Draft Paper, first version (not to be cited from):

Emergence and growth of two firms in the southwest Norwegian oil and gas cluster: Explained by entrepreneurship and external conditions

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ABSTRACT

The purpose of the paper is to contribute to the understanding of how companies within an industrial cluster emerge and grow. The focus in on the Norwegian oil and gas industry, which is described as located in the periphery seen in a global context, and whose critical mass of companies is concentrated in the Stavanger region.

The emergence and growth of two firms currently enjoying a customer-supplier relationship is studied and assessed against the background of theoretical approaches addressing the emergence and growth of firms and clusters. The resource perspective of firms is included as one of these approaches. Semi-structured interviews were used to gather the primary data.

Both firms have succeeded by being innovative in their special areas. The Norwegianisation policies of the Norwegian Government have had no detectable impact on the development on firm located in Stavanger, whereas these policies were crucially important for the emergence of firm located on the periphery of the oil and gas cluster. Another main finding is that the Government's safety regulations, especially after the Bravo accident, have been a significant impetus for technological development. They opened up opportunities for small companies to fill the technological gap which existed within offshore drilling by modifying and combining state-of-the-art technology in new ways. However, the histories of the two studied firms cannot be fully understood without understanding the entrepreneurship which lies at the basis in each case, and the ability to draw on external resources in the development process. Furthermore, the company in Stavanger seems to have enjoyed considerable advantages on account of it localisation with regard to the communication of tacit knowledge and proximity to its customers, while international associations within drilling have also been equally important.

The contribution of this paper is above all that another two examples have been added to the material which helps us understand the diversity of this area, and the role played by contingency in the emergence and growth of firms in clusters.

Keywords: oil and gas cluster Norway, emergence and growth of firms, conditions and prerequisites for emergence and growth

Introduction

Much of the literature on interaction between firms seeks to explore existing relations; see for example Ford et al. (2003), and papers published by the Industrial Marketing and Purchasing group[1]. The starting point for this paper is also an existing relationship between firms, namely two engineering and production companies engaged in a dyadic, knowledge-intensive customer-supplier relationship with each other. However, my emphasis is on explaining the events and factors which have brought the companies into the relationship we can observe today. In addition, I focus on showing the significance of the region and the business and research environment for the development of the firms. This paper poses a somewhat different question, then: "How do firms emerge and grow, and which aspects can be explained by external conditions in this context?"

The question requires an evolutionary perspective in order to allow for an understanding of the emergence and development of firms; whereas cluster theory, and a relational and interactive resource-based approach, is applied to the analysis of the firms as part of a regional context.

American-owned National Oilwell Varco (NOV) in Stavanger, and British-owned HERNIS Scan Systems in Arendal were selected for the case studies. The companies are part of a value chain – as customer and subcontractor – and there is a considerable level of activity in the relationship between the two. In year 2000, the Norwegian company Hitec sold its drilling activities to National Oilwell Varco, and NOV has continued Hitec's former business with oil companies, providing complete drilling packages for drilling ships and platforms. NOV's in-house specialisation is engineering, production and delivery of digital remotely operated control systems for drilling. This includes drilling cabins and drilling rig drive systems, which are part of the machinery equipment for which the company makes its control systems. Data logging information from the drilling operations is digitally processed, and integrated into the

[1] www.impgroup.org

steering of the drilling machinery. HERNIS is a supplier of customized explosion-proof CCTV systems. For safety and operational reasons, CCTV systems (Closed Circuit Tele Vision) are a necessary component in offshore state-of-the-art drilling operations. Engineering work constitutes a relatively large proportion of both suppliers' output, and they both pursue the market interaction strategy of "engineering-to-order" (Berry and Hill 1992). Both companies are engaged in global operations, and both are production units belonging to multinational corporations.

