1982 and one third in 1985. These figures are arrived at by comparing information from the following: KMaritim, binder on historical documents, reference list, 1981 (undated); CA-KM-Simrad, Simrad Subsea board minutes, 21 December 1981; KV-ex 12, Thoen, memorandum to Fjell, 22 January 1985, and; Knut Sogner's private papers, Simrad accounting department, historical figures, 1996 (undated). Ahead of the public offering, Albatross was invited to buy shares in Simrad Subsea, but KV declined.

[447] For a comprehensive account of Simrad during these years, see Sogner, *God på bunnen*.

touchy, sparked disagreement on the board,[448] and made competing oil companies reluctant to do business. In 1976, Statoil sold its shares to KV.[449] Although Statoil remained a customer, the oil company paid less generously for its services, and Statex's losses increased. In 1977, Statex merged with Geophysical Company of Norway A/S (GECO).[450] GECO did well and became one of the world's three largest seismic service providers by 1979 with 80 per cent of its sales originating abroad.[451] During 1982 and 1983, KV sold some shares in GECO and netted NOK 134.2 million while the value of KV's remaining 27 per cent share grew to several hundred million. Appreciation of these shares and other oil-related assets helped KV balance its books and contributed to a feeling that escape from KV was profitable for all parties involved.[452]

With regard to offshore oil, Qvenild began to withdraw from businesses that failed to meet expectations. The CCB workshop outside Bergen, the one KV had seized from Kone OY to perform maintenance work on Statfjord, lost money throughout the 1970s. Waiting for Statfjord to come on stream, KV had to focus on the maintenance of drilling rigs. Business was slow, or rather uneven, since drilling ceased during the rough winter season – a fact that kept surprising KV, at least to the extent the company was unable to budget for an annual, seasonal downturn.[453] KV returned the property to the Costal Center Base in 1981. Another Kongsberg operation at the CCB, the Terotech/Teronor gas turbine workshop, struggled against hard and dirty

[448] For a subjective but informed assessment, see Osmundsen, *Gjøkungen: Skal statoil styre norge?* The two dissenters, Vidkunn Hveding and Per Hanssen, were removed in a reshuffle when Hauge retired as chairman in 1975.

[449] RA-Arntzen-Oil, Board reports 9 September 1975, November 1976, and 1 March 1977. The nominal price of the shares was NOK 1.1 million.

[450] Andersen and Collett, *Anchor and balance: Det norske veritas 1864-1989*. When Veritas and KV agreed to merge their seismic surveying companies, KV had to contribute NOK 4 million to maintain a 50 per cent stake.

[451] RA-Arntzen-Oil, Board report dated 6 November 1979, and attachment to letter from KV to Ministry of industry, 23 February 1979. The merger agreement was signed on 25 March 1977.

[452] KV-Cor 239, Qvenild, confidential memo to Jan Sollid, Lasse Hansen, et. al., spring 1983 (undated).

[453] RA-Arntzen-Oil, Board reports 20 June 1974, 10 October 1974, 9 September 1975, 26 April 1976, 25 August 1977, 2 May 1979 and 6 November 1979.

competition.[454] In the late 1970s, KV and Kværner merged their turbine maintenance activities, but continued to compete for sales. This tug "tug-of-war" split across on to the maintenance business.[455] The issue was resolved only in 1985 when KV sold out to Kværner.[456] KV also withdrew from advisory engineering. In the 1970s, Kongsberg Engineering suffered substantial losses on most work, but its 10 per cent stake in Norwegian Petroleum Consultants provided well-paid assignments. KV struggled to recruit a sufficient number of qualified engineers and few Kongsberg employees wanted to work out of Drammen or Asker where Kongsberg Engineering set up shop. An effort to merge Kongsberg Engineering with IKO Software Service A/S in Oslo, a financially troubled provider of engineering planning software, was not entirely successful.[457] In 1984, KV sold 49 per cent of the shares in Kongsberg Engineering to McDermott for NOK 15 million.[458] Following these retreats, KV's offshore interests centred on Albatross dynamic positioning and subsea systems.

6.3 Independence for Albatross

Albatross was the one business unit that best exemplified the new sentiments in organizing businesses. The dynamic positioning business also exemplified the difficulties involved in allowing parts of a conglomerate to pursue independent goals.

Albatross's transformation into a limited liability company was gradual. In 1983, Qvenild agreed to establish an Albatross board that played much the same role as the board of a limited liability company - although the independent director, Thorbjørn Gjelstad, made little difference while KV's top management formed the rest of the board.[459] Then, in January 1984,

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[454] RA-Arntzen-Oil, board report, 8 May 1980; Husemoen's private papers, Leif Husemoen, memorandum on the history of Kongsberg Offshore Systems, 22 September 1998.

[455] Daling et al., *Offshore Kongsberg*.

[456] KV-ex 9, memo from Fjell (CFO) to Qvenild on the sales process, 28 October 1985.

[457] RA-Arntzen-Oil, Board reports dated 12 February 1974, 1 November 1974, 3 May 1975, 21 August 1978 and 2 May 1979.

[458] RA-Arntzen-Oil, board reports dated 6 November 1979, 12 March 1980, 8 May 1980, and board proposal dated, 7 May 1984.

[459] KV-Cor 238, Albatross [internal] board minutes, 22 December 1983; KV-Cor 238, Qvenild to Gulhaugen, 5 October 1984.

Albatross switched status from product group to division. Qvenild might well have incorporated the dynamic positioning business, if not for its generous remuneration policy that caused envy.[460] Management was particularly conscious about rewards. Productivity and commitment, they argued, required compensation in excess of what salaried workers received elsewhere. Without extraordinary pay, the group's "ability to develop and maintain motivation and … take on additional burdens" would suffer.[461] Many earned considerable sums: a service engineer at the time could earn NOK 600 000. Developers earned twice the wages at SINTEF.[462] Things like this made people feel special. As a limited liability company, existing tariff agreements would not apply to Albatross, and the equality-conscious trade unions at KV were likely to object. Gradually, however, the division gained more freedoms such as the final say in hiring and firing and permission to grant sales bonuses for deals made abroad.[463]

Having gained additional freedoms, the Albatross management responded by passing authority on to middle managers and employees. In effect, the company adopted *management by objectives*.[464] The company's mission was broken down into specific goals for the various departments handling tasks such as training, quality assurance and service.[465] To encourage those technologically disposed to engage with customers and salespeople, there was no dedicated research or development function;[466] only in the summer of 1985, when rapid growth threatened to absorb all resources, did Albatross establish a dedicated development team headed by Terje Løkling and a

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[460] KV-Cor 238, "Albatross – Quo vadis", assistant managing director Rolf E. Rolfsen to Albatross management, 9 February 1984.

[461] KV-Cor 238, Albatross [internal] board papers on "Personalomsorgen", not dated but probably from late 1983, translation by the author.

[462] On its attractiveness as an employer, cf. Interview with Sælid, 12 October 2004 and with Jenssen, 14 October 2004;

[463] On the increased freedoms, cf. KV-Cor 238, Albatross [internal] board minutes, 16 May 1984; on deliberations about not to incorporate Albatross, cf. KV-Cor 238, Albatross [internal] board minutes, 23 March 1984.

[464] A term popularized by Peter Drucker his 1954 book *The Practice of Management*, cf. http://en.wikipedia.org/wiki/Management_by_objectives.

[465] KV-ex 9, Albatross market philosophy, 29 September 1983.

[466] Conservation with Gulhaugen, Kildal and Løkling, 29 October 2004, confirmed by interview with Jenssen, 14 October 2004.

budget equalling about 10 per cent of turnover.[467] Regardless of department, Albatross insisted on setting goals, offering coaching on how to reach these goals and granting compensation in line with achievements.[468]

When the conglomerate split into independent business units, KV lost some of its ability to run consorted joint development efforts. Some worried the disintegration would destroy synergies – others saw an opportunity to escape from dysfunctional binds. A particularly heated conflict related to Albatross and computer development.

When KV went into dynamic positioning in 1974-1975, its KS 500 computers were state of the art and quite suitable for automation. Most commercially available mini-computers could not solve exponentials (X^n) fast enough for automation purposes, but KS 500 solved the task using a dedicated chip in the same fashion a game console would employ a dedicated graphics card. Such floating-point calculation in hardware improved the speed of specific operations, albeit at the cost of added complexity.[469]

By the early 1980s, single-chip architecture made rapid gains. Every 18 months or so - as prescribed by *Moore's Law* – chips manufacturers doubled the number of circuits on a given silicon surface. The cramming allowed more memory, cut the distance a signal needed to travel, and increased processor speed. A single central processing unit (CPU) could handle signal processing, memory access and most other tasks by subdividing jobs into a mind-boggling number of operations performed in rapid succession.[470] Powerful CPUs allowed a simple architecture as exemplified by the success of affordable personal computers (PCs) powered by Intel x86 chips. By 1982, such inexpensive and powerful off-the-shelf computers could be employed for dynamic positioning, but Albatross was stuck paying high prices for dysfunctional KV computers. The KS 500's huge frame looked deceptively robust: the hardware inside was running on the edge of capacity

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[467] KV-Cor 238, Albatross board minutes, 27 June 1985; KV-Cor 238, Albatross board minutes, 17 October 1985.

[468] On the ability to integrate successfully, cf. KV-Cor 238, Albatross [internal] board minutes, 29 September 1983.

[469] Interview with Corneliussen, 19 October 2004.

[470] Ph.D. student Gard Paulsen of the BI Norwegian School of Management, Department of innovation and economic organization, has been helpful in pointing out the changing concepts of computer chip development in the 1970s.

and frequently backfired. KV intended to develop a new generation of computers and insisted Albatross should wait for this future platform.

People at Albatross doubted KV could develop a useful replacement on time, but distrusted most commercially available alternatives. PCs were designed for non-critical applications with some tolerance of system crashes. Norsk Data supplied reliable computers, but ran on an outdated operating system.[471] To resolve the dilemma, Albatross ignored specific instructions and built a computer from components. A team led by Vidar Solli used *Intel 186* chips for the CPU but settled for a more straightforward and reliable architecture than contemporary PCs. Every component fitted onto a single motherboard, hence the name *Single Board Computer* (SBC) 1000.[472] After strong exchanges of opinion, KV resigned itself to the fait accompli.[473] By the time single board computers had replaced KV computers on every DP system, in 1986-1987, KV's computer business had imploded. To my best knowledge, the KS 900, which replaced the KS 500, found no application except as a control system on board a few Norwegian submarines.[474] It is hard to see how Albatross could have survived in a competitive market if Kongsberg computers were at its core.

Effective from 1 January 1985, Albatross became a limited liability company, *Kongsberg Albatross AS*, albeit with KV as sole shareholder. Potential investors seemed to favour employee shareholding[475] and, by threatening to quit collectively, the employees secured a right to buy five per cent of the shares ahead of a foreseen public offering (listing).[476] Albatross

[471] Interview with Sælid, 12 October 2004.

[472] Interview with Sælid, 12 October 2004 and with Corneliussen, 19 October 2004.

[473] KV-Cor 238, Albatross [internal] board minutes, 29 September 1983.

[474] On the increasing cost of quality assurance, cf. interview with Mathiesen, 13 October 2004. On the 1980 decision to replace Norwegian made chips with Motorola merchandise in the MKIII Penguin air to sea missile, see Erlandsen, *Flygende pingviner: Historien om sjømålsraketten penguin*, pp. 253-254.

[475] KV-ex10, memo from CFO Olav Fjell to Managing Director Qvenild, 28 October 1985. In 1985, the employers' union generally recommended employee co-ownership, cf. *Aftenposten Morgen*, "N.A.F. har vurdert medeierskap: Aksjer i egen bedrift styrker tilhørigheten", 25 April 1985. Several companies that did well on the Oslo Stock Exchange had offered shares to their employees, including *Norsk Data*, *Standard Telefon og Kabelfabrikk* and *Simrad Subsea*.

[476] KV-Cor 238, Qvenild to Gulhaugen, 5 October 1984; conversation with Gulhaugen, Kildal and Løkling, 29 October 2004. Løkling on one occasion led a team of technicians to the KV managing director with an ultimatum.

offered shares to everyone in an egalitarian approach.[477] In addition, senior management had the option of buying additional shares at NOK 267 per share. The latter number valued Albatross at NOK 120 million, a rather small discount on the predicted trading price, but bullish employees bought 95 per cent of the shares on offer.[478]

The business grew rapidly – cf. table below – and Albatross was profitable. Its margins remained close to 10 per cent, way above other business lines at KV, but not impressive for a company with an 80 per cent market share selling mission-critical applications in an industry awash with money. Albatross claimed to be running at or above capacity, putting priority on timely delivery rather than costs and investing in the training of new people,[479] but we may suspect the albatrosses were disinclined to pour profit down the drain at the arms factory. KV meanwhile lacked the instruments and routines, but also the authority, to demand higher dividends.

[477] The approach used by Albatross was egalitarian in relation to the practice of large American companies, but not much different from contemporary practice in Silicon Valley. At least since 1997, most big American firms granted options almost exclusively to senior executives, but the high tech industry differed with some 80 per cent of share options granted to employees below the top five executives, cf. *The Economist*, "Who wants to be a billionaire?", 6 May 1999, citing Pearl Meyer and Partners, a compensation consultancy.

[478] On the share programme, cf. KV-Cor 238, Qvenild to Albatross, 27 November 1985. In 1983, the few Norwegian companies that offered employee co-ownership were valued at 4 billion; the employees had paid 45 million for stocks worth 137 million (that is 67% rebate on shares worth 3.4 per cent of the total), cf. *Aftenposten Morgen*, "Aksjer med stor rabatt", 25 February 1984. In comparision, the proportion of shares promised as options in the United States reached an all time high of 15.7 per cent in 2002, about twice the share held in 1989, cf. *The Economist*, "Fat cats feeding", 9 October 2003.

[479] On the capacity problems, cf. KV-Cor 238, Albatross board minutes, 17 October 1985; on the market share, cf. KV-Cor 239, deliberations about the 1985 Albatross annual report, 13 February 1986.

Figure 29) ***Albatross take off: orders, turnover, employees and profit, 1979-85***[480]

	1977	1978	1979	1980	1981	1982	1983	1984	1985
Orders (mNOK)			62	60	105	155	176	196	242
Turnover (mNOK)	20	35	51	74	86	141	169	162	233
Operating profit			2.8	6.2	9.4	11.4	14	10.3	23
Number of employees			50	61	74	135	146	152	166
Margin (per cent)			5.5	8.4	10.9	8.1	8.3	6.4	9.9

On 22 November 1985, exactly ten years after the signing of the *Seaway Swan* contract, there was a terrific party. Albatross chartered a train and brought every employee from Kongsberg to an Oslo hotel where some 200 people watched a cabaret written specifically for the occasion and dined on plates engraved to commemorate the occasion. Qvenild read an excerpt from Kahlil Gibran's *The Prophet* about childhood and adulthood, or rather about the pleasures of breaking free and the response of a wise parent.[481] He praised *Theory Albatross* unreservedly for its customer focus and recognition of employees and shared the honour of success generously with Nils Willy Gulhaugen, Jacob Stolt-Nielsen and Bjørn Barth Jacobsen (there was no mention of Professor Balchen).[482] As a grand finale, Qvenild announced the board had agreed to float Albatross. The night was dizzy with success.

6.4 The unravelling

Regardless of the odd success, KV's financial position deteriorated throughout 1985. The group was heavily indebted, and annual interest payments ran at NOK 120 million.[483] Only defence contracts provided a steady profit – and the steady appreciation of various oil-related assets. KV hoped the restructuring and sale of these assets could provide a lifeline. When the oil price fell in 1985, the company succumbed. Albatross and

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[480] The table is assembled from various soruces. Turnover in 1977, interview with Jacobsen, 9 September 2004; turnover 1978, RA-Arntnzen-Oil, board report, 15 March 1979; accounts 1979, cf. KV-Cor 238, KV board papers, 12 September 1984; accounts 1980-85, cf. KV-ex 12, Albatross board minutes, 22 January 1987. All figures are in nominal NOK millions except, of course, the employee count.

[481] KV-Cor 238, 10 year anniversary, 22 November 1985.

[482] Interview with Sælid, 12 October 2004; with Jacobsen, 29 November 2005.

[483] KV annual reports, 1983-1986.

Kongsberg Offshore were sold, albeit at a fraction of the price that KV had hoped for.

Figure 30) ***Oiloholic: relative performance of the Oslo Stock Exchange***[484]

Since the onset of the Iran-Iraq war in 1980, oil prices had remained high, underpinned by Saudi Arabian policy. The kingdom acted as a swing producer, cutting production in periods of low demand and, in effect, guaranteeing a high and stable oil price. The effect of this approach was a tumbling Saudi market share as other OPEC members produced beyond their quotas and high-cost producers in the North Sea and elsewhere brought oil to market. In August 1985, the Saudis tired of restraint and gradually increased the Kingdom's output from two million barrels per day to five million barrels. They accepted whatever price the spot market offered and the price of crude plummeted below USD 10 per barrel by mid-1986.[485] In response to the changed market conditions, the Oslo Stock Exchange fell markedly, and the book value of KV's various oil-related assets collapsed.

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[484] Hogne I. Tyssøy and Holbergfondene, "'buy' eller 'bye, bye' oslo børs?" (paper presented at Oslo Børs Investorseminar, Bergen, 1 June 2005). The dark line shows how the main stock index on the Oslo Stock Exchange behaved in relation to an index composed of various global stock exchanges; a value of 110 on the left hand scale indicates that the Oslo Stock exchange is outperforming the global capital markets by ten per cent. Evidently, the relative performance correlates with the price of crude (grey line, right-hand scale) – since 1983, the Oslo Stock Exchange has performed comparably well in periods of expensive oil and less well in periods of cheap oil.

[485] James L. Williams, *Oil price history and analysis* (WTRG economics, 2006 [cited April 2007]); available from http://www.wtrg.com/prices.htm.

In the autumn of 1986, KV could no longer pay its creditors; losses were mounting and the company's assets were worth less than its liabilities. On 21 November, the Ministry of industry appointed a new board chaired by Karl Glad. Parliament then extended an emergency credit line. In January 1987, the board decided to spin off everything but the defence business and hired Tor Espedal as temporary managing director.[486] The new team pushed for a clear break with the past, established each business unit as a limited liability company roughly in line with the previously established divisions, and sold everything but the defence business to investors.[487]

* * *

Albatross was the one business at Kongsberg most directly hit by collapsing oil prices. Everywhere, oil companies cut back on exploration and required fewer services from the various vessels providing diving support, anchor handling, underwater engineering and other offshore activities. Low demand resulted in low day rates and, eventually, an almost complete halt in new orders new of petroleum support vessels (see figure below). Equipping such newly built vessels was the mainstay of Albatross dynamic positioning, and now that mainstay vanished.

A few more problems originated with the fragile state of KV's finances. All profits were returned to KV in the shape of dividends; financially, the dynamic positioning company started each year from zero and a single bad year would be sufficient to break the company. Although the core business of selling dynamic positioning broke even, KV had loaded Albatross with 20 million in interest-carrying debts and a portfolio of questionable assets from its struggling foray into marine electronics.[488] These assets included some shares in Bird and all shares in Norcontrol Automation – sold in 1986 at for NOK 22 million less than their book value.[489] After this, the share capital of Albatross was probably gone.

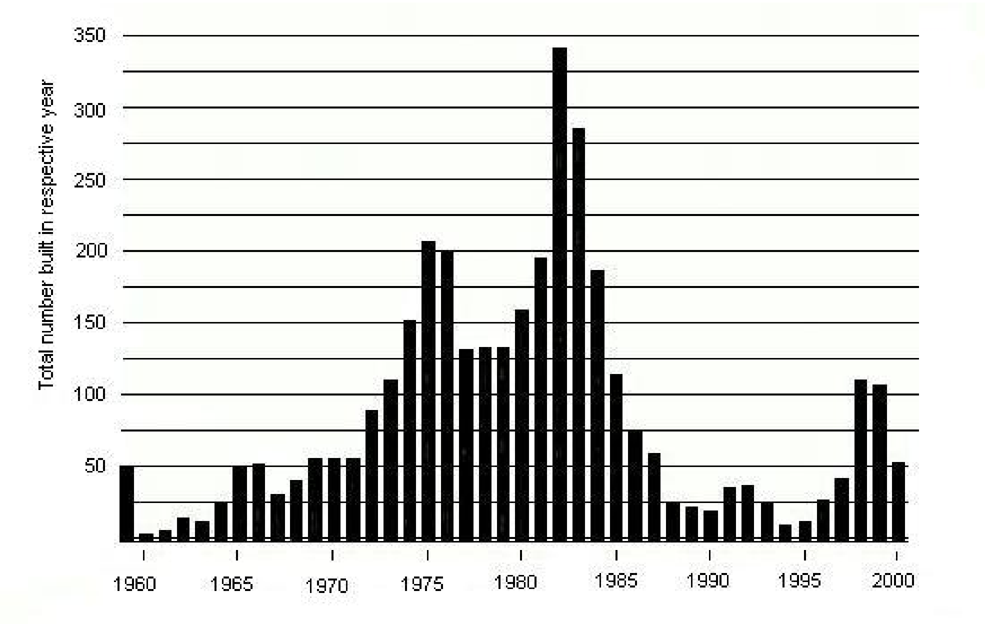
[486] KV-utvalget and Arntzen, "Nou 1989:2".

[487] John Eriksen, "Næringsøkonomiske virkninger av nedleggelse av store bedrifter", *ECON-rapport*, 35, (Oslo: ECON Senter for økonomisk analyse, 1993).

[488] KV-Cor 238, Albatross board minutes, 27 June 1985.

[489] KV-Cor 238, Albatross board minutes, 27 June 1985; KV-Cor 238, papers for the 29 March 1985 board meeting; KV-Cor 238, Albatross AS 1986 annual report. Albatross lost 5.14 million on Bird and 17 million related to Norcontrol Automation. The non-performing Bird shares were the payment from the sale of Robertson Radio Elektro in Egersund to Bird. Robertson was a manufacturer of ship radios that later

Figure 31) ***Bubble: Annual building of petroleum support vessels, 1960-2000***[490]



By early 1987, when KV was in effect bankrupt, the board hired a corporate finance house, *Samuel Montagu*, to assist in the speedy sale of Albatross.[491] The Norwegian financial markets were in disarray and the likely buyers of Albatross were industrial companies that knew the market. A Swedish provider of maritime electronics (*Concilium*), a British electronics and defence contractor (*Ferranti*), and an Italian manufacturer of automation gear (*Carlo Gavazzi*) took an interest. Honeywell looked at the opportunity, but withdraw upon learning the employees threatened to leave.[492]

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shifted to radio navigation equipment and various other electronic equipment for ships.

[490] Reconstructed based on Bob Beagle, *The gulf offshore market: A broker's view* (Marcone International, 2001 [cited April 2007]); available from http://www.marcon.com/marcon2c.cfm?SectionListsID=86&PageID=262. The original data source seems to be Clarkson Research Studies, “The Offshore Service Vessel Register – 2001”, London 2001.

[491] KV-ex 10, Samuel Montagu AS, letter to Kåre Thoen, 5 December 1986.

[492] For an overview of potential bidders (long list), cf. KV-ex 10, Samuel Montague Co Ltd, letter to Samuel Montague AS, (not dated); specifically on Honeywell, cf.

A management buy-out was an option at the time. Gulhaugen, Løkling, Kildal and the head of sales, Svein Thorsen, made an attempt. They discussed a deal with Kreditkassen, a bank, but could not agree on the terms of a loan. At the time, there were few Norwegian institutions willing and able to see through a management buy-out. The available money pursued companies with a positive cash flow and foreseeable risk. Few investors did venture financing, the kind of deal where investors needed to prepare well in order to assess a high risk – possibly losing on the great majority of deals while earning handsomely on a few. Some nevertheless managed to pull through such deals. The managers and employees of KV's automotive division did raise sufficient funds to buy their place of work. Unlike the Albatross case, the automotive business was untouched by falling oil prices. Unlike the Albatross case, the deal involved risk sharing among a broad range of employees, and; unlike the Albatross case, the automotive people had the courage to mortgage their homes fully. Failing a leveraged buy-out, Albatross management preferred acquisition by Simrad Subsea.[493] Some were left with the feeling that management preferred being bought by Simrad than a broad alliance of employees.[494]

In March 1987, Samuel Montagu invited interested parties to submit offers for KV's shares in Kongsberg Albatross AS. Some of the bidders were mainly interested in Albatross's controlling stake in Norcontrol Simulation AS and KV decided to sell each business separately. In the end, only Simrad bid for Kongsberg Albatross and acquired all KV's assets and liabilities related to dynamic positioning for NOK 20 million.[495] Did Albatross come cheap? Simrad claimed to take on debts worth 10 million more than Albatross's assets. In addition, Simrad had to spend NOK 9.4 million acquiring shares from employees.[496] This meant Simrad put NOK 39.4

KV-ex 11, Honeywell AS (Birkeland) to KV (Fjell og Arentz-Hansen), 3 April 1987.

[493] Gulhaugen recalls how acting managing director, Tor Espedal, in a hurry to liquidate KV's various holdings, encouraged Albatross's search for a new owner, cf. interview with Gulhaugen, 29 October 2004.

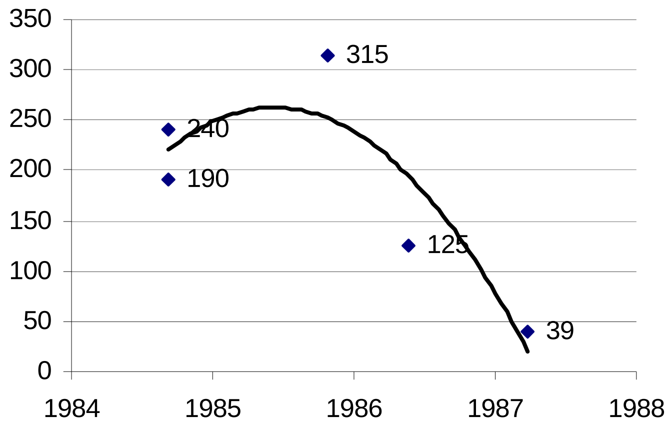
[494] Interview with Sælid, 12 October 2004.

[495] For Simrad's revised offer, cf. KV-ex 11, Fax from Simrad (Hansen) to KV (Fjell), 21 April 1987 – the Simrad board, cf. CA-KM-Simrad, Simrad Subsea board minutes, 30 April 1987; the transaction is recapitulated in KV-ex 11, KV board minutes, 5 May 1987.

[496] The financial logic, including an assessment of the employees' claim, cf. KV-ex 11, Samuel Montagu AS (Carpenter), letter to KV (Fjell), 27 April 1987. On the conditions governing employee shareholding, cf. KV-Cor 238, Managing Director

million at risk when buying Albatross. Not much in the light of recent earnings, but more than anyone else would stomach.

Figure 32) ***Albatross crashing: valuations 1984-1987, nominal NOK millions***[497]



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As with Albatross, KV attempted to sell the subsea business; as with Albatross, the eventual sale in 1987 raised but a fifth of the sums foreseen a year earlier. Effective from October 1986, the arms factory incorporated the

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Qvenild, memorandum, 10 December 1985. Although the employees owned only five per cent of the shares, they received almost a third of the compensation for the sale. Their holding was subject to a guarantee. Back in 1985, KV had agreed to buy untradable Albatross shares at NOK 267 by the end of 1987 – a guarantee against any retreat from the plans to float Albatross. The deal implicitly valued Albatross at NOK 120 million. The employees, furthermore, demanded a part of the proceeds from the sale of Norcontrol Simulation. They eventually got 326 per share – probably as a gesture of goodwill from Simrad. Simrad paid for the shares with 1.7 million in cash and Simrad shares worth NOK 7.7 million.

[497] Trend line based on valuations in the following documents: KV-Cor 238, "Issue no. 6: Establishing Albatross as an incorporated company", excerpts from KV board protocol, 12 September 1984; KV-ex10, CFO (Fjell), memo to Qvenild, 28 October 1985; KV-Cor 238, Albatross board papers, 21 November 1985; KV-Cor 239, board minutes of 22 May and 3 July 1986; KV-ex 11, Samuel Montagu AS (Carpenter), letter to KV (Fjell), 27 April 1987.

Oil Division and formed Kongsberg Offshore Systems AS (KOS).[498] This unit employed 45 people working on surveillance systems (SCADA), 135 people working on subsea systems, 35 advisory engineers based in London, and a 51 per cent share in Kongsberg Subsea Controls A/S, where 15 people made subsea control systems based on Ferranti's technology. KOS was thinly capitalized.[499] Several suitors showed an interest, including Ferranti, shipping magnate Terje Mikalsen, Norwegian Contractors and Elektrisk Bureau. In the end, Siemens AG, a German conglomerate, bought the subsea supplier.[500]

Kongsberg had appeared on the Siemens horizon even before KOS was officially for sale. Siemens owned a diverse range of businesses including *Kraftwerkunion*, whose 15,000 employees built power plants. By the mid-1980s, opposition to nuclear power had grown and the company looked for new applications of its automation expertise. Siemens identified subsea engineering as a promising area. The basics of a deal were agreed in March 1987 and finalized in June. Siemens agreed to pay NOK 53 million on certain conditions, but ended up paying 47.7 million when it turned out their acquisition was in worse shape than initially stated.[501]

* * *

In the spring of 1987, the majority of the board members hoped to refinance KV while Glad and another director favoured bankruptcy. The Ministry of industry eventually settled for a compromise of sorts: compulsory composition. KV discontinued the payment of outstanding (old) debt and requested court-administered negotiations with its creditors. In March 1988, the debt commission (*gjeldsnemd*) recommended a solution: small creditors got payment in full, the rest in relation to the size of their verified claims. A large majority of the creditors voted in favour of the arrangement, because the government had offered to put another NOK 300 million on the table. When books were finally closed, the government had lost about NOK 1.15 billion in equity and outstanding loans - financial institutions and suppliers lost another billion.[502]

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[498] KV-Cor 244, KV board papers dated 27 February 1986, 23 April 1986, 21 August 1986, and 3 October 1986.

[499] KV-Cor 244, KV board minutes, 14 October 1986.

[500] Correspondence related to the sale is stored in KV-ex 10.

[501] Daling et al., *Offshore Kongsberg*; KV-utvalget and Arntzen, "Nou 1989:2".

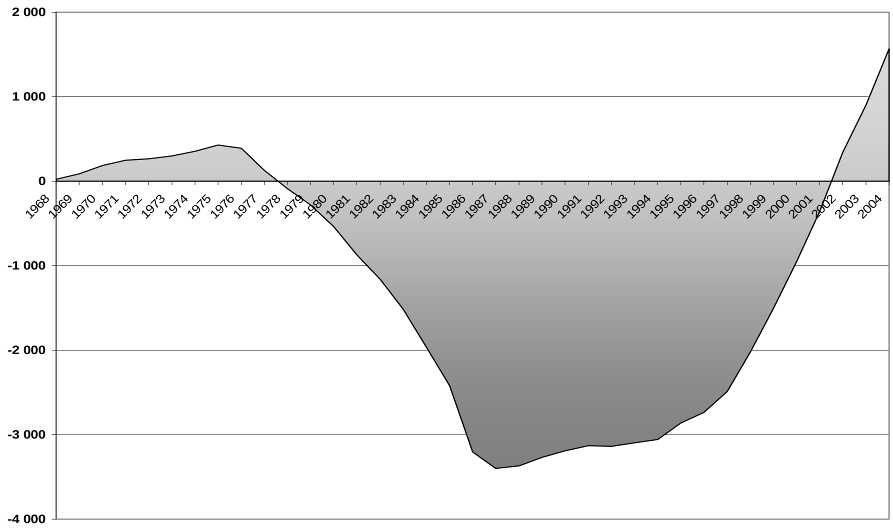
[502] KV-utvalget and Arntzen, "Nou 1989:2". Accumulated nominal figures.

6.5 *Explaining downfall and recovery*

The harsh criticism that followed KV's collapse fed on an air of ineptitude. Although years of strained financial results preceded the crisis, management seemed caught by surprise.[503] Equally stunning was the rapid recovery of the Kongsberg industry in the years that followed. In each of the dozen companies that picked up pieces of KV, results began to improve. In the first decade after the compulsory composition, the Kongsberg family earned enough to handle an imaginary debt the size of KV's total losses (see figure below).

The figure indicates that KV might have been able to continue as a going concern, if someone had been willing to provide financing. That is misleading. The bleeding stopped because the companies that replaced the arms factory discontinued its mission-driven technology development, its less than vigorous cost focus and reinforced customer orientation.

Figure 33) ***Phoenix just off the ground: accumulated profit and loss in NOK millions (1998) in the Kongsberg family, 1968-2004***[504]



[503] The department of industry established an independent committee to establish how the money was lost and who bore the responsibility. The official government inquiry into the affair is published: Ibid.

[504] The figure contains numerous assumptions. For details, turn to Appendix 11.2 on page 301

KV's success in the first post-war decades, when KV employed few engineers and sported little experience, had been reminiscent of what is frequently seen on a macro level: a lagging party rapidly catching up by copying the technologies of the more advanced companies and countries. Another particular advantage of KV was soft financing to invest in property, plants, equipment and research, but also working capital to finance operations. Most financing was public or guaranteed by the state: the armed forces, for example, paid in advance; the government provided some extra share capital, and government connections meant KV had easy access to loans.[505] Throughout the 1960s and 1970s, interest rates were locked by political decree below the rate of inflation and the burden of KV's loans depreciated over time.[506] Furthermore, the armed forces entered into cost-plus contracts whose concept of a cost allowed KV to write off investments in general manufacturing capacity.

Hurlen, furthermore, pursued a slightly nonchalant attitude to financing. Like a general or a philosopher, he would not accept that an important project could be held back from lack of money, but forged ahead with a certain ignorance as to how money would eventually emerge.[507] Hurlen frequently analyzed industry in terms of power relations: success flowed to the ones that exercised power and influence. Costs and profits counted less. Irresponsible as the sentiments may sound, they were mostly right with regard to the core businesses that KV pursued: defence, oil and public procurement. In the political economy of the 1960s and 1970s, success in these areas relied a lot on connections (cf. chapter 5.1).

The engine of diffusion slowed in the 1970s and 1980s. Norwegian wages rose, there was less room for catching up and fewer easy victories. With rising cost levels and new competitors emerging, borrowed technology could

[505] From 1970 to 1986, the balance sheet of KV expanded by NOK 3.9 billion – to which retained profits contributed NOK 150 million, increased equity contributed 537 million, and debts to customers and lenders contributed the rest. Particularly in the aftermath of the crisis, numerous lenders claimed they had been enticed by an implicit guarantee the company was government-backed. The government white paper that looked into the crisis concluded the issue was highly blurred, cf. KV-utvalget and Arntzen, "Nou 1989:2".

[506] On the policy of offering low interests, cf. Øyvind Eitrheim and Jan Tore Klovland, *Historical monetary statistics for Norway 1819-2003*, Norges banks skriftserie; no 35 (Oslo: Norges bank, 2004) – figure 14 on page 21shows the interest rate on bonds was negative from about 1965 to the early 1980s.

[507] Interview with Næsset, 10 October 2004. The eventual fate of KV is additional evidence.

not sustain a low-productivity manufacturing operation at Kongsberg. Each consecutive development effort was considerably more expensive than the previous round. While development costs escalated, market conditions in general were difficult in the late 1970s. The global economy grew less rapidly than in previous decades and although counter-cyclical spending in anticipation of oil revenues cushioned the home market, the cost level spiralled and threatened export industries.

Gradually a pattern emerged. On its own or through connections at the defence research establishment, KV would identify a promising new technology and develop a product. This product would enjoy modest success at first, almost recouping the initial investment, upon which KV would raise the stakes and develop a next-generation product. Although KV hired ever more graduate engineers and no doubt gained in capability, the second-generation products were generally less successful than their predecessors were. This second attempt would face unexpected cost hikes, technological problems and stiffening competition … whereupon KV would redouble its efforts and make a third-generation product. These third-generation failures undid KV in the 1980s.

Figure 34) ***Twice bitten, never shy: KV's declining success on competitive markets***[508]

Product line	**1960s**	**1970s**	**1980s**	**Accumulated loss by 1987 (NOK 1998)**
Gas turbines	*KG2* Small loss	*KG5* Very big losses	*KG 3* Very unprofitable	1.1 billion
Turbofan parts		*F-16* Profitable	*PW 4000* Very unprofitable	2.4 billion
Computers	*SM3* Few stand-alone sales	*SM4* Losses	*KS 500-900* Very unprofitable, abandoned	Not available
Robotics (numerical control)	*Essi* Profitable	*CNC 2000* Lossmaking	*CNC 3000* Abandoned, lossmaking	1.1 billion

* * *

In explaining why KV failed to act on its failures, it is useful to consider a set of mechanisms that cause its *escalation of commitment*, i.e. the economic,

[508] Useful information is assembled in KV-utvalget and Arntzen, "Nou 1989:2".

psychological, sociological and structural mechanism that caused decision-makers to redouble their commitment to projects gone wrong.[509]

KV's gas turbines provided an instructive case of escalating commitment. In the 1960s, KV had developed a radial gas turbine - the first such undertaking in-house, neither on license nor on blueprint from the defence research establishment. The first generation KG 2 was reliable, easy, robust and adjustable to various types of fuel; it became a moderate success and gained 30 per cent of the market for small turbines in the early 1970s.[510] Alas, it was rather inefficient - just 17 per cent of the inherent energy in its fuel transferred into useful power and the 1973 price hike on fuel made KG 2 unsuited as a source of permanent power.

Having come close to full-scale success, the decision to develop a new gas turbine did not seem controversial. KV aimed to supply offshore oil platforms with gas turbines – a market that demanded larger and more efficient turbines. Despite long and costly development efforts, the new turbine (KG 5) failed to impress customers. At the time of its launch in 1979, the offshore market had settled on aircraft-derived turbines that were lighter and burned fuel at a higher temperature – their efficacy and efficiency was superior to conventional gas turbines.

When KV again faced a choice between discontinuing the turbine business and escalating its commitment, the decision had grown increasingly painful. A large internal constituency had based their careers on gas turbine development. KV's board of directors remarked on the difficulties of agreeing "to terminate" the turbine business and ensuring "that the gas turbine competency in Norway would not be lost".[511] They felt that the very thought of withdrawal felt like an "amputation".[512] The board went along

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[509] Barry M. Staw and Jerry Ross, "Behavior in escalation situations: Antecedents, prototypes, and solutions", *Research in Organizational Behavior*, 9 (1987), pp. 39-78.

[510] KV-utvalget and Arntzen, "Nou 1989:2".

[511] KV board meeting on 13 August 1979, referred to in Ibid., p. 111: "Det ville være vanskelig å resignere med å avslutte gassturbinvirksomheten ved KV med KG2 og KG5. […] Styret ville til neste gang be om å få seg forelagt en plan for en ny familie av turbiner basert på anvendelse av ny teknologi og nye materialer. Med full satsing på fornyelse burde også volumet kunne økes. Det ville imidlertid neppe være mulig for KV alene å bære frem slike nyutviklinger. Det måtte sies å være en nasjonal interesse å hindre at gassturbinkompetansen i Norge gikk tapt."

[512] From the deliberations of the board on 15 December 1981; the minutes are cited in Ibid., p. 115.

with the head of the gas turbine division who proposed a new concept called KG3: a small, light gas turbine burning fuel at a high temperature with correspondingly high fuel efficiency. Drawing on political connections, KV got a public institution, *Industrifondet* ("the Fund") to help finance the project. KV lacked the capacity to finance and market such a turbine, and acknowledged the need to enlist an industrial partner. In order not to lose time, the board agreed to begin development without a partner. The only forthcoming partners were Tenneco and Phillips Petroleum Company, two oil companies under obligation to spend money on research in Norway. This support was insufficient to see the project through, but out of reluctance to see investments done in vain, KV and the Fund decided to continue without an industrial partner.[513]

The enlisting of external partners created structural ties that made KV's commitment to gas turbines ever deeper. In February 1979, with several product lines running into trouble, KV supplied the Ministry of Industry with a detailed recovery plan. The plan required additional equity, and KV got an additional NOK 200 million by resolution of parliament. No more then six months later, management realized they could not deliver according to the plan; KV risked making the ministry look stupid – or worse, dishonest - in front of parliament. The company responded with heavy investments in the development of data systems, gas turbines and jet engines. For a vivid parallel, imagine the psychology of a gambler who, having borrowed excessively from the mafia, found his luck running out, scrambled together his available resources and upped the bets to regain lost investments. Although the gas turbine project fell behind schedule, turning back became more painful with each passing month.