Drilling operations are becoming automated and remote controlled to an ever increasing degree, and what used to be high-risk operations are now conducted by joystick and keyboard from the relatively safe environment of a driller cabin. As the automation process proceeds, the demand for CCTV systems increases. The function of CCTV systems is to assist the drillers by providing a visual verification of the drilling operation in progress, and of any occurring problems. Explosion-proof camera stations certified for operation in rough climates and in environments where there is a danger of gas explosions constitute a core element in the CCTV supplier's product. The scale of the business can be exemplified by a recently delivered order to the offshore oil and gas exploration industry. It included three interconnected CCTV systems, and each system had some 100 cameras.

The cases are taken from the oil and gas industry. Aarseth et al. (2006) argue that this is probably one of the world's most complex industries, whose value creation and future depend on its ability to make the transition from a focus on the "*competitiveness of the autonomous firm*" to "*the competitiveness of the value chain of firms*". Offshore projects are unique; they are engineering intensive; and they involve great uncertainties caused by the disproportion in magnitude between what Nature can do to us, and what we can do to Nature with our technology (Stinchombe and Heimer 1985). The suppliers in the oil and gas industry rarely have the competence and strength to deliver based solely on their own resources; they therefore depend on extensive collaboration throughout the value chain (Reve and Jakobsen 2001). In most cases, the companies in such chains share information and communication technologies, and such close collaboration increases the complexity of a relationship (Bititci et al. 2004).

The main sources of primary data are two of the three founders/pioneers of Hitec, and two of the four founders of HERNIS. The founders of HERNIS were interviewed in 2008, whereas the primary data from Hitec was collected in 2010. In addition, articles written by one of Hitec's pioneers have been used as source material, and systematic searches have been conducted of back issues of the regional daily newspaper *Stavanger Aftenblad*, and of other openly available information about Hitec and the other involved firms. Structured interviews with people currently employed by the companies are also part of the source material. These are key professionals directly involved in the interaction between the two companies at different levels and in different functions, covering market and strategic issues, software development, and procurement. In addition to the interviews with the founders/pioneers, a total number of 10 interviews (2008-2009) were conducted. One of these was a group interview involving three respondents.

The structure of the paper is as follows. After introducing the theory informing this study, a broad presentation is given of the Norwegian oil and gas cluster centred on Stavanger, which both NOV and HERNIS are part of. This is followed by an exploration of the early history of each of the two firms. The data is then analysed according to the theoretical framework, and conclusions are offered.

Evolution and emergence of firms

In the same way that the European Commission (2002, p. 14) explains the emergence of clusters, the emergence of firms can also to a great extent be explained by distinguishing between particular *prerequisites* or assets present in a locality (location factors) prior to the emergence of the firm, and the *triggering events* that turn the location factors into new productive use, and thus initiate the firm’s inception.

Triggering factors are often the activity of entrepreneurs. Hence, Feldman and Francis (2006) point out that the presence of entrepreneurs and the formation of new firms often spark the emergence and growth of clusters. Active entrepreneurship may emerge in response to some exogenous shock, such as a technological or market opportunity. In Feldman and Francis’s (op cit., 120) conceptualization, “some initial change, whether a crisis, a discontinuity in an industry, or a technological opportunity, creates the impetus for latent entrepreneurs to become active and engage in starting companies”. Innovation economist Joseph Schumpeter (1934) also argued that technological innovation or other exogenous shocks may generate growth in some industries, while causing others to contract.

Entrepreneurship is an inherently local phenomenon. It is ‘home-grown’: individuals start companies in the location where they have formed business networks and have access to resources (Feldman and Francis 2006; Delaney 1993; Feldman 2001; Romanelli and Feldmand 2003; Stuart and Sorenson 2003). A certain measure of location inertia is often involved: individuals start companies based on previous knowledge, experience, and contacts in a specific locality. Feldman and Francis (2006) argue that the location of entrepreneurs with the skill and opportunity to capitalize on an emerging technology has a significant impact on where high technology clusters can be expected to emerge. Successful entrepreneurs also proceed from their initial venture to the creation of new companies, thus becoming serial entrepreneurs with deep roots in the community, according to Feldman and Francis (2006). Moreover, Feldman and Francis conclude that the history of each cluster is unique. We can expect the same to apply to the history of firms.

The evolutionary approach is highly relevant in analyses of clusters which build on experience-based knowledge (see for instance Karlsen 2008), while the institutional approach may be particularly relevant in explaining the growth of R&D-based clusters. However, in this paper we also want to examine the role of government institutions and policies in an evolutionary approach to the path of development pursued by the different companies. In this context, we draw on elements from Regional Innovation Systems (RIS). This consists, in principle, of two subsystems (Cooke et al., 2000). The first of these is constituted mainly by firms in the main industrial clusters of a region and includes their support industries, customers, and suppliers. The second subsystem is the knowledge infrastructure which supports regional innovation in several industries and clusters (i.e. institutions of research and higher education, technology transfer agencies, vocational training organisations, business associations, etc.). In a well-functioning RIS, continuous innovation and entrepreneurial activity are stimulated by inter-firm collaboration, by knowledge flow between firms and knowledge organisations, and by supportive socio-cultural structures and institutional environments.

No company can be an island in today's business world (Håkanson and Sneota 1989). All companies are locked into a complex network of relationships with suppliers, customers, and other business partners. In the resource-based network theory of the IMP school of thought[2], marketing, purchasing, technological development, and management are approached from an interactive perspective, in a B2B context. Collaboration offers an opportunity to improve, by strengthening one's capabilities through the complementary resources encountered in other companies. Collaboration contains the potential of creating dyadic and collective forces or glue between resources and activities, as the resources often do not constitute a fixed entity. A

[2] Also known as the Uppsala school.

basic idea is that collaboration offers an opportunity to maximise resources. Furthermore, the firm is regarded more as a result of interaction than as the starting point as such for interpreting what a firm is than as the starting point as such in an interpretation of what a firm is, and contextual knowledge is also conceived as vital to the interpretation (Ford et al. 2003).

Bathelt et al. (2004) define the innovative capacity of a region as the combination of local buzz (for the internal capacity of innovation) and a global pipeline (for keeping in touch with innovations made elsewhere). The buzz is related to what we understand by industrial clusters and agglomerations, which are characterised by short distances between the different participants, enabling the easy exchange of tacit knowledge through face-to-face contact and other forms of human interaction (Storper and Venables 2004; Gertler and Wolfe 2010). "Global pipelines" stands for institutional and social contacts which overcome geographical distances to form channels of communication allowing a diffusion of knowledge in a larger context (Bathelt et al. 2004).

The Norwegian oil and gas cluster

In 1969, the American Phillips Petroleum company made the first discovery of commercially exploitable oil deposits on the Norwegian continental shelf. The discovery was made at Ekofisk, from the "Ocean Viking" oil rig. On 2nd June the following year, Phillips confirmed the discovery of vast oil deposits. Esso had started exploratory drilling in 1966. The decision to invite bids for oil exploration licences had been announced in 1965, and coincided with the creation of the Norwegian Oil Council (Oljerådet). Regular oil production started at Ekofisk in 1971 [3], and the Ekofisk tank was constructed at Hinnavågen in Stavanger.

The 1971 law regulating the exploration and exploitation of subsea natural resources stated that subsea natural resources are the property of the Norwegian State. A few days before the law was introduced, Norway had signed the 1958 UN Convention which defined the extension of the continental shelf as the line along which the sea reaches a depth of 200 metres, or alternatively along a half-way line drawn between bordering countries[4]. From the very outset, the Norwegian government sought to gain control over the exploitation of oil and

[3] Production in the very beginning was based on a jack up rig and pumping to oil tankers.

[4] There is reason to believe that an important reason why the UN resolution was not ratified earlier is the Norwegian trench (3-400 metres outside Mandal), which separates continental Norway and the continental shelf. The Norwegian trench also created technical challenges in relation to bringing oil ashore in Norway.

gas in order to maximise the "ripple effect" for Norwegian commerce and industry, and in 1972, Statoil and the Norwegian Petroleum Directorate were established. There was disagreement in the Storting about the localisation of these institutions. The options were Stavanger, Bergen, and Trondheim. Lerøen (2002) gives the city's mayor at the time, Arne Rettedal, much of the credit for the eventual choice of Stavanger as the petroleum capital of Norway, describing him as representing everything Stavanger needed. He was strong-willed, action-oriented and at times autocratic, and he introduced an entrepreneurial style of management to the running of the municipality. Plans for construction were all well and good, but they had to be translated into action, and sooner rather than later.