A similar escalation of commitment unfolded in the jet engine division. In the mid-1970s, when the Norwegian air force was about to acquire F-16 fighter-bombers, KV secured a re-purchase agreement: the American manufacturer of the airplanes was obliged to source turbo fans from Kongsberg. The contract was lucrative, but volumes were lower than expected. As with gas turbines, KV was loath to quit a business that (almost) had achieved a decent success. As with gas turbines, KV secured certain benefits from foreign oil interests that improved the economics of the business somewhat.[514] As with gas turbines, KV hesitantly attempted a state-

[513] Ibid.

[514] In 1979 Elf received gained concessions in the North Sea in return for, among other favours, a deal where Société Nationale d'Etude et de Construction de Moteurs d'Aviation (SNECMA), an air engine factory owned by the French government, bought manufacturing services from KV, cf. KV-Cor 248, Qvenild, letter to

of-the-art development project and bought into Pratt & Whitney's effort to develop a new civilian jet engine. As with gas turbines, KV failed to meet expectations. As with gas turbines, the cost of withdrawal eventually grew so high that retreat was no longer an option (the contractual arrangements specified huge liabilities if the parts failed to arrive on time or failed to meet quality standards). KV could not afford either to continue or to withdraw.

Somewhat simplified, the projects that escalated out of control were initiated for financial reasons, but continued in no small part for reasons of psychology. Eventually, the projects gained momentum and binding, enlisted structural support, and became ever harder to close. In the final stages, financial arguments again surfaced to keep the projects running: writing off the sunk costs threatened to break the company. Accepting failure and expensing the costs in the early 1980s would have drained the share capital of KV and threatened bankruptcy or the involvement of private shareholders. Only failure and restructuring helped terminate KV's commitment.

The successor companies lacked KV's commitment. Some of KV's unprofitable business lines closed, including several businesses involved in computing and robotics. Elsewhere, the companies shred costs. Norsk Forsvarsteknologi AS (NFT), a state-owned company established to run KV's defence business, hired a managing director, Jan T. Jørgensen, who set out to handle Kongsberg's cost problem with a certain brutality. He was unsentimental about workers, heeded the recommendations of his economic advisors, and cut capacity whenever old product lines lost markets.[515] The abrupt turnaround after 1987 was in no small part attributed to a change in mentalities. Such a profound awakening is hard to measure objectively, but certainly influenced business practices. It was not a matter of transforming the average employee, engineer or manager into profit-maximizing entrepreneurs, but new owners and managers met less resistance in their efforts to streamline and commercialise the businesses.[516]

* * *

Ministry of oil and energy (Himle), 4 May 1982; RA-Arntzen-Oil, "En orientering om aksjoner og planer for 1983", November 1982.

515 Interview with Solberg, 27 March 2003; with Korssjøen, 27 March 2003.

516 Interview with Solberg, 27 March 2003. The same sentiments from a contemporary source, cf. Managing Director Espedal in *Laagendalsposten*, 12 March 1987: "Vi er ingen vernet bedrift. KV er en kommersiell virksomhet, der det er resultatene som teller. Vi skal ta hånd om det positive fra fortiden – ellers får vi legge den bak oss. Denne holdningen må ned til hver eneste ansatt."

Those businesses that were profitable to begin with faced same demands for prudence. Albatross was a case in point. In the early 1980s, when the company basked in money and success, the Albatrosses had developed a towering self-esteem and a touch of arrogance e.g. in relation to competition. Occasionally, when discussing Honeywell, someone would fake the recollection of a distant memory and remark: “Oh, the *thermostat* people” (Honeywell Corporation manufactured ventilation systems, and the Honeywell logo was displayed on the air-conditioning control panel in the Albatross meeting room). The culture “went cowboy” according to then employee representative Steinar Sælid. The Albatrosses certainly used some of their freedom to develop previously unheard-of spending habits, for example hiring planes to bring customers in for events.[517] Such habits, too, disappeared in the wake of the crisis.

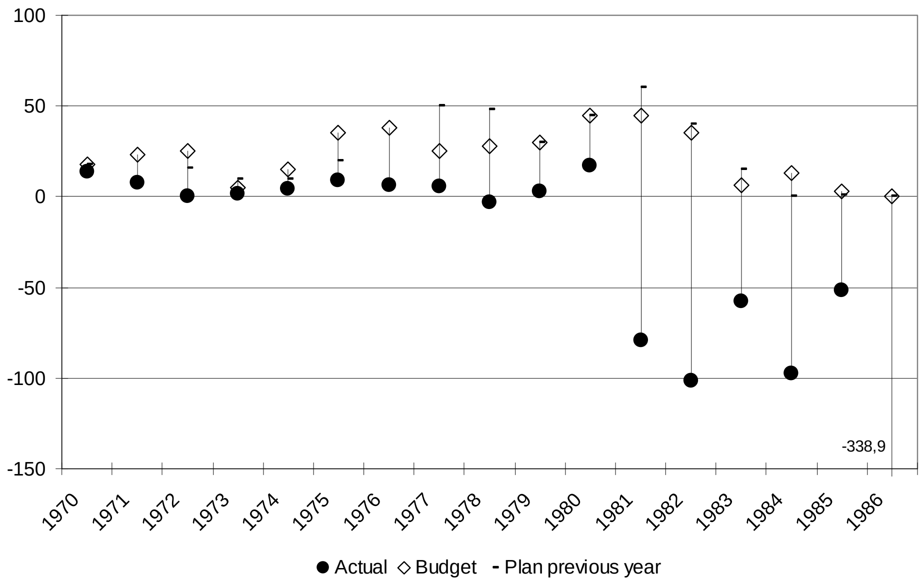
KV’s approach to financing is evident in the graph below. A financially minded reader will notice a consistent discrepancy between budgets, plans and actual results. Actual results always failed to match budgets and prior plans, a condition known as “KV sickness”.[518] Middle managers thought the budgets surreal; they were encouraged and leaned upon to set high targets, but were rarely sanctioned for their failure to deliver. Secondly, we suspect top management held accounting in some disdain: nine years in a row, KV’s profit and loss statement returned an almost exact zero. Partly, KV aimed to spend as much as it earned; partly, the company valued such items as unsold goods retrospectively to avoid losses. In addition, the company wrote off its investments at historic prices irrespective of the costs of actually replacing worn-out plants and equipment.[519] In short, the graphs reveal a company in which economics was not allowed to overshadow such considerations as engineering excellence or strategic initiatives to modernize the country.

[517] The arrogance has been commented upon by several sources apart from Sælid, cf. interview with Jenssen, 14 October 2004, and conversation with Gulhaugen, Kildal and Løkling, 29 October 2004.

[518] KV-utvalget and Arntzen, "Nou 1989:2".

[519] Bernt-Ivar Amundsen and Morten Bjerke, "Prisnivåjusteringer, a/s kongsberg våpenfabrikk", (Seminaroppgave, Norges Handelshøyskole, 1976).

Figure 35) ***Cooked books: budgets, profits and losses at KV, 1970-1986 (nominal NOK millions)***



Simply by installing greater discipline, the new owners and managers that took charge of KV's various successor companies managed to improve their businesses. There was an intangible effect of the 1987 crisis: after 1987, a business mentality cautioned the predominant engineering mentality. Most would admit the weapons factory had been no model of efficiency. Nevertheless, the crowned capital "K" that formed KV's logo had been a symbol of something fundamentally sound and solid. The collapse of the weapons factory was a tremendous blow. After 1987, Norsk Forsvarsteknologi AS preferred not to refer to "Kongsberg" in its name. People at Kongsberg, furthermore, suffered through 50 stories on Norway's sole national TV-news show in the course of one year – each incident a reminder of the fiasco and a demeaning experience. [520] Making matters worse, the US Senate threatened to block all import of KV equipment because the company had supplied numerical control systems to Soviet naval yards that employed the technology in the making of very silent submarine propellers. [521] In the aftermath of 1987, people at Kongsberg steeled themselves "swearing never again to be the laughing stock of national

[520] Interview with Korssjøen, 27 March 2003.

[521] Wicken, "Stille propell i storpolitisk storm: KV/Toshiba-saken og dens bakgrunn".

television news”.[522] Almost immediately, the new sentiments made an impact on in company accounts. The business lines at Kongsberg stopped bleeding cash.

The KV crisis of 1987 was a period of uncertainty and discomfort for most employees and managers at Kongsberg. The collapse of the company was an apocalyptic event, a shock sufficiently strong to reshape mentalities. The wide-ranging recovery following 1987 was in no small part made possible because people accepted the need for change. In this, the crisis of 1987 became an opportunity. New owners and managers, from within or without Kongsberg, were able to reconfigure the businesses they had acquired.

6.6 Conclusions

Some of the conditions for the rapid growth of KV in the years from 1950 to 1980 were not worth having in the end. They included lax corporate governance, soft financing, captive customers, political privileges, the pursuit of engineering excellence irrespective of demand, and a lack of competition. Prompted by low oil prices after 1986, cost consciousness had taken hold in the industry and the *oil industrial complex* behaved slightly more as a regular industry in a market economy. Statoil ceased treating Kongsberg Offshore as a sibling and regarded the company simply as a favoured supplier.

The companies that adjusted to new and less hospitable settings became stronger than the company that succumbed in 1987. In no small part, the crisis and the recovery were connected. Some of the changes that eventually served to create successful industries were well underway before the disintegration of KV. By 1987, KV had come a long way towards establishing separate profit units and abandoning the monolithic practice of the 1970s. The change was too slow to avoid a meltdown and the company hesitated to discontinue once-successful product lines.

The environment that faced Kongsberg Offshore and Albatross was simultaneously hostile and promising. Lower oil prices paved the way for new technology, but KOS lost its favoured status with the oil companies and struggled to reposition itself. Despite its former dominance, or possibly *because of* this dominance, new competitors emerged to challenge the company’s previous near-monopoly of subsea assignments off the Norwegian coast. Albatross, meanwhile, suffered from an almost complete halt in the market for new offshore support vessels.

[522] Interview with Korssjøen, 27 March 2003.

7 Inventing simplicity, 1986-1991

Difficult years from 1986 onwards honed business skills at Kongsberg. An absence of work and the emergence of strong competitors sharpened minds and made engineers more focused on markets and customers. In these years, both Albatross and Kongsberg Offshore refocused on making the lives of their customers simpler. Unrelated at first sight, the innovations covered in this chapter addressed a roughly similar demand: the need to handle complexity.

The low oil prices that helped undo KV also helped refocus the Norwegian oil industry. In Norway, the introduction of new technologies needed political backing – or, more precisely, non-interference. Following 1986, the will to impose a certain style of field development took a hit with the oil price collapse. Alternative development styles were allowed to challenge gravity platforms. This offered much more room for deepwater technology. In that respect, the mid-1980s were a turning point for the two businesses we have been tracing. The offshore industry became much more receptive to the nimble and cost-efficient ways of developing oil fields. This fundamental shift favoured the Kongsberg-based supplier industry.

Although the market moved in ways that favoured Albatross and Kongsberg Offshore, recovery was slow. For a number of years, the sale of DP systems remained well below its mid-1980s peak. The oil price collapse in 1986 had in effect pricked a bubble in rigs and offshore supply vessels, and the market did not recover in line with the price of oil. Kongsberg Offshore, having won every contract up to 1984, missed the major opportunities that arose in the late 1980s. To make matters worse, the company lost its main supplier (Cameron). Only through product innovations did Albatross and Kongsberg Offshore reposition their business.

If last chapter was mainly about disintegration, reintegration was a more fitting label for the period that followed. System sales forced an integration of technologies and at times an integration of companies. Albatross profited somewhat from the extended marine electronics competencies of its owner, Simrad, but also from the parent's service network and organizational skills. In this setting, the exceptionality that had served Albatross well in the previous decade was less of an asset. For suppliers of subsea systems, a complementary product range was increasingly of essence. Kongsberg Offshore found a partner in Food Machine and Chemical Corporation (FMC), which supplied Christmas trees and other equipment that matched the control systems made at Kongsberg.

A second response to complexity was standardization. Albatross had streamlined its product offering almost from the very beginning: the company offered a set of defined Albatross dynamic positioning products such as the ADP 501 (non-redundant) ADP 503 (triple redundant) and strived to limit variance.[523] Oil companies, by contrast, tended to introduce some novelty in every subsea field development. Around 1990, Kongsberg Offshore initiated an effort to standardize wellhead technology. The company postulated there would be considerable economies of scale if they could allow standardization. By locking on to a limited product range, Kongsberg Offshore delivered cost savings that served to make subsea systems a more compelling option.

7.1 Cost consciousness and competition in the oil industry

The low oil prices of the late 1980s challenged every company involved in offshore oil. In Norway, the development of fields continued much as before, but low prices somewhat undermined the economics of large, gravity platforms. The relative decline of Statoil and the rise of competing centres of expertise helped introduce competition on the Norwegian Shelf. Statoil, too, changed. It came to behave more like an ordinary, profit-seeking company, aiming to cut the cost of developing and running offshore fields – not as a regulatory tool to secure maximum Norwegian content. Kongsberg Offshore suffered, but the transformation eventually helped advance the kind of cost-efficient development styles that the company offered.

Oil companies became more cost-focused and self-critical, and in Norway, the public joined in an outcry against large expenditures.[524] Arve Johnsen had to leave Statoil in 1988 following huge overruns at Mongstad where Statoil botched the rebuilding of a petroleum refinery. Offshore, the cost of developing fields seemed palatable in the light of eventual earnings, but cost overruns in the downstream industries were transparent. Mongstad looked set to lose money on a scale that captured the public mind. Apart from home-grown anger with spendthrift development projects, a global prudence also made inroads. Johnsen's predecessor developed close ties with British Petroleum. The British shelf matured earlier (cf. the cream curve on

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[523] The naming philosophy was inspired by a Peugeot car series – Jacobsen, the Albatross manager during 1976-80, loved his car.

[524] For an elaborate argument reflecting the public outcry, cf. Sissel Myklebust and Espen Søbye, "Overinvestering og statlig styring i oljevirksomheten", *Nytt Norsk Tidsskrift* 1988, pp. 25-40.

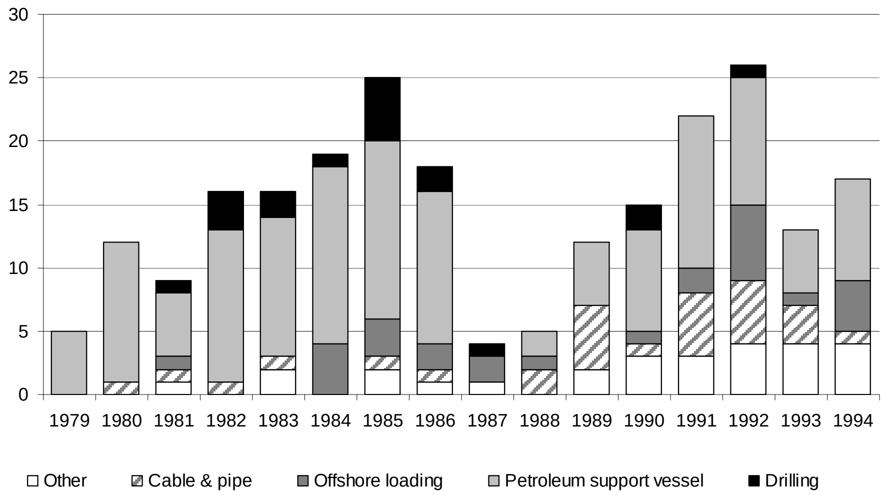
page 218) and operators on the British shelf turned to cost cutting and outsourcing early. Statoil took notice.[525]

Everywhere, companies became more concerned about investing in offshore oil. Albatross was hard hit. Some two-thirds of its market disappeared when shipping companies stopped ordering new petroleum support vessels.[526] In 1988, Albatross lost a few million; in 1989, Albatross earned a few million. As the price of dynamic positioning fell and reliability improved, dynamic positioning found applications on naval vessels, icebreakers and other specialist vessels unrelated to the oil business. In the 1990s, such diverse customers accounted for 20-30 per cent of Albatross's deliveries (cf. figure below). When telecom companies rushed to put down overseas telecommunications cables around 1990, Albatross secured contracts to equip a number of cable-laying vessels with dynamic positioning that in effect worked like a very precise autopilot.

[525] On the British inspiration, cf. Engen, "Rhetoric and realities", p. 156, with reference to a speech by Harald Nordvik: ”Norsk Petroleumsvirksomhet - Internasjonale utfordringer og muligheter” (Norwegian Petroleum Activities - International Challenges and Opportunities), Den Polytekniske Forening, Oslo, 20 March 1990.

[526] CA-KM-Simrad, Simrad AS board minutes, 24 August 1987.

Figure 36) ***Not just oil: Albatross deliveries by vessel type, 1979-1994***[527]



Throughout the downturn, Kongsberg's market share in up-market dynamic positioning remained high, possibly reaching 90 per cent of the market,[528] and Albatross continued to earn money on support, training and after sales.[529] In the late 1980s, the Norwegian Maritime Directorate (NMD) underpinned the certification arrangement by issuing prescriptive regulations in the 1980s that linked DP classes with specific operations and circumstances.[530] If, for example, a failure to maintain position threatened human life, serious environmental damage or large economic consequences, the vessel conducting that operation needed a class 3 certificate (fully redundant DP system). Outside Norway, oil companies were not legally obliged to apply specific DP equipment for specific tasks, but tended to heed the advice of classification societies nevertheless. Originally intended as guidelines assisting investors and insurers in the assessment of risk, the class system grew into an institution that governments could rely on when

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[527] The figure is calculated using various sources, most importantly reference lists published in 1981 and 2001 from KMedu. The lists correspond with the company's ad-hoc sales database, which is somewhat more difficult to draw on for grouping sales according to vessel type.

[528] *Laagendalsposten*, 19 February 1987.

[529] KV-ex 12, Albatross board minutes, 22 January 1987.

[530] Bray, Dynamic positioning.

specifying environmental standards or health and safety regulations. Such arrangements created a demand for dynamic positioning, but compared to previous years, business was down.

* * *

For Kongsberg Offshore, the cost focus was rather advantageous. It eventually shifted focus from huge gravity platforms into deepwater technology. Up until 1986, the oil industry in Norway thought large-scale subsea developments were feasible only where the waters were deep and rough or the geology was difficult. Subsea systems addressed their physical constraints – not the economic constraints of the industry - and oil companies channelled their research money into diverless systems for extreme conditions.[531] The subsea developments that de-facto took place on the Norwegian shelf prior to 1986, however, were satellite developments for economic reasons. Gradually, the economic advantages of subsea field developments became their most attractive feature and the mainstay of new field development styles. This shift began in the late 1980s, when low oil prices provided a push away from gravity platforms. The will to protect existing practices irrespective of cost was diminishing. The oil industry's share of Norway's gross national product declined from almost 20 per cent in 1985 to 10 percent in 1988. In 1986, the state coffers received no oil money at all and exploration activities came close to halt because the costs involved in building Condeeps destroyed the economics of every project except for such giants as Troll.[532] Despite heavy lobbying, successive governments intervened less and allowed new development styles to take hold although the shift away from Condeeps exposed the supplier industry to international competition.

Particularly on marginal fields, low prices triggered a new development style. Tommeliten was a case in point. At the time of its discovery, in the mid-1970s, KV had proposed a field development based on subsea technology, but Statoil continued to search for ways of developing the field in an economic way using manned platforms. *After* the fall in oil prices, however, Phillips Petroleum proposed to develop the field with subsea installations only. "Paradoxically enough, we may conclude that it was the fall of the oil price in 1986 that led to the building of Tommeliten," writes

[531] For a typical and contemporary recollection of the arguments in favour of subsea systems in the early 1980s, cf. Pedersen et al., "Introduction to subsea production systems".

[532] Cf. the figure on p. 38.

Engen. Only when oil prices had fallen to a point where the old style of developing fields was obviously unprofitable, was it “legitimate” in the Statoil organization to consider subsea field development.[533] In October 1986, when Statoil asked various suppliers to submit bids for subsea systems, KV’s financial health was fast deteriorating. That was probably why Statoil bypassed Kongsberg Offshore and ordered equipment from Aker-Hughes A/S.[534]

Another opportunity emerged in the summer of 1987, when Kongsberg Offshore had gained the financial backing of Siemens. At the time, Hydro arranged a tender for *Troll Oseberg Gas Injection* (TOGI), a plan to extract Troll gas from subsea wells, ship it across to Oseberg in a pipeline, inject the gas to increase reservoir pressure at Oseberg and hence extract more oil. With backing from the Ministry of energy, Hydro overturned the opposition of Statoil and Shell, which thought the concept too adventurous, and went ahead with a tender for subsea equipment.[535] Kongsberg Offshore’s relationship with Cameron disintegrated in preparation for the bid. The Kongsberg engineers shifted track and offered a subsea system based on valve trees and other critical components from WKM and Dril-Quip. The change arguably introduced uncertainty and Hydro awarded the contract to Kværner, which was now cooperating with Cameron.[536] In August 1987, Kongsberg Offshore was about to run out of work. The company had lost a string of bids in a row. During the next few years, Siemens injected about 100 million (2008) to keep its acquisition afloat.[537]

Kongsberg Offshore’s losses were the gains of other engineering companies. In the course of two years, Hydro awarded contracts to several Norwegian engineering companies worth NOK 740 million and offered each an opportunity to invest and expand. During Kongsberg Offshore’s difficult years, a host of competitors gained footholds including Aker, Kværner and

[533] Wallace, Duberg, and Kirkley, "Dynamics of the oil and gas industry in the Gulf of Mexico: 1980-2000: Final report".

[534] ”Rimeligere utbygging av Tommeliten?”, NTB, 4 February 1986; ”Trolig 4.8 milliarders utbygging på Tommeliten”, NTB, 10 March 1986; ”Tommeliten-kontrakt til nytt Stord-firma”, NTB, 27 September 1986.

[535] Lie, Oljerikdommer og internasjonal ekspansjon: Hydro 1977-2005

[536] ”250 millioners kontrakt til Kværner”, NTB, 3 August 1987.

[537] A rough estimate of accumulated losses in the late 1980s as they appear in annual reports and Eriksen, "Næringsøkonomiske virkninger av nedleggelse av store bedrifter", See also appendix 11.6.

Elektrisk Bureau. Most established themselves supplying Hydro. In effect, Hydro's effort to produce oil at Oseberg created a new industry.

Like Statoil on Gullfaks, Hydro adopted the EPC contract strategy and asked suppliers to take full responsibility. This created a market for subsea deliveries where KOS had previously enjoyed a near monopoly. By the late 1980s, four players were able to take on subsea system assignments (EPC contracts) on the Norwegian shelf. None actually manufactured pressure-containing equipment in Norway, but sourced such equipment from companies based in Houston. All companies focused on control systems and systems engineering.

Kværner was the single company best placed to compete against Kongsberg Offshore. The company had acquired a well of general engineering experience and had taken part in various paid subsea studies that arrived through the technology agreements. In the second half of the 1980s, Kværner Subsea outgrew Kongsberg Offshore in terms of revenue. Kværner built subsea systems for East Frigg, Tommeliten, TOGI and Snorre. From 1987 to 1991, Kværner worked in cooperation with Cameron.[538]

Around 1990, Elektrisk Bureau (EB) emerged as a leading supplier. EB looked into the subsea field on several occasions during the late 1980s and considered buying Kongsberg Offshore Systems A/S in 1986.[539] The next year, Asea Brown Boweri (ABB) bought a controlling stake in EB and then (1989) in Skeie Gruppen, whose portfolio included the Seanor subsidiary that offered subsea engineering.[540] In 1992, having bought out all minority owners in its Norwegian operations, ABB assigned overall responsibility for offshore activities to ABB Norway and put the former EB office at Billingstad in charge of the large offshore engineering business of Vetco Gray, which ABB acquired in 1991 through the purchase of Combustion Engineering. Vetco Gray was a global market leader in valve trees and other subsea technology.[541] ABB gained a strong position on the Norwegian shelf, most notably through a NOK 400 million contract (1992) to supply subsea systems for oil extraction at Troll and subsequent assignments for Saga on Tordis and Vigids.

[538] On Snorre, cf. ”Kværner får ny Snorre-kontrakt”, *Dagens Næringsliv*, 11 March 1989; on TOGI, cf. Martin Brakas, "Kværner har fått viktige undervannskontrakter", *Offshore Norge* 1987, p. 9.

[539] ”Elektrisk Bureau blant interesserte KV-kjøpere”, NTB, 12 March 1987.

[540] Sverre A. Christensen, "EBs historie [forthcoming]" (2009).

[541] Ibid.

Aker had been looking into subsea engineering since the 1970s, but succeeded only in the 1990s.[542] Around 1990, Aker Subsea employed some 40 people who distributed third-party control systems. In 1991, Aker Subsea acquired the control system business of Hughes Aircraft, allied itself with National Oilwell (valve trees) and GEC Avionics (control system specialist) and invested in facilities to mach Kværner and Kongsberg Offshore.[543] In 1992, following the acquisition of Norwegian Petroleum Consultants, Aker had a quite broad subsea portfolio. That year, the company secured a subsea systems delivery contract at Lille-Frigg.[544] By then, four companies based in Norway were capable of supplying turnkey subsea systems.

Apart from the large engineering companies, specialist suppliers emerged to do work on subsea systems. One of the most significant was Frank Mohn (Framo) in Bergen. The company was renowned for ship pumps (80 per cent market share in 1988) and did innovative work on multi-phase pumping (the pumping of more or less untreated well-stream).[545] Other companies came up with complimentary products to support subsea developments. Simrad, for example, used its acoustics knowledge to develop systems capable of detecting gas leaks or the presence of sand in gas pipelines.[546] Moreover, various shipping companies came up with specialized offshore supply vessels capable of installing, servicing and maintaining the various pieces of equipment on the seabed. Many of these vessels employed dynamic positioning equipment from Albatross.

In the short run, Kongsberg Offshore obviously had a lot to lose, and little to gain, from competition. In the end, however, the plethora of subsea providers

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[542] In the 1970s, Aker looked at solutions to complement its competencies in floating installations and cooperated with industry specialists such as FMC, Vickers Offshore Development and ASEA, cf. Smeby's private papers, Smeby, "A Norwegian activity on subsea completion / deep water production systems", 11 November 1975; KV-Cor 248, Smeby, minutes from meeting with Cameron Iron Works, 9 January 1978.

[543] S.N. Asgaut, "Aker Subsea bygger ny undervannsbase", *Dagens Næringsliv*, 2 August 1991.

[544] Torgeir Anda and Kjell Østerbø, "Strømlinjet Aker vetner på oppgangen", *Dagens Næringsliv*, 21 January 1992.

[545] "Ny teknikk gir mer olje", *Dagens Næringsliv*, 18 May 1988; Morten Woldsdal, "Landplattform for fremtiden", *Aftenposten*, 9 March 1987; "Teknologisk nyvinning med store vyer", NTB, 23 March 1988; "Ny teknikk gir mer olje", *Dagens Næringsliv*, 18 May 1988. On multi-phase pumping, cf. p. 277.

[546] Tron Bø, "Milepæl for norsk undervannsteknologi", *Aftenposten*, 13 July 1989.

had a beneficial effect. Because oil companies on the Norwegian shelf could draw on various providers, they felt assured there would be a competitive market for subsea tenders. This made subsea developments a more attractive option. In this sense, the competitiveness of the industry contributed to an eventual shift in field development styles.

7.2 Pulling an act together

Both Albatross and Kongsberg Offshore suffered in the late 1980s - Albatross from a disappearing market, Kongsberg Offshore from a string of losses. Both needed time and the support of their respective new owners to realign.

Prior to 1986, Albatross had thrived without extensive checks on spending; there were few incentives “to return money rather than have fun” according to one long-timer.[547] The profligacy worried Simrad’s board and its managing director, Kåre Hansen. His instructions were to “closely follow” developments at Kongsberg.[548] Simrad was a financially conservative company with stringent control. A favourite of the stock exchange, Simrad knew how to communicate goals and fulfil promises. Hansen transferred these qualities to Albatross.[549]

Albatross encountered a company that was quite tolerant of diversity. Being less certain their company was exceptional, people at Simrad were better able to appreciate, incorporate and accommodate others. The renamed Simrad Albatross AS retained a distinct identity, a separate location and a clear-cut product line. Nevertheless, relations between Simrad and Albatross produced a clash of cultures. From Albatross’s point of view, the Simrad people were conservative and controlling, somewhat resembling people at KV. There was “something of a clash” before things levelled.[550] In part, the conflict centred on Hansen. His business talent was undisputed, but he was a domineering manager, something of a loner and not a good listener. As with other technicians turned managers he tended to involve himself in minute

[547] Interview with Jenssen, 14 October 2004.

[548] CA-KM-Simrad, Simrad AS board minutes dated 24 August 1987 and 23 August 1990.

[549] Interview with Kildal, 29 October 2004.

[550] Conversation with Kildal, Gulhaugen and Løkling, 29 October 2004.

details, annoying the engineers in charge who in turn responded with a variety of obstructive techniques.[551]

Simrad hoped to forge a new identity on top of the specific Albatross culture, as evident in successive re-brandings.[552] In 1989, the Albatross name disappeared from subsidiaries abroad. The most controversial move was replacing a logo, substituting the Albatross bird with the Simrad wave. Like losing the standard in battle, the change was an emotional and psychological blow. The dynamic positioning people lost some of their identity and nothing came along to replace it. When the business was rebranded Kongsberg Simrad AS, employees stubbornly continued to speak of Albatross.[553]

One of those who lost heart was Gulhaugen. A few years prior, a slightly populist business magazine, *Kapital*, had pronounced him a genius. He had become a sought-after and engaging conference speaker on the subject of success and motivation. When the downturn stuck, he had to initiate a cost-savings initiative named *Target ´90* to save NOK 20 million[554] and insist on selling products in stock at the expense of distant opportunities. As a response, many employees accused him of insufficient knowledge in matters technological and plotted to get rid of him. While most of the management team was abroad, employee representatives launched a “technicians’ mutiny”. The incident wore heavily on Gulhaugen. He switched some attention from daily operations and took interest in aloof public relations or mundane work.[555] In December 1987 he formally transferred to Simrad’s corporate headquarters - in effect he stepped onto the sidelines. Torfinn Kildal, who had been handling finance and economics at Albatross since 1979, became managing director.[556]

On Kildal’s watch, there was another defection - this time it affected the sales department. Sales had been the subject of special scrutiny during the

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[551] Interview with Jenssen, 14 October 2004. On Hansen’s business talents and some of his conflicts, cf. Sogner, *God på bunnen,* pp. 160 ff.

[552] Cf, Appendix 11.1.

[553] Interview with Helle, 14 April 2005.

[554] Jahnsen’s private papers, Albatross company communications, *Target ’90*, number 2, 1987.

[555] Interview with Sælid, 14 October 2004; conversation with Kildal, Gulhaugen and Løkling, 29 October 2004.

[556] Conversation with Kildal, Gulhaugen and Løkling, 29 October 2004.

cost-cutting effort. Arguably, Albatross could do with a degree of prudence and the salespeople were more flamboyant and high-flying than the average albatross, sometimes in a fashion bordering on the irregular. Rather than cutting back, key people in the sales department wanted to pursue an expansionist strategy, establish a trade company independent of Simrad and sell dynamic positioning alongside third-party products. When denied this opportunity, three key people left: Sven Thorsen, Vidar Djønne and Ingvald Løvdal.[557] They founded a company, *Alba International*, and moved on to buy Valmet's Norwegian subsidiary in 1997. Four years later, Thorsen became the biggest earner in Norway when CAE (Canada) acquired their business.[558]

Although Albatross at times had a troubled relationship with Simrad, the connection carried advantages. Albatross gained some work from Simrad's NOK 381 million (1990) contract to equip nine Norwegian catamarans for the handling of mines. While Simrad and Thompson provided detection sonar, mine avoidance sonar and operation planning software, Albatross provided a system that kept the catamarans at a safe working distance from the explosives.[559]

Simrad possessed the bureaucracy and the systematic approach needed to run a large, diversified, international company. This approach sometimes clashed with established practices at Albatross, but gradually, the Simrad approach prevailed. The 1991 annual report contained a passage about "little rivalry" within the group – an indirect acknowledgement there had been controversies. It probably helped Kildal himself who went on to manage Simrad's affairs. He doubled as head of group finances before he stepped in to replace Hansen when the latter took time off to establish Simrad in the Pacific Rim in 1989-1990.[560] Terje Løkling, the head of technology, became managing director of Simrad Albatross AS. Like several others, he held a diploma in cybernetics from Trondheim. At Albatross, his first job was as a

[557] Conversation with Kildal, Gulhaugen and Løkling, 29 October 2004. Specifically on the spending habits, cf. interview with Sælid, 12 October 2004.

[558] "Vanlig å havne på ligningstoppen", *Dagens Næringsliv*, 17 December 2002.

[559] On the technology, cf. Sogner's private papers, Simrad Newsletter, issue 1, 1992. On the thinking at Albatross about naval deliveries, cf KV-Cor 239, board minutes, 3 July 1986 and 23 October 1986; KV-ex 12, Albatross board minutes, 22 January 1987. On the value of mine hunting contract, cf. CA-KM-Simrad, Simrad AS board minutes, 26 February 1990.

[560] Sogner, *God på bunnen*; CA-KM-Simrad, Simrad AS board minutes dated 20 December 1988 and 6 April 1989.

problem solver in the operations department. He had a view for the totality, rarely placed himself in the limelight, but strived to “make other people good”.[561]

Albatross remained the most permissive business unit at Kongsberg,[562] but some dynamism was gone. When the energy of 1975-85 receded, some found an outlet for talents outside Albatross. There was Vidar Solli, who took Albatross onto a new hardware platform based on Intel processors; he established his own company in 1985, devised a tactical trainer for the navy and earned serious money.[563] There was Ragnvald Otterlei, who established MikroMar and took his unmanned surveillance craft to Discovery Channel and Newsweek, if not to economic fortune. There was Jon Hognestad, who established a company that bundled magazines for delivery (Bladsentralen).[564] As a contrast, this author has come across very few successful ventures set up by employees from KV’s defence division, air engine division or automotive division. In general, Kongsberg conformed to a predominant collectivist strain, and a social stigma attached to self-made men, something that is claimed to be a distinguishing feature of Norwegian one-company towns.[565]

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While Simrad struggled to incorporate Albatross in its overall business, Siemens ran Kongsberg offshore at arms length. Tore Andvig stayed on as managing director supplemented by a German chief financial officer who imposed financial controls. The head of Siemens Norway became chairman of Kongsberg Offshore a.s. and Siemens placed several of its high-ranking technology experts as directors.[566]

Siemens withdrew KOS from some lines of business. Kongsberg Offshore possessed some control system technology (*SCADA* and *Octopus*) for use on production platforms. Siemens had more advanced products in its portfolio

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[561] Interview with Sælid, 22 May 2006.

[562] Interview with Kildal, 4 January 2006.

[563] KV-Cor 239, Albatross board minutes, 13 February 1986.

[564] Interview with Sælid, 12 October 2004.

[565] On the social stigma attached to entrepreneurship, cf. *Buvikutvalget*, NOU 1983:10 – a governmental inquiry.

[566] Daling et al., *Offshore Kongsberg*; interview with Halvorsen, 4 October 2004.

and ditched this product line.[567] Kongsberg Offshore also offered a subsea control system through its 51 per cent share in Kongsberg Subsea Controls AS (KSC). This company relied on technology from Ferranti, which owned the remaining 49 per cent.[568] Alas, Ferranti was one of Siemens's fiercest competitors. Having bought Kongsberg Offshore Systems, Siemens discontinued the cooperation and sold its shares to Ferranti in 1987.[569] Following this move, Kongsberg Offshore had few proprietary products. Its role as a main contractor was based on offerings made by Siemens and Cameron.

Shortly after Siemens assumed control, however, the uneasy relationship between Cameron and Kongsberg Offshore collapsed. On the surface, the dispute was about technology: KV had thought the connectors provided by Cameron were lacking in capability and began designing proprietary equipment despite its obligation to stick to Cameron equipment. Cameron discovered this and demanded all product rights stay with Cameron; in the aftermath of the subsequent quarrel, the cooperation was discontinued in 1987.[570] At the heart of the dispute were different perceptions as to what a *main contractor*, the party handling an EPC contract, should do: Cameron considered the main contractor a glorified procurement company sourcing technology from established oil tool manufacturers; the Kongsberg people foresaw a larger role for the main contractor.

In the short term, the break with Cameron added to Kongsberg Offshore's difficulties. Turnover collapsed in 1987-1988 and some employees had to leave. Siemens responded calmly and sent senior people to Kongsberg to signal commitment and avoid a brain drain. They granted the company another five years to prove its worth, but pushed hard to get action plans

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567 Siemens had contributed considerably to the supervisory control and data acquisition (SCADA) system that Mobil/Statoil bought in 1975. In the early 1980s, when KV had gained some experience, the arms factory petitioned Statoil for a development contract, ditched Siemens, and developed the Octopus control system for Gullfaks Ibid. See also KV-Cor 243, Qvenild, memo in preparation for Statoil meeting, 6 June 1983.

568 ”Britisk på Kongsberg”, *Aftenposten*, 5 August 1987.

569 Ferranti trimmed its Norwegian workforce, failed to secure more contracts, and closed the business down in 1989. Kjetil Wiedswang, ”Ferranti-fall”, *Dagens Næringsliv*, 4 October 1989.

570 Daling et al., *Offshore Kongsberg:* interview with Halvorsen, 4 October 2004.

and milestones. In the fall of 1987, Tore Andvig withdrew as managing director and made room for Henrik Reimers.[571]

As part of the recovery plan, Siemens agreed to reposition Kongsberg Offshore in control systems. The people who knew topside control systems went to work on fiscal metering systems – the kind of technology used to measure output for tax and revenue-sharing purposes. In November 1987, Siemens decided to fund the development of a control system to replace Ferranti's technology. The initiative came from Kongsberg Offshore, but agreeing came naturally to Siemens. Having supplied control systems to nuclear reactors, the German conglomerate was familiar with the challenges and rewards involved in developing technology for unfriendly environments.[572] Indeed, control systems were one of the components that served most to limit the range and usefulness of subsea systems. Systems based on electronics or electronics in combination with hydraulics (multiplex systems) were liable to short circuit and control systems in general were less reliable than the valve trees and manifolds they guided.[573] Because of the difficulties involved in employing electricity below the surface, many oil companies relied on direct hydraulic control of each subsea valve using long hydraulic pipes from the surface down to each valve.

Siemens and Kongsberg Offshore intended to address the problem by way of modularity – building a control system that could be decoupled from the subsea system. In case of failure, the well would shut down, and a regular offshore support vessel could replace the system and haul the faulty one to the surface for repair. Kongsberg Offshore argued that each intervention would cost 2 million less then replacing a competing system.[574] Siemens also provided knowledge in the field of *inductive couplers* (the concept of joining two halves of a transformer – like a plug in a socket – to create a single transformer through which signals and power may travel).[575]

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[571] Interview with Halvorsen, 4 October 2004.

[572] Interview with Halvorsen, 4 October 2004.

[573] Andvig, "Undervannskonstruksjoner".

[574] Sigurd Moe, "Utvidet bruk av rov ved undervannsproduksjon", *Norsk olje & gass informasjon* 1990, pp. 12-13.

[575] Daling et al., *Offshore Kongsberg*.

Enlisting early customers and gaining field experience was a critical step in launching new offshore technology. Kongsberg Offshore went out of its way to convince Saga about the reliability of their system and its applicability for the subsea wells that Saga wanted to add to its Snorre platform. The Kongsberg engineers built a prototype for the all-important industry fair in Stavanger, complete with hydraulic power, control system and valves. Saga agreed to buy in December 1988.[576] Kongsberg Offshore offered the system at a fair price, which counted, and the effort they put into the sale was probably convincing. On top of this Saga admitted a concern for its supplier base: somebody had to nurture a domestic supplier of control systems.[577] Buying a novel product was risky. Indeed the new couplers failed the acceptance test and Kongsberg Offshore had to develop a temporary solution. Only in September 1993 was a permanent control system in place on Snorre, easily retrofitted by a ROV.[578]

From a strategic point of view, subsea control systems were an excellent point of departure. The control system relates to most components in a subsea system; whoever mastered the control system mastered systems building and systems assembly. Hence, although no other parts were manufactured at Kongsberg, the company nevertheless mastered the assembly of turnkey systems for subsea oil production.

In order to supply subsea systems, Kongsberg Offshore needed to partner with a supplier of valve trees and other critical components. It fell upon Reimers and the head of the subsea department, Jørgen O. Haslestad, to secure a useful product range. In March 1988, Kongsberg Offshore signed a memorandum of understanding with FMC.[579] This conglomerate originated as a California-based manufacturer of machinery for the food industry (Food Machinery Corp.), and added military equipment during WWII. After the war, the company bought some chemical companies and rebranded itself as Food Machine and Chemical Corporation. In the 1950s, FMC continued to expand in various businesses and bought Oil Center

[576] Ø. Finstad, “Julegaver fra Oljeindustrien”, *Dagens Næringsliv,* 19 December 1988.