However, Stavanger already had an advantage over its competitors in the question of where to localise Statoil and the Petroleum Directorate in that a small offshore petroleum milieu had settled in the city at this stage, largely independently of any political direction. Vatne (2008) underlines that the first oil companies (Esso, Phillips, and Elf) opted for Stavanger because this made sense in terms of traditional localisation factors such as transportation costs, logistics systems, local maintenance and repair capacity (Kvaerner Rosenberg), and so forth. In addition, local initiatives ensured that housing and schooling adapted to an international workforce were in place. And once the oil companies had arrived, the overseas service companies and supply industries were not far behind. For, as Mcgill puts it, "*the oil companies have the money, and the rest of us follow the money around*".

From 1966 to 1972, two offshore supply bases were established, and several companies from abroad established operative units in Norway for the purposes of exploration and production of oil, and development of oilfields. "*A nascent industrial cluster was established, and a path-dependent course of development had begun*"[5] (ibid, 107).

The concession system and the development of Statoil were the government's primary tools in the efforts to Norwegianise the oil and gas industry[6]. In addition, the domestic companies Hydro and Saga emerged as competitors to Statoil. It was a central political objective that oil

[5] Translated from Norwegian

[6] Even though a unanimous Storting supported the setting up of Statoil, there was great political controversy as to how strong the company was to be allowed to become. For example, Lerøen (2002) describes the political manoeuvring surrounding Statoil's takeover of Mobile's operator responsibility at Statfjord, during which there was a deep division between left and right in the Norwegian political landscape, with the private oil companies and Hydro playing active parts in the political game. It belongs to this story that Mobile wanted to withdraw from an earlier agreement that Statoil was to take over the operator responsibility, and that the Oil Directorate argued that Statoil lacked the capacity to take on this responsibility, which was part of the Norwegianisation process.

and gas be brought ashore in Norway, if at all possible. Political signals were given to the licensing authorities that a promise to use Norwegian goods and services offshore was to be given positive emphasis in the evaluation of applicants in connection with the allocation of licences (Berrefjord and Heum 1983). In 1982, the Government ordered that a construction job for the Heimdal field be given to the shipbuilding yard Fredrikstad Mekaniske Verksted. Berrefjord and Heum refer to this example, and to the increasingly active part played by Norwegian companies in the activities on the shelf, as explanations for the fact that the Norwegian share of total deliveries rose to 70 % for Statfjord and 60 %[7] for Valhall [8]. In comparison, in connection with the American Phillips company's development of Ekofisk, half of the deliveries originated in the United States; and in the development of Frigg by the French Elf company, a third of the deliveries were imported from France. As part of the Norwegianisation policy, Mobile was for example ordered to include Statoil as a "trainee" in its organisation while developing the Statfjord field, and consequently to hand over the entire operator responsibility to Statoil [9]; and Brown and Root, the engineering contractor for Statfjord, was instructed to invite the Norwegian company Norwegian Petroleum Consultant (NPC) onto the team (Nerheim 1996). The technology agreements also contributed to the transmission of competence and financial resources from foreign oil companies to many domestic supply companies and research milieus (Keilen 2005).

Reve and Jakobsen (2001, 175) emphasise that the rapid expansion and great technological advances of the Norwegian oil and gas milieu were a result of the government's "protectionist policies". They describe the policies in this area throughout the 1970s and 80s as "rearing policies", designed to ensure that the operators used Norwegian suppliers, and that the operators themselves were located in Norway. Seeing oil policies from a trade union perspective, Berrefjord and Heum (1983) argue that generally speaking, the supply companies are in a weak position. This can be ascribed to many factors. For example, it is up to the oil companies to describe the necessary tasks and requirements, and foreign companies are

[7] However, these are gross figures, and are not adjusted for import; thus, there is reason to assume that the real shares are smaller. See for instance the descriptions of Norwegian Hitec-Dreco deliveries of turn-key drilling packages, where a large proportion of the manufacturing took place in Canada (Dreco), and machines were delivered from the United States (Varco), but where much of the engineering, not least for the steering and control systems (Hitec), and the assembly took place in Norway (Haugesund).