[577] Daling et al., *Offshore Kongsberg*; interview with Steenstrup, 14 October 2004.

[578] CA-FMC-board, Kongsberg Offshore 1993 Annual Report.

[579] Daling et al., *Offshore Kongsberg*. The cooperation deal covered marketing, sales, fabrication, development installation and service of subsea equipment.

Tool Co. in Houston, Texas.[580] This Houston unit made valve trees and wellhead equipment.

By 1990, both Albatross and Kongsberg Offshore had settled. The head of the subsea department, Haslested, succeeded the man from Siemens as managing director.[581] Kongsberg Offshore and FMC entered into a proper agreement on system deliveries.[582] The company had repositioned itself and regained capabilities. Albatross, meanwhile, had weathered the difficult years in the late 1980s through cost cuts, non-oil customers for its dynamic positioning technology, and the handling of more subsystems onboard offshore vessels. That is the subject of the section below.

7.3 AIM – Albatross's control system for vessels

A *system* is an integrated whole – change one component and the change will affect the remains of the system. With regard to large, complex systems, there are many opportunities to identify *sub-systems*. For example, we may divide a dynamic positioning system into various navigation systems, a system that attempts to identify the exact position, a thrusters control system, etc. In case of a dually redundant DP system, one computer may act as a *control system* to monitor the performance of two DP systems working independently.

In a wider setting, the DP system itself was but one sub-system in the complexity that made up a vessel. Albatross's customers increasingly worried how dynamic positioning would fit with numerous other sub-systems employed on board their vessels. They demanded integrated solutions that addressed the working of a ship as a whole, not just a specific task like navigation or maintaining position in specific circumstances. *Integrated control systems* served to address the task of guiding and coordinating the performance of multiple sub-systems. They were essential parts of *system integration*.

The demand for system integration was long coming. In 1963, when an optimistic engineer produced the freehand drawing (below) of a happy

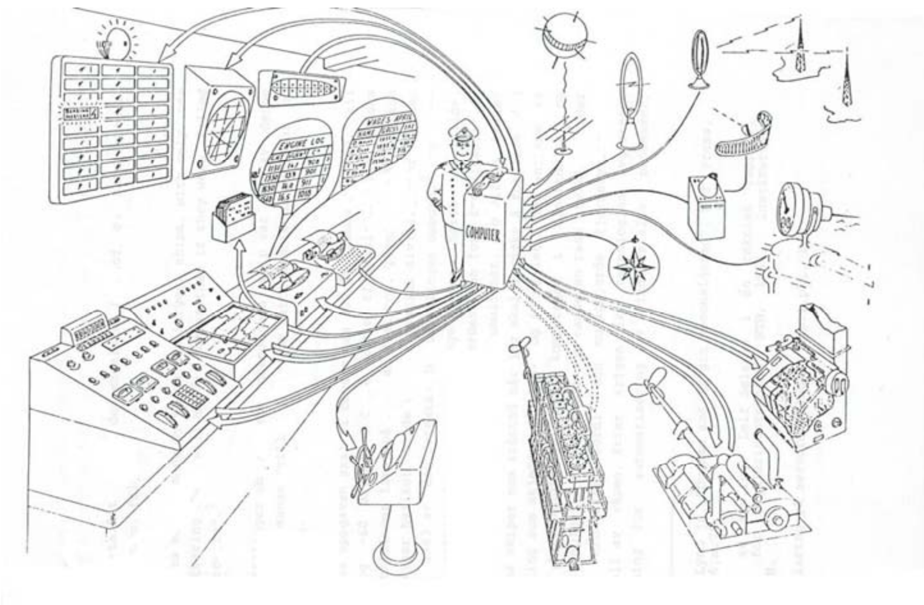
[580] For a short history of FMC, cf. http://en.wikipedia.org/wiki/FMC_Corp. Note, FMC Kongsberg Subsea is a fully owned subsidiary of FMC Technologies, a company that was demerged in 2000 and no longer has any formal links to FMC Corp.

[581] "Ny sjef for Kongsberg Offshore", *Aftenposten*, 27 December 1989.

[582] Daling et al., *Offshore Kongsberg*.

captain and his computer, there were a number of opportunities for ship automation.[583] By the 1970s, several companies had entered the market including Norcontrol in Horten, a provider of machine room automation, collision warning and other naval systems. By the mid-1980s, a ship with nothing to do but propel itself had a lot of room for automation and specialized ships even more so. As the number of systems onboard multiplied, these customers increasingly wanted integrated solutions. Yards could not easily handle advanced electronics, and there was an opportunity for electronics suppliers to provide interfaces and come up with integrated solutions. This triggered a long-term trend towards fewer suppliers that took upon themselves to integrate their systems and provide guidance and automation.[584]

Figure 37) ***Octopus: Ship automation as perceived in 1963***



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[583] Signy Overbye, "Fra forskning til industri: Utviklingen av skipsautomatiseringsbedriften norcontrol", (Masters thesis [hovedoppgave], Universitetet i Oslo, 1989), pp. 66-69. The freehand drawing of the happy captain (cf. Octopus: Ship automation as perceived in 1963) also appeared in this thesis, a reproduction of a drawing by Leif Sølsnes from a technical report published by *Institutt for Reguleringsteknikk*, NTH, 1963.

[584] KV-ex 9, memo, Gulhaugen to Maritime Division, 17 March 1983.

In the mid-1980s, Albatross faced competitors capable of handling a much broader range of tasks on board a ship than could a company limited to dynamic positioning. A particularly alarming incident occurred in 1985, when British Petroleum asked for tenders to equip its *Single Well Oil Production System*, a conceptual vessel that combined the qualities of a production ship and a shuttle tanker. Albatross had excellent relations with BP, but lost out to General Electric Company (GEC) as the latter offered not only dynamic positioning, but also gas turbines, diesel engines, generators, switchboards and power distribution.[585] Besides, GEC had a large service network in Britain.

Alas, Albatross's software platform was less than ideally suited for general automation. Designed to handle a mission-critical task, Albatross employed a single-purpose console that committed one button to every function – not a viable strategy for general automation. Kalman filtering was a successful approach when handling erroneous information, but overshot the requirements when handling mundane tasks or reliable inputs. The dynamic positioning system was ill suited as the basis for a general-purpose control system.

Realizing its limitations, Albatross invested in a new product, *Albatross Integrated Multifunction System* (AIM). Like dynamic positioning, AIM originated with cybernetics experts at Trondheim where Sælid and Tor Onshus began looking into generic control systems in the late 1970s using public funding. In 1982, Sælid tired of bureaucracy, called friends at Kongsberg, got a position at Albatross and brought his project with him.[586] Managing Director Gulhaugen was supportive, but urged the developers to avoid the fate of Norcontrol, which was "paradoxically experiencing a crisis", and urged them to take "markets [not technology] as our point of departure".[587] Albatross could not spare people, but Sælid hired four SINTEF people to write the code. When the concept grew into a product, the development effort shifted to Kongsberg.

In part, AIM was inspired by the shortcomings of existing solutions. Around 1980, companies such as Valmet, Foxboro and Honeywell provided general-purpose automation that lacked in user-friendliness. To change a work process, e.g. if the customer added a valve to a boiler, a programmer had to

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[585] KV-ex 10, Buchanan, memo to Albatross management, 24 September 1985.

[586] Interview with Sælid, 22 May 2006.

[587] KV-ex 9, memo, Gulhaugen to Maritime Division, copy KV management, 17 March 1983.

rewrite the software and adjust every equation in which the boiler played a part including report formats.[588] Sælid thought object-oriented programming would improve this cumbersome procedure and introduced software *objects* representing physical components in a system. In software, a new valve (or rather the object that represented the valve) carried information about its maximum throughput, its ability to block a flow and - most importantly - about its very existence. In the virtual machine, each part made itself known to the control system – if a valve was present, it would appear on screen, in reports, etc. If the user changed his work process and removed the valve, AIM would reconfigure itself and show workflows and outputs unconstrained by the valve. AIM, furthermore, allowed users to build complex objects from simple objects and store these in a library for repeated use. A mundane parallel would be a carpenter who previously used nails, boards, metal, bricks and sheets of glass to assemble a house could now utilize pre-fabricated doors, windows and numerous other modules. AIM embodied a similar simplification when configuring the control system.[589]

* * *

A second strength of AIM was its support for distributed computing. Previously, central mainframes were at the heart of most attempts at automation – cf. the happy captain and his central computer in the drawing on page 203. In the mid-20th century, computers were expensive and it seemed sensible to install a small number of mainframes capable of diverse tasks. (The popular imagination of a robot, a general-purpose mechanical man with robotic hands capable of different tasks, has a similar origin.[590]) When the cost of computing fell, the appeal of mainframes diminished and distributed computing ascended. Distributed computing meant chips embedded in various machines and systems. One particular beauty of this concept was modularity, i.e. the ability to replace one sub-system and leave the remaining electronics in place. AIM could run on top of such various sub-systems, coordinate the data traffic between them and provide a single user interface to ease the process of automating and monitoring the various systems.[591]

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[588] Interview with Sælid, 22 May 2006.

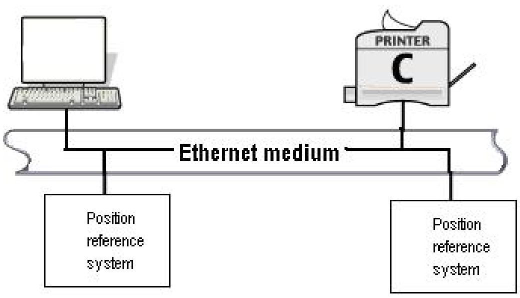
[589] Interview with Sælid, 22 May 2006. Sælid's private papers contain ample product information on AIM.

[590] "The gentle rise of the machines", *Economist*, 11 March 2004.

[591] Interview with Sælid, 22 May 2006; KV-ex 9, Gulhaugen, letter to Hurlen and Qvenild, 23 October 1984.

The Albatross Single Board Computer (cf. page 169) worked well with AIM because the computer employed an innovative networking standard. In the early 1980s, it was common to link each peripheral to a computer through a dedicated hardwire (again, cf. the happy captain on page 203). Fitting a DP system onto a vessel required kilometres of wiring. To simplify the process, the SBC's creators decided to trust the *Ethernet* protocol, possibly the first application of Ethernet for industrial purposes. Ethernet technology allowed numerous position reference systems to communicate with the computer through a single shared cable (the notion of *ether* is a parallel to wireless radio amateurs who communicated on a shared frequency). In 1982, when Albatross began looking into Ethernet technology, it was widely assumed such non-deterministic communication was unsuited for industrial applications because heavy signal traffic could cause undue delays. Albatross calculated, however, the likelihood a signal jam would fail to resolve within the required timeframe was less then the chances of being hit by lightening.[592] Developments in the subsequent years proved the company right. The standard was open and assumed data might come from all sorts of different media. Furthermore, rather than relying on a central unit to control the way data was routed, the Ethernet protocol shunted the heavy-duty work of plucking data out of the ether to PCs and other end-devices and has thus evolved in tandem with improvements in computing power. Since about 1990, Ethernet technology has enjoyed a total hegemony obliterating competition such as IBM's proprietary network solutions.[593]

Figure 38) ***Ethernet configuration***



[592] Interview with Sælid, 12 October 2004.

[593] On the impact, cf. "The big three-O", *Economist*, 22 May 2003; on technology, cf. www.wikipedia.org on "ethernet".

AIM could handle most work processes,[594] but Albatross did not attempt to sell AIM through licensed dealers. Rather, the sales network of Simrad Albatross focused on offshore applications, mainly in connection with customers who considered buying dynamic positioning. In this market, Albatross secured some very significant contracts just as the market tipped into recession. From 1986 to 1990, Albatross installed AIM and dynamic positioning on a huge crane vessel owned by Microperi. Albatross integrated dynamic positioning with ballast control – ballast pumps and propellers had to work in concert during heavy lifting. A second and larger order arrived in December 1986 while the oil price remained depressed; Albatross supplied dynamic positioning, ballast control and power control for *Scarebo 5*, the world's largest drilling rig at the time. Because thrusters used half of the power, Scarebo wanted to integrate dynamic positioning and power management: it was wasteful to run the engine at full throttle when the thrusters were idle - and it was dangerous to save on energy consumption when the vessel was in danger of drift.

Albatross relied on dynamic positioning as a door-opener when selling AIM. Having secured a DP delivery, Albatross was sometimes able to add more automation for use on board various special-task vessels in bundles with dynamic positioning. AIM had been designed with the needs of oil companies in mind, but no oil company ordered AIM for their platform operations. Indeed, selling untested control systems for the offshore oil industry was a difficult and time-consuming task.

Although the oil companies were missing from the list of customers, Albatross enjoyed considerable success with advanced petroleum support vessels. The value of the Microperi contract (NOK 30 million) and the Scarebo contract (NOK 50 million) equalled some 19 per cent of Albatross's turnover in 1987, 1988 and 1989 and provided important references and employment during the downturn.[595] In due time, process automation

[594] *Norsk Leca* bought the first system in 1986 to automate a factory that made large bricks (building materials) out of porous clay spheres, cf. CA-KM-hist, *Laagendalsposten*, 19 February 1987. Later sales involved Norwegian processing and manufacturing businesses, including Hafslund Nycomed (pharmaceuticals), Kronos Titan (melting), a water purification plant and three wood processing plants. The sales are listed in CA-KM-sup, historical file, Kongsberg Simrad reference list, December 2001. Some details also occur in Sogner's private papers, Simrad's annual reports 1988, 1989, 1990 and 1992.

[595] On the logic of integration, cf. interview with Jenssen, 14 October 2004. On the Mikroperi contract, CA-KM-hist, Micorperi file. On the Saipem contract, cf. KV-ex 12, Albatross board minutes, 22 January 1987. On the Scarebo contract, cf. CA-CA-

became the more important product to emerge from Albatross, and dynamic positioning the less important.

7.4 Standardization in the subsea industry

By the mid-1980s, following 25 years of subsea development, there had been but a few attempts to standardize production systems.[596] Around 1990, when Kongsberg Offshore reclaimed its position as a leading supplier, its success depended in no small part on a successful standardization drive.

In the late 1980s, the Brazilians were at the front end of a drive to implement standards.[597] Petrobras operated some 200 subsea wells linked to 10 floaters and 14 fixed platforms. This complex used a variety of tools, risers, wellheads, Christmas trees, etc. Perplexed by the expanding diversity, Petrobras strived to be coherent when ordering equipment and introduced some standards to specify requirements for such features as what forces the equipment should be able to withstand, what shape and dimensions to use in interfaces, and how to set up contract terms, documentation and testing requirements.[598] The Brazilian effort stopped short of comprehensive standardization, however, and Petrobras continued to order a variety of tailor-made equipment.[599]

In most cases, each new sale involved a system with a number of new components specific to the demands of the customer. The suppliers answered a request without much reference to what other customers ordered or what the oil company in question had ordered previously.[600] To people like Haslestad at Kongsberg Offshore, it seemed ”every oil company engineer connected with subsea systems desires a particular touch on a building block

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KM-info, *Laagendalsposten*, 28 March 1990. For additional information on turnover, cf. Figure 52) on page 270.

[596] Jon Harald Kilde, "Undervannssystemer: Anvendelse og kostnadsutvikling", *Ingeniørnytt* 1986, pp. 5-7.

[597] Ribeiro, Paulo, and Neto, "Campos basin subsea equipment: Evolution and next steps".

[598] C.A.S. Paulo, C.C. Moreira, and Petrobras, "Programme for standardization of subsea equipment" (paper presented at Offshore Technology Conference, Houston, 3-6 May 1993).

[599] Ribeiro, Costra, and Petrobras, "Deepwater subsea completions: State of the art and future trends".

[600] Halvorsen, "Havbunnsinstallasjoner".

in his project".[601] Since 1986, Haslestad and Tore Halvorsen repeatedly used articles and speeches to propagate standardization.[602] Haslestad questioned the rationale for each customer to employ three or four different approaches to a basic operation, e.g. mixing vertical tie-ins and horizontal tie-ins. Sooner or later, the industry had to apply the logic of manufacturing industries and stop considering each assignment as a development project.

The most obvious advantage of standardization was cost savings. Variety carried a cost in the shape of development costs and, more importantly, the heavy costs of testing new equipment before delivery. Furthermore, standardization was likely to improve quality because the supplier industry could accumulate more experience with any given component. Conversely, changing but a few items deprived the industry of an opportunity to build a record of accomplishment and a portfolio of "field proven" equipment.[603]

In the spring of 1990, Kongsberg Offshore encountered an opportunity for standardization. Shell was building a simplified Condeep for the Draugen field with six dry trees and nine subsea wells 250 – 280 metres below the surface. The subsea wells would drain distant parts of the reservoir and inject gas and water to maintain reservoir pressure.[604] Meanwhile, on Statfjord, Statoil decided to add 18 subsea wells clustered on six templates. This development was an afterthought: Statoil knew from early on there were pockets of oil north and east of the main reservoir, but it took some twenty years before the opportunities were acted upon, partly because subsea developments were not in fashion and partly because the processing capacity of Statfjord was all tied up between 1986 and 1991. The head of subsea technology, Tore Halvorsen, reckoned Kongsberg Offshore could win both Draugen and Statfjord by standardizing the offering. The requests from Shell and Statfjord differed, but Kongsberg Offshore decided to deviate somewhat from the tender invitations. The company lobbied Statoil and Shell independently to make the oil companies consider bids that were

[601] Jørgen Haslestad, "Kostnadseffektive teknologiske byggeklosser: Subsea løsninger" in Kostnadseffektive utbyggingsløsninger under nye rammebetingelser (Grand Hotel, Oslo: Norwegian Petroleum Society, 1986). The full quotation runs: "Til nå i subseasammenheng, har det sett ut som om hver ingeniør som er i befatning med subsea innenfor hvert oljeslskap vil ønske å se sin spesielle vri på en undervannsbyggekloss bygget inn i sitt prosjekt."

[602] Halvorsen, "Havbunnsinstallasjoner".

[603] Haslestad, "Kostnadseffektive teknologiske byggeklosser: Subsea løsninger".

[604] Draugen (Norsk Teknisk Museum, 2005 [cited April 2007]); available from http://www.histos.no/oljemuseet/vis.php?kat=1&id=53.

slightly outside the specifications. Kongsberg Offshore then submitted bids to Statoil and Shell that reused much equipment and offered the two companies a very affordable price.[605] At NOK 480 million (1991), the price for the Draugen delivery was substantial – but the closest competitor asked for 300 million (1991) more.[606] The difference was such Shell would not immediately accept the offer, but summoned KOS to "sift through every detail of the tender" and make sure there were no misconceptions. After two days of secretive meetings, Shell was convinced and offered KOS the contract.[607] Statoil followed in April 1991, and offered Kongsberg Offshore the Statfjord contract worth NOK 1.4 billion.[608]

Such was the cost savings involved in standardization that Kongsberg Offshore continued to pick up orders. In August 1991, the Condeep foundation destined for Sleipner East collapsed while being tested at Gandsfjorden. Statoil rushed to build a new foundation, but the company risked breaking its obligation to deliver a certain volume of gas by October 1993. Although Kongsberg Offshore was running at capacity, the company accepted an order for two extra well templates for Sleipner and Loke. These early production systems enabled Statoil to deliver gas on time.[609] In 1992, Kongsberg Offshore added Conoco to its list of subsea customers. Conoco was in charge of developing the Heidrun field. Conoco planned a tension-leg platform that would drain the reservoir. While the TLP used dry wells only, Conoco wanted to add six subsea wells to inject water and increase the output.[610] The oil company asked Kongsberg Offshore to supply the equipment - without bothering to use a tender.[611] At NOK 400 million the price was hard to match, particularly because Statoil (which would receive the operatorship from Conoco once the field was developed) could reuse tie-in and maintenance equipment from the Statfjord satellites.[612]

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605 Interview with Halvorsen, 4 October 2004. Daling et al., *Offshore Kongsberg*.

606 Tor Husby, "Kongsberg offshore til aberdeen", *Offshore & energi*, 1991, p. 34.

607 Daling et al., *Offshore Kongsberg*.

608 "Milliard-kontrakt til Kongsberg Offshore A / S", *Dagens Næringsliv,* 25 April 1991; N. Asgaut, "Stor Heidrun-kontrakt til Kongsberg-selskap", *Dagens Næringsliv Morgen*, 2 June 1992**.**

609 Steenstrup's private papers, contracts overview; Daling et al., *Offshore Kongsberg*.

610 Steenstrup's private papers, contracts overview.

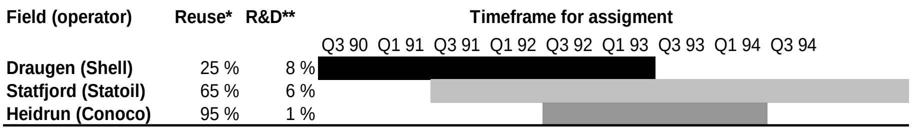
611 CA-FMC-board, 1992 annual report.

612 "Heidrun-kontakt verd 400 millioner til Kongsberg", NTB, 1 June 1992.

* * *

Putting together the Draugen tender was an all-encompassing effort. When deliveries began, the company was short of engineers and had to rely extensively on overtime particularly when the Statfjord project began in the summer of 1991. This resource shortage triggered a certain in-house standardization effort. Kongsberg Offshore introduced new project management routines with more responsibilities delegated to self-contained teams in charge of systems and sub-systems. Eventually, project management became a competitive advantage for Kongsberg Offshore.[613] The standardizing effort allowed Kongsberg Offshore to design items once and stick to that design. Besides, the similarities of the projects allowed considerable knowledge transfer in less tangible areas: there were fewer unexpected expenditures due to suppliers misreading contracts, less hassle in handling sub-suppliers and fewer mistakes during engineering and manufacturing.[614] The orders arrived in a convenient sequence that allowed experiences from one to be applied in the next. The figure below illustrates some of the cost savings. On Draugen, for example, only 25 per cent of the contract value related to components that had been qualified in previous field developments, 75 per cent required development and numerous engineering hours of research and development. Subsequent projects reused more components and successively cut back on the time spent doing research and development. The benefits of standardization also showed in delivery times for important components. Getting a Christmas tree ready for Draugen took 16 months, on Heidrun only 10 months.

Figure 39) ***Relay race: time and labour savings from reusing components***[615]



*) Value of already qualified equipment in % of total value
**) The labour costs involved in engineering (development) as % of total contract value

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[613] Interview with Smeby, 20 September 2004.

[614] Tore Halvorsen and Louis Araujo, "Standardization of subsea production systems: Practical experience from draguen, statfjord satellite, and heidrun projects" (paper presented at Offshore Technology Conference, Houston, Texas, 3-6 May 1993), pp. 347 ff.

[615] Ibid.

The standardization effort that occurred at Kongsberg in the early 1990s was far from comprehensive and the deliveries far from uniform. The projects spanned a five-slot template for water injection, a four-slot template for production and water injection, single satellites, etc. The single most difficult and fundamental issue was agreeing on a single Christmas tree; variances in the tree design would spill across to intervention systems, valve arrangements, production bore, workover operation, etc. Hence, the use of a standard Christmas tree was a precondition for extensive standardization in other parts of the subsea system. In the end, Kongsberg Offshore managed to coerce its customers into using fundamentally equal valve trees for water injection and petroleum production.[616] Most standardization occurred in subcomponents while the main components retained a degree of variety. For example, each delivery sported a different workover and completion system, but each system used many standardized subcomponents. The engineering of these various nuts and bolts was time-consuming and the cost savings on the subcomponent level were correspondingly large (the appendix on page 314 contains an overview of where KOS succeeded in its standardizing effort and what remained).

Although Kongsberg Offshore secured the contracts, little actual manufacturing took place at Kongsberg. More than half the contract value was spent procuring products from subcontractors of templates, umbilicals – and obviously Christmas trees.[617] Draugen was the first project where Kongsberg Offshore could draw on its cooperation with FMC initiated back in 1988.[618] This project also involved subsea pumps from Framo – allegedly the world's first commercial, as opposed to experimental, application of multi-phase pumping to shift untreated oil, gas and water back to the processing plant at Draugen.[619]

Standardization came at a cost. In return for a low price, customers sacrificed the freedom to design systems according to specifications. Some, like Saga, declined to purchase a standardized subsea solution for its Tordis

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[616] Ibid.

[617] "Milliard-kontrakt til Kongsberg Offshore A / S", *Dagens Næringsliv*, 25 April 1991; N. Asgaut, "Stor Heidrun-kontrakt til Kongsberg-selskap", *Dagens Næringsliv Morgen*, 2 June 1992**.**

[618] Interview with Halvorsen, 4 October 2004.

[619] Interview with Steenstrup, 14 October 2004.

field although Kongsberg Offshore offered the job at NOK 400 million (1991) less than the competition.[620]

The initial standardization gains were won sub-component by sub-component and not the result of any grand new design. The ability to use fundamentally the same Christmas tree for several projects laid the foundation for standardizing adjacent equipment and the procedures used to install and maintain the systems. The sum of these small standardization efforts was huge efficiency gains. To the extent this was innovation, the major change took place in the realm of business practices not engineering. Only in the years to come did Kongsberg Offshore turn out technological innovations to exploit the opportunities that arrived when oil companies had accepted the logic of standardization.

7.5 Conclusions

At any time during the approximately 30 years covered by this thesis, it would be truthful to remark that "technology was becoming more complex". The truism triggered a reaction – an antithesis of sorts – and technology became more standardized and easier to mix. Albatross and Kongsberg Offshore contributed to the standardization and developed technology that helped customers cope with the complexity that remained.

Both Albatross and Kongsberg Offshore worked on control systems. Except for the need to insulate everything and make the system work under water, Kongsberg Offshore relied on established electronics. Albatross, meanwhile, combined a set of state-of-the-art techniques to develop a control system: Ethernet, distributed computing and object-oriented software solutions. Each, however, aimed to solve pressing tasks for their respective customers and simplify the operation of mission-critical equipment.

Developing a new control system could be less difficult than selling a new control system. In the late 1980s, Albatross struggled to gain access for its control system on board oil platforms. Kongsberg Offshore put down a focused sales effort, and managed to secure contracts with Saga for a new and untested system. Such customers were invaluable for new entrants.

Directly, or by stealth, the mid-1980s were a period of settlement when the ways of doing business turned into established patterns. The EPC approach,

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[620] Engen, "Rhetoric and realities", with reference to interview with Tore Halvorsen (Kongsberg Offshore) on 23 October 1997.

which this thesis suggests was instrumental in fostering innovations in the subsea supplier industry, became ingrained in the late 1980s. Hydro asked for EPC deliveries when the company placed orders for subsea systems with Kongsberg Offshore’s various competitors: Elektro Union (ABB, Vetco), Kværner, Aker and Frank Mohn. Losing contracts and facing increased competition obviously hurt KOS in the short run, but the long-term effect was to create a handful of able competitors each capable of handling systems deliveries, which in turn made the oil companies more willing to delegate responsibility to suppliers. Besides, the rivalry fostered innovation and created a competitive subsea environment on the Norwegian shelf.

Apart from control systems, Kongsberg Offshore succeeded in its effort to sell standardized and less costly subsea systems. The company led a drive to standardize subsea equipment that, in the course of a few years, made subsea systems much cheaper, faster to deploy, and more reliable. Through a fortunate staggering of projects from 1990 to 1992, Kongsberg Offshore was able to carry the experience of one project along to the next. At Draugen, Kongsberg Offshore offered to build a subsea system for 300 million less than the closest competition; although not commercially sound, the pricing became the opening move in a standardization and cost-cutting drive that moved Kongsberg Offshore and its technology partner FMC into the top league in Norway.

By leading this drive towards cost-efficient systems, Kongsberg Offshore and Albatross contributed to a shift of development styles. During the years of low oil prices (1986-1990), the Norwegian Style of field development based on huge concrete platforms lost ground. Building such giants was prohibitively expensive, particularly since most new discoveries were smaller than the giant discoveries of the 1970s and early 1980s. Oil companies everywhere looked for less expensive ways of extracting oil. In place of concrete gravity platforms, a nimbler technology began to appear – techniques that relied on electronics and subsea engineering rather than the building of islands in concrete capable of hosting conventional oil tools. That shift is the subject of next chapter.

8 Deepwater technology replaces fixed platforms, 1991-1996

In perspective, the early 1990s saw the business practices pioneered by shipping companies making full inroads in the world of offshore oil. Competitive tenders and turnkey deliveries were already in place. Now, oil companies on the Norwegian shelf increasingly considered floating and moving production facilities. Ships replaced platforms. Around 1990, both the dynamic positioning business and the subsea systems business at Kongsberg revived – for reasons partly related. The oil industry had become more accommodating to innovative technology. Everywhere, inventions made in previous decades were turned into innovations in a struggle to find economic ways of extracting oil from beneath the oceans – and the markets for Albatross and Kongsberg Offshore expanded in line with the introduction of floating production facilities.

Around 1990, Albatross offered integrated process control to the new floating platforms that replaced the Condeeps. In expanding from dynamic positioning to process control, Albatross also moved from the peripheral, if lucrative, petroleum support business into the core of the oil business itself. Among oil companies, Albatross found customers willing to pay a premium for spotless execution, service and reliability.

Kongsberg Offshore continued to exploit the inherit potential in standardization, modularization and miniaturization. The company helped develop a hardware platform that offered its customers choice and flexibility while retaining the cost and quality advantages of standardized equipment.

8.1 A challenge to the Norwegian Style of development

A number of industry observers have commented on the lack of technological development in offshore oil in the years before to 1986. For more than a decade, from around 1974-75 when Statoil established its position as a dominant decision-maker and regulator until the oil price collapse of 1986, large concrete gravity platforms with a fully integrated production facility on top dominated almost every field. Few innovations took hold in this period; the technology used in the mid-1980s was but giant escalations of early platforms: simple and robust iron works on top of a platform whose legs were stretched to handle great depths.[621] "It is surprising," the head of Kværner Subsea Contracting admitted in a 1986 interview: "after 20 years of extensive activity offshore, few truly novel concepts and solutions have been put to use." Apart from the use of reinforced concrete in large platforms, no new techniques had emerged from the oil companies in the North Sea.

The technological stagnation occurred in every offshore oil province. A study of the oil and gas industry in the Gulf of Mexico, commissioned by the United States Department of the Interior, remarks on how for "a decade or more prior to the mid-1980's collapse of oil price, cost reduction through the application of technology was not a critical industry strategy".[622] The price of crude remained high and looked set to rise higher. High prices put a high premium on speedy development and a high penalty on the risk that was present in technology development.

The Norwegian Style was doubly expensive: the platforms themselves cost billions and the policy of sourcing Norwegian added to the costs. In the mid-1980s, the average Norwegian supplier was considerably more expensive than the average foreign supplier was. Interestingly, the gap was larger for advanced equipment (21 per cent) than plain steel structures (just five per cent).[623] Put simply, the Norwegian supplier industry was further behind in technology than in labour productivity. In the mid-1980s, Norwegian suppliers had a strong position on the protected home market, but achieved "remarkably" little in terms of exports.[624] The supplier industries that

[621] A slightly revised quote from *Offshore i Vest*, no. 2, 1984 ("Taper den norske stat milliarder på foreldete produksjonsformer?" *Offshore i Vest*, 1984, p. 15. The citation runs: "Dagens plattformer er jo bare en gigantisk videreføring av de tidligste oljeplattformer. Man har bare flyttet dem offshore og forlenget beina stadig mer for å rekke ned til havbunnen."

[622] Wallace, Duberg, and Kirkley, "Dynamics of the oil and gas industry in the Gulf of Mexico: 1980-2000: Final report".

[623] The price estimates were arrived at by comparing tenders for specific packages – ideally identical requests - and (if need be) adjusting for what was included or left out of the quotations, SINTEF and A/S, "Norsk offshoreindustris konkurranseevne".

[624] Ibid., In explaining the lack of competitiveness, the report hinted that political protection had induced a certain laxness: "Ved for sterk styring av kontraktene til norske bedrifter, er det også en fare for at dette kan bli en sovepute for industrien. Det kan synes enklere å be om politisk hjelp til å sikre kontrakter, framfor å gjennomføre nødvendig omstilling og rasjonalisering med sikte på økt konkurranseevne."

emerged on this protected home market had failed to develop technological leadership.

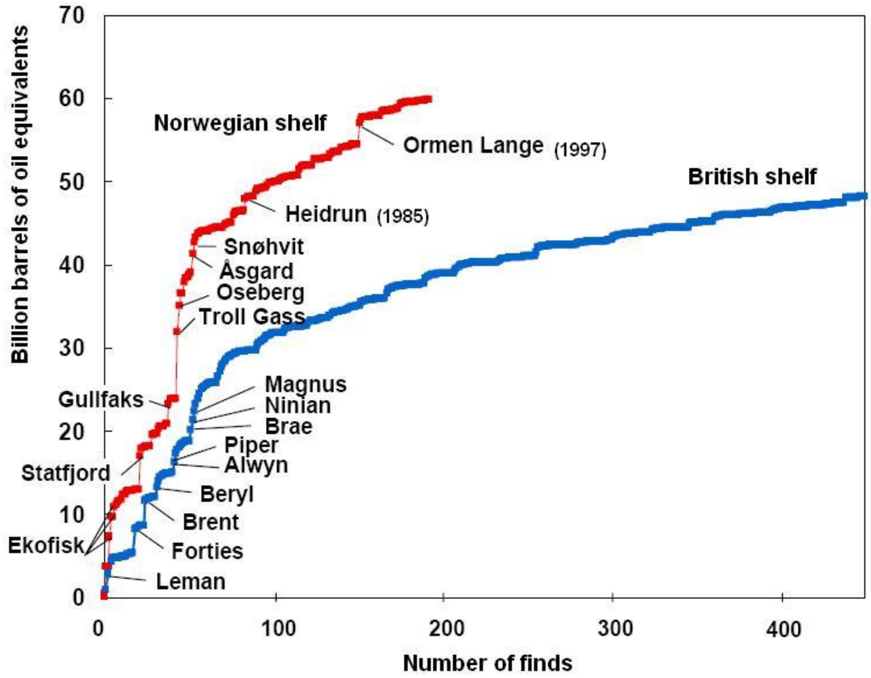
Oil companies on the Norwegian shelf seemed particularly relaxed at the prospect of high costs. Up until the mid-1980s, costly developments and cost overruns had been accepted, partly because the mindset at Statoil and elsewhere remained coloured by rich pastures. Some of the wells on Statfjord produced 50,000 barrels of oil per day – on par with the best Saudi wells and worlds apart from 830,000 American wells that managed less than 10 barrels per day.[625] At times, most profoundly at Statfjord in the 1970s, cost overruns had burdened Statoil, but the subsequent oil price hike around 1980 made costs look irrelevant. The size of the new fields discovered at the time contributed to a mentality in which costs seemed slightly irrelevant. Troll, Åsgard and Snøhvit, a string of rich gas fields discovered between 1979 and 1981, made people believe there were vast undiscovered resources of oil and gas.[626] Up until the early 1980s, the average new discovery was as big or bigger than previous discoveries and the *creaming curves* (such as the ones on the figure below) rose steeply. Field developments on the Norwegian shelf looked profitable irrespective of development costs.[627] Things were about to change, however. From 1985 (when Heidrun was found) until 1997 (Ormen Lange) the average new find was rather small compared to the early years of North Sea exploration. Gradually, the government and the oil companies realized the Norwegian shelf had become a mature oil province that could ill afford Statfjord-style developments.

[625] "Taper den norske stat milliarder på foreldete produksjonsformer?".

[626] For a delightful introduction to creaming curves, cf. Paul Thompson, Jargon [Blogg] (2007 [cited April 2007]); available from http://wolf.readinglitho.co.uk/mainpages/jargon.html. - a blog dedicated to proving the world is running out of oil. A creaming curve plots the total amount of oil that is discovered against the total number of exploratory wells. Because the first wells generally aim for the most promising geological structures, they find the “cream of the crop” – subsequent discoveries tend to be less prolific.

[627] On the mentality of oil companies, cf. Engen, "Rhetoric and realities", citing e.g. Ole Melberg (Smedvig), interview 6 September 1997.

Figure 40) ***Cream of the crop: succession of rich early finds in the North Sea***[628]



When oil prices fell after 1985-86, a range of technologies was employed worldwide to extract oil in an economic way. From the late 1980s onwards, horizontal drilling enabled a single platform to cover a larger area, movable offshore installations allowed re-use, gas and water injection increased output from fields, subsea satellites made better use of the infrastructure, etc. Some of these technologies were novel, e.g. logging-while-drilling tools. Mostly, however, the industry responded to falling prices by actually applying inventions that had been known for decades. A report on technology in the Gulf of Mexico remarked on how in "the early 1980's, much of the technology that would later have major impacts on the industry's costs was in place, but was not making a substantial difference to operations." The report listed seismic imaging with three-dimensional capabilities (first tested 1974), horizontal drilling (first used onshore 1953,

[628] The figure includes both proven and probable reserves, cf. Johan Nic Vold, Norsk petroleumsaktivitet ved et veiskille (Oljeindustriens Landforening, 2003 [cited November 2005]); available from http://www.olf.no/naringspolitikk/konkraft/prosjekt/?15529.pdf. The original source appears to be an analysis performed by Wood Mackenzie based on input from McKinsey (internal reference number 45537-01-08.03).

offshore 1981) and floating platforms (first used in the mid-1970s). Only in the second half of the 1980s did oil companies start to employ these techniques extensively.[629]

In Norway, powerful interests helped prolong the use of costly Condeeps. The money spent building the giants offered jobs to 30,000 – 40,000 people, a constituency anxious to retain the *status quo*. Bjørn Rasmussen, Hydro's director of oil technology, once likened this yard lobby to Luddites.[630] The chief advocate of large platforms was Norwegian Contractors, headquartered in Stavanger with 4000 employees skilled in the construction of concrete foundations, but Statoil belonged to the conservative camp as well. In 1986, the company copied the routines and procedures from Gullfaks A onto Gullfaks C. When Statoil's Sleiper platform sank in December 1991, the company opted for a new Condeep – a style the company hoped to establish as a "technological hegemony".[631] Besides, the field development bureaucracies at Statoil and various foreign oil companies that had set up office in Norway had grown accustomed to Condeeps and held little experience with alternative field development styles. Out of NOK 130 billion (1997) spent on developing oil and gas field in Norway between 1986 and 1993, 80 per cent went to fields that employed integrated Condeep platforms including the 472-metre Troll platform. Planned before the 1986 oil price collapse, it was the largest platform ever built. Nevertheless, deepwater technology came to dominate the satellites on the margins of the large reservoirs. Here, the developer would usually tie the subsea wells back to some existing platform. Up until the 1990s, every subsea installation on the Norwegian shelf served as satellites, draining some distant pocket of oil and gas and feeding the output onto a fixed platform in the vicinity.

8.2 Floating production and economic field development

Increasingly, nimble technology made inroads into the larger fields. The main attraction, obviously, was the prospect of cost savings.

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[629] Wallace, Duberg, and Kirkley, "Dynamics of the oil and gas industry in the Gulf of Mexico: 1980-2000: Final report".

[630] Alf Ole Ask, "Ingen fremtid for offshoreverft", *Dagens Næringsliv*, 4 October 1999. The interviewee did not use the term "Luddite" but drew a parallel with a story of textile workers destroying a Spinning Jenny (allegedly) in 1743, that is, 70 years before the Luddite movement … and some twenty years before the Spinning Jenny was invented.

[631] Engen, "Rhetoric and realities", drawing on Odd Mosbergvik (Statoil), interview on 3 June 1998.

Comparing Brazilian and Norwegian development styles may offer a clue to the economics of deepwater technology. Such a comparison is not straightforward, but there were remarkable similarities. In the mid-1980s, both extracted oil offshore in the same market conditions; both countries insisted on a high degree of national content reaching 90 per cent in the Brazilian case. The Norwegian fields were larger, much more productive and on average in shallower waters. Petrobras, however, had the advantage of lower labour costs and apparently the advantage of a cost-efficient development style. When using fixed platforms, Petrobras needed an oil price (a break-even price) of USD 14 (1985) to turn a profit – roughly in line with the USD 16-20 required from fixed platforms in the North Sea. Using subsea systems and floating production, Petrobras could turn a profit with prices running at USD 8-10 and no more than USD 6-7 at the prolific Piuhana field.[632]

On the Norwegian shelf, floating production first arrived at the main fields in the shape of tension-leg platforms (TLPs). Above the surface, a TLP resembles a regular platform such as the integrated Condeep designs: a huge concrete structure with living quarters, production and processing works. These platforms, however, had no gravity foundation, but floated on air-filled tanks. The topside structure was firmly fixed to the seabed with hollow steel tubes (tethers) and not subject to heave. Aker had advocated the concept since the mid-1970s. The first TLP was introduced on the British shelf in 1984, with no link to Norwegian industry at all.[633] Saga Petroleum A/S, a privately owned Norwegian company, looked into the concept for use on Snorre, a reservoir discovered in 1979 at 300-350 metres of water. The company spent almost a decade considering how to develop the field in which Hydro and Statoil were in the licensee group. In 1987-1988, Hydro advocated a floating installation against fierce opposition from Statoil. Saga eventually settled for the mid-way solution, a tension-leg platform.[634] A couple of years later, Conoco ordered a TLP for Heidrun.

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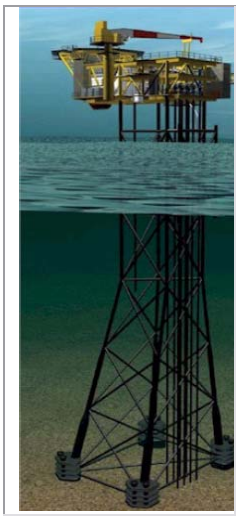
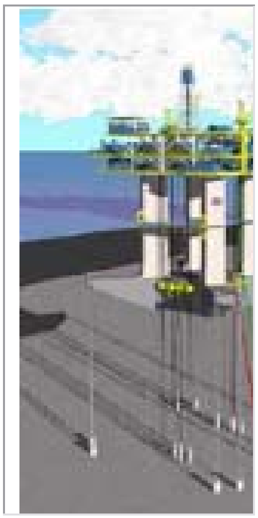
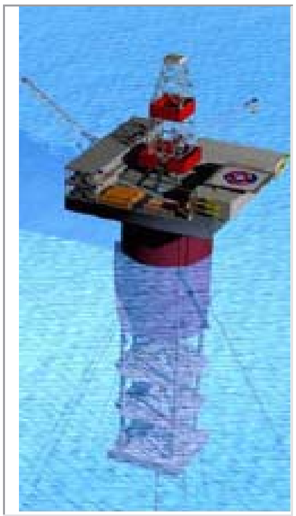
[632] Zephyrino Machado, "Utbygging av mindre felt kan gjøres mye rimeligere", *Offshore-Norge* 1985, p. 6.

[633] Smeby's private papers, Smeby "A Norwegian activity on subsea completion / deep water production systems", 11 November 1975.

[634] Engen, "Rhetoric and realities", referring a.o. to interview with Jan Wennesland, (Aker Maritime), 14 November 1997.

Figure 41) ***Basic platform designs for deep waters***[635]

	Compliant steel structures[636]	**Tension-leg platforms**	**Spar**
First devised	1960s	Conceived in 1970s, deployed in 1984	Mid-late 1980s
Theoretical depth limit	1 500 feet	4 000 feet[637]	7 500 feet
Actual (2002)	1 000 feet	3 000 feet	4 800 feet
			

As conceptual halfway points between fixed and floating production facilities, TLPs resembled the *Spar*-type installations developed on the

[635] Drawn mainly from Pieter Wybro, "Floating production system: Deepwater development options" (paper presented at MTS Field development workshop, Houston, September 28-30 2004). The illustrations are adopted from Wallace, Duberg, and Kirkley, "Dynamics of the oil and gas industry in the Gulf of Mexico: 1980-2000: Final report".

[636] A compliant structure attempted not to withstand the forces of the ocean (as did Condeeps) but to ride off the forces. These structures oscillated, albeit not at a frequency that threatened to break down the platform. For an introduction, cf. Pratt, Priest, and Castaneda, *Offshore pioneers*.

[637] Wallace, Duberg, and Kirkley, "Dynamics of the oil and gas industry in the Gulf of Mexico: 1980-2000: Final report".

British shelf and used mainly in deep water in the Gulf of Mexico.[638] Both techniques did away with the huge foundations required for gravity platforms and, when firmly moored, the Spars and TLPs suppressed heave to a point where the operator could use dry valve trees on top the platforms. In harsh weather, however, the moored platforms would sway.

* * *

The logical succession to Spars and TLPs was truly floating – and moveable - production facilities: semi-submersible production rigs and floating production, storage and offload (FPSO) ships. Semi-subs had limited storage capacity and relied on storage tankers or export pipelines to offload its oil; FPSOs resembled tankers with production equipment mounted on the deck and storage tanks beneath the deck. Unlike fixed installations, these floaters required complementary deepwater technologies; because they were subject to heave, they required subsea systems; because they were subject to sway, they frequently employed dynamic positioning to supplement their mooring lines. In no small part, floating production was limited by the shortcomings of complementary deepwater technology.

Moveable production platforms gained ground on the Norwegian shelf in line with the growing acceptance of subsea systems. Their introduction in the mid-1990s was eased by years of experience with subsea systems and the fact these subsea systems worked quite well; the technology started to look reliable. Elf's installations around Frigg initially suffered from some minor leakages of methanol and hydraulic fluids and some shortcuts in the electro-hydraulic control system, but mostly, however, the systems worked well.[639] North East Frigg was completed in late 1983 and began producing six to seven million cubic metres of gas per day in 1984. It continued to work without major problems until the reservoir ran dry in 1997. The hydraulics would occasionally leak, and there were certain problems with flexible pipes, but it worked.[640] Gullfaks A went on stream on 22 December 1986.

[638] On platform developments from the perspectives of suppliers, cf. Pratt, Priest, and Castaneda, *Offshore pioneers*. For a general history of technology offshore, cf. Veldman and Lagers, *50 years offshore*.

[639] ”Suksess for Elf med Superskuld-test på Andenes”, NTB, 14 August 1987; ”Produksjonsplattform på havbunnen”, NTB, 6 August 1987; Nina Skram Gil and Eyvind Grude, "Driftserfaringer fra nord øst frigg og øst frigg" in Undervannsteknologi frem mot år 2000: Hvordan kan 80-årenes erfaringer omformes til en ny strategi for teknologivinning og nye metoder for prosjektgjennomføring (Stavanger: Norsk Petroleumsforening, 1991).

[640] Ibid.

The four subsea wells turned out 50,000 barrels of oil – more if not for bottlenecks in the adjacent topside systems.[641] Statoil had calculated the subsea systems would work 85 per cent of the time – after one year of operations their regularity was close to 100 per cent. The total costs of the subsea development ran at NOK 1.5 billion offset against an annual increased output worth NOK 2.5 billion regardless of low oil prices in the late 1980s.[642]

By 1990, subsea systems not only seemed reliable, but their introduction allowed relatively speedy and inexpensive field development. Both Tommeliten and East Frigg had been completed *below* budget and *ahead of* plan.[643] Tommeliten began shipping gas to Ekofisk less than two years after the project was initiated, 25 per cent below budget and only half as expensive as the calculated cost of a platform-based development.[644] The subsea systems that extracted gas from Troll to increase reservoir pressure at Oseberg began working eight months ahead of plan and contributed NOK 10 billion in extra revenues by increasing the output of oil from Oseberg.[645]

What transformed the perceivably unreliable systems of 1980 into the reliable systems of 1990? Ironically, in no small part, the answer was "nothing". Part of the problem had been psychological; people trusted what they saw and distrusted systems out of reach. Part of the problem was false analogy; practical people of the oil industry knew valve trees above surface

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[641] Svein-Erik Tosterud, "Havbunnsbrønner gir gullfaks flyvende start", *Teknisk Ukeblad*, 2 April 1987 1987, pp. 12-13.

[642] Svein-Erik Tosterud, "Havbunnsbrønnene på gullfaks tjener penger", *Teknisk Ukeblad*, 28 January 1988, pp. 32-33.

[643] "Øst-Frigg-utbyggingen redusert med 20 prosent", NTB, 10 December 1987.

[644] The estimate for a fixed platform development ran at NOK 5.5 billion (1985) not including the cost of drilling. The subsea development cost NOK 2.8 billion (1987) excluding drilling but including the work spent rebuilding a platform at Ekofisk to accommodate the output from Tommeliten, cf. "Ros til Statoil for Tommeliten-prosjektet", NTB, 1 December 1988. On the project in general, cf. H. Hatlestad, "Feltutbyggingsløsninger: Tommeliten" in Kostnadseffektive utbyggingsløsninger under nye rammebetingelser (Grand Hotel, Oslo: Norwegian Petroleum Society, 1986).

[645] That is 12 million tonnes of oil at 1991 prices; the cost of the project ran at NOK 3.2 billion (1991) plus another billion to rebuild Oseberg. It was expected that some four-fifths of the injected gas would be extracted towards the end of the Oseberg project. Claude Roland Olsen, "Mer olje ut av Oseberg", *Dagens Næringsliv*, 25 January 1991.

were susceptible to hick-ups, and assumed subsea systems would be even less reliable. The reverse was more likely true. Equipment onboard platforms tended to fail. Once on the seabed, inaccessible for clumsy roughnecks, the same equipment worked better. It seemed that much of the servicing and maintenance tended to upset, rather than smooth, the working of valve trees.[646] Besides, in anticipation of the need for maintenance, the industry had added complexity to the subsea systems. TFL techniques (where tools circulated through the system in a U-tube) were a case in point; they required dual flowlines and dual completion that limited the dimensions of the tubing, required more components, more complexity, and less reliability – and some extra space on the production platform.[647] Often, the best maintenance strategy was building a simple and robust system, and a philosophy of "let it be, and intervene only when necessary".

Some new techniques did take hold and served to make subsea systems more reliable. Modular designs that allowed oil companies to remove active components for servicing, as pioneered with Skuld in the early 1980s, became a permanent feature of subsea systems.[648] The industry also placed increasing emphasis on redundancy and designs that allowed workarounds – ways of keeping a system operational despite a single point failure. Finally, the performance of subsea systems improved steadily due to utterly ruthless quality control. In sum, a less interventionist maintenance strategy combined with steady improvements in design served to allay many concerns about subsea systems – and pave the way for more nimble development styles.

* * *

Almost 20 years after the Brazilians employed floating production, and almost ten years after Hydro employed a ship for early production, movable floaters arrived in earnest on the Norwegian shelf. The figure below shows how floating production gained acceptance globally and what technology the industry employed – particularly the success of FPSOs and semi-submersibles. These could move from one field to another and exploit marginal fields that ran dry in a few years. In principle, they would work at any depth. Offshore Norway, they began to arrive in the mid-1990s on the

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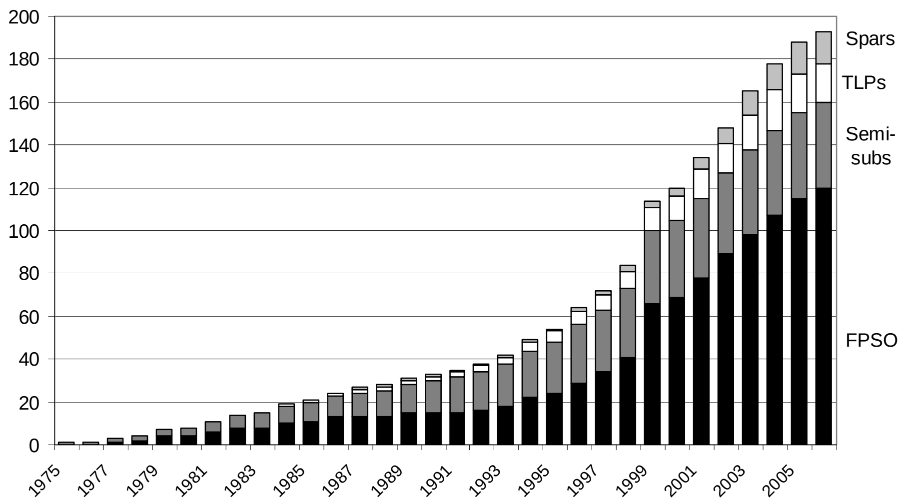
[646] Interview with Halvorsen, 4 October 2004.

[647] Tore Andvig, "Present development and trends for production in the Norwegian sector of the North Sea", in Offshore Northern Seas Conference and Exhibition (Stavanger: Norsk Petroleumsforening, 1986); Tosterud, "Havbunnsbrønner gir gullfaks flyvende start".

[648] Haslestad, "Kostnadseffektive teknologiske byggeklosser: Subsea løsninger".

somewhat deeper waters of Norne (380 metres of water depth), Visund (335 metres), Balder and Åsgard (240-300 metres).[649] These fields were located in the Norwegian Sea far north of the platforms and pipelines in the North Sea.

Figure 42) ***Mobility beats stability: floating platforms installed, 1975-2006***[650]



The shift to floating production placed a premium on speedy subsea completion. In the 1980s, an operator ordering a subsea system for a new field on the Norwegian shelf would not be much concerned about delivery times: the building of an adjacent platform would require more time than any subsea development. Floating production concepts could arrive quickly; the oil company would hire a semi-sub from a shipping company or ask a yard to convert an existing tanker into an FPSO.[651] Hence, the time spent building

[649] The annual fact sheet and the various web pages of the Norwegian Petroleum Directorate, www.npd.no offers an excellent overview. For some additional insights in the Balder development, cf. *Balder, north sea northern, norway* [Industry portal] (SPG Media Limited, [cited April 2007]); available from http://www.offshore-technology.com/projects/balder/.

[650] The figure is inspired by, and has drawn much data from a graph assembled by James R. McCaul, *Growing requirement for floating production systems* (May 2006) (International Maritime Associates, Inc., 2006 [cited January 2008]); available from http://www.imastudies.com/id25.htm.

[651] J. Rosnes, H.J. Lindland, and O. Inderberg, "Subsea production systems: Improve cost efficiency and further reduce cost per barrel produced" (paper presented at Offshore Technology Conference, Houston, 5-8 May 1997), pp. 155-163.

and installing a subsea system became all the more critical. Since fast development meant fast revenues, and frequently cost savings, the supplier industry had every incentive to continue developing modularized, standardized subsea systems.

The shift of development styles and the introduction of floating production coincided in time with an overall standardization drive on the Norwegian shelf – and subsea standardization was in the forefront. The single most vivid manifestation of the general effort was the 1993 Norsok programme where public authorities, oil companies and suppliers agreed on measures in a corporatist manner. Inspired by a preceding programme on the British shelf (CRINE), Norsok aimed to cut life-cycle costs and encourage reuse of equipment. The outcome of the programme was a series of initiatives to standardize technology and improve the collaboration between users and producers.[652] Possibly the most important impact of the programme was the systematic use of EPC contracts, an approach long established when ordering subsea systems. Norsok also encouraged cooperation on standards. The programme, we may say, sanctioned as best practice what Kongsberg Offshore had been doing with Shell, Conoco and Statoil since 1990.

8.3 Norne and the concept of interchangeable modules

When floating and movable production started to arrive, the market for subsea systems looked set to expand. Kongsberg Offshore was well positioned to take advantage of the opportunity, but feared competition. To improve its chances, the company added an innovative touch that added flexibility to Statoil’s ordering procedure.

Statoil’s first FPSO for permanent use was devised for Haltenbanken (*Norne*). Between 1994 and 1997, Statoil equipped a ship that resembled a regular tanker with a processing plant on the deck, storage capacity in the hull and facilities to offload oil to a tanker on its heck.[653] Oil would flow from the subsea system through a flexible riser onto a giant cylindrical turret in the hull of the production ship.[654] After being processed, a pipe carried the oil across to another ship for storage and offloading. Another pipe carried gas from Norne to the nearby *Åsgard* field.

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[652] On the British inspiration of for the standardizing Norsok drive, cf. Ryggvik, "Norsk oljevirksomhet mellom det nasjonale og det internasjonale".

[653] Norne (Norsk Teknisk Museum, 2005 [cited April 2007]); available from http://www.histos.no/oljemuseet/vis.php?kat=&id=38.

[654] *Facts 2007* ([cited), p. 119.

For Kongsberg Offshore, the Norne opportunity arrived at a most welcome time. By 1994, work on Heidrun would be finished and Kongsberg Offshore lacked orders to fill the slack. Oil prices slumped in 1993 following a period of high prices in the wake of the 1991 Gulf War. Several field developments on the Norwegian shelf were postponed.[655]

Although Statoil and Kongsberg Offshore had a close rapport, the subsea supplier faced stiff competition. Companies like ABB and Kværner had proved to be efficient in planning and administration, and the competitors quickly learned tricks from one another.[656] To gain an edge, Kongsberg Offshore offered Statoil a simplified ordering procedure for subsea systems – in effect a catalogue of parts and prices.

The innovative act at Norne was to make options in the assembly process sufficiently transparent for customers to become involved. The subsea engineers decomposed a subsea system into component parts, posted clippings of parts on a board, reassembled the pieces in a document, and put a price on each part based on recent assignments. Unlike a tender, the catalogue involved customer choice. Statoil could choose from a limited number of optional parts and add-ons centred on a Christmas tree. The approach allowed economies of scale while Statoil retained a feeling the system could be tailor-made or at least configured to fit evolving needs. Statoil liked the approach and signed a deal with Kongsberg Offshore in April 1994. The transparent approach to pricing allowed Statoil to circumvent the hassle of a tender and choose a supplier early.[657] Statoil ended up buying five templates with 14 Christmas trees from the Norne catalogue.[658]

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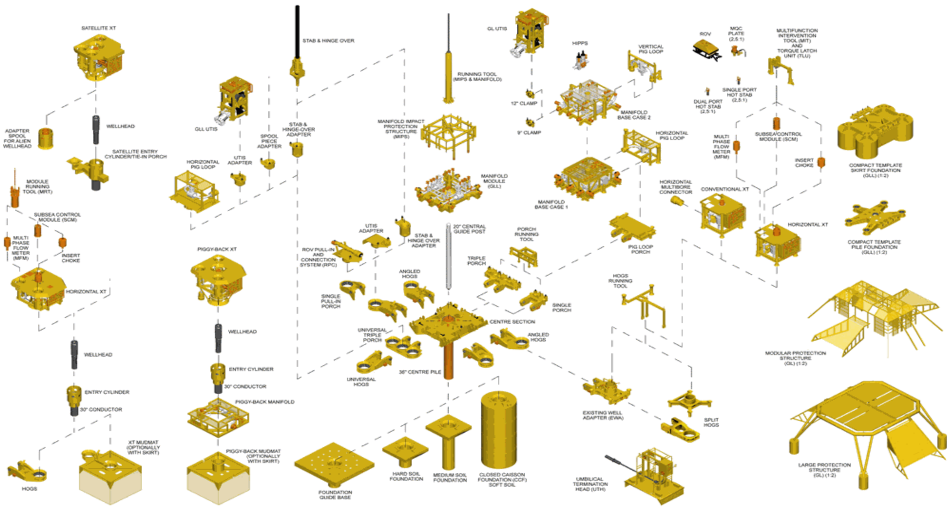
[655] CA-FMC-board, 1993 annual report.

[656] Daling et al., *Offshore Kongsberg*.

[657] Nina Olkvam, " Norne-oppdrag plassert ", *Dagens Næringsliv*, 14 April 1994.

[658] Steenstrup's private papers, orders overview.

Figure 43) ***Seabed Lego: a decomposed subsea system***[659]

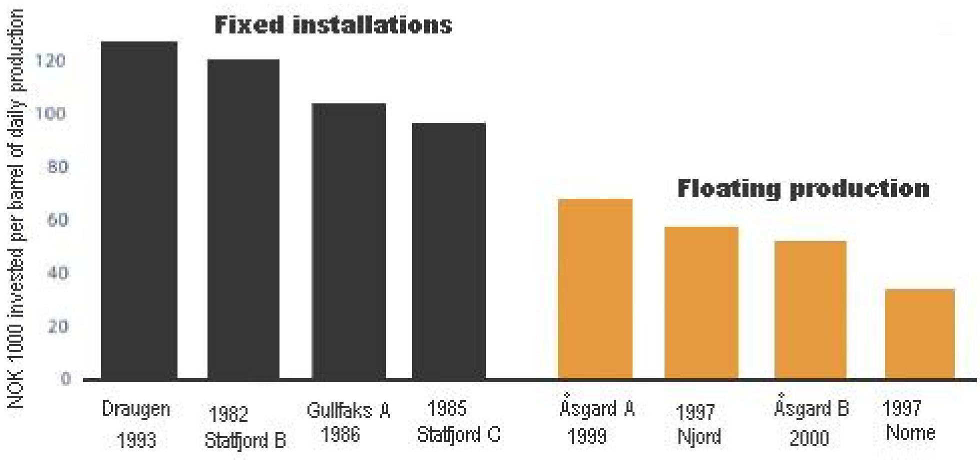


Norne marked the beginning of a new area. Before Norne, Condeeps had been the dominant development styles for new fields. The radically lower costs of floating production put an efficient stop to Condeeps on the Norwegian shelf and indeed everywhere. The figure below shows what investments were required to extract oil from gravity platforms and floaters. [660] Although floating production saved costs, Statoil initially struggled to develop floating concepts on time and budget. Several production ships were delayed and there were numerous cost overruns. A cost overrun at Åsgard forced Harald Norvik, the managing director of Statoil, to resign in 1999.

[659] Steenstrup’s private papers, Steenstrup, "The changing philosophy of contracting: An international perspective".

[660] On the overruns, cf. Knut Kaasen, "Analyse av investeringsutviklingen på kontinentalsokkelen", *NOU*, (1999).

Figure 44) ***Cheap and floating: investment per barrel for fixed and floating installations***[661]



The cost overruns that did follow rarely related to subsea systems. By 1994, Norwegian subsea developments were cheaper than projects elsewhere in Europe and the industry was on track to achieve global cost leadership.[662] Tellingly, the cost reduction drive had only just begun.

8.4 HOST and the second standardization drive, 1995-1998

At Norne, Kongsberg Offshore offered products from its existing portfolio – developed largely by FMC. The new managing director, Tore Halvorsen, knew the potential of further standardization and modularization of subsea equipment.

In the wake of the low oil prices that that curbed exploration activities in the mid-1990s, a new opportunity arrived: the day rates of drilling rigs fell much below the rates for heavy cranes and other specialized construction vessels. By substituting the former for the latter, oil companies could develop subsea fields cheaply. Drilling rigs employed cranes centred on a hole in the middle (a *moonpool*), but a standard moonpool was designed to lower drillbits and strings, not large subsea equipment. Halvorsen thought of a subsea template with foldable wing elements that would unfold only when the equipment was

[661] The figure appears in a government white paper (St.meld 38. 2003-2004) with Statoil credited as the original source.

[662] Arnt Even Bøe, ”Oljeselskaper samarbeider: billigst i verden på havbunnen”, *Stavanger Aftenblad*, 15 October 1994.

in place on the seabed. A drilling rig might lower such a system through its moonpool and save considerable sums. In the mid-1990s, Kongsberg Offshore introduced a range of equipment named *HOST* - acronym for “hinge-over subsea template”.

HOST enticed Statoil, partly because the system allowed 40 per cent savings on installation cost, but also because Kongsberg Offshore offered to cut the hardware cost by a further 25 per cent.[663] In July 1994, the oil company contributed NOK 40 million to finance half the costs of a three-year development programme. Six months later, Mobil signed on as partner. Elf and Shell joined in October 1995. In total, Kongsberg Offshore raised NOK 110 million from oil companies to develop HOST.[664]

Part of the project was the design of a single versatile, high-capacity Christmas tree, made by FMC. Although the quality and the capabilities of the tree were excessive in many circumstances, the approach allowed Kongsberg Offshore to cut back on the time spent doing expensive tailoring. The engineers thought their standard solution would be applicable for 70-80 per cent of the future field developments. At the time, HOST was developed, Statoil and Kongsberg Offshore still thought there were arguments for two different standards: one for marginal fields with a short life where priority was on keeping costs and risk down; another standard for prolific reservoirs where the emphasis was on high availability and maximal recovery. The prolific fields could justify development projects.[665] Over time, however, components used for the high-end standard migrated onto marginal fields as the cost advantages of standardization and volume manufacturing outweighed the cost of such items as higher-grade steel. HOST helped to make subsea equipment more affordable.

The most thorough redesign related to templates: the frames that offered protection and support for subsea equipment. Before the mid-1990s, each subsea project usually involved a purpose-built template. From lack of experience and analysis, people preferred to play safe, built structures that could withstand any impact and made the templates large enough for divers or remotely operated underwater vehicles to inspect and repair the system within. Besides, the Norwegian Petroleum Directorate insisted subsea systems should sport a protective structure capable of withstanding a force of

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[663] Interview with Halvorsen, 4 October 2004.

[664] Daling et al., *Offshore Kongsberg*.

[665] Rosnes, Lindland, and Inderberg, "Subsea production systems: Improve cost efficiency and further reduce cost per barrel produced".

100 tonnes in any direction, equal to the impact of a trawl.[666] The requirements made the templates difficult and time-consuming to install, inspect, retrieve and maintain. In the 1990s, the arguments for large and solid templates seemed outdated. The emphasis had shifted from repair by divers and ROVs to modular structures whose individual parts could be hauled to the surface for repair or replacement. Besides, the rules that specified a subsea system should withstand a trawl were reinterpreted to allow structures that would simply deflect a trawl.[667] Doing away with excessive protection, the HOST project cut template weight from 600 tonnes in the 1980s to less than 100 tonnes. This allowed for a degree of "serial" production and cut the time and effort required for installation. The company in charge of the completion could ship the template using ordinary supply vessels or even an aircraft.[668] Time spent installing a compact HOST system was only seven days compared to almost a month for conventional subsea completions.[669]

A second novelty of the HOST template was its increased flexibility. In the 1980s, Kongsberg Offshore made systems with specially designed components to fit the field and the operator's tastes. Beginning with Draugen, Kongsberg Offshore succeeded in standardizing subcomponents - the nuts and bolts of the system. As exemplified with the Norne "catalogue", this approach could accommodate a degree of choice by allowing the customers to select from among interchangeable components that fitted like pieces of Lego. The Host equipment took this principle a step further by introducing the Lego principle not only to subcomponents, but also to the basic building blocks of a subsea system – the design allowed oil companies to play with big Lego pieces to do actual field design. When drilling began at a given field, the initial seismic results may have indicated the need for four wells. The oil company would then order a template and drill four wells through that template; once the template was down, the field layout could not be changed. HOST, however, allowed the operator to change plans while developing a field. While drilling outside Equatorial Guinea, Mobil made extensive use of this feature. Mobil drilled one well and tested the output. Based on the test results, they decided where to drill next. The company made 90 changes, without delay or additional costs, before the 40 wells were

[666] Andvig, "Present development and trends for production in the Norwegian sector of the North Sea"; Haslestad, "Kostnadseffektive teknologiske byggeklosser: Subsea løsninger".

[667] Interview with Halvorsen, 4 October 2004.

[668] Daling et al., *Offshore Kongsberg*.

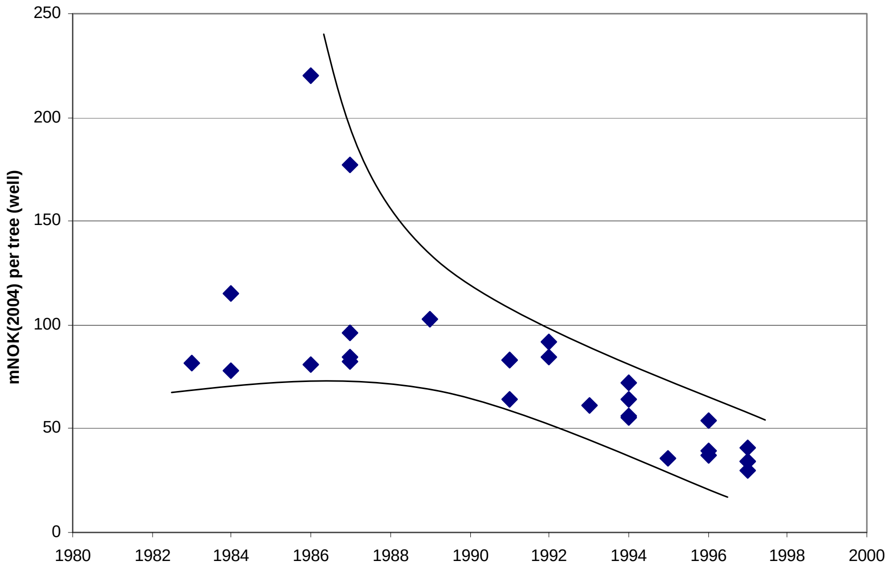
[669] "Statoil: Kongsberg Offshore vant overlegent på pris", NTB, 28 August 1995.

in place. Some of the wells were on templates, some were separate wells tied in to manifolds.[670] To achieve this kind of functionality, the component parts of the HOST system had to be versatile, e.g. by allowing flowlines to be attached from opposing sides. In the years that followed, Kongsberg Offshore kept adding orders for its HOST technology, not only from Statoil but also from Mobile, Hydro, Agip, Elf and others.

The steady modifications made subsea systems smaller, more standardized and modularized, and significantly affected the cost of building such systems. The figure below plots the price of subsea systems on the Norwegian shelf (inflation adjusted price per completed well not including drilling, installation, umbilicals, topside work and flowlines). Several objections could be voiced regarding the plotting – appendix 11.10 explains how the numbers are arrived at – but although any single observation may be inaccurate, the trend itself is not in question: prices were falling and the price corridor narrowed - a sign the systems were becoming more standardized. In a decade, the hardware costs fell to less than a third of its former level. Meanwhile, the variance between expensive high-end systems and regular systems almost disappeared.

[670] C.P. Henderson, "Host to innovations in subsea technology", *Scandinavian oil-gas magazine*, 1998, pp. 12-15 Interview with Halvorsen, 4 October 2004.

Figure 45) ***Down the drain: price of standardized subsea system, 1982-1997***[671]



Reduced construction costs were but one of the circumstances that caused a fall in prices. Changes on the side of demand were equally important. By the mid-1990s, general-purpose subsea systems for moderate waters (e.g. HOST) had become reliable and fairly standardized. The standardization effort that helped make the subsea systems reliable and less costly to manufacture turned the systems into more of a commodity – simpler to order and simpler to compare in terms of pricing. Oil companies have been looking more to prices and less to technological excellence and other "soft" issues when awarding contracts. The ability of to oil companies to compare and calculate prices improved, and the prices tumbled albeit from a very high level.

8.5 Steady improvements in dynamic positioning

While subsea systems continued to drop in price and improve in quality, something similar occurred with marine electronics as exemplified by Albatross. Dynamic positioning improved considerably and improved the fortunes of anybody involved in mission-critical operations involving floating vessels.

[671] For sources and methods, please refer to appendix on page 222: Calculating the price of a subsea system.

Since the onset in the 1960s, the reliability of dynamic positioning has improved continuously. When the world's first dynamically positioned vessel, *Eureka*, was assembling ocean-floor core samples in 1961, the operator experienced 20 per cent downtime (the *Eureka* would still gather several times as many core samples per day as her anchored rivals and from much greater depths). Since then, drillship operators have sought to reduce downtime. DP drilling vessels introduced dual or triple redundancy in points of frequent failure, and by the early 1980s, leading firms showed a consistent average of one position failure or disconnect every six months. Due to damage and delay, such incidents cost an average USD 1 million (xxx) in 1983[672] and served to keep the industry focused on reliability. In 1990, the first attempt to drill from a dynamically positioned vessel in Norwegian waters actually ended in a drift-off and the rig lost position outside Sognefjorden.[673] A fault in the (non-redundant) power distribution panel caused an engine failure, although the Albatross system worked fine in isolation. Indeed, computer failures had become a rarity.

From 1987 to 1997, improvements in computing and satellite navigation made the DP systems more reliable. To gain a reliable position reference, the industry increasingly put its trust in Navstar global positioning system (GPS). The navigation system was launched by the US Navy in the 1980s, and for a while the armed forces added signal errors. Nevertheless, civilian users found ways of improving accuracy. The deviation could be handled by *differential GPS* – a service that measured the distortion and broadcasted a correction (any observation in a whole region would be distorted in a similar fashion – e.g. 30 metres north of the true position). In the 1990s, American authorities abandoned the policy of scrambling and offered civilians access to signals with nearly the same accuracy as military users.[674] This offered a boon for precise offshore navigation.

The figure below plots how prices on dynamic positioning systems have tumbled while the reliability of the systems has improved. The common measure for reliability is mean time between failures (MTBF) – a statistical measure indicating the number of months a vessel can work before a freak

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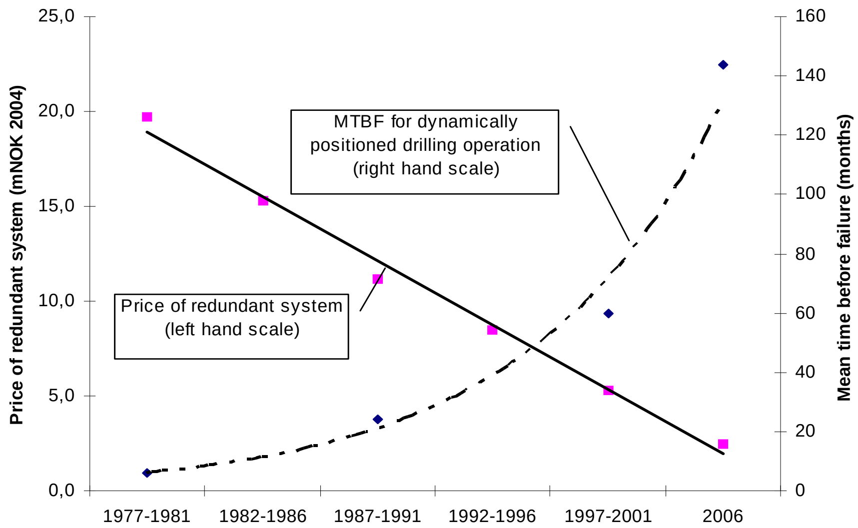
[672] Shatto, "Reliability and risk analysis".

[673] Interview with Røkeberg, 9 May 2006; Asgaut Næss "Boring ved Sognefjorden", *Dagens Næringsliv*, 22 August 1990; Svein-Erik Tosterud, "Yatzy borer i høy sjø - uten oppankring", *Teknisk Ukeblad*, 22 November 1990, pp. 8-9.

[674] Slightly revised from Wikipedia's entry on GPS, cf. http://en.wikipedia.org/wiki/Gps.

incident cause a loss of position.[675] In the course of three decades, the systems became 50 times more reliable. If previously, the DP would lose position every third month, the typical incidence has reached once every 10 or 15 years. Meanwhile, the price of a high-end system fell by 90 per cent (down to one tenth) in real, inflation-adjusted, terms.

Figure 46) ***Cheaper and more cheerful DP: falling prices and improved performance, 1977-2006***[676]



At first sight, the link between prices and quality seemed counter-intuitive – one would expect high quality to mirror high prices. However, the basic technological advances in computing and navigation that made dynamic positioning more reliable also simplified the process of making a DP system,

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[675] Shatto, "Reliability and risk analysis".

[676] Historic data on MTBF are drawn from Ibid. On the reliability of dynamic positioning in 2004, cf. *Dp trends and traits* (2004 [cited April 2007]); available from http://www.kingdomdrilling.co.uk/drillops/equipment/DWDP01.pdf. The pricing data are calculated top-down by dividing tunover (cf. figure page 270) by the number of sales (cf. figure page 192). Prior to this calculation, I have subtracted revenues from aftersales (rising from nothing to roughly one third of turnover) – actual numbers where these are known and assumptions where they are not. The prices arrived at through this calculation correspond closely with the estimations of various people offered in interviews with the author and with those references that are found in the historical project archive of Kongsberg Maritime(CA-KM-hist).

lowered the barriers of entry for new suppliers and put pressure on prices. Since a marginal rise in the number of competitors pushed the prices down, while a marginal rise in the number of customers affected the price less, potential new entrants put a lid on prices.

At the high end of the market, the competitive pressure was less pronounced. The tearing of a riser during drilling caused downtime, possible rig damage, and a remote possibility of losing control of a well. In 1997, the average mishap would set the operator back about NOK 15 million.[677] Customers facing such risks were reluctant to compromise on quality.

At the low end of the DP market, an increasing number of companies began offering joystick systems (easy thrusters control) linked to autopilots. With little redundancy and heavy reliance on GPS, such systems were much easier to design and build than fully redundant systems. Robertson Radio Elektro (RRE) in Egersund, Norway, competed in the low end of the DP market from 1986 onwards.[678] Simrad bought RRE in 1994, but after a few years of internal strife, the stripped-down DP version was withdrawn from the market in order not to cannibalise the high-end products. Rather than giving in, the main proponent of the mini-systems, Jan Arild Mikalsen, left Egersund for Louisiana and set up a competing company, Marine Technologies LLC, sponsored by Edison Chouest Offshore.[679] This business has sold a number of systems to workboats on the Mississippi. Meanwhile, thruster manufacturers such as Brunvoll and Rolls-Royce Marine PLC (formerly Ulstein) added DP capabilities to the operating system that modern ship engines use to guide propulsion.[680]

Interestingly, the margins enjoyed by Albatross have not suffered much in three decades despite of falling prices. A major innovative effort of

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[677] Shatto, "Reliability and risk analysis". The calculation uses an exchange rate of 7.3 – cf. *Statistisk Årbok 1997*, Norwegian Bureau of Statistics.

[678] KV acquired RRE in the mid-1970s, but sold the business to Bird in 1984. From 1986, the Bird group offered simple and less expensive positioning products, somewhat in competition with Albatross, cf. KV-ex10, memorandum on strategic issues and action points, early 1986.

[679] Some brief information can be found on the Marine Technologies home page http://www.marine-technologies.com/contact.htm, but I rely mainly on Helle, interview with Helle, 14 April 2005. Jan Mikalsen, *Marine technologies news* [Newsletter vol. 13] (Edison Chouest Offshore, 2004 [cited May 2007]); available from http://www.chouest.com/Newsletters/Vol_13.pdf.

[680] Interview with Helle, 14 April 2005.

Albatross has been to identify sufficient savings to offset falling prices. After the crisis of 1986, some gains occurred simply from scaling back on discretionary spending and from the introduction of financial discipline. Albatross, furthermore, made large gains by sourcing technology. The company saved considerable sums by replacing the KS 500 computers,[681] partly because computers based on off-the-shelf chips were cheaper, but also because new hardware required less maintenance. Since then, the price of computer components and position reference systems has kept falling.

Another category of savings originated with internal efficiency. For each additional installation, and each problem solved, the team gained in experience. Albatross assessed new jobs more exactly and completed these tasks faster, with less hassle and fewer cost overruns. Routines, too, played a part. By consciously designing the procedure for a customer acceptance test – the final check of the DP systems to assure every process and subsystem was functioning smoothly – Albatross cut back on the number of man-hours involved. In 1989, testing a complex, triply redundant system at a yard might require 300-400 hours of testing. By consciously focusing on getting things right the first time and assigning responsibility for the correction of faults in subsystems to the relevant supplier, the time spent testing came down to 30-40 hours in a few years.[682] From about 1986, Albatross invested in software to configure the systems. We recall how Albatross relied on Balchen's approach, which required a mathematical model of the ship to predict how the ship would respond to e.g. one knot of stream from a certain angle. A model designed in advance cut back on the need for extensive and expensive work on board the vessel.[683] In the course of more than a decade, Albatross refined software tools that helped configure the DP system prior to delivery.[684]

The strongest pressure on prices affected the less advanced DP systems sold to customers with some tolerance of fault. Today (2008) a talented programmer can probably assemble a working DP solution with tolerable performance from off-the shelf equipment, particularly a GPS and a personal computer.[685] By the late 1990s a simple system consisting of a single

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[681] Cf. KV-Cor 238, Albatross board minutes, 17 October 1985.

[682] CA-KM-sup, newsletter, Tross'ern September 1992.

[683] KV-Cor 238, Albatross board minutes dated 27 June 1985 and 17 October 1985; interview with Sælid, 12 October 2004. On the model-based approach to dynamic positioning, cf. page 88.

[684] Interview with Helle, 14 April 2005.

[685] Interview with Sælid, 12 October 2004, and with Jenssen, 14 October 2004.

computer getting data from a single GPS receiver could be designed and implemented with comparably few resources and nevertheless provide accuracy and reliability in excess of anything in 1985. Such "small" systems have been able to gain markets, albeit not in the high end of the market where the classification regime required strict standards of redundancy.[686] Redundant systems are hard to program. Class 2 and class 3 certificates called for mutually independent position reference systems capable of validating or replacing inputs from navigation satellites. These might, on very rare occasions, malfunction in ways that were hard to detect. An even harsher requirement in the classification regime is the demand for *Failure Mode and Effect Analysis*, i.e. the identification of what maximum environmental forces (wind, stream) a vessel could handle before a worst-case failure turned disastrous.[687] In effect, a system capable of doing this would have to adapt the approach of Albatross and build a computer model of the vessel in question.