[8] Statfjord was discovered in 1974 by Mobil and confirmed commercial viable the same year and the first installation, Stafjord A, started production in 1979. Valhall was discovered in 1975 by BP and came in production 1982 (Valhall A).

[9] See footnote 6

therefore in a position to filter out the domestic suppliers; due to the shipbuilding crisis, there is a dearth of alternative markets for the suppliers; the government has created over-optimistic expectations; and the oil companies are more powerful than the suppliers – and therefore in a position to play them out against each other. Finally, because of the oil companies' far superior resources, the public authorities in charge of overseeing supply policies have a comparatively limited impact.

In their Porter analysis, Reve et al. (1992) highlight the fact that the oil and gas sector and the maritime industries constitute the strongest and most significant cluster industries in Norway. Norway's offshore industry can be described as a broad industrial cluster concentrated primarily on the south-western coast of Norway, with Stavanger as its national centre. Furthermore, a corresponding cluster is found in Aberdeen, while the international centre is still located in Houston.

Reve and Jakobsen (2001) confirm that Rogaland is Norway's largest county for oil and gas activities by a wide margin, with Oslo in second place. Oslo is larger in this respect than all of the rest of Norway combined. However, the growth from 1988 to 1998 occurred primarily in the counties of Hordaland, Vestfold, and Møre and Romsdal, and in the two Agder counties. Akershus (in the Oslo region), which has a considerable amount of activity within offshore engineering, suffered a significant decline in the second half of the 1990s (ibid.; Isaksen 2003). According to Reve and Jakobsen, the "engineering Valley" milieu seems to be splitting down the middle: ICT-related activities appear to be pulled towards Oslo, whereas production-related activities are pulled towards Rogaland. In the year 2000, some 36,000 people were employed in the oil industry in Rogaland – 14,000 of these worked for oil companies, and 22,000 for the offshore supply industry. In the Agder counties, 2,300 people were employed in the supply industry[10].

According to John Mcgill – one of the pioneers of the Hitec supply company – the strict rules imposed on the drilling activities by the government had a very positive impact on his business, since they required new approaches and innovative thinking. Mcgill identifies the shock of the 1977 Ekofisk Bravo accident, which involved an uncontrolled oilwell blowout, as a safety policy turning point[11]. He comments, though, that the safety regime was less strict

[10] From a lecture given by Knut Aaneland, TBL Offshore, at the Norwegian Offshore Day 2004

[11] Three years later, the accommodation platform Alexander Kielland capsized during a storm.

in the British sector of the North Sea. In the 25th anniversary corporate odyssey of Dreco – the firm which joined Hitec to form the partnership Hitec-Dreco A.S. in the 1990s – the claim is put forward that only in areas such as the North Sea, "where equipment specifications are mandated largely by government regulations, can higher cost, innovative equipment be expected to make any inroads into the market place" (McBean 1997, 230).

The drilling rig supplier

Hitec's drilling activities were sold to the American company National Oilwell in 2000. Although Hitec had initially been founded by Gjedebo, Sætre and Mcgill also joined the company early on as owners, and made significant contributions to its development, according to gathered data.