Apart from any increase in demand that occurred as a result of improved quality, Albatross also faced less hostile market conditions in the early 1990s. The oil price recovered sufficiently for oil companies to take a fresh look at exploration. The price of used jack-ups and semi-submersibles doubled or even tripled from a low around 1989-1990. Exploration was the bellwether of recovery and Simrad Albatross got numerous orders for upgrading and replacing old equipment.

While Albatross continued to deliver dynamic positioning to petroleum support vessels, a new market emerged on the processing platforms – increasingly oil production took place on floating structures with qualities and challenges that resembled those that faced a ship.

8.6 Albatross into the oil industry's core

The investments that went into oil infrastructure dwarfed the cost of building offshore support vessels. The introduction of nimble production technology provided numerous opportunities and turned Albatross Integrated Multifunction System (AIM) into the most important product in the Albatross portfolio.

[686] On redundancy, cf. page 119.

[687] Interview with Røkeberg, 9 May 2006. A worst-case failure would typically involve the failure of an engine.

Introducing a new system to the oil industry was a tedious task. In principle, there was no lack of tasks for AIM. The system could monitor and improve a range of functions including heat, water and ventilation, ballast, processing of oil and gas, power generation, pumps and drilling equipment along with various systems designed to detect leakage, tension and fire.[688] However, contracts were hard to get by without prior experience in offshore process automation.[689] All the more important when Statoil awarded Simrad Albatross a NOK 30 million contract to install AIM 1000 on the three platforms at Statfjord in December 1989.[690] Statoil cited reliability as the most importantly consideration guiding its choice.[691] Albatross may well have been competent, but the breakthrough assignment on Statfjord depended in no small part on strategic considerations as Statoil sought to decrease its dependence on systems from Siemens. Whatever the leitmotif, Albatross proved perfectly capable. In just 15 days during 1991, the albatrosses tied together 60 single board computers monitoring 3300 signals on a *hot* platform – that is a platform in full operation. Albatross Managing Director Løkling relished the experience and foresaw more jobs with offshore process control.[692]

The Statfjord platforms were massive Condeep constructions – a huge complex on an immovable foundation. The main competitive advantage of Albatross related to the new generations of platforms that were floating. In such environments, Albatross found more applications of its know-how. In 1991, Albatross received an important contract supplying Snorre – Saga's tension leg platform – with ballast control. The ballast and bilge control system (BBCS) guided the process of installing the floating platform. During installation, BBCS controlled the filling of ballast tanks. This lowered the platform down to a position where hull and deck could be hooked onto the tethers. The system then emptied the tanks and allowed Snorre to hover. After the regular equipment was in place, BBCS pumped ballast around to stabilize the platform. While the platform began operations,

[688] Sogner's private papers, *Simrad Newsletter*, December 1993.

[689] KV-Cor 239, summary of strategy gathering, 27 January 1986; KV-Cor 238, Albatross board minutes, 2 September 1985.

[690] The installation replaced the platforms' SCADA (supervision, control and data acquisition) system, cf. page 51.

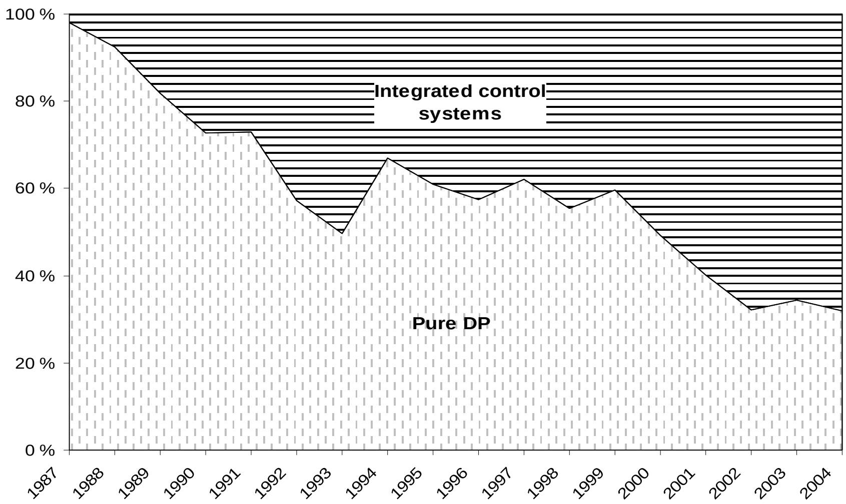
[691] Sogner's private papers, *Simrad Newsletter*, July 1990.

[692] CA-KM-Simrad, Simrad AS board minutes, 25 June 1991.

its software helped monitor the placement of tethers and collected data on tether stretch and tension in response to the environment.[693]

The less the operator relied on permanent structures, the more opportunities for dynamic positioning and complex process control. At *Heidrun* outside Trøndelag, Conoco decided to build a TLP. The field was beyond the reach of existing pipelines, and relied on tankers to ship the output. The operator decided to do without storage facilities and rely on just-in-time shipping with purpose-built tankers. These would pull an underwater buoy onto the hull and load crude almost regardless of the weather.[694] Between 1991 and 1993, Simrad Albatross secured a number of process control contracts for platform, subsea wells and tankers bound for Heidrun. The main process control contract was worth NOK 80 million - equipping two of the three tankers with dynamic positioning, power management, ballast management, alarms etc. earned Albatross another 34 million.[695]

Figure 47) ***Shift from DP to integrated deliveries, revenues 1987-2004***



[693] Sogner's private papers, Simrad Newsletter, September 1991.

[694] To assess the field development, or indeed the development of any major field on the Norwegian shelf, cf. Heidrun (Norsk Teknisk Museum, 2005 [cited April 2007]); available from http://www.histos.no/oljemuseet/vis.php?kat=1&id=22.

[695] "80 millioners kontrakt til Simrad", *Dagens Næringsliv*, 2 December 1991; "Simrad kontrakt på 34 mill.", *Aftenposten*, 24 February 1993.

Even larger opportunities arrived when the oil industry moved from gravity platforms and TLPs onto production ships and semi-submersibles. Such movable installations offered more opportunities and larger orders than anything related to fixed platforms. At Norne, Albatross supplied instrumentation, process control and safety systems for the production ship. At Åsgard, Albatross supplied a complete integrated automation system: position mooring equipment to keep the vessels in place, control systems for the equipment that processed oil and gas, training simulators, monitoring and metering equipment.[696] At NOK 110 million (Norne) and 100 million (Åsgard), these contracts were of a larger magnitude than anything Albatross had received previously.[697] The oil companies preferred to buy one integrated control system to keep the number of engineering hours down, simplify testing and save on maintenance.[698] The winner took all – and sometimes the winner was Albatross. The 1995 annual report claimed a 30 per cent market share for automation offshore. Outside Norway, however, Albatross rarely got such contracts except as an add-on to its thriving DP business.

For Albatross, the Norne and Åsgard contracts were harbingers of a closer relationship between customer and supplier. In the maritime shipping markets, suppliers and customers might enjoy cordial relations, but their relationship was contractual and carried few obligations except for delivery and payment. The constellations put together to perform offshore field development in the North Sea during the 1990s were different. The oil companies worked closely with their suppliers; deliveries could not always be specified in great detail ahead of the contract, and to keep up speed the oil company sat down with its suppliers to assist in making decisions on the run, cut development time and develop standards for wider use.[699] Statoil would grant block contracts and secure its partners a steadier flow of contracts in return for favourable terms of business. There was less need for the

[696] Sogner's private papers, *Simrad Inside*, issue 2, 1995; KMedu, *Kongsberg Simrad: Offshore and ocean survey products*, product brochure, 1998.

[697] "Milliardoppdrag for to Statoil-felt", *Dagens Næringsliv*, 9 January 1996; "Norne-kontrakt til Simrad", *Aftenposten*, 10 June 1995. The technological and particularly the organizational outlay of Åsgard is the subject of a recent PhD thesis, cf. Beate Karlsen, *Organisatoriske valg etablering og utvikling av nye arbeidsformer offshore*, Doktoravhandlinger forsvart ved det samfunnsvitenskapelige fakultet, universitetet i oslo nr. 67 ([Oslo]: Senter for teknologi, innovasjon og kultur, Det samfunnsvitenskapelige fakultet Unipub, 2007).

[698] Sogner's private papers, *Simrad Inside*, issue 2, 1995.

[699] Sogner's private papers, *Simrad Inside*, issue 2, 1995.

commercialism that had served Albatross well in previous decades. One sign of the times, possibly, came in 1993 when Løkling tired of management and left the position to Steinar Gregersen, who became Albatross's next managing director.

When Albatross succeeded in supplying integrated control systems to various floating production systems in the North Sea, its business began to resemble that of Kongsberg Offshore. After some twenty years of distinct business with distinct customers, the two converged towards the same kind of capitalism. Whether selling a subsea system for the seabed at Åsgard, or an integrated process control system for the various production ships anchored above that subsea system, the same rules applied.

8.7 Corporate winds of change

Both Albatross and Kongsberg Offshore changed owners and managing directors in the mid-1990s. Neither sale had anything to do with the other, nor with deepwater technology.

For a while, Siemens had considered closer coordination between its general offshore automation business, e.g. its SCADA-type systems, and Kongsberg Offshore. When Siemens realized there would be few synergies in integrating the two, the company considered buying the petroleum-related business of FMC and establishing a global market leader in subsea systems. The Americans rejected the offer in the summer of 1992,[700] and Siemens eventually decided to put Kongsberg Offshore KOS up for sale. Apart from FMC and ABB, the most eager suitors were Kværner and Aker. The employees at Kongsberg were particularly concerned about the Norwegian suitors, who were likely to incorporate Kongsberg Offshore in their overall organization. In the contest that followed, FMC offered the highest price - NOK 455 million. Siemens, having paid 47.7 million in 1987 and infused maybe 100 million during the next few years, received a decent return on its investment while FMC bought a company with considerable reserves.[701] On 30 June 1993 all assets and obligations in Kongsberg

[700] The acquisition is treated extensively in Daling et al., *Offshore Kongsberg*, albeit with slightly diverging information. Peter Kinnear of FMC is quoted saying an offer was made; Tore Andvig (KOS) is quoted saying he recommended a deal, but Siemens thought the cost and management resources required were forbidding.

[701] Ibid. ; Sogner, *God på bunnen*.

Offshore was transferred to FMC Norway A/S. The single most important consideration for FMC was market access.[702]

In Norway, the sale caused political concern. The acquisition coincided with the sale of iconic chocolate manufacturer Freia Marabou to Kraft Foods (Phillip Morris Corp.) and a heightened public awareness of foreign ownership. When FMC was about to acquire Kongsberg Offshore, the employee representatives insisted FMC honoured a set of concessions similar to those that Siemens had accepted in 1987.[703] In a subsequent arrangement, the Americans promised intellectual property would stay with Kongsberg Offshore and that FMC would allow Kongsberg Offshore an international role. Furthermore, FMC promised to grant Kongsberg Offshore operational freedom. Despite its 100 per cent ownership, FMC placed only one of its directors on the board and left the initiative with independent directors and employee representatives.[704]

The transaction set in motion a few profound changes. Haslestad decided to pursue a career at Siemens. FMC was disappointed, but allowed the board to pursue its business independently and to hire a Kongsberg insider, Tore Halvorsen, as managing director. Halvorsen had been with the business since 1980 and became managing director in July 1994.[705] Although FMC did have an in-house metering business already, the company decided to make Kongsberg a "global centre of excellence" for gas metering. A year later, however, FMC bought into Smith Meter Inc and the importance of metering at Kongsberg somewhat diminished. Mostly, however, the sale implied business as usual.

* * *

While the sale of Kongsberg Offshore was "friendly" in the language of corporate finance, Albatross succumbed to a hostile takeover when Kongsberg Gruppen bought Simrad. The conditions that allowed such a takeover were long coming.

In the early 1990s, Hansen enjoyed absolute control at Simrad. He hoped to acquire Norcontrol and Bird Technology and thus unite most of the

[702] Interview with Halvorsen, 4 October 2004.

[703] Interview with Fjelldal, 29 October 2004.

[704] Inteview with Christiansen, 19 February 2007; with Halvorsen, 4 October 2004.

[705] Interview with Christiansen, 19 February 2007; with Halvorsen, 4 October 2004.

Norwegian marine electronics industry. Hansen's ambitions required financial backing, but his fierce independence upset investors. He rejected offers from Thomson for closer ties and hoped to offer Statoil a controlling stake as a shield against "foreign ownership". When Statoil preferred to stay aloof of its suppliers, Hansen turned to Kværner, a company that shared his thoughts on restructuring the electronics industry.[706] With this backing, Simrad acquired *Osprey*, a British supplier of naval sonar, and Hydro Vision International Inc, a producer of underwater cameras. When the owners of Bird Technology decided to liquidate the company in 1993, Simrad got hold of Bentech Subsea AS (experimental parametric sonar) and Robertson AS (autopilots and various navigation solutions). In February 1994, Simrad acquired the Danish *Shipmate Group* whose retail network addressed yachts and fishing vessels.[707] For a while, Simrad looked set to dominate marine electronics.

From then on, a number of issues conspired to frustrate Hansen's ambitions. Most importantly, Norsk Forsvarsteknologi (NFT) – the restructured remains of KV's Defence Division, also took an interest in marine electronics. The trauma of 1987 had made NFT's board and management reluctant to rely on government funding and correspondingly eager to secure stock market funding, but the stock exchange was unlikely to stomach a pure defence company. When the Soviet Union collapsed in 1991, and defence spending looked set to fall, NFT decided to diversify. Marine electronics was a familiar field, and in 1992, NFT bought Norcontrol.[708] From then on, both NFT and Simrad aimed to expand in marine electronics.

Secondly, Simrad started to perform below expectations. Although Albatross and the rest of Simrad's offshore business continued to return a handsome return, margins were lower than in previous years. The company misjudged a mine-hunting project, booked large profits in 1990 and 1991, but reported losses in subsequent years making the project only marginally profitable.

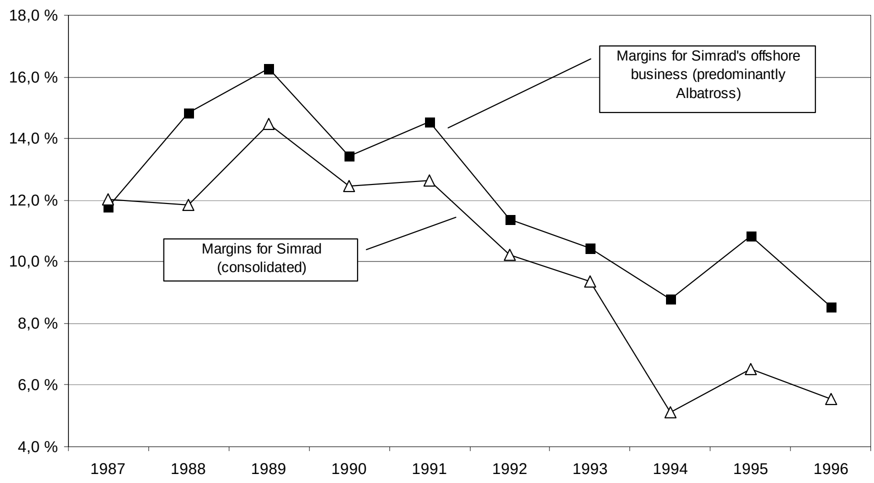
[706] Sogner, *God på bunnen* pp. 205 ff. Simrad's ambition with regard to the maritime electronics industry was stated in CA-KM-Simrad, Simrad AS board minutes, 14 April 1992.

[707] Sogner's private papers, Simrad annual reports 1991, 1992, 1993 and 1994. Shipmate cost NOK 16.3 million plus debts running at 36.2 million; a 44 per cent stake in Bird (1992) cost 61 million.

[708] On the thinking of Kongsberg Gruppen, cf. interview with Jørgensen, 21 September 2004; with Solberg, 27 March 2003. For details on the initial public offering, cf. Sogner's private papers, Norsk Forsvarsteknologi AS, annual report 1993.

Osprey was losing money outright.[709] As if to prove a common argument against conglomerates, profits fell in line with the number of acquisitions, from 12 per cent in 1987-1991 to 10 per cent in 1992-1993, and down to less than 6 per cent in 1994-1996. When Simrad performed below expectations, shareholders no longer put up with the independent ways of Hansen. Deprived of influence, many wanted to leave.

Figure 48) ***The Simrad group, EBITA as a percentage of turnover, 1983-1996***[710]



While Simrad's valuation diminished, NFT gained better access to funds. In December 1993, NFT went public - 49 per cent of the shares were sold to private shareholders while the government retained 51 per cent.[711] The business was renamed *Kongsberg Gruppen* – and aimed to expand its civilian product line. In the spring of 1996, Simrad became vulnerable. Kværner sold its ten per cent holding to help finance its forthcoming acquisition of Trafalgar House, and Simrad lacked the support of dedicated

[709] On the difficulties with Osprey and the naval project, cf. Sogner, *God på bunnen*.

[710] Sogner's private papers, figures prepared by the accounting department of Simrad AS, undated.

[711] On the thinking of Kongsberg Gruppen, cf. interview with Jørgensen, 21 September 2004; with Solberg, 27 March 2003. For details on the initial public offering, cf. Sogner's private papers, Norsk Forsvarsteknologi AS, annual report 1993.

owners.[712] On 11 April 1996, Kongsberg Gruppen offered to buy Simrad shares at a 44 per cent premium on the average 1996 stock price, and shareholders representing a majority agreed within a matter of hours. Hansen faced a *fait accompli* and left the company a few weeks later.[713] Another early casualty was Gregersen, who failed to get along with the new management and left after a clash with the head of *Kongsberg Maritime*, the marine electronics division of Kongsberg Gruppen.[714] Gregersen, who ran Kongsberg Simrad from 1993 to 1996, watched margins strictly and was reluctant to take on new people. When he left for Kongsberg Offshore, following conflicts with the new owners, Hans Christian Helle became head of Vessel Systems (DP and automation) and Steinar Aabelvik head of the Albatross (DP) unit.[715] Overall, the business continued much as before.

8.8 Conclusions

The early chapters of this thesis frequently returned to the considerable differences between the world of shipping, where Albatross resided, and the realms of Statoil, where Kongsberg Offshore found work. In the period covered by this chapter, these worlds became blurred. When Albatross succeeded in supplying integrated control systems to various floating production systems in the North Sea, its business began to resemble that of Kongsberg Offshore. After some twenty years of distinct business with distinct customers, the two converged towards the same kind of capitalism. Whether selling a subsea system for the seabed at Åsgard, or an integrated process control system for the various production ships anchored above that subsea system, the same rules applied.

What mattered was the fact that the institutional setting on the Norwegian shelf had become a lot more dynamic. The early sections of this and the previous chapter provided many examples of how oil companies and public authorities became more receptive to costs and earnings. The most evident change occurred as floating production systems replaced Condeeps despite

[712] *Tradewinds*, 8 March 1996.

[713] On the disappointment of shareholders, cf. interview with Jørgensen, 21 September 2004, and the account in Sogner, *God på bunnen*. On the bid and its reception by the Simrad board, cf. CA-KM-Simrad, Simrad AS board minutes, 26 April.

[714] Before subsequent restructuring, Kongsberg Maritime was a holding company that comprised Kongsberg Simrad AS (i.e. Albatross), Kongsberg Norcontrol AS, Kongsberg Norcontrol Simulation AS and Simrad AS.

[715] Interview with Helle, 14 April 2005.

the strong constituencies that fought to preserve this costly way of developing offshore fields.

A new style of field development provided a set of opportunities for the deepwater companies that worked out of Kongsberg. National and global competition, however, disciplined these suppliers and forced a remarkable drive towards lower costs, both in relation to dynamic positioning and subsea systems. If anything, the competitive pressures increased.

In this setting, the suppliers managed to innovate repeatedly. Both companies introduced new products (the HOST product range and various integrated control systems for use onboard floating platforms). Both companies also led a remarkable drive towards cost-efficient deliveries. Whereas Kongsberg Offshore cut prices as part of a conscious effort to gain a market, price cutting at Albatross was part of a never-ending struggle to keep competition at bay. Computing and navigation technology matured to the extent that any electronics company with some resources could develop a basic DP system – and the product became subject to strong price pressures. In a setting where quality and functionality improved, the overall costs of dynamic positioning and subsea systems fell by roughly 50 per cent from 1991 to 1997. The deepwater industry showed every sign of vitality.

In explaining this dynamism, a number of issues played a part. Some credit goes to culture, experience, improved economies of scale and pure talent. Another explanation should recall the fact that suppliers on the Norwegian shelf were granted considerable freedom and trust. The practice of awarding EPC contracts was a key success criterion in the drive to standardize subsea equipment and devise control systems for floating production platforms; they offered the suppliers the necessary authority to make design choices. In some contrast to the established procedure in most oil provinces, companies that issued tenders on the Norwegian shelf refrained from excessive specification before choosing a main contractor. The oil companies expected these suppliers to carry extensive risks and responsibilities and to make decisions that oil companies had traditionally reserved for themselves. The more discretion left to suppliers, the more functional requirements and the fewer specific requirements, the larger the room for innovation and standardization. Since critical knowledge rested with the supplier industry, not with a single oil company, the benefits of standardization and technological improvements travelled faster and spread wider. Petrobras's effort at standardization, for example, had fewer immediate gains for the offshore industry in general.Beginning in the late 1990s, Norwegian deepwater suppliers with this independent streak found promising opportunities abroad.

9 Profiting from geology and globalization, 1997-2007

In the final decade covered by this thesis, both Albatross and Kongsberg Offshore experienced success. Largely, the strong performance occurred when business practices pioneered on the Norwegian shelf travelled abroad.

Initially, global oil companies elsewhere continued to procure Christmas trees as one package, templates as another, control systems as a third package, tie-in services as a fourth, and so on. As late as the mid-1990s, the EPC approach was fairly unique to the Norwegian continental shelf where oil companies (like shipping companies) trusted their suppliers with extensive responsibilities for turnkey deliveries. From the mid-1990s onwards, such practices spread rapidly to other oil provinces. EPC contracts simplified the business of oil companies and lowered their transaction costs. In the 1990s, offshore oil companies increasingly explored setting up business in new oil provinces without an established supplier industry and with weak institutions – they faced higher risks and embraced the opportunity of offloading technological risk on to suppliers capable of taking on every responsibility through EPC contracts. Early exposure to systems delivery provided the Norwegian supplier industry with valuable experience and a beachhead for export sales when the practice took off globally in the 1990s.[716]

Like EPC contracts for offshore installations, class certificates served to simplify the process of procuring dynamic positioning. As with EPC contracts, the practice originated with the Norwegian shelf. As with EPC contracts, the practice travelled abroad.

If contracting strategies such as the use of class certificates and turnkey contracts have shaped the deepwater industry, how may changes in the institutional framework affect the future? That issue is somewhat beyond the topic covered in this thesis, but is fascinating nonetheless. The concluding sections of this chapter deal with recent trends that are yet to have a profound effect on the industry.

Apart from those advantages that were unique to Norwegian companies, the decade that began in 1997 was favourable for any competent provider of deepwater technology. The global oil industry addressed

[716] Cf. interview with Halvorsen, 4 October 2004.

increasingly inaccessible oil fields and provided numerous opportunities for companies that offered nimble solutions for smaller fields, far away in deep waters.

9.1 How demanding procurement practices helped Norwegian suppliers expand abroad

The companies we have followed succeeded in part because they knew the challenges of oil production in deep waters and managed to innovate. A visible contributor to success, furthermore, was the ability of these companies to expand abroad. Their way of doing business travelled easily to meet the demanding conditions faced by the offshore industry in new oil provinces.

In the oil industry, globalization showed in development styles. If previously there was local technology (e.g. Condeeps in Norway, semi-submersibles in Brazil and Spars in the Gulf of Mexico), recent development projects relied on a global technology base where one global supplier industry served a global market in which prices converged. Host countries continued to demand local content, but rarely prevented global suppliers from playing a major role.

Albatross had served a global shipping industry almost from the moment its business was established. The company had a worldwide presence quite early. Up until the 1990s, however, the most promising markets resided in the North Sea. In the mid-1980s, two-thirds of Albatross's sales originated with North Sea operations.[717] Hardly any petroleum support vessels in the Gulf of Mexico used dynamic positioning in the 1970s and Albatross spent barely a tenth of its marketing budget on the American market in 1985.[718] Although the United States remained a technological base for North Sea oil, the US oil industry in general appeared technologically conservative and cost conscious.[719] Most export sales went to Singapore, Japan and Korea, whose shipbuilding industries came to dominate the global market.[720]

[717] KV-Cor 238, Albatross [internal] board papers on marketing strategy, 23 September 1983.

[718] KV-ex 10, marketing budget, 4 February 1986.

[719] On the conservative inclination of the US offshore oil industry, cf. KV-Cor 238, marketing strategy, 23 September 1983.

[720] KV-Cor 238, Albatross board minutes, 2 September 1985.

Albatross's export orders grew in line with the introduction of new procurement practices. The shift was most evident in the Gulf of Mexico where Albatross received a wave of orders in the mid- and late 1990s reaching 30 per cent of total orders for dynamic positioning.[721] In recent years, some two-thirds of Kongsberg Offshore's offshore-related orders classify as export.[722] Oil activity in deeper waters played a part, but also a global adoption of class certificates for dynamic positioning. First introduced in the late 1970s (cf. chapter 4.7), the practice of placing orders by reference to a class regime became entrenched for North Sea operations in the 1980s. From Norway, the use of class certificates spread abroad. Lloyds Register began issuing class regulations that roughly matched those of DNV,[723] but until the 1990s, the reliance on classification societies to specify how crucial electronic equipment should work remained a North Sea phenomenon. In June 1994, however, the International Maritime Organization (IMO), advised its members to adopt a classification regime for dynamic positioning.[724] American regulators and the US oil industry heeded this advice and guidelines from this United Nations body helped speed the adoption of dynamic positioning in the Gulf of Mexico.

Regardless of public guidelines, global oil companies have in effect harmonised standards somewhat independently of the classification societies. The oil industry preferred uniform standards everywhere to simplify ordering – such concerns tended to favour a convergence towards the highest requirements. Owners of petroleum support vessels, furthermore, would normally hedge their bets and build vessels capable of competing for the widest possible range of assignments; an American shipping company might invest in advanced dynamic positioning, not because its present customers demanded such systems, but because its future customers might appear in the North Sea sometime in the future.[725] Increasingly, shipping

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[721] Paul Erik Hattestad, "Kongsberg simrad as: Valg av inngangsstrategi i mexico gulfen med tanke på produktet dynamisk posisjonering", (Diplomoppgave, Norges Handelshøyskole, 1998).

[722] Cf. Inge K. Hansen et al., "Internasjonalisering", *KonKraft rapport no. 4*, (KonKraft, 2008). Recent figures no longer track separate product lines such as dynamic positioning and integrated control systems – a twist that reflects the integrated nature of many deliveries.

[723] Maritime, "Interview: Holger røgeberg".

[724] IMO's "Guidelines for vessels with dynamic positioning systems" are available online at http://www.imo.org/. Their wording resembles the DNV requirements, cf. Bray, *Dynamic positioning*, p. 207.

[725] Interview with Røkeberg, 9 May 2006.

companies around the globe ordered dynamic positioning in order to be eligible for the occasional North Sea order.

* * *

At Kongsberg Offshore, export orders picked up even more rapidly than at Albatross, and from a much lower base. Prior to 1995, Kongsberg Offshore had no export orders of any importance. Although the Norwegian shelf remains an important market, the strongest growth is elsewhere. In 2005, some two-thirds of FMC Kongsberg Subsea's sales were exports.[726] Again, the spread of familiar procurement practices greatly assisted the export drive.

The growing internationalization of Norwegian oil companies since 1997 provided only limited assistance to the Norwegian supplier industry. Although both Statoil and Hydro invested heavily abroad, deepwater was not their prime focus[727] - only after year 2000 did Statoil and Hydro buy into deepwater fields in the Gulf of Mexico. Rather, foreign companies with experience on the Norwegian shelf invited Kongsberg Offshore to expand deliveries to new oil provinces, most evidently to fields in the sea west of Africa and to Asia.

The extent of the export sales surprised FMC. The Houston-based company had bought Kongsberg Offshore primarily to gain access to the Norwegian shelf,[728] and offered Kongsberg Offshore responsibilities for "total subsea systems" as part of an effort to build goodwill.[729] Total subsea systems meant the practice of EPC contracts. Such contracts had taken hold on the Norwegian shelf whereas oil companies on the British shelf and in the Gulf of Mexico mostly ordered products and took upon themselves to handle interfaces.

In the second half of the 1990s, when subsea developments became increasingly common, oil companies everywhere found EPC rewarding and easy to administer. The practice of awarding total contracts spread and within the FMC family, Kongsberg Offshore handled many of the

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[726] The percentage of sales abroad varies from year to year. Some figures are cited in Hans Ohrstrand, "'Juletrær' hyllevare i oljen", *Adressaeavisen*, 6 December 2005 and Hansen et al., "Internasjonalisering", p. 48.

[727] Acha and Finch, "Paths to deepwater in the international petroleum industry".

[728] Interview with Fjelldal, 29 October 2004.

[729] CA-FMC-board, Kongsberg Offshore 1993 annual report.

deliveries.[730] FMC relied on Kongsberg Offshore whenever a customer in the Eastern hemisphere wanted total systems. FMC's then vice president, Peter Kinnear, credited the Kongsberg business with having "helped us to see the big picture in subsea systems, with the emphasis on systems. FMC has traditionally been a product-oriented company. Now we have learned the architecture of building systems."[731]

The approach of multinational oil companies outside Africa was a case in point. No major equipment manufacturer could claim West Africa as a home market. In the late 1990s, FMC Kongsberg Subsea gained orders from Elf for the huge Girassol field off Angola,[732] and from British Petroleum on Block 18 outside Angola. BP had a long-standing relationship with Cameron and usually bought subsea equipment from Cameron. Off Angola, however, where building anything was difficult, BP chose to offload the risk through EPC contracts. By 2004, Kongsberg Offshore had secured subsea orders for 100 wells and a turnover of more than NOK 5 billion related to West African fields.[733]

Kongsberg Offshore had experience with EPC contracts, but also a company culture that helped the execution of such contracts. Kongsberg Offshore sported an engineer culture, not unlike KV in its heydays. Mostly everyone at Kongsberg Offshore was trained an as engineer except for the people at the finance department. Popular talk centres around technical challenges: the pleasures of finding a way to withstand hydrogen embitterment of metal at 1500 metres, the excitement of being a thought-leader on the physics of couplings, etc.[734] Such people got along fabulously with their clients' engineers and formed teams that sorted out whatever issues would occur in EPC contracts and alliances. This congenial, problem-solving, technical attitude was conciliatory by nature; this author is not aware of any lawsuit filed by customers during the 30 years covered in this study. Other companies may have been better at extracting concessions from their customers.

[730] Interview with Halvorsen, 4 October 2004.

[731] Daling et al., *Offshore Kongsberg*, citing interview with Peter Kinnear (FMC).

[732] Dag Tinholt, "Storkontrakt til Kongsberg", *Dagens Næringsliv*, 10 July 1998.

[733] Asgaut Næss, "Subsea i 100 utenfor Angola", *Dagens Næringsliv*, 27 August 2004.

[734] Daling et al., *Offshore Kongsberg*, citing interview with Jan Thoresen.

FMC Kongsberg Subsea was probably a permissive company. That diverges from the popular impression of competitive global businesses and Anglo-American capitalism. Kongsberg Offshore had become a wholly owned subsidiary of FMC Technologies.[735] Like most listed American companies, FMC Technologies ran a tight ship. Subsidiaries were subject to strict reporting and control; SAP software suits kept track of all activities. Each quarter FMC Technologies reported its earnings to the stock market and quarterly earnings carry weight. The company insisted on a decent return on capital, not only in the long run, but also in the short run and in every product and project.

How come *quarterly capitalism* co-existed with cosiness at Kongsberg Offshore? One line of thought points to the legal restraints that FMC Technologies have to abide by in Norway. When FMC bought Kongsberg Offshore, the company promised its acquisition a degree of independence: access to international markets, ownership of intellectual property, etc. The board of directors, furthermore, has a majority of Norwegian directors whose mandate by law is to look after the subsidiary – not the American stock market.[736] More likely, the continued independence of Kongsberg Offshore and tolerance of its ways had something to do with the company's stellar performance. Why would Houston change a subsidiary that consistently outperformed the competition and other energy-related businesses of FMC? Rather, the Norwegian operations were allowed to influence the global operation. In 2001, FMC split into two companies: oil and engineering (FMC Technologies) and chemicals (FMC). At the time, FMC Technologies considered a listing at Oslo Stock Exchange alongside the New York Stock Exchange.[737] Due to the sharp growth in subsea systems, offshore became ever more important for FMC Technologies. In February 2007, Peter Kinnear, the Vice President who oversaw the Kongsberg Operation, became CEO and Tore Halvorsen assumed overall responsibility for all subsea activities in FMC Technologies.

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[735] FMC demerged its engineering business in April 2000, set up FMC Technologies as a separate listed stock company and sold off the shares, cf. http://en.wikipedia.org/wiki/FMC_Technologies. The subsequent annual reports offer more details, cf. *Annual reports* (FMC Technologies, [cited May 2007]); available from http://ir.fmctechnologies.com/annuals.cfm.

[736] Interview with Fjelldal, 29 October 2004.

[737] Thor Chr. Jenssen, "FMC vurderer Oslo Børs", *Dagens Næringsliv*, 9 November 2001.

The spread of EPC contracts for subsea systems was a boon for Kværner and ABB Norway as well.[738] Each had gained their experience with EPC contracts on the Norwegian continental shelf. Each then went on to tell clients around the world about the advantage of buying systems. Besides, the oil industry saw three companies willing to bid for EPC contracts, which meant there would be sufficient competition among suppliers capable of handling systems integration.[739] As of 2007, there were five major suppliers of subsea systems; three of these have a strong technology base within one hour's drive of Oslo: ABB/Vetco, Kværner Oilfield Products and Kongsberg Offshore. All thrived on a worldwide adoption of EPC contracts similar to the arrangements that had been pioneered on the Norwegian shelf in the 1980s.

9.2 On competition

Tracking every competing company that offers deepwater technology has been beyond my scope. Nonetheless, when discussing the success of Albatross and Kongsberg Offshore, the competition needs consideration. Quite impressive efforts might be a relative failure in the face of advanced competitors, and laggards might succeed when facing a worse laggard – or no competition at all.

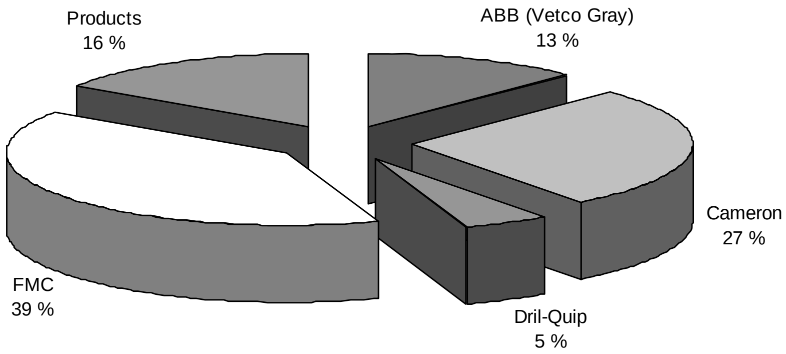
Gaining ground in the late 1990s, FMC (of which Kongsberg Offshore was part) established itself as the market leader during the first few years of the new millennium. Since 2002-2003, the company's market share has stayed above 40 per cent.[740] When FMC emerged as a market leader, some of the credit should be assigned to the greater disarray of its competitors.

[738] Yngve Hellestøl, "Norsk kamp om milliardkontrakter i Vest-Afrika", *Aftenposten*, 18 March 2000.

[739] Interview with Halvorsen, 4 October 2004.

[740] The figure is reproduced from the limited materials that are available to the public on *Quest offshore resources* ([cited). According to Chrisiansen, FMC Technologies' market share remained in this range during 2004-2006, interview with Chrisiansen, 19 February 2007.

Figure 49) ***Global market share for subsea systems, cumulative 2002-2004***[741]



Cameron used to be the market leader in subsea technology, but Cameron *Iron Works* Inc. remained focused on products and production. Cameron's business thrived from tight alliances with customers, particularly BP, and the sale of *products*. When oil companies began placing orders for full systems, not individual components, Cameron fell behind.[742] In 1998/99, the Houston-based company developed a control system and finally came around to offer turnkey systems, but Cameron had lost ground.

Other competitors stumbled, not because of technological choices, but due to financial instability that undermined trust. Kværner expanded rapidly in the late 1990s. Its business was diverse, more so following the acquisition of a troubled British engineering company, Trafalgar House, in 1996. The deal caused Kværner serious financial problems in the late 1990s and undermined the company's trustworthiness. Around year 2000, ABB ran into financial problems as well: asbestos litigation in the United States almost forced its American subsidiary, Combustion Engineering, into receivership.[743] With tumbling stock prices, ABB was reluctant to offer guarantees. Private equity investors eventually bought the subsea systems business of ABB and the supplier business eventually regained business on the Norwegian shelf winning contracts to supply Ormen Lange with experimental gas compression and power supply technology and Snøhvit with subsea

[741] Adapted from Ibid. (cited). The numbers include market share from Q1 2002 until Q1 2004.

[742] Interview with Halvorsen, 4 October 2004.

[743] "Unpleasant stuff", *Economist*, 24 October 2002.

production systems.[744] Kongsberg Offshore by contrast remained a paragon of stability throughout the period.

Apart from the four established suppliers, Dril-Quip emerged as a competitor during the 1990s. Dril-Quip had a somewhat limited assortment, with no in-house control system technology. Other companies retreated. Frank Mohn stopped offering third party production systems; Aker failed to gain a proper foothold in subsea production systems and refocused on Spar technology out of Texas. Aker divested this business in year 2000 to help finance its acquisition of Kværner.[745]

Distinguishing the products on offer in recent years (1997-2007) invariably runs into difficulties. The product converged rapidly due to the fact competitors were able to imitate most improvements; each of the five copied and incorporate new developments. There were few patents or patentable technologies and in terms of technology, no single company ever got far ahead.[746] Although Kongsberg Offshore made far wider use of the patent institute than other Kongsberg-based industries,[747] oil companies such as Hydro and Statoil patented more extensively and mostly publish what they choose not to patent – a common strategy to prevent the formation of a monopoly in technologies considered key to business.[748]

* * *

Like subsea systems, dynamic positioning was sold on a competitive market. As of 2005, there were three significant players in the high-end of the

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[744] On the revival of ABB/Vetco, cf. NTB 12 July 2004; *Adresseavisen*, 13 July 2006; Steve Sasanow, "Special report: A sub-sea history", *Offshore & Energy* 2004, pp. 46-48.

[745] On the divestiture of Aker's deepwater technology, cf. Helge Keilen, "Røkke og offshoreteknologi", *Dagens Næringsliv*, 1 November 2000. On the origins of Aker as a systems provider, cf. p. 196.

[746] Interview with Halvorsen, 4 October 2004.

[747] "Ipr database" (The Norwegian Patent Office) accessible at https://dbsearch.patentstyret.no/. The author counted 256 patent applications from the various Kongsberg industries: Kongsberg Våpenfabrikk (prior to 1987) held 31, Kongsberg Automotive 36, Kongsberg Offshore [systems] (1986-2000) held 40 and FMC Kongsberg Subsea 56.

[748] *Mandag Morgen*, no. 1, 9 January 2006. The article referred to an international comparison made by *Zacco Analysis* and interviews with Brit Ragnhildstveit (Statoil) and Bjarne Skeie (Sinvest).

market: Kongsberg Maritime (formerly Albatross), Nautronix of Australia (formerly Honeywell) and Alstom of France (formerly General Electric, but subject to several changes in name and owners). Albatross remained the most successful with possibly 70 per cent of the world market for high-end systems – a position the company had been able to defend for 25 years.[749]

Any lack of competition was not for lack of attempts. Several stranded, not only because of technological challenges, but also because upstarts lacked sufficient scale to remain. Staying in the high-end of the market required investments in continuous R&D. Besides, any provider would have to dedicate resources to provide a 24-hour global stand-by service. The supplier with the more complete service network got more orders – and could better afford a finely masked network. For shipping companies, who rarely knew where their support vessels would eventually end up working, access to worldwide support was of the essence.[750] A potential entrant would also have to match the costs of Albatross – not easy since these depend on scale, past investments in software libraries and *application knowledge*: each new job improved the ability of engineers to install a system efficiently. ABB entered the race in the 1990s, sold but seven systems in a decade, and eventually handed its business to Albatross (Kongsberg Maritime). Navicon, another upstart, never got off the ground – but served to keep the incumbents alert and the market vital.

9.3 Dilemmas related to success

In the decade from 1997 to 2007, both Albatross and Kongsberg Offshore enjoyed international success and profited profoundly. Their strengths contributed to a spectacular revival of the engineering industry at Kongsberg (of which the turnover figures below are evidence).[751] During this

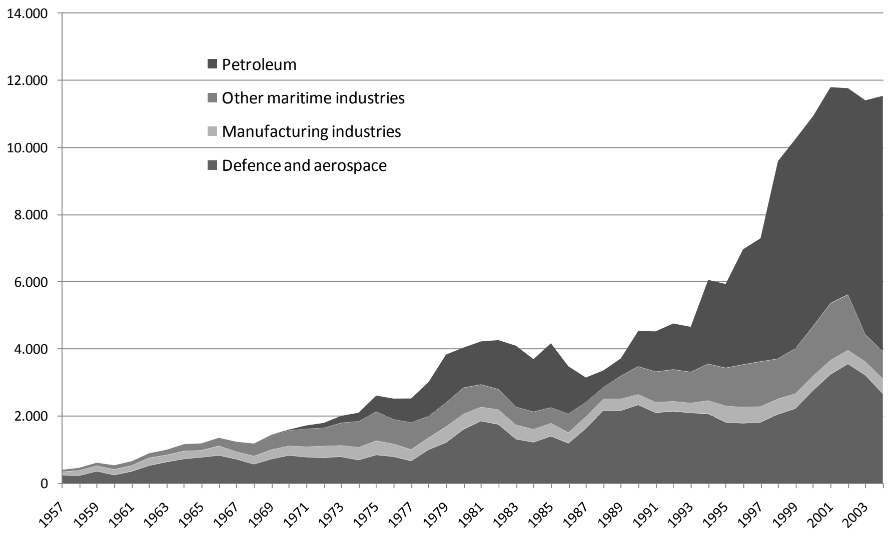
[749] The author is not aware of any proper market survey. The information in this paragraph is stitched together from the author's interviews with, among others, Sælid, Jenssen, Kildal, Gulhauguen and Røkeberg.

[750] Interview with Helle, 14 April 2005; Hattestad, "Kongsberg simrad as: Valg av inngangsstrategi i mexico gulfen med tanke på produktet dynamisk posisjonering".

[751] The chart depicts the combined turnover of a family of companies that either originated with Kongsberg Våpenfabrikk or later merged with a company that was part of KV, not a specific company nor a specific geographical location. For methodological concerns and a list of included businesses, please refer to appendix 11.2. The approach serves to retain focus on organic growth and eliminate the effect of mergers, acquisitions, sales and de-mergers. An even better comparison would involve value-added rather than turnover. Some of the growth implied in Figure 50) originates with the increased value of inputs as KV and associated businesses

period, offshore-related businesses came to dwarf all other industrial activities at Kongsberg.

Figure 50) ***Oil in the machinery: the revenue of KV and associated businesses by segment, 1957-2004, in NOK millions (1998)***



In the decade from 1997 to 2007, both Albatross and Kongsberg Offshore faced dilemmas and problems worth having: challenges that originate with success. Both companies became very profitable. Were the historic profits from dynamic positioning placed in an interest-bearing bank account, the balance would have read NOK 2.4 billions by yearend 2004 – enough to finance a takeover of almost the entire Norwegian marine electronics industry. Using the same approach, the subsea business would have generated NOK 1.7 billions in cash by yearend 2004.[752]

The turnover of Kongsberg Offshore grew fivefold in real terms between 1996 and 2006 (cf. figure below) and the company struggled to add capacity.

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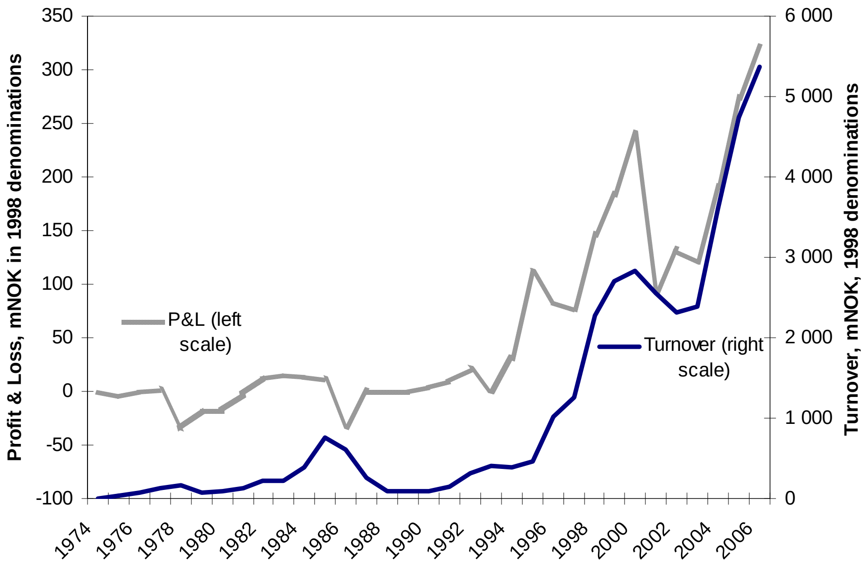
limited the extent of in-house production and relied increasingly on the packaging of components into systems. The effects on profitability is covered in chapter 9.3.

[752] For an introduction to the methodology, cf. appendix 11.2, particularly page 304. The figure does not include substantial revenues from Albatross integrated multifuncion system (AIM).

Stellar growth in turnover did not result in stellar margins; these remained at about six per cent and grew mostly in line with turnover.

Figure 51) ***The surge I: turnover, profit and loss in subsea systems, 1975-2006***[753]



The growth pushed Kongsberg Offshore against capacity boundaries. In 1995, new office quarters were added turning the complex into a maze – confusing for visitors, but an improvement on the improvised structures of old. An extra floor in the electronics building was completed in 1999 and a 10,000m^2 hall in 1998 for assembly, testing and storage.[754] These and other facilities enabled the company to assemble 120 subsea modules per year and test each for pressures up to 20,000 psi.[755]

Workers, however, remained in short supply. During the recent boom, hiring and retaining skilled workers became difficult. Kongsberg Offshore proved to be an attractive employer and managed to hire, among others, a cohort of employees from Albatross with a strong technology focus. In the late 1980s, Albatross's core "system engineering group" consisted of five people. As of 2005, only Nils Albert Jenssen remained at Albatross. Another

[753] Cf. Appendix 11.6.

[754] Daling et al., *Offshore Kongsberg*.

[755] "Dobler kapasiteten", *Teknisk Ukeblad*, 30 January 2007.

cybernetics expert, Steinar Sælid, founded an engineering consultancy, Prediktor AS, and went to work for his start-up in 1995. The remains of the systems engineering group eventually ended up working for Kongsberg Offshore: Terje Løkling, Steinar Gregersen and Sverre Corneliussen.

New recruits could solve only part of the demand for extra capacity and Kongsberg Offshore had to make better use of its existing engineers. Before 1996, the company ran project groups with employees assigned full time to a single project. In 1996, the company reorganized and shaped product groups in which engineers worked on several projects simultaneously albeit with a more consistent set of tasks. The change improved productivity and reflected a long-term trend from few and big projects towards more, but smaller, projects.[756]

When Kongsberg Offshore actually managed to handle a steep rise in demand, the reason rested in part with a long established practice of outsourced production. Initially, this was less of a strategy and more of an accident. Back in the mid-1970s, Kongsberg Våpenfabrikk ventured into the offshore market without a defined set of products and with much uncertainty about volumes; subsequently, KV refrained from building a dedicated oil-tool factory – divisions apart from the oil division were set up to do manufacturing – and asked the Oil Division to source parts and services from other divisions. The limbo continued into the 1980s because Cameron was protective of its intellectual property and resisted KV's calls to establish a Norwegian oil-tools manufacturing operation.[757] Ironically, the path this business had taken at a time of unpredictable and low volumes was equally suited for surging and high volumes. FMC's factories in Scotland provided valves and pressure containing equipment (roughly 20 per cent of the value of a typical contract in 1995), while a variety of mostly Norwegian subcontractors produced the remaining equipment (50 per cent of contract value). Kongsberg Offshore manufactured only control systems in-house. The company relied on a variety of strategies to source equipment ranging from competitive tenders for such items as umbilicals and longer-term alliances for other items such as templates.[758]
As subsea systems providers began exporting to the world outside Norway, they faced demands for local content similar to what the Norwegian

[756] Daling et al., *Offshore Kongsberg*.

[757] On the origins of outsourced production, cf. page 297.

[758] Asgaut Næss, "Milliard-jubel på Kongsberg", *Dagens Næringsliv*, 29 August 1995.

authorities insisted on in the 1970s and 1980s. Kongsberg Offshore has tailored bids to accommodate local industry in Canada, West Africa and Australia and learned how to choose the best partner among those present. In countries such as Canada, local industry was capable of making parts according to drawings.[759] Elsewhere, deliveries needed adjustment to accommodate local suppliers. Before Angolan workers applied their torch blowers to a template, for example, the equipment had been jigged by FMC to improve accuracy and system engineers on site had been equipped with tools to improve upon the deliveries.[760] Much like foreign oil companies had found on the Norwegian shelf around 1980, the locals were necessary to secure contracts, but of limited assistance in actually building subsea systems.

* * *

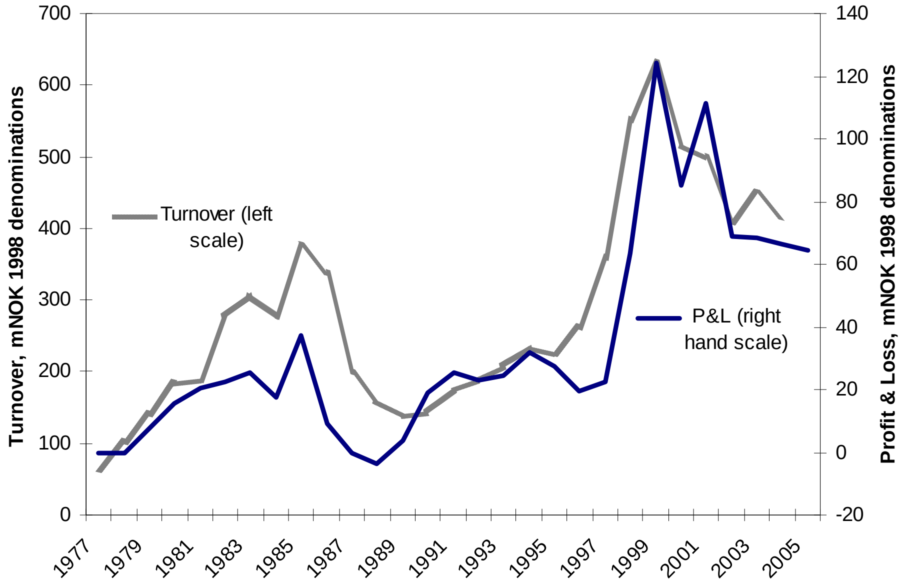
Like Kongsberg Offshore, Albatross enjoyed spectacular success from the late 1990s onwards. Sales grew and profits shadowed sales. Despite a prolonged fall in prices,[761] the direct variable unit costs remained at around fifty per cent, and gross margins ran between 12 to 17 per cent - somewhat higher in peak years such as 1999 and somewhat lower in periods of recession (1987-88) or rapid growth (1997-98).

[759] Daling et al., *Offshore Kongsberg*.

[760] Interview with Halvorsen, 4 October 2004. On the manufacture of manifolds in Angola, cf. “Ny storkontrakt til Kongsberg”, *Aftenposten*, 9 September 2004.

[761] On the price fall, cf. chart on page 240.

Figure 52) ***The surge II: turnover, profit and loss in dynamic positioning, 1977-2004***[762]



Albatross always had ambitious owners and, except for a few turbulent years, Albatross always enabled its owners to be ambitious. Revenues from Albatross financed a string of acquisitions at Simrad (cf. chapter 8.7) and continued to finance a string of acquisitions at Kongsberg Maritime: in 2000, Kongsberg Gruppen bought Navia ASA including the Seatex (GPS) and Autronica (fire alarms) product lines, then KonMap Maritime Systems AS (naval maps) in 2001 and Seaflex (riser technology) in 2002.[763] This growth by acquisition caused controversy about the sprawling nature of the business.

[762] For numbers prior to 1987, cf. appendix 11.6. The 1987-2004 figures are stitched together from Simrad AS annual reports, Kongsberg Gruppen annual reports, Sogner's private papers and correspondance between the author and Steinar Aabelvik, CFO of Kongsberg Maritime CFO, June 2006. For 1996-1998, this author has not found a product specific account for dynamic positioning. For these years, we assume growth and profitability in line with the offshore buisness of Kongsberg Maritime of which Albatross was part.

[763] Kongsberg Gruppen annual reports 1996-2005; Our maritime history (Kongsberg Gruppen, [cited May 2007]); available from http://www.Kongsberg.com/eng/kog/AboutUs/History/default.asp?page=/ENG/KOG/About%20us&id=32693.

Like Simrad in the early 1990s, growth driven by acquisition apparently did not help margins. The former Norcontrol and the rest of Kongsberg Maritime's *Merchant marine* segment returned less than four per cent margins on sales - *Yachting and fishery* likewise. After 2002, Kongsberg Maritime ceased to report on its most profitable and least profitable segment but rather merged the two into an *Offshore and marine* segment. Possibly eying a case for reorganization, *Nordic Capital*, a Swedish private equity group, offered to buy Kongsberg Maritime for NOK 3.3 billion in September 2004 – half a billion more than the stock market value of Kongsberg Gruppen's combined civilian and military activities.[764] The offer came to nothing. The state's 51 per cent shareholding ruled out any hostile takeover and Kongsberg Gruppen's board rejected a friendly takeover claiming there were considerable synergies in the various business lines. However, in a move that partly proved the critics right, Kongsberg Gruppen announced the sale of its yachting business in September 2005.[765]

9.4 The quest for oil and its effect on deepwater technology

In part, the success of the deepwater supplier industry reflected a shift in the oil industry onto more extreme conditions. A scarcity of oil in the regions most accessible to the oil majors triggered a search for oil in regions with very deep waters, very weak infrastructure, smaller deposits of petroleum and challenging geological structures. Overall, this shift increased demand for deepwater technology and inspired innovations to make the technology more applicable.

For a century, oil companies strived to access the oil that lay just out of reach. At times the intensity of the search ebbed, while at other times it intensified. In the late 1930s, for example, when large quantities of oil appeared in the Middle East, the offshore oil industry progressed less rapidly. Similarly, a gush of cheap oil in the late 1980s deterred deepwater exploration. The long-term trend, however, was for oil companies to explore deeper waters, and the trend accelerated in the 1990s. As of year 2002, deepwater fields supplied some 3 per cent of the global oil supply – a

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[764] "Er klar for høye bølger", *Dagens Næringsliv*, 17 September 2004.

[765] On the sale of the yachting business, cf. "Halv milliard for fritidsbåtene", *Gjengangeren*, 27 September 2005. The deal is also cited in Kongsberg Gruppen's 2005 annual report available online at www..com. On the stock market's skepticism regarding the acquisitions and the profitability, cf. Engen, interview with the author on 13 September 2004.

proportion expected to reach 10 per cent by 2012.[766] In politically stable regions such as Brazil and the Gulf of Mexico, more than half of all offshore crude originated from fields at depths of more than 400 metres.[767] This surge affected the demand for deepwater technologies.

Progress was evident in numerous ways. Around 1970, in offshore jargon, “deep” meant 100 metres of water. A decade later, Norwegian oilmen thought “deep” meant waters in which concrete platforms were infeasible, i.e. beyond 250-300 metres. After successive reinterpretation, trade publications in the new millennium seemed to distinguish between “deep” waters of around 1000 metres and “ultra-deep” meaning 2000 metres and below.[768] As of the year 2005, state-of-the-art production technology was deployed down to 2500 metres, and exploratory drilling down to 3000 metres, close to the limit where outside water pressure could rival pressure in the well itself.[769]

From the mid-1990s, the demand for subsea systems grew exponentially – as did the depths in which they were applied. The figure below shows a freak correlation between application and the maximum record depth. Between 1975 and 2000, the accumulated number of installed systems offered a good approximation of how deep the oil industry had ventured – and vice versa. Hence, by 1980 there were some 180 systems in place capable of withstanding 180 metres of water; by 1990 there were about 500 systems capable of withstanding 500 metres of water; by year 2000 there were 2000 systems capable of withstanding 2000 metres of water.[770] Recently, the number of systems sold has surged ahead of the depth records.

[766] Hansen et al., "Internasjonalisering", The report does not define “deepwater”.

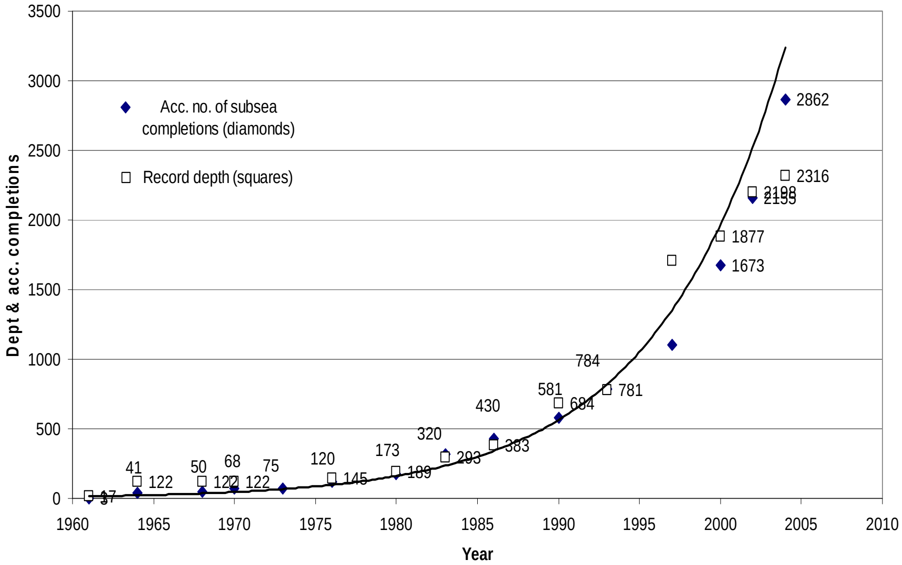
[767] Numbers from 2002, cf. "Deepwater Gulf of Mexico 2004: America's expanding frontier", ed. U.S. Department of the Interior, OCS Report (Gulf of Mexico OCS Region, 2004). On petroleum production outside Brazil, cf. Ribeiro, Costra, and Petrobras, "Deepwater subsea completions: State of the art and future trends".

[768] Acha and Finch, "Paths to deepwater in the international petroleum industry".

[769] Interview with Halvorsen, 4 October 2004. There is no principal reason why oil cannot be extracted from such depths, but state-of-the-art (2005) designs are made to contain the well pressure, not to protect well and equipment from external pressure and problems that may be caused by water penetrating the wellhead.

[770] The figure is assembled from a number of sources of which the two most useful have been "Subsea technology", and *Quest offshore resources* (cited).

Figure 53) ***More common and more capable: accumulated number of subsea systems and deepest recorded completion, 1960-2005***[771]



In ultra-deep waters, production became more difficult, as did drilling. In order to drill where the water depth reached 2000 metres or more, a rig would need very long risers, lots of mud, strong winches, forceful mud pumps and separation equipment. This added thousands of tonnes to the weight.[772] Most operational rigs in the mid-1990s could not work beyond 500 metres,[773] and capable rigs fetched very substantial daily rates.[774] Demand was particularly high in the Gulf of Mexico, where Shell had discovered its Auger field at 900 metres depth offshore Louisiana in 1990-1991. It contained roughly three times more oil and gas than Statfjord and somewhat more than Troll. The find triggered a rush to explore the deep

[771] The figure is assembled from a number of sources of which the two most useful have been *Quest offshore resources* (cited) and "Subsea technology".

[772] Mamdou M. Salama, "Some challenges and innovations for deepwater developments" (paper presented at Offshore Technology Conference, Houston, 5-8 May 1997).

[773] Ibid.

[774] R.S. Platou Offshore, *Offshore rig market status report* (www.platou.com, 2005 [cited 23 February 2007]).

waters in the central Gulf of Mexico,[775] particularly after 1995 when the U.S. authorities suspended royalties on some discoveries.[776] Partly as a response to this demand, the second-hand value of a modern (third generation) rig rose from USD 60 million in the summer of 1995 to USD 150 million in the summer of 1998.[777] Dynamic positioning cut back on the time required deploying the rig, the costs of the support vessels that handled anchors, the weight of the mooring lines, and the drift that would occur regardless of the mooring.[778] In deep waters, these advantages offset the cost of extra fuel and a slightly increased risk of a drift that might disconnect the marine riser. Fully 58 per cent of all rigs working on more than 1000 metres of water employed dynamic positioning – as opposed to two per cent of the rigs that worked on shallower waters.[779] Besides, when an increasing number of drilling operations shifted from deep to very deep waters, the various petroleum support vessels that accompanied the rigs requested advanced DP equipment too.

In various ways, the geological difficulties of oil companies contributed to rapid growth at Kongsberg. Gravity platforms and traditional approaches to offshore oil were best suited for large finds in shallow waters - conditions that were harder to come by with each passing year. Deepwater technology was better suited for the large depths that oil companies had to address in order to escape political risks in places such as Russia, the Middle East and Venezuela. Meanwhile, the remaining fields on shallow shelves were smaller than in previous years. Here, too, mobile production equipment was better suited than traditional platforms because such equipment could move from one emptying field to another. Regardless of the nature of the challenge, deep waters or smaller reservoirs, the kind of technology provided by Albatross and Kongsberg Offshore was increasingly in demand.

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[775] Salama, "Some challenges and innovations for deepwater developments"; Mike Forrest, "Wildcat recollections: 'bright' investments paid off", *AAPG Explorer*, August 2000.

[776] Wallace, Duberg, and Kirkley, "Dynamics of the oil and gas industry in the Gulf of Mexico: 1980-2000: Final report".

[777] Offshore, Offshore rig market status report ([cited).

[778] Ribeiro, Paulo, and Neto, "Campos basin subsea equipment: Evolution and next steps".

[779] Krall, "Keynote speech from Exxonmobil development company".

9.5 Reverse salients, continued

Not to deny the good fortunes of difficult geology, Albatross and Kongsberg Offshore contributed to the success by continuously improving their offering. The ability to innovate, which this thesis has linked to industrial architecture and company cultures, continued to yield results in new areas. From the late 1990s onwards, the reliability of deepwater technology was increasingly taken for granted. Rather, the main concerns of the industry shifted to the practicalities of operating in large depths, the struggle to get more output from declining fields and a venture into a new area of offshore technology where oil companies could do away with platforms altogether and pump the produce directly to shore. The deepwater industry at Kongsberg took part in a number of initiatives aimed at overcoming *depth*, *distance* and *dearth* – long-time reverse salients of offshore oil production. I return to each issue in sequence.

Depth had always been an issue for the offshore oil industry. With regard to subsea systems, depth affected their design – not so much the design of the system itself, but the various techniques to install and maintain installations far below the surface using remotely operated vehicles.[780] Depth also tended to affect reservoir *pressure* – the further from the surface, the more weight on top of the reservoir. Outside West Africa, where oil resided typically 1000-1200 metres below the seabed, pressure and temperatures were comparably low. In the North Sea, where oil and gas resided 2000-3000 metres below the seabed, the pressure was higher. Some fields in the Gulf of Mexico contained petroleum 6000 metres below the seabed with enormous pressures.[781] In 1997, Kongsberg Offshore modified its Host system to handle 10,000 pounds per square inch, sufficient for most tasks down to water depths of 2500 metres. Around 2005, subsea systems were tested for pressures up to 15,000psi, but some known offshore reservoirs had an internal pressure of 20,000psi.[782]

Dynamic positioning also became more demanding at great depths. A particular challenge related to navigation: fully redundant DP systems could not simply rely on GPS but required alternative position reference systems. The second best alternative was hydro-acoustic systems, but their accuracy decreased in line with water depth and the systems were slow to detect a deviation because sound waves had to travel several kilometres.

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[780] Rosnes, Lindland, and Inderberg, "Subsea production systems: Improve cost efficiency and further reduce cost per barrel produced".

[781] Interview with Halvorsen, 4 October 2004.

[782] Interview with Halvorsen, 4 October 2004.

Making such data reliable required advanced software, cybernetics expertise and mathematical models. Low-end systems mostly failed the challenge and left a profitable market for the most advanced suppliers.[783] Albatross (Kongsberg Maritime) profited handsomely from the mid-1990s boom in deep water drilling rigs. Between 1995 and 2001, the number of rigs capable of working in depths below 1500 metres (5000 feet) increased from 40 to 120.[784] Albatross controlled most (maybe 80 per cent) of the market.[785] These rigs bought complex systems that frequently included advanced process control, power management, ballast handling, riser management, etc.

* * *

Recently, the most rapid progress seems to be taking place on a second frontier - *distance*. If pipelines could carry the output straight from an underwater installation onto shore, the industry could do away with fixed and floating topside facilities, save considerable sums and circumvent the challenge of harsh climates. The industry pursues two broad approaches to ship wellstream: multi-phase pumping and subsea processing. Both techniques reduce the backpressure that otherwise lowers ultimate recovery, and both techniques can do away with production platforms (fixed or floating) altogether. Marketing materials boast that these techniques have *game changing* impact.[786] Such techniques have been on the drawing board for decades. Their slow emergence is evidence of the conservative attitude of oil companies.

Multi-phase transport is an industry term for shipping untreated wellstream. *Phase* in this respect means a substance such as oil, natural gas, water or vapour. Multi-phase was commonly shipped across short distances, for example ten or 15 kilometres from a satellite well onto a nearby platform. Shipping stuff further frequently required a technique to increase pressure (pumping). Considerable sums of research money have been channelled into multi-phase pumping[787] - a task complicated by the unruly nature of oil and gas. Petroleum often occurred as a mix of substances with diverse qualities

[783] Interview with Jenssen, 14 October 2004.

[784] Offshore, Offshore rig market status report ([cited).

[785] Anders J. Steensen, "I stødig posisjon", *Teknisk Ukeblad*, 18 February 1999, p. 38, citing an Albatross market director, Finn Søberg.

[786] FMC Technologies, "New challenges, new solutions for subsea systems" in *Oil & Gas Journal* (Undated, probably 2006).

[787] On Frank Mohn AS, cf. page 195.

such as methane (which boils at minus 164°C) and heptadecane (which boils at plus 303°C). Gases affect oil in the same unpredictable way as air in a water hose; and if the temperature drops, gases turn to liquid and liquids sometimes to wax that clog the pipeline.[788] Most inconveniently, at about 20 degrees Celsius, hydrocarbons may act somewhat like water at 0 degrees. The supplier industry has come up with various responses ranging from the mere adding (and recycling) of antifreeze, insulating and heating subsea pipelines, or simply stirring the wellstream to create a mixture that resembles "slush".[789] The subsea systems that control these processes require power supply and long distance signal transfer – both tasks are challenging underneath water. Only recently have such techniques been applied offshore: the first multiphase pump for use subsea was installed in 1993.

Keeping in mind the difficulties of multi-phase transport, the benefits of *subsea processing* were obvious. Processing mostly involves the separation of phases to simplify the task of pumping the produce onto shore or to some faraway production facility.[790] The fewer the phases, the easier to ship multi-phase. Besides, the separation of water and sand from petroleum on the seabed reduced backpressure and increased output from a reservoir. Processing can be very simple: an early example at Troll C separated (light) oil from (heavy) water in a gravity tank. In deep waters, however, such tanks would have to withstand high pressure and might not work very well.[791] Kongsberg Offshore ventured into subsea separation in the late 1990s and gained ground in 2003 when FMC Technologies bought CDS Engineering.[792] The company focused on *inline separation*: when spinning fluids pass through a pipe at high velocity, centrifugal forces push heavy components such as oil and sand towards the wall and retain gas and other light substances in the centre for capture in an inner pipe.[793] In fields that

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788 Nils H. Lundberg, "Flere faser - færre plattformer", *Norsk Olje Revy* 1989, pp. 16-19.

789 Interview with Halvorsen, 4 October 2004.

790 Based on *New challenges, new solutions for subsea production systems* [Product brochure] (FMC Technologies [cited May 2007]); available from http://www.fmctechnologies.com/Subsea.aspx.

791 Perry A. Fischer, "Subsea production systems progressing quickly", *World Oil Magazine*, November 2004.

792 *Fmc technologies to provide subsea separation and boosting system for Statoil's Tordis field: 10 November 2005* [Press release] (FMC Technologies, 2005 [cited December 2006]); available from www.fmctechnologies.com/tordis.

contain pure, dry gas, such as Ormen Lange and Snøhvit, less processing is required.

Figure 54) ***Changed game: Options for the offshore oil industry, 2005***

	Drilling (Ability to host a rotary rig)	**Production** (Ability to host a Christmas tree)	**Processing** (Ability to host separation equipment)
Fixed platforms	✓	✓	✓
Floaters (Ships. rigs. semisubs)	✓	✓	✓
Subsea templates		✓	✓

A final technological challenge dealt with *dearth* – how to increase recovery from emptying fields. The degree of recovery depended on reservoir characteristics, how many wells the operator chose to sink, tactics to maintain reservoir pressure e.g. by injecting gas or water, but also techniques to fine-tune production and intervene in the well to prevent clogging.

Up until the 1990s, operators intervened reluctantly and infrequently. Systems that allowed for easy well intervention were costly and complex. In the 1990s, more technologies appeared to help extract more oil from each well. One set of improvements centred on control systems, popularly known as *intelligent* subsea control. The concept encompassed *close loop control* – i.e. the fine-tuning of output from multiple wells by monitoring temperature and output. Temperature would typically vary between wells; if temperature dropped in one well, the system could compensate by increasing output from another well and maintain the desired flow (warm oil flows more freely).[794]

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[793] The technique has been installed at Tordis to separate a slurry of water and sand from the petroleum. Roald Sirevaag, "Subsea production: Status and challenges" (paper presented at International offshore contracting & subsea engineering conference, Aberdeen, 29-31 October 1996) Anders J. Steensen, "Tordis – første faste undervannseparator", *Teknisk Ukeblad*, 26 August 2005.

[794] Interview with Halvorsen, 4 October 2004.

Other techniques analysed the presence of sand in the wellflow, predict erosion and suggested when to service or replace certain parts. A third technique automated *emergency procedures*; rather than alert an operator in case of an emergency, a control system could be entrusted to employ standard operating procedures in case of such incidents as an abnormal fall in pressure. These techniques were sometimes referred to as *e-fields*, a drive to automate and remotely control ever more aspects of petroleum production above or below the surface.[795]

A second drive to increase recovery centred on well intervention. Wells may clog just as arteries do, but oil companies could rely on various techniques to keep petroleum flowing. Kongsberg Offshore pioneered *through tubing rotary drilling* where a dynamically positioned drilling rig would fit a blow-out preventer onto a subsea Christmas tree, insert a dill-bit down the tubing and perform directional drilling. If performed repeatedly, the well eventually resembled a tree trunk with multiple roots to drain petroleum.[796] Statoil signed a deal in 2005 to try out the new approach in cooperation with FMC Production Services, a subsidiary of FMC Kongsberg Subsea.[797] FMC Kongsberg Subsea (Kongsberg Offshore) has also done work on *riserless light well intervention* in cooperation with Statoil and Prosafe.[798] Using compact tools and comparably light umbilicals, this technique aimed to cut the costs of well intervention.[799] Kongsberg Offshore began applying the technique to Statoil's 245 subsea wells in 2006.[800]

[795] For a principled introduction, cf. interview with Halvorsen, 4 October 2004. For specific applications of the e-fields approach, cf. information on the Troll field in St.meld 38, 2003-2004 [a government white paper]. On the effect of fine-tuning to increase the regularity of prolific fields, cf. Rosnes, Lindland, and Inderberg, "Subsea production systems: Improve cost efficiency and further reduce cost per barrel produced". On close loop control, cf. Sirevaag, "Subsea production: Status and challenges".

[796] Anders J. Steensen, "Får mer ut av undervannsbrønner", *Teknisk Ukeblad*, 27 October 2005.

[797] *Statoil signs agreement with FMC Kongsberg Subsea on new technology: Kongsberg, 11 March 2005* [Press release] (FMC Technologies, 2005 [cited December 2006]); available from www.fmctechnologies.com.

[798] "Kongsberg Subsea bak økt utvinning", *Aftenposten*, 12 November 2003.

[799] FMC technologies' product brochure: New challenges, new solutions ([cited).

[800] FMC technologies to provide Statoil with subsea riserless light well intervention technology over multi-year period: Houston, 6July 2005 [Press release] (FMC Technologies, 2006 [cited December 2006]); available from www.fmctechnologies.com.

The innovations cited above often involved not the core deepwater technologies covered so far in this thesis, but complementary equipment and techniques. Such a shift in focus indicated that the most pressing concerns of oil companies no longer related to subsea production systems and dynamic positioning, but other components in the technological system that surrounded offshore oil production. Submersible pumps, for example, found more applications related to depth, distance and dearth. In deep waters, they could drain heavy oil away from the well, decrease back-pressure, and increase the rate over recovery. At Lufeng outside China, Kongsberg Offshore employed pumps from Frank Mohn (FRAMO) in Bergen to devise a system for Statoil.[801] A host of techniques such as the insulation and heating of flowlines, subsea separation and new approaches to drilling contributed significantly to the advances of the offshore oil industry in the late 1990s and early 2000s. This is not to argue the techniques covered in this thesis were stagnant.

* * *

Albatross made some significant contributions to dynamic positioning towards the end of the 1990s. The company introduced *Green DP* in 1998-99. Interestingly, this twist was exactly what had motivated Professor Jens Glad Balchen to develop a new dynamic positioning system in the late 1960s: the promise of smoother manoeuvres.[802] Albatross did not initially implement optimal dynamic positioning. This shortcoming was not because of any lack of theoretical insight, but because of the economic and practical limitations placed by computing technology. In the 1970s and 1980s, a computer sufficiently powerful to do optimal dynamic positioning would have been horrendously expensive compared to mooring.[803] In the 1990s, however, computers were able to handle the very complex algorithms that guide Green DP. The previous DP had turned the thrusters on or off. By making predictions further ahead in time, and applying corrective action earlier and on less than full throttle, Green DP saved some 20 to 25 per cent on fuel costs. Initially sold as an option, it shortly became part of the standard DP delivery form Kongsberg.[804] Some 25 years was required before

[801] Sirevaag, "Subsea production: Status and challenges"; Fraga et al., "Campos basin: 25 years of production and its contribution to the oil industry".

[802] Cf. Chapter 4.2, page 91 ff.

[803] Interview with Jenssen, 14 October 2004.

[804] Interview with Helle, 14 April 2005.

an optimal regulatory strategy based on Kalman filtering and forward coupling was implemented in line with cybernetic theory.

The sections above cover numerous improvements and innovations. Many originated in the crossroads between several actors, e.g. Statoil, Kongsberg Offshore, CDS engineering of the Netherlands and FMC Technologies of Houston, Texas. Apart from such cross-pollination, innovations could draw on knowledge gathered in previous decades and new insights provided through science and research.[805] As in previous decades, however, we should not downplay the dynamics of the companies involved: innovative developments occurred in no small part because suppliers had the freedom to suggest original solutions and engineers in these companies were expected to show initiative. Such sentiments contributed to innovation, but also to deliveries far beyond the traditional home markets of Albatross and Kongsberg Offshore.

9.6 New approaches to contracting

Throughout this chapter, and frequently throughout the remains of the thesis, I have returned to the beneficial effect of innovative procurement practices – strategies that allow suppliers responsibilities and leeway in exchange for taking risks. The EPC contracts introduced in the 1980s exemplified this approach, but contracting strategies were evolving. As subsea technology matured and the inherent risks in deploying subsea systems diminished, oil companies became less concerned about technical excellence - and the procurement procedures changed accordingly. The established practice of granting EPC contracts was refined in ways that shifted additional risks onto suppliers, e.g. by specifying extensive guarantees.[806] The more fundamental change involved entirely new procurement formats.

In the 1990s, it became more common to buy hardware and services as a single package through *life of field contracts*. If previously the supplier sold a subsea system and a tie-in system to install the equipment (and then be placed in store), oil companies increasingly preferred to buy only the production system and ask the supplier to handle installation. Tie-in and installation became separate industry niches procured as a service. Since the mid-1990s, most subsea assignments result in two contracts – one for the

[805] Helge Keilen, Åse Pauline Thirud, and Stein Arve Tjelta, *Petroleumsforskning lønner seg* (Trondheim: Offshore Media Group, 2005).

[806] Interview with Steenstrup, 14 October 2004.

equipment and one for services.[807] Kongsberg Offshore responded by establishing a service business at the Coast Center Base outside Bergen. This unit would install subsea systems on behalf of an oil company, and the oil company would then verify and survey its operations. In case of a malfunction, the supplier would take a module to the surface for repair, maintenance or replacement.[808] The procedure served to make suppliers more attuned to the operational challenges of oil companies.

The 1990s also saw the emergence of new approaches to the ordering of hardware. *Framework contracts* were a case in point. Like life-of-field contracts, they aimed to align the interests of users and producers. A framework agreement would last several years. In this period, the customer stuck to one supplier and a specified product range in return for guaranteed prices and terms of delivery. In 1995, Statoil invited suppliers of subsea systems to bid for a framework contract. Statoil indicated the company would buy turnkey systems worth NOK 3 billion (80 wells) in a five-year period, and asked in effect for a list of prices and conditions.[809] Kongsberg Offshore secured this contract in competition with Kværner, ABB and Cameron.[810] The contract secured Statoil a decent price and Kongsberg Offshore economies of scale – the volume ended up at twice what Statoil had indicated.[811]

Framework agreements cut back substantially on the time required to develop a field. These agreements derived the operator of the opportunity - and saved him the time – of deal-making: the “framework” determined options and prices. The operator saved months by skipping the tender

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[807] Daling et al., *Offshore Kongsberg*.

[808] Interview with Halvorsen, 4 October 2004.

[809] Sirevaag, "Subsea production: Status and challenges". The procedure somewhat resembled the approach that Kongsberg Offshore suggested in relation to Norne, cf. chapter 8.3.

[810] Asgaut Næss, ”Milliard-jubel på Kongsberg”, *Dagens Næringsliv*, 29 August 1995; ”Statoil: Kongsberg Offshore vant overlegent på pris”, NTB, 28 August 1995.

[811] Interview with Steenstrup, 14 October 2004. The framework contract covered deliveries for Yme Beta (1996), Lufeng in China (1996), additional Gullfaks satellites (1999) and most importantly for Åsgard (1995-97) with 16 templates and 52 Christmas trees. Embracing three discoveries (one gas reservoir and two reservoirs with a combination of oil and gas), Åsgard was large by Norwegian standards. Statoil decided to develop the field using a FPSO for oil production and a moored, semi-submersible production platform to process gas for shipment.

process and the time spent assessing offers and clarifying terms.[812] More importantly, the supplier could cut delivery times because the framework made demand foreseeable and allowed the supplier to keep items with long lead times in stock. Template was a case in point. Before the Host technology (cf. chapter 8.4) and the framework contracts, Kongsberg Offshore might spend four months designing and 12 months manufacturing and installing a template. In the late 1990s, Kongsberg Offshore would simply supply one from its stock.[813] (Appendix 11.11 contains a list of framework agreements entered into by Kongsberg Offshore between 1995 and 2004).

Oil companies used framework contracts to cut costs and deployment times, but these were not the industry's only concerns. Sometimes a subsea project involved great technological uncertainty or the development of new technology, i.e. technological risks. Responding to such challenges, oil companies sometimes employed alliance strategies.

Kongsberg Offshore gained some experience with innovative new ways of offloading risk when working outside the Norwegian shelf. Petro-Canada had little offshore experience, and faced a major technical challenge in developing a field off Newfoundland where large icebergs threatened installations both topside and subsea. In 1995, inspired by a new contracting strategy on the British shelf, Petro-Canada invited suppliers to form alliances and submit bids for the handling of every aspect related to the field development: facilities design, procurement, drilling, construction and installing of equipment – everything that had to be in place until the first tanker left *Terra Nova* with a load of oil. Only then would the suppliers get their success fee.[814] This contracting strategy forced a number of suppliers with complementary technology to align their work. Unless one company had every skill in-house, the suppliers would have to form alliances and work out between themselves how to share risks and rewards.[815] The winning team, *Grand Banks Alliance*, was managed by Brown & Root and

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[812] Interview with Steenstrup, 14 October 2004.

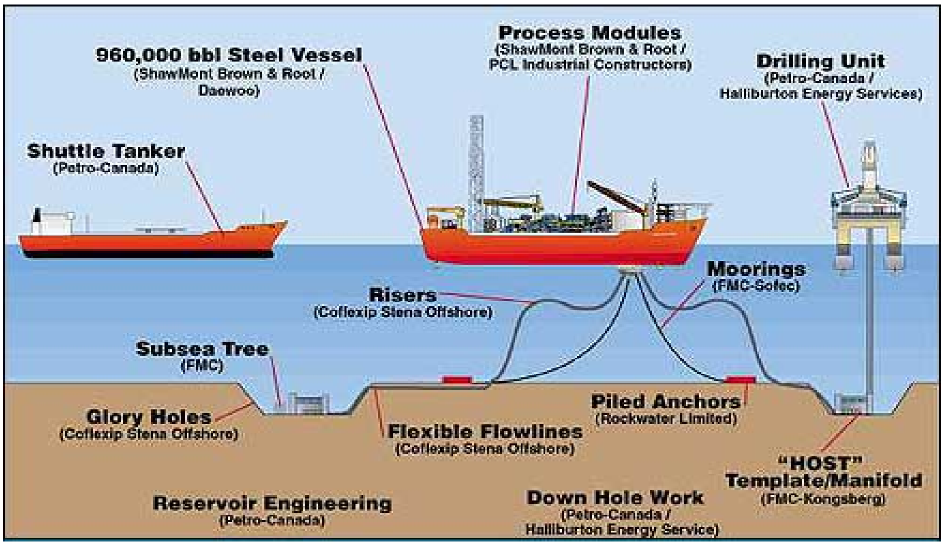
[813] Sirevaag, "Subsea production: Status and challenges"; Rosnes, Lindland, and Inderberg, "Subsea production systems: Improve cost efficiency and further reduce cost per barrel produced".

[814] G.V. Lever, B. Dunsmore, and J.R. Kean, "Terra nova development: Challenges and lessons learned" in Offshore Technology Conference (Houston: 2001). The alliance resembled what BP had pioneered e.g. in the BP ETAP project.

[815] Ibid.

included subsea systems from Kongsberg. [816] Brown & Root designed a FPSO capable of absorbing the impact of a 100,000-tonne iceberg or disconnect at short notice to avoid danger. Coflexip Stena Offshore moved 290,000 cubic metres to dig glory holes that offered protection for the subsea systems, [817] and Kongsberg Offshore supplied subsea systems. The figure below indicates the division of labour.

Figure 55) ***The Terra Nova alliance***[818]



The contract structure of the Grand Banks Alliance (and a few other similar alliances of which Kongsberg Offshore was part) made the partners jointly liable for the full scope of the work.[819] Within certain limits, the alliance shared extra cost, shared eventual profits and shared the bonuses that were to

[816] Ole Peder Enger and Yngve Andreassen, "Internasjonalisering i offshorebransjen og bruk av strategiske allianser: Kongsberg offshore as: Et casestudium", (Semesteroppgave, Norges Handelshøyskole, 1998). Interview with Steenstrup, 14 October 2004. Aker, Maersk, and Flour Daniel headed other teams that bid for this assignment.

[817] Lever, Dunsmore, and Kean, "Terra nova development: Challenges and lessons learned".

[818] Interview with Steenstrup, 14 October 2004.

[819] Steenstrup, "The changing philosophy of contracting: An international perspective".

be paid when oil began to flow and when the field reached a certain capacity.[820] Such terms served to keep all parties aligned and focused on objectives and deliverables. The suppliers had to acquire an overview and a very wide skill-set – rivalling and possibly surpassing that of a small oil company. In addition, deepwater suppliers assumed operational risks and sometimes pay in relation to the output of a field. The introduction of such collaborating strategies has blurred the boundary between supplier industry and upstream oil industry. One may wonder what exactly constitutes an oil company and what constitutes a supplier?

9.7 Conclusions: the shape of things to come

In the field of competitive strategy, if not in business history, it is common to reflect on the implications of any finding the author has come across. In our case, these reflections are not so much guesswork, as an attempt to link the Kongsberg-based supplier industry's 35 years history with some recent developments on the Norwegian shelf.

Assume, as do materialist (and Marxist) historians, that owning the means of production really matters. In a world of liquid capital markets and outsourced manufacturing, actually owning a tool or a piece of machinery is probably less important than owning design, patents and knowledge. These immaterial rights increasingly belong to engineering companies rather than the large integrated oil companies that have dominated oil and gas exploration.

When offshore oil production relied on integrated platforms, the very size of these undertakings did not allow a single supplier to gain an overview, but rather presumed significant central planning by the oil company or a large engineering firm. In the 1970s and 1980s, Statoil further diminished the role of individual firms by sharing out the work of building the topside structure amongst numerous suppliers while the oil companies and their advisors retained responsibility for all interfaces in the complex projects. The development style, that is, did little to encourage independent designs from innovative suppliers; a reluctance to relinquish control of key technology helps explain the drawn-out shift away from Condeeps.

Nowadays, independent suppliers control the technology most suited for deep waters, small fields and low oil prices. What oil companies previously

[820] Lever, Dunsmore, and Kean, "Terra nova development: Challenges and lessons learned"

controlled in-house, suppliers such as Albatross and Kongsberg Offshore now offer on a market. This has been a precondition for the emergence of what the Norwegian trade press has named *oljemygger* (literally oil mosquitoes) - small oil companies that place bets in fields that escape the attention of the oil majors. The newcomers have hardly any in-house organization and count on outsourcing exploration, development, operations and servicing. The crossroads between shipping and oil, mobile oil installations, provide a particularly fertile ground for the specialists. The floating production company that services one mature field today may move on to another when that well is dry. The shuttle tankers that carry the oil to market are even more flexible. These companies operate in the crossroads between a very dynamic, risk-seeking shipping industry, and a conservative, risk-averse oil industry – and the scope they can handle grows in line with the increased competencies of the supplier industry.

Where oil companies retain a large role, they may choose to cooperate with their suppliers in ways that reshape the current industry architecture. The increased involvement of Kongsberg Offshore in services and the emergence of field-development alliances are examples. Such approaches may extend to life-of-field alliances where suppliers agree to provide, not only equipment, but also the services required to make them run throughout the life of a field. Going further, oil companies may prefer to lease the production equipment from suppliers in the same manner a company may lease a floating production, storage and offloading (FPSO) vessel. It is not inconceivable to lease subsea equipment in the same manner.[821] Besides, why pay for the service at all? A small oil company with a promising field may forge deals whereby one or more suppliers may provide equipment free in return for a cut in the revenue stream. On the Norwegian shelf, Kværner and Aker considered applying for licenses on the Norwegian shelf.[822] Aker-Kværner was close to forging an alliance with Hydro when the latter preferred acquisition by Statoil. Whichever way, the growth of a supplier industry capable of handling the core skills of the oil companies permits innovative and entrepreneurial ways of exploiting oil offshore. Given a sustained period of low oil prices, interesting things will happen.

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[821] Steenstrup, "The changing philosophy of contracting: An international perspective". Similar thoughts were expressed by Jon Kløve in Daling et al., *Offshore Kongsberg.*

[822] Engen, "Rhetoric and realities".

10 Conclusions: shipshaped progress, 1972-2007

In the mid-1970s, huge islands of concrete looked set to dominate the Norwegian Shelf. As of 2008, this author is not aware of any large gravity platform on order. Oil exploitation moved beneath the surface where the number of subsea completions grows rapidly supported by dynamically positioned vessels.

The path to deepwater oil production opened with a string of radical inventions around 1960. Although technology developed constantly in subsequent years, the basic principles remained in place. A shipping company in the 1990s would relate to similar concerns as the *Glomar Challenger*, which pioneered dynamic positioning in 1960-61; an oil company ordering subsea technology today relies on a technology whose principles were pioneered in the waters outside California in 1960-61. One may even argue the basics have changed little since the early 20th century when wildcatters in Louisiana submerged valve trees into the marshes. Like most experimental techniques, deepwater technology was first applied where nothing else would work – beneath the icy surface of Lake Erie, for example, or on drillships above the extreme depths where scientists hoped to penetrate the crust of the Earth. Only later did deepwater technology enter the mainstream.

Whatever the exact exaltation time, we are left wondering it took so long. Why did these techniques take thirty or forty years to reshape the offshore oil industry and Norwegian oil?

From the point of view of oil companies, reliability was the main argument against deepwater technology. Thus, engineers and developers had to provide robust solutions *before* the oil industry would do away with fixed platforms and mooring. Field developers knew the risks involved in untested technologies: only when the payback was exceptional would oil companies experiment - and the pace of progress lingered until technology eventually became sufficiently reliable. This line of thought implies a *linear view of technological development* – i.e. the tendency to place science and R&D at the beginning of a causal chain followed by innovation, diffusion and eventual productivity growth.[823] Put simply, the problem and its eventual

[823] Few actually advocate a linear view of technological development – it is a term used in the long running effort of historians to reclaim technology and innovations for the social sciences rather than placing science and R&D at the beginning of a causal chain followed by innovation, diffusion and eventual productivity growth.

solution rested with what economists dub the *supply side* – the providers of technology.

This thesis has investigated advances and setbacks on the supply side in order to understand how subsea systems and dynamic positioning systems advanced. Mapping what went on at Kongsberg, we have chronicled the progress in some detail. We looked at innovative new uses of cybernetics and statistics to develop model-based dynamic positioning with powers of prediction. We looked at advances in computing that cut costs and improved reliability. We followed ever more techniques aiming to simplify repair and maintenance of subsea production systems, beginning with diver access and atmospheric chambers before moving on to remotely operated vehicles, modular designs, wireline techniques, duplication strategies and control systems aiming to reduce wear and tear. We saw trial and error, extensive labour, and constant improvement through incremental innovations.

There were patterns to the efforts that took place. One observation in this thesis, as in a rich body of research on large technological systems, is the futility of improving only the advanced hallmark components when the nature of a technology is systemic. A brilliant novelty would fail to make inroads due to the lack of complementary technologies and the prevalence of *reverse salients* – parts of the technological frontline that failed to move on and held back the very field of which it was part. Dynamic positioning could only advance as far as contemporary computers and position reference systems; subsea systems could not advance beyond the limitations of its weakest components, usually repair and maintenance. For most purposes the industry needed not only a working wellhead system, but also a floating production system, a control system and everything else that had to be in place for a technological system to function properly.

In due time, a dominant design became firmly entrenched. Suppliers experimented less with various solutions and settled for official or unofficial standards. The developments resembled a common pattern in studies of the

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The linear view is often coupled with technological determinism and portrayed as a *deux ex machina* – something important yet unpredictable that appears on the scene to be taken into account but not influenced – much as a farmer acknowledges the effect of the weather. The argument, often implicit, is that inventions originate from genius and is not subject to generalizations – or else we assume the genius applies his rationality, listing the various options before selecting, based on reason, the solution with best functionality that subsequently succeeds. For an eloquent introduction, see Andersen, "Manna fra himmelen: Om teknologihistorie og teknologideterministisk historie".

history technology: large variety in an early stage, standardization in a later stage. Eventually, the product settled on a path, not only because of trial and error, but also because users' habits favour established techniques. Regulations and other formal specifications further enforced homogeneity.[824] We may also point to company-internal influences that served to maintain standards. In the mid- and late 1980s, Kongsberg Offshore was among the most vocal proponents of standardization as a road to affordable and reliable field developments. Possibly, the act of perfecting a technology undermined the producer's capacity for radical improvements. For example, the sheer volume of dynamic positioning orders forced a certain bureaucracy upon the people who deliver; one cannot possibly deliver hundreds of systems the way one used to deliver a few. To cut costs and improve efficiency, Albatross had to codify procedures and rely less on discretion – a discretion that frequently caused cost overruns, but sometimes innovation.

Although technological evolution followed familiar patterns, we should not assume inevitability or automation. Social sciences frequently ascribe innovation to *organizational learning, firm-wide competencies*, *systems of innovation* or some other term that credits organizations and networks with the qualities of humans. This thesis prefers to give credit to humans. Inventions mostly rested with a few who were sufficiently unbound by convention and sufficiently informed about business and research. Jens Glad Balchen, the entrepreneurial professor who suggested model-based dynamic positioning, was a case in point. There was Steinar Sælid, who played a prominent role in designing both dynamic positioning and Albatross's integrated control system – and Tore Halvorsen, who habitually launched ideas that improved upon existing subsea systems. There was Bjørn Barth Jacobsen, who introduced new business practices, and a few individuals who turned them into a company culture. Like a number of case studies on innovation, this thesis finds that breakthroughs rested with a few, not with teams and organizations.[825]

Alas, a superior product may count for less than one may think. This thesis has stressed the need to look beyond technology and examine attitudes to adopting new techniques. For example, the early success of Albatross dynamic positioning relied less on a functionally superior technology, but

[824] For a review of the *life cycle* literature, cf. Nelson, "The co-evolution of technology, industrial structure, and supporting institutions".

[825] For an illustrative account of individual contributions, cf. the emphasis on the impact of Hugo Holtermann in the development of modern contrast media, Sogner, "An innovative culture: Nyegaard & co, Norway and the environments of business".

mainly on intense footwork that managed to overcome the system's early flaws; only in the medium term did Albatross dynamic positioning become accurate, tolerably error-prone and affordable. In explaining eventual success, much credit must go to people who bought the systems, suffered from the uncertainty and offered feedback. That is the *demand side* of the equation.

10.1 The effect of venturesome consumption

The advent of new techniques in the North Sea and elsewhere ultimately depended on customers. These users affected the Kongsberg suppliers in various ways – in some cases contributing actual ideas and designs – and most fundamentally, they made innovation possible by paying for the end products.

When contrasting oil and shipping in the first few decades covered by this thesis, we notice an unequal propensity to adopt new techniques. Oilmen everywhere, with a few noteworthy exceptions, tended to shun technological risk. That attitude came with the business: price fluctuations and political uncertainty caused enough concern without adding unnecessary technological risk. Oil companies ran tight ships, strived to impose uniformity by way of hierarchy and centralized procurement policies in part to avoid experimentation with untested products and suppliers. The conservative sentiments in the industry contrasted with the shipping paradigm – where customers bought Albatross dynamic positioning before the concept remotely resembled a product. Consequently, subsea systems took decades to gain a following amongst oil companies based in Norway whereas dynamic positioning rapidly caught on among shipping companies servicing offshore oil installations (cf. chapter 3).

How can we know whether the differences belong to the realm of culture and mentality, not hard technological or economic rationality? How can we know whether the differences were unrelated to the maturity of the respective deepwater technologies? For one, we note how conservative sentiments in the oil paradigm slowed or hindered not only the adoption of subsea technology, but also the adoption of innovative techniques in general. Industry observers fail to recall a single innovative technology that originated with the oil industrial complex between 1973 and 1986.[826] Such

[826] Rolf Kvamsdal and Terje A. Totland, "Undervannsteknologi: Noe for de få eller for de mange?" *Jernindustri* 1986, pp. 52-56. Kvamsdal (Kværner Subsea Contracting A/S) was quoted saying "på tross av den store offshoreaktiviten vi har

conservatism in the application of technology was not unique to Norway, but the early Norwegian oil industry was possibly less prone to change than offshore oil companies in oil provinces in which oil companies had more freedom to decide on development styles. When Statoil and public authorities insisted on Condeeps, they did so in part because they knew and trusted this technology and in part because such platforms provided the most work for the influential ship-building industry. This affection for fixed platforms at times turned into opposition to subsea systems and floating production, what Hydro's director of oil technology once likened to the Luddites.[827] By contrast, shipping and drilling companies rapidly improved the capacity of their ships and rigs adopting new technologies such as dynamic positioning.

Besides, if subsea systems were irredeemably unreliable and the conservatism in the oil industry well founded, how is it the less orthodox parts of the oil industry applied them successfully? Chapters 3.3 and 8.2 contrasted developments on the Norwegian Shelf with developments in the Campos Basin to show how Petrobras deployed subsea systems and floating production. Closer to home, across the border on the British shelf, Hamilton Brothers introduced floating production two decades before these systems gained acceptance with Statoil. Such experiments, pioneered by industry mavericks and entrepreneurs with meagre resources, challenged the notion there were no viable alternatives to gravity platforms and no room for subsea systems on the Norwegian shelf in the 1970s.

A comparison in time provides a final reason for de-emphasising the idea that technologies succeeded based on their own merits or *readiness*. Although the subsea systems improved continuously, the systems that gained acceptance around 1990 much resembled the systems that failed to catch on in Norway around 1980. What changed was not primarily technology, but the propensity to apply the technology. By 1990, oil companies had become more tolerant of technological risk and more open to third-party technology development – somewhat resembling shipping companies.

When examining the role of customers, we have noticed their importance, not only as a source of revenue, but also as a source of sentiments. In part because Albatross and Kongsberg Offshore faced different customers, they developed distinct cultures. Particularly in chapter 4, I have pointed out how

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hatt i Nordsjøen i de siste 20 år, er det allikevel forbausende hvor få virkelig nye konsepter og løsninger som er lansert og tatt i bruk."

[827] Cf. footnote 630.

culture helped coordinate the effort of numerous innovative people at Albatross. I have pointed to the various productive outcomes of Theory Albatross, how it spurred technology development and drove sales.[828]

Intriguingly, some of the most noteworthy innovations originated with improved business processes rather than technical invention. At Albatross, for example, a flat and customer-centric organization aligned customers, salespeople, developers and support personnel. This approach to organizing helped the company identify numerous applications for its technology such as dynamic mooring, applications for offshore loading and pipe-laying. Another set of improvements streamlined the delivery process and cut back on the time spent configuring and testing systems at the customer's premises. A third set of improvements introduced a trade in tasks that replaced proprietary manufacturing with components and services from specialized suppliers. Such improved business processes helped Albatross maintain its considerable margins on high-end dynamic positioning although real prices in 2007 (not to mention nominal prices) were but a fraction of the levels in 1977. Meanwhile, the reliability and accuracy of the systems kept improving. Kongsberg Offshore's efforts to standardize deliveries and introduce scale economics to subsea systems involved some technical refinement, but much of the gains stemmed from improved business practices.

10.2 Ingenious when left to one's own devices

At times, this thesis reads like an argument why the practices of the shipping industry – the shipping paradigm - fostered innovation. From the 1980s onwards, innovation in the Norwegian oil industry frequently stemmed from the adoption of shipping techniques, shipping attitudes, shipping institutions and shipping's industry architecture. In explaining why, this thesis has argued implicitly and explicitly that entrepreneurship met less resistance in the shipping paradigm because hierarchies played a less prominent role. Relaxing hierarchies played a crucial role in fostering innovation. This disintegration occurred *within* firms in which empowered employees took on larger responsibilities and *between* firms. The ability of people to sort out things themselves, rather than conforming to directions from above, helped foster innovation, and build a robust supplier industry.

[828] Not only a personal judgement, but one also shared by others such as Helle and Jenssen, interview with Hans Christian Helle, 14 October 2005, and Nils Albert Jenssen, 14 April 2005.

In a library database or on the web, there is an abundance of articles about individual companies inventing and innovating for the offshore oil economy. Attempts to generalize what went on frequently take a government agency or policy as a vantage point. At times, the role of companies remain in view, as is the case with Ole Andreas Engen's thesis about the Norsok cooperation; he readily points out how formal coordination frequently sanctioned established industry practices.[829] Some attempts to explain innovation as a function of wise industrial policies are distorting. A panegyric publication sponsored by the Norwegian Research Council, for example, claims the technological foundation of the Norwegian subsea companies originated in voluntary communal work ("dugnad") between Norwegian research institutes and oil companies. The research efforts initiated around 1980, when foreign oil companies committed themselves to do as much research as possible in Norway, brought about innovation. Without the "active participation of the government and the strong support of the three Norwegian oil companies" the subsea companies would "never have had today's strong position in the market" the research council claims.[830] In the deepwater industry that I have followed, I struggle to identify direct and positive effects of publicly guided research and development. People with research background helped spot oportunities, but public funding played a limited role in further developments. Kongsberg Offshore received considerable support in the early 1980s, but did rather worse in subsequent years than ABB and Kværner, which received far less in research grants. In the 1990s, when subsea industry became a great export success, this discipline was not a favoured recipient of research funds.[831] Public research in general has probably strengthened the supplier industries covered in this thesis, but related public policies served to prolong the use of conventional techniques and delay the introduction of deepwater technology. Hans Mjelva, who has written a solid thesis on large Norwegian yards between 1960 and 1980, exonerates the policy of offering these yards large subsidies.

[829] Engen, "Rhetoric and realities", conclusions, p. 296.

[830] Cf. Keilen, Thirud, and Tjelta, *Petroleumsforskning lønner seg*. The quotation runs: "Uten myndighetenes aktive medvirkning, og sterk støtte fra de tre norske selskapene, ville disse bedriftene aldri hatt dagens sterposisjon i markedet. Det samme kan man si om de norske forskningsinstituttene."

[831] A mapping of the "institutional knowledge base" of Norwegian oil and gas made in 1997 tracked how oil companies did research in Norway alongside 26 research institutes and 24 university departments. The study grouped the effort into 19 major technological fields and 30 main knowledge fields of which "sub-sea production catered to the smallest R&D network". Aslaug Mikkelsen et al., "Country report: Upstream oil and gas in Norway", *Sectoral Case Studies in Innovation*, (NIFU-STEP: TIP focus group on energy innovation system, 2003).

He argues this funding helped prepare the engineering industry for success in the 1990s.[832] I suggest the reverse is more to the point.

This is my key argument: the cooperative efforts we call innovations usually gained in pace when people in authority failed to direct progress – a *weakening* of hierarchies contributed to innovation and entrepreneurship. When left to their own devices, salespeople, engineers and suppliers made numerous choices large and small that shaped industrious businesses. As the presumed safe hands lost control, individuals further down the former line of command assumed responsibilities themselves - and the outcome was mostly shipshaped. I should hasten to add that the freedoms that people experienced when hierarchies disintegrated generally brought no ease. Customers, investors and self-imposed pride replaced the discipline of plans, orders and authority. Corporate life rather became harder for each lost certainty… but arguably more innovative.

On the **level of individuals** and in matters internal to companies and businesses, the disintegration of hierarchies offered individuals opportunity. No organization was ever strictly hierarchical; every organization offers some leeway to those who actually perform tasks - possibly more than is assumed. Although Hurlen employed a chauffeured limousine and insisted on a chain of command, the workings of the arms factory obviously depended on numerous people making informed decisions. Nevertheless, Kongsberg Våpenfabrikk was not an entrepreneurial sort of place. Some of the of deepwater technology development related to the undoing of the old factory and the unleashing of initiative and decision-making among line managers and ordinary employees. In the 1970s, for example, Albatross succeeded in no small part by loosening hierarchies. Albatross embraced *empowerment* and *management by objectives* – concepts advocated by progressive management thinkers for half a century. At Albatross, the term was “Theory Albatross”, an attempt to codify a company culture and a mission statement. The culture of Albatross grew in opposition to Honeywell

[832] Mjelva, "Tre storverft", pp. 227-230. The argument is restated in the concluding remarks: ”Det er tvilsamt om denne avhandlinga vil gjere så mykje til eller frå her, men den har i det minste fått fram at veksten fram til oljekrisa hadde viktige føresetnader i politiske tiltak som langt på veg oppheva ’marknadens dom’ i ein av dei viktigaste vekstindustriane i perioden. Vidare har eg argumentert for at dette kan tolkast positivt, ikkje berre fordi det skapte tusenvis av arbeidsplassar, men fordi det bygde opp ein industriell kompetanse som var grunnleggjande for det norske industrielle oljeeventyret på 1980- og 1990-talet. Det var med andre ord ikkje berre fornorskinga av oljepolitikken som gav den ’vellykkede oljeindustri’ som Sejersted prisar, men òg det statlege vernet av skipsbyggingsindustrien på 1960-talet.”

and KV, took delight from being faster, and developed an attitude that allowed and encouraged lowly employees to fix things. The entrepreneurial energy was evident, not only in the way people overlooked ridiculous difficulties to corner the market for dynamic positioning, but also by the dozen employees that went on to set up companies upon leaving Albatross.

On the **level of the company** or business unit, the prevailing theories of management changed in the period covered in this thesis. There was less belief in hierarchal corporations with emphasis on scale, directed from the top in an army-like fashion; more belief in self-contained business units with goals and strategies in their own right. This change in sentiments arrived in earnest at Kongsberg around 1980. The restructured engineering companies that replaced KV mostly organized employees and resources around a customer segment and a business idea. The effect was to make achievements more transparent – e.g. by highlighting what businesses earned money and what businesses lost money. One source of improvement involved nothing but abandoning less successful operations and avoiding an escalation of commitment of the kind that bankrupted KV (cf. chapter 6.5). Rather than maintaining an extensive set of operations in-house, companies increasingly became involved in a trade of tasks to save costs. Besides, I have referred to some episodic evidence of how detachment from manufacturing helped sharpen focus on system building. Because Albatross made no position reference technology, the company was less inhibited than Honeywell when considering clients' needs. Because Kongsberg Offshore was denied an opportunity to actually manufacture a range of subsea components, the subsea group focused on being a *main contractor* (i.e. system integrator). Initially seen as a weakness, and a source of frustration, [833] a certain detachment from manufacturing served to develop capabilities that in the end would provide a higher value added.

Yet more disintegration took part on the **level of the industry** or market. The great unsettling event in Norwegian oil was the prolonged period of low prices after 1985. Although investments in Condeeps kept up for some years after 1986, something fundamental shifted and the industry began considering costs more seriously (cf. chapters 7.1 and 8.1). Geology reinforced the new sentiments on the Norwegian shelf. Whereas discoveries of large field had been almost habitual until the early 1980s, later finds were progressively smaller, further away, in deeper waters, and more difficult to

[833] The frustration was evident e.g. in KV-Cor, box 242, Qvenild to Hurlen, memorandum, 9 October 1975, or in Jørgen Haslestad's recollection that KV's various departments had the same tendency to fight as daughter companies elsewhere, cf. "Et naturstridig offshoremiljø", *Offshore & Energi*, 1991, p. 30.

develop. By the 1990s, cost-efficient deepwater technology looked a lot more attractive.

Interestingly, as a rule of thumb, the correlation between oil price and technological change has been reverse. High oil prices put a premium on speedy field development and a correspondingly high price on the delays and uncertainty associated with new technology development. *Low* oil prices, on the other hand, fostered creativity. The connection was particularly apparent on three occasions. A fall in oil prices in the late 1970s made the Norwegian authorities more concerned about industry knowledge, not only jobs, and paved the way for new thinking on the role of suppliers. Low oil prices following 1985-86 paved the road for a series of new techniques and the demise of the large gravity platforms. Low oil prices around 1993-1994 spurred extensive standardization on the Norwegian shelf, and closer collaboration between suppliers and oil companies.

Even before the oil price fall of 1985-1986, Statoil began to modify its centralized approach to technology development. The Norwegian Style remained intact, but with regard to specific modules, Statoil began considering Engineering, Procurement, Contracting (EPC) deals. Inspired by the shipping industry, oil companies working out of Norway allowed suppliers to take on more responsibilities for system design and system integration. The client and the contractor each carried risks, and they carried these risks separately by assigning specific responsibilities to the contractors. In return for taking on some of the oil companies' worries, Norwegian suppliers gained more enlarged room for discretion, more room for innovation, and an enhanced interest in addressing the most pressing concerns of their customers. Rather than perfecting the fabrication of a valve or a template, the main contractor poured resources into the issues that most restricted the subsea systems. The approach allowed a few suppliers, rather than many oil companies, to mastermind the design of subsea systems and subsea completions changed from a continuous series of development projects into an industrial activity. Kongsberg Offshore used its newly gained oversight to foster reliable, less-expensive and standardized products.

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A final disintegration, or rather disentanglement, took place on the **level of the country or politics**. Hauge and Johnsen had assembled power and initiative in Statoil. The constellation they built was rather too resourceful for the common good and its disintegration proved correspondingly productive.

The diminishing ambitions of Norwegian politicians corresponded with a wave of neo-liberal policies that affected most Western governments in the 1980s. In Norway, these sentiments gained momentum when the 1986 oil price collapse triggered a shortfall of government revenues while the European Economic Community began its effort to implement a common market.[834] Politicians of all shades were less intent on dirigisme and more concerned about the squandering of resources. In 1986, a Labour government refrained form re-financing KV. Governments both left of centre and right of centre abandoned some of the policies aimed at national preferences and oil companies faced less opposition when suggesting cost-efficient development solutions.

At first sight, the change affected Kongsberg adversely. Preferential treatment had secured many early assignments and helped the company secure a dominant position in subsea systems by the mid-1980s. From 1985 to 1990, however, the Kongsberg people failed to secure a single order for a subsea production system. ABB (Vetco), Aker and Kværner emerged as subsea suppliers alongside Kongsberg Offshore during these years. Part of the explanation had to do with KV's financial woes, another part was KV's falling out with Cameron, and yet another part was the diminished role of the network that KV had relied upon to secure contracts. A string of losses in the face of able competitors helped Kongsberg Offshore improve. Arguably, the presence of multiple competing providers of subsea systems triggered dynamism on the Norwegian shelf from the mid-1980s. Hydro challenged the wisdom of the Norwegian Style and rivalry between several providers of subsea systems created the kind of competitive pressure that spurred innovation and kept costs in check. Large-scale exports of subsea technology from 1997 onwards were proof of a viable deepwater industry.

[834] For an assessment of both national and international developments, cf. Rolf Tamnes, *Oljealder: 1965-1995*, vol. 6, Norsk utenrikspolitikks historie (Oslo: Universitetsforlaget, 1997), pp. 221 ff.

11 Appendices

11.1 Names and legal structures

ALBATROSS (DYNAMIC POSITIONING)				
Mother company	**Owner**	**Name of business unit**	**How business was organized**	**Year**
Kongsberg Våpenfabrikk AS	Oljedivisjonen	O6 Fartøy automasjon	Product group and profit centre	1975-1979
Kongsberg Våpenfabrikk AS	Maritim Divisjon	Dynamisk posisjonering	Product group and profit centre	1979-1982
Kongsberg Våpenfabrikk AS		Albatross	Semi-independent division with internal board	1982-1984
Kongsberg Våpenfabrikk AS	KV (ca 95%)	Kongsberg Albatross AS	Privately held limited liability company	1985-1987
Simrad Subsea AS (100%)		Simrad Albatross AS	Division - formally a limited liability company	1987-1988
Simrad AS (100%)		Simrad Albatross AS	Division - formally a limited liability company	1988-1995
Simrad AS	Simrad Norge	Dynamisk posisjonering	Business unit in matrix organization	1995
Kongsberg Gruppen ASA / Kongsberg Maritime AS	Kongsberg Simrad AS	Vessel System	Division	1996-1999
Kongsberg Gruppen ASA	Kongsberg Maritime AS	Offshore and Ocean Science - 2004	Matrix (product specialists serving various industry specific business units)	2000-2008

KONGSBERG OFFSHORE (SUBSEA SYSTEMS)			
Owner	**Business unit name**	**How business was organized**	**Year**
Kongsberg Våpenfabrikk AS	*O3 Marine systemer* (part of *Oljedivisjonen*)	Product group and profit centre	1975-1985
Kongsberg Våpenfabrikk AS	Kongsberg Offshore Systems a.s.	Privately held limited liability company	1985-1986
Siemens AG	Kongsberg Offshore Systems a.s.	Privately held limited liability company	1987-1993
FMC Inc.	Kongsberg Offshore a.s.	Privately held limited liability company	1993-1999
FMC Technologies Inc.	FMC Kongsberg Subsea AS	Privately held limited liability company	1999-2008

11.2 *Profit and turnover from the Kongsberg family*

Some graphs in this thesis strive to make comparisons across 50 years without undue distortion due to mergers, de-mergers, acquisitions and sales. These graphs strive to capture organic growth – or decline. Such approximations occur e.g. in Figure 33) on page 178, Figure 50) on page 259, Figure 51) on page 260, and Figure 52) on page 263.

In order to create these overviews, I have assembled accounts from a number of companies that I claim constitutes a family – a going concern based on Kongsberg Våpenfabrikk as if the company had avoided compulsory composition in 1987. Included in this "family" are the marine electronics companies of Horten: Norcontrol and Simrad. When Kongsberg Våpenfabrikk acquired a company, e.g. Norcontrol back in 1977, I have incorporated Norcontrol's historic accounts dating back to its establishment in 1965. Particular care has been taken to incorporate the accounts of Simrad, which bought Albatross in 1987, and was itself bought by Kongsberg Gruppen in 1997.

As far as possible, I have excluded the turnover and profit of foreign subsidiaries (or parent companies). The turnover from Kongsberg Offshore, for example, does not include the turnover of Siemens or Siemens's remaining Norwegian subsidiaries. The turnover of FMC Kongsberg Subsea does not include the turnover from FMC Technologies (the parent company), and the turnover from Kongsberg Automotive does not include the turnover from the substantial number of subsidiaries this automotive manufacturer has acquired abroad. The turnover from regular sales operations, however, is included, e.g. Natco (KV's North American operation for the sale of gas turbines).

As for legal entities, Figure 50) may serve as a point of departure. The information in the chart has been drawn from a multitude of sources, mostly annual reports and (for KV prior to 1968) memos originating with the Norwegian Ministry of industry. The "**defence and aerospace**" stream combines the turnover of KV's defence division (1957-87), Norsk Forsvarsteknologi (1987- 1993), Kongsberg Defence & Aerospace (1993-2004), the jet engine division of KV (1979-1987), Norsk Jetmotor AS (1987-1998), Volvo Aero Norge AS (1998-2004) and turnover in the naval division of Simrad Subsea AS and Simrad AS (1983-96).

The "**Manufacturing industry**" stream in the same figure combines the estimated turnover of KV's automotive business (1957-1973), which became a division in 1973 before being spun off as Kongsberg Automotive AS in

1987 and sold to its staff and management. Following five more changes of ownership, the company went public on the Oslo Stock Exchange. The graph includes only turnover from the Rollag and Hvittingfoss factories in Numedal (less than 25 per cent of Kongsberg Automotive Group's NOK 2.18 billion turnover (2004) according to information supplied in connection with the initial public offering (2005). Furthermore, the "Manufacturing" stream includes turnover from mechanical contract manufacturing at KV and NFT from 1987 to the early 1990s and sales at KV's computer business, drawing machine business and numerical control system. The various attempts to supply industrial electronics mostly went out of business in the early 1980s; the drawing machine business survived for a while with SysScan AS (1984-88) and some of the heritage lives on in Esko Graphics AS.

The "**Petroleum**" stream includes the gas turbine business of KV, which has been a fully integrated part of Dresser Rand since 1987. Also included is the turnover of KV's oil division and its offspring, Kongsberg Offshore and Albatross (cf. appendix 11.1).

The "**Maritime industries**" stream combines the revenues of Simrad's Horten-based sonar and eco-sounder business from 1957, the turnover at Robertson Radio Electro's Egersund-based autopilots and other equipment since 1975 and the ship automation business of Norcontrol in Horten from 1967, parts of the Trondheim-based Navia/Autronica sensor business from 1999. These businesses were all part of the offering of Kongsberg Maritime in 2005.

Occasionally, the consolidation of accounts creates a challenge. When Albatross AS (owned part of KV) bought hydroacoustic position reference systems from Simrad Subsea AS in 1984 and incorporated these in the sale of dynamic positioning services, the turnover from both transactions will occur e.g. in Figure 50) on page 259. Three years later, in 1987, when Albatross had been acquired by Simrad, the consolidated accounts would report only the sale of the DP system, not transactions internal to the group. The same phenomenon (accounting for inputs to a final delivery) is obviously important in explaining the quite extraordinary growth in turnover from the Kongsberg "family". These companies shifted to system sales, and a large part of the turnover originates with inputs from suppliers (with few exceptions, the sale of subsea systems out of Kongsberg consisted mostly of components manufactured elsewhere). In this respect, the turnover figures are misleading as an indicator of the amount of work that took place at a specific location (for that purpose, *value added* is a better measure) but accurate in depicting capacity to serve a customer.

An unfortunate consequence of assembling accounts from a dozen companies across 50 years is the occasional missing series, particularly when splitting the revenue stream of Kongsberg Våpenfabrikk into particular product lines (e.g. oil or maritime electronics). Occasional missing numbers have been smoothed by averages: if 1975 data are missing, that year is assumed to be an average of 1974 and 1976. None of the missing inputs relates to dynamic positioning or subsea systems.

Most graphs depict turnover in *real* value, i.e. a number that takes inflation into account (not *nominal* values expressed in contemporary money). The basis for conversion is the consumer price index published by the Norwegian Bureau of Statistics. Nominal values are identified by (NOK, GBP, USD) followed by a year (1997, 2007).

* * *

When citing profit and loss, this thesis usually refers to earnings before interest, tax, depreciation and amortization (EBITDA). Occasionally, I rely on accounts where the method of calculation is not stated. Such numbers may include interest payments or the occasional income from selling a business. Earnings (EBITDA) from dynamic positioning and subsea systems are listed in a consistent manner.

Some particular conditions relate to **Figure 33) on page 178**. This figure shows the financial health of KV and the businesses that originated with the armaments factory. It summarized almost four decades of profit and loss. Appreciation and depreciation of assets are included in the numbers behind the graph, but in a manner that departs from the public accounts. On several occasions during the 1980s, KV wrote off the value of various ventures. When the assets of the armaments factory were sold or when businesses were closed, the asset frequently fetched less than accounted for in the books. The official accounts operate with sudden write-offs, most notably in gas turbines and jet engines. The market (a consortium in which the government participated alongside private firms) valued the jet engine factory at NOK 800 million (1986) less then the value that figured in KV's balance sheet. In KV's accounts, the loss appears as a sudden gigantic write-off in 1987. Using discretion, I have backdated this and other losses to the period in which they actually occurred – in the case of jet engines, the whole 1977-1986 period. This method does not offer an exact picture of the financial health of KV, just a better picture than contemporary accounts. No such restating has been necessary for dynamic positioning or subsea systems.

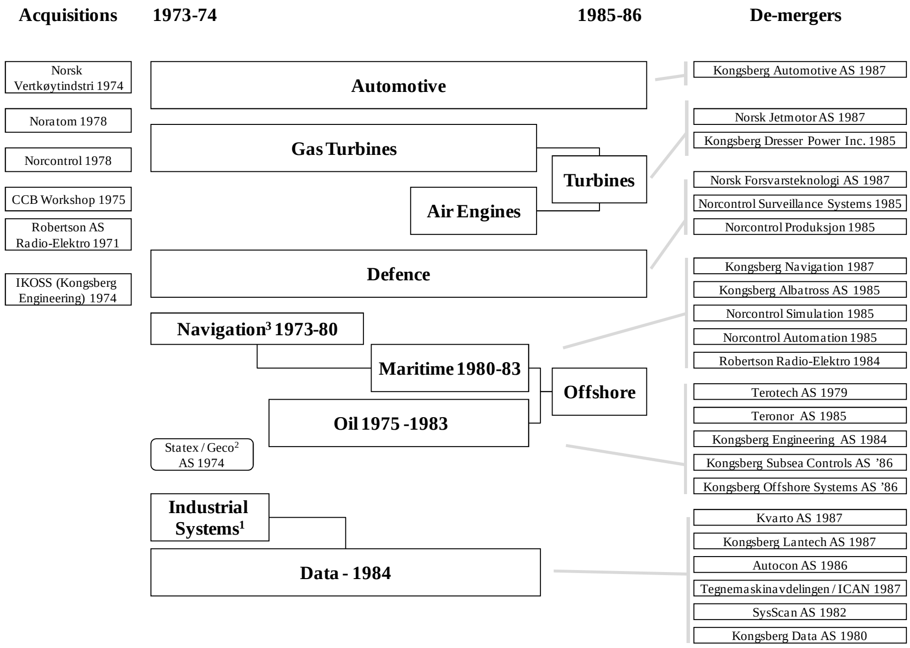
As for financial profit and loss, Figure 33) imposes a condition not present in accounting standards. I recognize no sunk costs: for calculation purposes, the profitable jet engine business of Volvo Aero Norge AS (1998-) still has to service the huge debts that KV's turbine division accumulated in the 1970s and 1980s, etc. Conversely, I assume that any sums that Simrad or any other company earned in the 1960s are placed in an interest-bearing bank account (where they continue to generate earnings). I have accumulated the earnings and superimposed a financial income (or loss) each year equal to the interest rates on low-risk bonds with yields as listed by the Norwegian Bureau of Statistics. Before the 1980s, these were fixed by the government and generally ran at values below the rate of inflation.[835] This approach produces results that are unaffected by share capital increases or the payment of dividends.

What are the main findings using this approach? This long-term view on profit and shows how the Kongsberg family accumulated profits until the mid-1970s, then suffered escalating losses totalling NOK 3.6 billion kroner (1998) by 1987. For the first decade after the compulsory composition (1987 to 1996), the Kongsberg family was sufficiently profitable to service its imaginary debt. Kongsberg became cash flow positive by 1987 but provided a return on investment only in 2003. In a 35- or 50-year perspective, the return on any initial investment has been very low for the Kongsberg family. For most of this period, the Kongsberg family consumed scarce resources, capital and engineers, without being able to match the return one would expect from any bank.

Although the Kongsberg family is no obvious success in the long term, the last decade has been very impressive. In the second half of the 1990s, there was a surge in profitability and sometime in financial year 2003, the accumulated accounts of the Kongsberg family again turned positive. For the past decade, the Kongsberg family has been a spectacular success with 4.8 billion in profits (1995-2004).

[835] Cf. Sverre Knutsen, "Staten og kapitalen i det 20. Århundre: Regulering, kriser og endring i det norske finanssystemet 1900-2000", (Ph.D., University of Oslo, 2007).

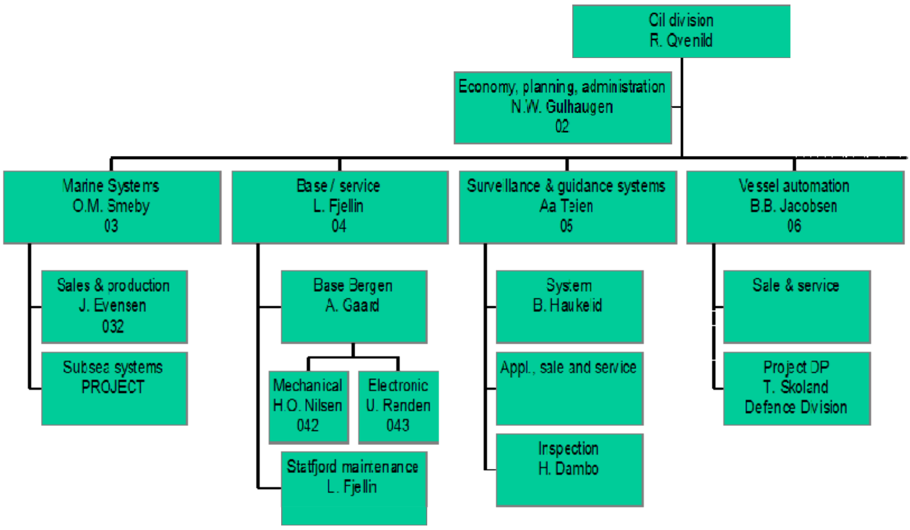
11.3 KV's divisions (1973-1986)



Assembled from annual reports and NOU 1989:2 *Kongsberg Våpenfabrikk*

1) The Industrial Systems division manufactured numerical control systems, drawing machines and other electronics for industrial purpoes. It was merged with the computer business (the Data Divsions)
2) Statex was a seismic survey company founded by KV and Statoil in 1974 – following a merger with the seismic survey business of Veritas, the company was renamed GECO. The company was listed and KV's shareholding gradually reduced
3) The Navigation department handled radio navigation, e.g. Decca systems.

11.4 Organizational chart for KV's Oil Division, 1975-1976



Organizational chart as of May 1975, copied from a chart in KV-Cor 242

The division quickly added a group to handle maintenance out of the Costal Center Base and a SCADA product group. Apart from the businesses listed on the chart above, the division also managed KV's interests in Statex, a separate legal entity, and Kongsberg Ikoss Consultants, a subsidiary that provided engineers for Norwegian Petroleum Consultants.

11.5 How a Kalman filter works

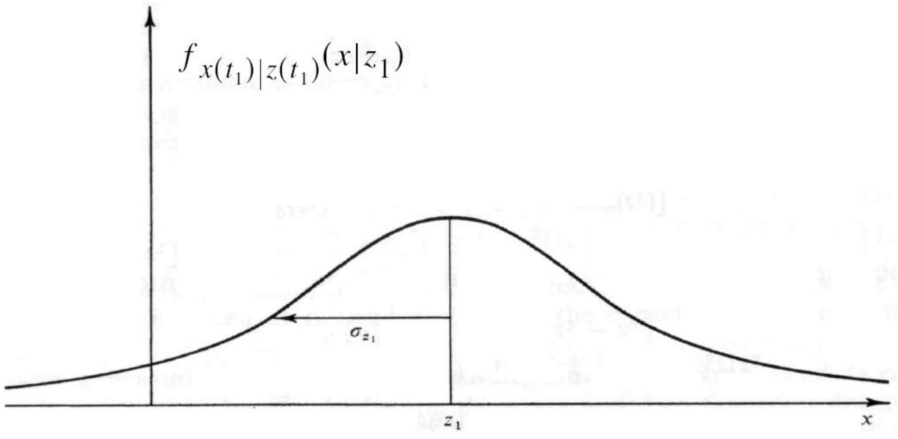
A Kalman *filter* is really an algorithm, for most practical purposes a piece of software, designed to provide accurate information out of inaccurate data and update a "best" estimate for the state of a system as new, but still inaccurate, data pour in. The eye-opening conclusion of Kalman was his proposition that the best estimate of a state, together with a covariance matrix for the error in the state-vector estimate, can be obtained recursively from the previous best estimate and its covariance matrix. In effect, the filter uses each new observation to update a probability distribution for the state of the system. (The Kalman filter does no more work for the millionth estimate than it does for the first.) Such algorithms are very neat for real-time applications, where data keep arriving and decisions have to be made on the spot.[836]

To examine how a Kalman filter works, consider yourself lost at sea during the night with no idea at all of your location. At a given time (t_1), you take a star sighting indicating a position *z* metres north of the equator. Star sighting, however, is an inexact technique; because of inherent measuring device inaccuracies, human error and the like you are likely to get a different value of *z* if you repeat the same procedure over again. The measurements will resemble a probability distribution (f_x) such as the one on the figure below where z_1 is the most frequent observation and σ_{z1} is the standard deviation – our measure of uncertainty.[837]

[836] The paragraph is in effect a digest of certain paragraphs in Maybeck, *Stocastic models, estimation, and control*.

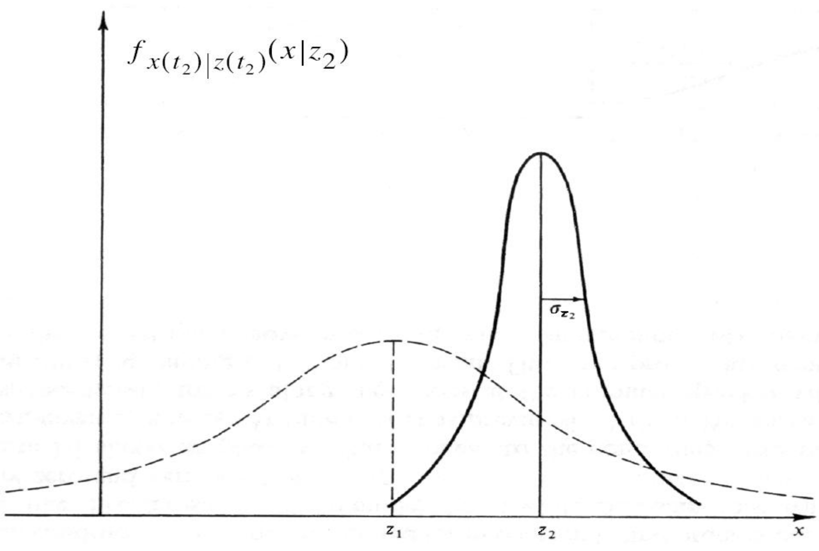
[837] I rely heavily on the very pedagogic introduction in Ibid.

Figure 56) ***Amateur astronomer: conditional density of position based on measured value z1***



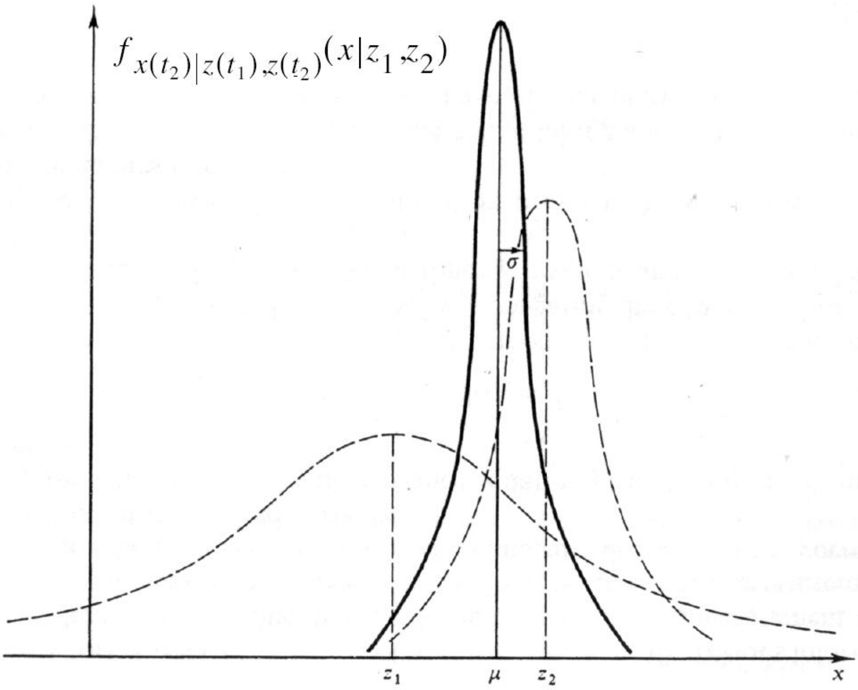
Imagine a trained navigator takes an independent fix right after you, so that the true position has not changed at all. Your friend estimates your position to be z_2. Because he has better skills, his measurements vary less and, the probability distribution appears as a narrower peak with a smaller standard deviation (see figure below).

Figure 57) ***Conditional density of position based on measurement z2***



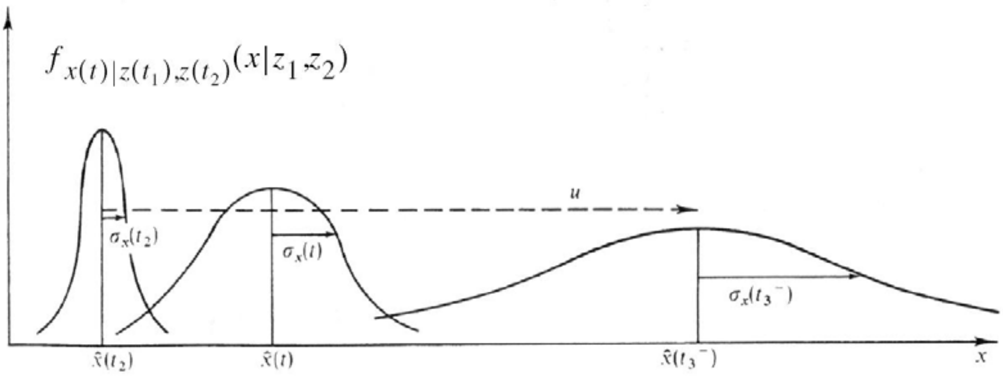
At this point, you have two sets of measurements available for estimating the position, one reliable, and one less reliable. Rather than disregarding the least reliable observation, a Kalman filter enabled recursive calculations; the algorithm considered all previously given information and all previous observations in calculating a probability, creating an eventual probability distribution like the one below where your position given both z1 and z2 is a Gaussian density with mean μ.

Figure 58) ***Conditional density of position based on data z1 and z2***



Now consider the time aspect. When in motion, a recent observation should obviously carry more weight than old observations. The Kalman filter handles this too. By comparing the most recent probability distribution with the previous probability distribution, the filter senses where you are heading and at what speed. Your position one minute ago and you position right now reveal speed and direction and hence the means to predict where you will be in one minute. When the next measurement is taken, the prediction is allowed to influence the calculation albeit with due consideration of its reduced value as time goes by. The figure below shows graphically what happens: as time progresses, the density travels along the x-axis at the nominal speed u, while simultaneously spreading out about its mean.

Figure 59) ***Propagation of conditional probability density***



11.6 Accounts

The accounts below are assembled from various sources – annual reports where these are available, otherwise company records. Several tables show turnover from individual business lines and (more demanding) profits from individual business lines. These numbers rarely figure in the accounts approved by accountants. The numbers may also depart from official accounts inasmuch as they show earnings before interests, tax, deductions and amortization.

All figures in nominal NOK millions.

Figures from Kongsberg Våpenfabrikk prior to 1968 (when KV became a limited liability company) are based on internal memos written by the Ministry of Industry.

Figures from 1968-1987 rely heavily on quarterly reports to KV's board of directors.

Between 1996 and 1998, turnover and profit figures for dynamic positioning are based on the recollection of managers.

ALBATROSS ACCOUNTS

	1977	1978	1979	1980	1981	1982	1983	1984	1985
Turnover									
Total	20	35	51	74	86	141	169	162	233
Of which DP sales	20	35	51	74	86	141	169	162	233
Of which integrated control									
Profits & Losses									
Total			0	3	6	9	11	14	10
Of which DP related			3	6	9	11	14	10	23
Of which integrated control									

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Turnover										
Total	224	150	137	142	192	244	327	427	388	399
Of which DP sales	224	144	123	112	120	151	166	188	214	212
Of which integrated control		3	10	25	45	56	124	190	106	136
Profits & Losses										
Total	6	0	-3	3	22	30	36	44	44	42
Of which DP related	6	0	-3	3	16	22	20	22	29	26
Of which integrated control					6	8	15	22	14	17

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Turnover									
Total	435	564	994	1084	1105	1353	1395	1476	1477
Of which DP sales	250	350	550	646	544	543	450	506	470
Of which integrated control	185	214	444	438	561	810	945	970	1000
Profits & Losses									
Total	33	35	114	184	157	182	179	133	151
Of which DP related	19	22	63	127	90	121	76	77	75
Of which integrated control	14	13	51	57	67	61	103	56	76

SUBSEA SYSTEM ACCOUNTS

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Turnover	0	37	82	125	165	66	87	125	228	226	387	764
P&L	0	-4	0	1	-34	-18	-18	-3	12	15	14	11

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Turnover	612	253	101	93	90	145	309	416	383	466	1025	1259
P&L	-33	-65	-11	0	5	9	20	0	30	111	83	77

	1998	1999	2000	2001	2002	2003	2004	2005	2006
Turnover	2285	2695	2833	2557	2316	2398	3611	4733	5380
P&L	146	184	240	92	133	121	191	273	321

KV’ OIL DIVISION

	1974	1975	1976	1977	1978	1979
Turnover						
TOTALT	6	10	24	40	72	57
Related to subsea systems						16
Related to surveillance						8
Related to turbine maintenance					0	2
Related to engineering			17	25	20	24
Related to maintenance						10
Profit and loss						
TOTALT		-1	na	0	-12	-7
Related to subsea systems						-2
Related to surveillance		LOSS	LOSS	LOSS	LOSS	-4
Related to turbine maintenance					0	-1
Related to engineering			na	na	1	3
Related to maintenance						

	1980	1981	1982	1983	1984	1985	1986
Turnover							
TOTALT	89	115	191	211	227	473	406
Related to subsea systems	35	42	72	100	67	311	
Related to surveillance	na	15	26	25	31	34	
Related to turbine maintenance	7	20	37	35			
Related to engineering	28	30	56	51			
Related to maintenance	21	9	Na	0			
Profit and loss							
TOTALT	-9	2	11	12	28	7	-22
Related to subsea systems	na	3	5	6	6	7	
Related to surveillance	LOSS	-4	1	3	2	3	
Related to turbine maintenance	-2	1	3	3			
Related to engineering	na	3	0	0			
Related to maintenance		-1		0			

KONGSBERG VÅPENFABRIKK – TURNOVER BY PRODUCT LINE

	1957	1958	1959	1960	1961	1962	1963	1964
Turnover / sales								
All military products	na	na	na	na	na	na	na	na
Small arms	5	6	3	3	1	1	1	1
Gun	23	20	40	24	28	40	36	46
Systems				3	13	17	27	18
Missiles	0	1	0	0	1	8	19	34
All civillian products	na	na	na	na	na	na	na	na
Civilian mechanical	8	10	10	8	8,9	10,5	11,6	14,3
Automotive	1	6	8	10	10	17	13	16
Industrial electronics							0,7	2

	1965	1966	1967	1968	1969	1970	1971	1972
Turnover / sales								
All military products	na	na	na	na	119	151	151	160
Small arms	8	22	31	35	34	35	34	36
Gun	27	27	13	24	41	38	39	47
Fuzes	2	na	na	13	13	9	4	5
Systems	37	47	50	11	15	27	21	16
Missiles	37	27	17	9	16	42	53	56
All civillian products	na	na	na	na	81	93	139	164
Gas turbines					1	4	18	30
Martime electronics			2	7	10	14	18	17
Civilian mechanical	11,3	20	18	14	14	13	14	14
Automotive	16	20	15	22	29	36	44	53
Industrial electronics	6,6	8	13	16	27	26	45	50

	1973	1974	1975	1976	1977	1978	1979	1980
Turnover / sales								
All military products	176	168	230	236	217	351	328	497
Small arms	39	22	7	4	10	11	7	na
Gun	40	29	80	70	25	19	25	48
Fuzes	17	19	17	40	25	26	8	11
Systems	35	64	97	73	51	76	76	69
Missiles	45	34	29	39	47	77	71	118
Avionics				10	59	64	127	225
Jet engines						78	129	155
All civillian products	194	247	345	420	454	698	951	979
Gas turbines	45	60	119	155	169	226	376	286
Martime electronics	19	21	21	24	33	119	178	245
Oil related			10	24	40	72	57	89
Civilian mechanical	15	19	19	17	7	15	17	32
Automotive	58	70	91	91	98	104	151	149
IT	57	77	85	109	107	162	172	178

	1981	1982	1983	1984	1985	1986
Turnover / sales						
All military products	609	631	531	477	618	630
Small arms	na	na	na	na	na	na
Gun	50	na	na	na	na	na
Fuzes	5,2	na	na	37	na	120
Systems	81	na	na	120	na	143
Missiles	217	na	na	158	na	46
Avionics	239	na	na	104	na	na
Jet engines	264	288	199	245	243	207
All civillian products	1125	1239	1478	1524	1297	1347
Gas turbines	316	301	413	464	205	16
Martime electronics	325	435	556	322	384	400
Oil related	115	191	211	227	473	406
Civilian mechanical	23	na	na	146	na	224
Automotive	164	188	197	221	235	201
IT	182	124	101	144	na	100

KONGSBERG VÅPENFABRIKK – PROFIT AND LOSS BY DIVISION

	1968	1969	1970	1971	1972	1973
Defence division	4,9	7,9	13,6	13,2	13,5	15,2
Automotive	0	0,4	1,9	1,5	3,4	4,6
Martime electonics	0,8	1,4	1,8	2,8	2,9	3,3
Industrial electonics and computers				-3,6	-8,7	-6
Mechanical engineering	-0,7	-2,7	0	-0,6	0,2	0
Gas turbines				-1,9	-8,2	-9,6
Jet engines						

	1974	1975	1976	1977	1978	1979
Defence division	14,8	17,6	15	15	15	14,5
Automotive	4,4	4,8	1	-1,3	-1	9,7
Oil		-1,2	0	0,4	-11,9	-6,6
Martime electonics	2,9	3	5	6	5	9,5
Industrial electonics and computers	1,5	na	-17,5	-8,4	-23,5	-21,8
Mechanical engineering	1,4	1,7	na	na	na	na
Gas turbines	-10,3	7,1	-8,6	-26,3	-6,4	-7,4
Jet engines						2,1

	1980	1981	1982	1983	1984	1985	1986
Defence division	20,7	22,2	7,6	11,6	10,8	13,8	18,2
Automotive	8,3	7,1	9,5	8	2,6	-1,7	-26,9
Oil	-8,5	1,5	11,1	12	28	7,1	-22,2
Martime electonics	11,4	7,8	1,6	-16,1			
Industrial electonics and computers	-57,9	-59	-21,2	-10,4	-25	-6,7	
Mechanical engineering	na	na	na	na	na	na	
Gas turbines	-13,1	-66,5	-97,5	-25,7	-68,9	-36,3	
Jet engines	5,2	18,8	30,9	2,2	-4,2	-25	-368

11.7 Early DP orders

Figure 60) ***DP orders, 1975 –1979***

	Deli very	**Vessel**	**System**	**Ref. systems**	**Vessel owner**	**Type**
Nov -75	Dec-77	*Seaway Swan*	ADP 503	HPR, Taut wire, Artemis, Navigation radar	Stolt-Nielsen	Service vessel
Nov -76	Apr-77	*Seaway Eagle*	ADP 501	HPR	Stolt-Nielsen	Service vessel
Dec -76	Oct-77	*Capalon ga*	ADP 502	Artemis, Taut wire, navigation Rader	SSOS / Talassa	Service vessel
Oct-77	Mar-78	*Seaway Hawk*	ADP 501	HPR, Artemis	Stolt-Nielsen	Service vessel
Nov -77	May -78	*Seaway Sand-piper*	ADP 502	Syledis, Puls 8, HPR, Artemis	Stolt-Nielsen	Pipe / Cable
Jun-77	Apr-78	*Cobla 1*	ADP 501	Artemis	Costain & Blanken-fort	Service vessel
Jun-77	Apr-78	*Cobla 2*	ADP 501	Artemis	Costain & Blanken-fort	Service vessel
Jun-77	Apr-78	*Cobla 3*	ADP 501	Artemis	Costain & Blanken-fort	Service vessel
Dec -77	Nov-78	*Wild-rake*	ADP 501	Artemis, HPR	Wilhelm-sen	Service vessel
Spri ng 78	Jun-79	*BP ESV*	ADP 503	Numerous	BP Tankers	Service vessel
Oct-78	Apr-79	*Swan Ocean*	ADP 501	Artemis, HPR, Taut wire	Swan Offshore	Service vessel
Aug -78	1979 -80	*Stena Cons-tructor*	ADP 503 MK II	Artemis, HPR, Taut wire	Stena Line	Service vessel
Aug	1979	*Stena*	ADP	Artemis, HPR, Taut	Steno	Service

-78	-80	*Sea-spread*	503 MK II	wire	Line	vessel
Aug -78	1979 -80	*Steno Inspec-tor*	ADP 503 MK II	Artemis, HPR, Taut wire	Steno Line	Service vessel
Aug -78	1979 /1980	*Steno Protec-tor*	ADP 503 MK II	Artemis, HPR, Taut wire	Steno Line	Service vessel
Oct-78	Sep-79	-	ADP 311	HPR, Radar, Taut wire	Parley Augusts son	Service vessel
Oct-78	Mar-80	-	ADP 311	HPR, Radar, Taut wire	Parley Augusts son	Service vessel
Oct-78	Jul-80	-	ADP 311	HPR, Radar, Taut wire	Parley Augusts son	Service vessel
Oct-78	Nov-80	-	ADP 311	HPR, Radar, Taut wire	Parley Augusts son	Service vessel
Jan-79	Apr-79	*Stand Troll*	ADP 501	Taut wire, HPR, Artemis	Seamiest Stand Troll	-
Jan-79	Apr-79	*Flexi service 2*	ADP 503	Artemis, HPR	Upland / Stub	Pipe / Cable
Apr-79	Jun-79	*Solar*	ADP 503	Artemis, HPR, Taut wire	BP Tankers	Service vessel
May -79	Jan-80	*Swan Suppor-ter*	ADP 503	Artemis, HPR, Taut wire	Shear-water Aqua Marine	Service vessel
Jun-79	Dec-79	*Range Due*	ADP 503	Numerous	Saipan	Service vessel
Jul-79	Oct-79	*Eddo Sky*	ADP 503	Artemis, HPR	Stub	Service vessel
Jul-79	Jan-80	*Steno Sea-Horse*	ADP 503	Artemis, HPR, Taut wire	Steno Line	-

11.8 Position reference systems, ca 1980

System	Accuracy and reliability	Reach / limitations
Omega (radio navigation)	1-3 nautical miles	Global
Decca (radio navigation)	100-500 metres; reliable	Ca 200 nautical miles off the Norwegian coast during daytime
Loran C (radio navigation)	100-500 metres; reliable	The Norwegian coast North of the North Sea
Pulse/8 (radio navigation)	30 metres; reliable	The North Sea out to 300 nautical miles
Autotape, Trident and other radio navigation	2–10 metres	Requires some beacons within 50-100 km of the vessel
Arthemis	2-5 metres when within 10 km of the beacon.	Requires one beacon within 30 km
Taut wire	Depends on depth and tide; 2.4 metre error margin at 100 metres depth and 28 metres at 300 metres depth with tide of one knot – less if no tide.	Depth not much more than 300 metres and reach no more than 25 per cent of water depth or else risk drag.
GPS / *Navstar*	Less than 10 metres error margin, but available only 50 per cent of the time.	Global – but signals were willingly distorted
Simrad HPR / acoustic systems	Usually within 1-2 per cent of water depth, up to 5 per cent when far from the transducer; somewhat unreliable	Unacceptable noise when the distance from the transducer equals 2-3 times the water depth

Source: Steinar Sælid’s private archive – various reports

11.9 *The first major standardization drive*

	Sub-component	Standardized
Permanent guide base		
	Outline in general	Already specified by the American Petroleum Institute
	Guideline anchor	Operator specific
	Location of locking mechanism	No
Wellhead system		
	General	Difficult due to secrecy from manufacturers
	Conductor Housing	No (different requirement of impact to withstand)
	Wellhead housing	Yes, Vetco H-4 mandrel profile
Tubing hanger system		
		Standardized on two varieties, less expensive slimline and extra security full bore
Christmas tree		
	Layout of block	Low for Draugen, regular for the rest
	Flowline	Yes
	Bore spacing	Yes
	Orientation	Yes
	Valves and actuators	Yes, 5000 psi
Protective structure		
		No
Control system		
	Arrangements	Already standardized by suppliers, different systems for templates vs. single satellites
	Number of systems	One module per tree if the tree employed a dedicated sensor, otherwise one per template
	What to survey and control	No standardizing

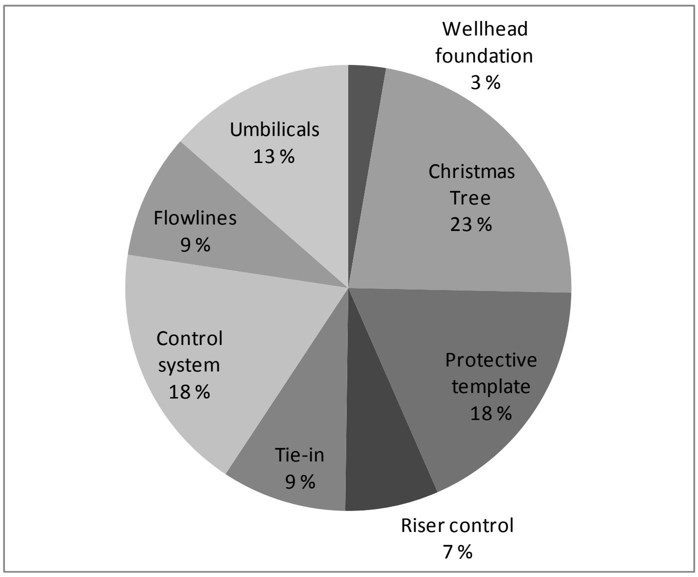
Workover and completion system		
	Lower riser package	Gate valve for Draugen, BOP outline for the rest
	Emergency disconnect	Yes, by standardizing on extreme requirements
	Workover riser	No, although savings could be substantial especially for reuse of risers
	Surface flow tree	Two different varieties used
	Workover control	No, but possible with some investments
Intervention System		
	Tie-in tools	Yes, mostly
	Component replacement tools	Yes, mostly
	Intervention control system	Yes, mostly
Test requirements		Yes, mostly

Source: Tore Halvorsen and and Luis Araujo, *Standardization Of Subsea Production Systems: Practical Experience From Draugen, Statfjord Satellite, And Heidrun Projects*, paper presented at the Offshore Technology Conference, Houston 1993.

11.10 Calculating the price of a subsea system

Prices on subsea systems are drawn from contemporary sources, frequently from newspaper articles or press releases to communicate the awarding of contracts. I have simply divided the contract sum by the number of Christmas Trees to arrive at the cost for an individual valve tree.

Prices are cited excluding the cost of installing and maintaining the system, excluding umbilicals and excluding the cost of pipes (flowlines) to connect the subsea system to other installations. This is the most frequent prices cited. However, sometimes the costs do not include control systems, protective structures (template) or another component. When these prices are not cited, I have used the following formula:



These proportions were said to be representative for a “typical subsea system” (Tore Halvorsen, “Havbunnsinnstallasjoner” paper presented at a conference “Flytende produsksjonssystemer for Olje og Gass”, 27 October 1986). The proportions closely resemble the cost structure on TOGI (late 1980s), Snorre (around 1990) and Statfjord Satellites (early 1990s). For those systems involved in the comparison, differences in the depth where the higher cost of building systems for deeper waters is not likely to make an impact.

11.11 Kongsberg Offshore's framework agreements

Figure 61) ***Kongsberg Offshore's experience base with framework contracts***[838]

Customer	**Timeframe**
Statoil Frame Contract	1995 – 2000
Statoil Subsea Service Agreement	2000 – 2002-
Mobil Enhanced Supplier Agreement	1996 – 1998
Shell Inc. US	1997 -
Agip Frame Contract	2000 – 2005
Norsk Hydro Frame Agreement	2000 – 2003-
BP GoM Frame Agreement	2001 – 2006-
Woodside Energy	2003 – 2005-
Talisman Energy	2003 -

[838] Steenstrup's private papers.

11.12 Sources

The businesses that have developed dynamic positioning and subsea systems have changed names and status several times during the three decades covered in this thesis. Appendix 11.1 offers a brief outline. Their records are somewhat dispersed.

The collections of Kongsberg Våpenfabrikk, stored at the Statsarkivet [public archives] in Kongsberg, contain documentation up to 1986 on issues that concerned board and top management. Numerous documents concerning corporate governance also exist in duplicate at the Riksarkivet [national archives] where files from the public inquiry into KV's 1987 collapse are stored. The files on operational issues in KV's various divisions are less complete – for example, I have only sporadic documentation from the 1979-1983 Maritime Division of which Albatross was part.

Figure 62) ***List of consulted collections in public archives***

Archive (location)	**Collection, series and boxes**	**Contents**	**Abbreviation used in footnotes**
Statsarkivet Kongsberg	Kongsberg Våpenfabrikk, Hovedserie 1 – Styret, Rekke VII (Styreprotokoll i orginal)	Board papers, 1947-, eight boxes in chronological order	KV-board
Statsarkivet Kongsberg	Kongsberg Våpenfabrikk under akkord, del I – Korrespondanse, I Direktørarkivet, Serie VI (virksomheter 1980-87)	Working papers transferred to the entity that ran KV after the company filed for protection from its creditors	KV-ex
Statsarkivet Kongsberg	Kongsberg Våpenfabrikk, Hovedserie 5 - Drift/produksjon, rekke IV	Plans for the overall production capacity at the factory	KV-operations
Statsarkivet Kongsberg	Kongsberg Våpenfabrikk, Hovedserie 12 - Diverse, rekke II, (Navigasjonsavdelingen 1969-1986)	Archives of the navigation department (marine electronics)	None

Statsarkivet Kongsberg	Kongsberg Våpenfabrikk, Hovedserie 2 – Korrespondanse, C 1 Direktørkorrespondanse, Rekke III (1945-1988)	Correspondence of the managing director	KV-Cor [box]
Riksarkivet Oslo	Nærings- og handelsdepartementets arkiv, kommisjonsarkivet, Arntzenkommisjonen, box 42 –43	Board papers related to KV’s oil-related business, copied by a commission (public enquiry) established 18 December 1987	RA-Arntzen-Oil

Archival materials on internal company affairs are less easy to come by after 1986, although both Kongsberg Gruppen and FMC Kongsberg Subsea have been forthcoming. Some historic files on Albatross from 1986 to 1995 are held by Kongsberg Maritime at the company’s premises in Horten. After 1995, dynamic positioning and the automation solutions that derived from dynamic positioning were product lines in diversified corporate structures. The historic projects archives of Albatross remain intact, as do various collections of papers, for example papers at the training and information departments of Kongsberg Maritime. The author has not consulted board papers from the post-1995 period.

The Subsea systems unit was integral to KV’s oil division until 1986. From 1986, the subsea business was incorporated and remained a distinct legal entity albeit with changing names and ownership. The whereabouts of any board papers from 1986-1993 are not known. FMC Kongsberg Subsea keeps a board archive from 1993 onwards. This author has not had access to confidential papers, but the company has been helpful in providing internal and external information including annual reports and reference lists such as lists of customers and deliveries.

Figure 63) ***List of company archives (private) consulted***

Company (location)	**Collection and contents**	**Abbreviation used in footnotes**
Kongsberg Maritime AS (Kongsberg)	Projects' archive – where contracts, plans, specifications of deliveries and other details are stored in folders according to delivery project	CA-KM-hist
Kongsberg Maritime AS (Kongsberg)	Working archive of the support & training department – information and training materials on various products	CA-KM-sup
Kongsberg Simrad (Horten)	A safe containing board papers and official documents related to the history of Simrad	CA-KM-Simrad
Kongsberg Maritime AS	Working archive of the PR department, mostly newspaper clippings and newsletters	CA-KM-info
FMC Kongsberg Subsea	Working archive of the PR department, mostly brochures, newspaper clippings, newsletters, etc.	
FMC Kongsberg Subsea	Annual reports and accounts, archive of the board secretary	CA-FMC-board

The author conducted some 60 interviews with 50 people. Most of the interviews were taped. Several people contributed documents from their private archives.

Figure 64) ***List of private archives consulted***

Owner	**Contents**	**Abbreviation used in footnotes**
Ole Næsset	Various speeches and articles by Bjarne Hurlen, mostly from the 1960s	Næsset's private papers
Jens Glad Balchen	Papers on cybernetics, articles and lecture materials	Balchen's private papers
Bjørn Tom Jahnsen	Collection of newspaper clippings, news bulletins and public communications from Albatross	Jahnsen's private papers
Nils Albert Jenssen	Internal company communications from Albatross, early 1980s	Jenssen's private papers
Tor Berdal	Company Whitepapers	Berdal's private papers
Thor Skoland	Scrap-books from late 1970s, product brochures, articles	Skoland's private papers
Steinar Sælid	An extensive private archive, particularly scientific publishing on dynamic positioning, 1974-1984	Sælid's private papers
Knut Sogner	Private papers related to his work on Simrad's business history	Sogner's private papers
Tore Halvorsen	Internal communication on the advance of KV into oil, mid-1970s.	Halvorsen's private papers
Ole Magnus Smeby	Extensive private archive with reports on subsea technology and KV's approach to the subsea field	Smeby's private papers
Carl Steenstrup	Recent files and speeches on contract strategy	Steenstrup's private papers
Bjørn Husemoen	Memorandum on the history of Kongsberg Offshore Systems, 22 September 1998.	Husemoen's private papers

Figure 65) ***List of interviews***

Family name	**Given name**	**Place**	**Date**
Asphjell	Arne	Trondhjem	September 15, 2004
Balchen	Jens Glad	Trondhjem	September 15, 2004
Barth Jacobsen	Bjørn	Sandvika, Bærum	September 9, 2004
Barth Jacobsen	Bjørn	Sandvika, Bærum	March 31, 2005
Barth Jacobsen	Bjørn	Nydalen, Oslo	November 29, 2005
Bendigtsten	Bjørn	Nydalen, Oslo	November 21, 2005
Berdal	Olav	Kongsberg	March 18, 2004
Berdal	Olav	Kongsberg	November 7, 2003
Berdal	Olav	Kongsberg	April 1, 2003
Christiansen	Erling	Oslo	February 19, 2007
Corneliussen	Sverre	Kongsberg	October 19, 2004
Daling	Ann Kristin	Trondhjem	September 15, 2004
Dølsplass	Terje	Kongsberg	January 24, 2006
Engen	Kristoffer	Oslo	September 13, 2004
Evensen	John	Kongsberg	June 23, 2004
Fagerlund	Svein	Kongsberg	October 14, 2004
Fjelldal	Hans Henrik	Kongsberg	October 29, 2004
Fjellin	Leif	Kongsberg	October 4, 2004
Gotaas	Sverre	Kongsberg	March 27, 2003
Gulhaugen	Nils Willy	Kongsberg	October 29, 2004
Halvorsen	Tore	Kongsberg	October 4, 2004
Helle	Hans Christian	Kongsberg	April 14, 2005
Husemoen	Bjørn	Drammen	October 13, 2004
Jahnsen	Bjørn Tom	Kongsberg	October 11, 2004
Jahr	Dagfinn	Bygdø, Oslo	September 23, 2004
Jenssen	Nils Albert	Kongsberg	October 14, 2004
Jenssen	Nils Albert	Kongsberg	May 16, 2006

Jørgensen	Jan T.	Lysaker	September 21, 2004
Kildal	Torfinn	Kongsberg	October 29, 2004
Kildal	Torfinn	Kongsberg	January 4, 2006
Korssjøen	Jan Erik	Kongsberg	March 27, 2003
Lied	Finn	Kjeller	December 6, 2005
Løkling	Terje	Kongsberg	October 29, 2004
Mathisen	Eldar	Kongsberg	October 13, 2004
Næsset	Ole	Kongsberg	October 11, 2004
Qvenild	Rolf	Kongsberg	September 29, 2004
Resaland	Ansgar	Kongsberg	October 21, 2004
Røkeberg	Holger	Nydalen, Oslo	May 9, 2006
Skoland	Thor	Kongsberg	January 4, 2006
Skoland	Thor	Kongsberg	January 24, 2006
Smeby	Ole Magnus	Kongsberg	September 20, 2004
Solberg	Arne	Kongsberg	March 27, 2003
Steenstrup	Carl	Kongsberg	October 14, 2004
Stensrud	Kjell	Kongsberg	October 21, 2004
Sælid	Steinar	Fredrikstad	October 12, 2004
Sælid	Steinar	Fredrikstad	May 22, 2006
Tveit	Martin	Oslo	October 26, 2004
Østlid	Øyvind	Kongsberg	October 21, 2004

A few library databases have been very useful for this project. *Atekst* includes business news from major Norwegian newspapers and news agencies, some articles dating back to 1984. As for matters of technology, the single most useful database has been *OIL*, assembled by the library of the Norwegian Petroleum Directorate and the Norwegian Safety Authority.[839] This citation database stretches back to the mid-1970s. Both “subsea” and

[839] The reference database OIL covers petroleum literature of Nordic origin. Approximately 25 per cent of the 60,000 articles are in English. Searching the database is free of charge. Many newer documents are also available in full text. http://www.npd.no/oil/

“dynamic positioning” are searchable terms. The *Energy Citations Database* maintained by the U.S. Department of Energy has a much larger collection stretching back to 1948, albeit with less materials on the North Sea.[840] Finally, all papers presented at the *Offshore Technology Conference* (OTC), the annual gathering of oil people in Houston that has taken place since 1969, are searchable in full text. Mostly anyone claiming to have made some kind of breakthrough in the field will attempt to make this known at the OTC along with various industry experts summarizing past, present (and less reliably) future trends.[841]

[840] Energy Citations Database, cf. http://www.osti.gov/energycitations/

[841] Cf. www.otcnet.org – the collection includes some 10,000 technical papers as of 2008. On the role of OTC for communicating industry news, cf. Veldman and Lagers, *50 years offshore*, pp. 86-91.

Abbreviations and acronyms

Acronym	**English**	**Norwegian name**
CMI	Chr. Michelsen Institute	Christian Michelsens Institutt
DNV	Norwegian classification society	Det Norske Veritas
FMC	US corporation - the full name behind the abbreviation is no longer in use	Food Machine and Chemical Corp.
IAE	Institute for atomic energy	Institutt for atomenergi
IMR	Institute of Marine Research	Havforskningsinstituttet
NDRE	Norwegian Defence Research Establishment	Forsvarets forskningsinstitutt (FFI)
NTH	The Norwegian Institute of Technology, *merged to form NTNU in 1996). NTH was primarily a polytechnic institute, educating master level engineers as well as architects.*	Norges Tekniske Høyskole
NTNF	Government research fund for technical research	Norges Teknisk Naturvitenskapelige Forskningsråd
OTC	Offshore Technology Conference	Offshore Technology Conference
ROV	Remotely operated underwater vehicle	Fjernstyrt undervannsfarkost
SSB	Statistics Norway	Statistisk Sentralbyrå
ÅSV	Defunct aluminium melter - The company was merged with Norsk Hydro in 1986 to create the light metal division Hydro Aluminium.	Årdal og Sundal Verk

Abbreviation	Full text
AIM	Albatross Integrated Multifunction System
BOP	blow-out preventer
Condeep	concrete deep water structure
DP	dynamic positioning
HPR	hydro-acoustic position reference system
LNG	Liquid Natural Gas
NOK	Norwegian currency (kroner)
psi	pounds per square inch
SCADA	Supervisory Control And Data Acquisition

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