Gjedebo qualified as a ship's engineer in Oslo in 1970. The first remote controlled ship engine room was constructed around this time, and the young naval engineer had envisaged that ship automation systems would be his line of work. However, with the dwindling of such job opportunities caused by the flagging out of the shipping trade, Gjedebo found his first position in Norway's largest control and automation firm. He worked on projecting and installation tasks in relation to shore-based industry. His employer was the American Honeywell company's agent in Norway. In 1973 he moved back to Stavanger[12] (which is also his wife's hometown), where he set up his firm, Jon Gjedebo Styringskontroll [Operation control], in the basement of their home. Later, he was entrusted with representing Honeywell as well as his former employer in the Stavanger region, Marstrand & Astrup. During the initial years, the market was constituted by the regional manufacturing industry, such as the canning industry in Stavanger and elsewhere in Norway, and the mechanical industry in the Jæren area (south of Stavanger). This was a small market, and according to Gjedebo, gaining access to the manufacturing industry in Stavanger was a particularly difficult challenge. He reports that his firm noticed the expansion of the oil sector from 1975-1976, however, and that at this point, they started to do more business with the oil industry. The first contracts involved supplying instruments and PVT (Pressure-Volume-Temperature) laboratories. Mcgill recounts that he first met Gjedebo when he visited the firm, still located in the basement of the family home, to buy monitoring instruments. During this early phase, the firm accepted a number of commissions for oil industry laboratories, and made a series of

[12] Gjedebo comes from Jørpeland, Ryfylke, which is fairly close to Stavanger.

deliveries of such labs. Gjedebo also sold a PVT laboratory to what was then known as Stavanger Regional College.

In 1979, the company name “Jon Gjedebo Styringskontroll” was replaced by the new name “Cybernetix”. “Hitec” was registered as a firm in 1985, and became operational in the following year. Sætre came on board with the setting up of Hitec. Gjedebo had met him in connection with a large commission in the past, when Sætre had represented Siemens Electro. According to Gjedebo, Sætre was “*a great sales talent*”, and Mcgill “*knew the ins and outs of the drilling industry*”.

Innovations

Mcgill joined Hitec in 1988/89. In those days, the firm had some 20 employees. He came to Norway from Britain with the first drilling contractor company at Ekofisk, Moran from Texas, and worked his way up to become drilling operation manager for Morco Ekofisk[13]. Mcgill has experience from the UK steel industry and their application of PLC control in production. He was working offshore as Project Manager for the new Platform Rig 2/4K (Ekofisk) when friends suggested to him, “*why don’t you start your own company and find a better way of making Platform Drilling Rigs*”. Mcgill knew Gjedebo through his purchasing of instruments for the drilling operations while Gjedebo’s business was still in his basement in Musegaten, and they used to exchange ideas on Drilling operations at the time. They also lived in the same neighbourhood. “W*hen I wanted to start my own company to design Platform Rigs,*” Mcgill recalls, “*I went to Gjedebo with my ideas. He gave me 12.5 % of the shares in Hitec for the ideas. Sætre owned the same amount, and Gjedebo controlled 75 %*”.

When Mcgill joined Hitec as an owner-manager, each piece of drilling machinery involved an individual stand-alone control system with all together more than 100 electrical cables. There was no integration or standardisation of hardware, and ergonomics was not considered. The early rigs were based on American technology, which had been developed primarily for onshore drilling, which is not so complicated. There was little focus on technological innovation or on adopting state-of-the-art technology. What mattered, according to Mcgill, was that the job was done cheaply and adequately.

[13] Morco is the Norwegian branch of Moran.

One of the central ideas of Mcgill's and of Hitec was to integrate the control systems into a drilling cabin[14]. Operation, control, and automation constituted Hitec's core competence. Drillers' cabins were initially simple shelters against the elements; today's cabins are sound insulated drilling control centres built to withstand the impact of heavy falling objects.

The way the oilfield development projects were organised made it difficult to integrate the different control functions. Based on specifications prepared by the operator, the drilling equipment was usually procured on a piece-by-piece basis, with fabrication of auxiliary equipment and installation contracted to a steel fabricator, usually a shipyard, which might not have any specific expertise in the area of drilling facilities. According to Mcgill, internal rules in the oil companies required that three competing quotes be collected for each unit of machinery that was part of a full drilling package. For Hitec, the key to realising the vision of developing integrated remote operated control rooms was to deliver the drilling rig as a turn-key package to the prime contractor building the platform on which the drilling rig was to be mounted. Hitec's first EPC job was at Draugen in 1991 (see further down for details); that is, Hitec was responsible for the engineering and procurement as well as the construction. "In the EPC job", McGill relates, "*we said to the suppliers of machinery, 'you deliver the machinery, and Hitec will make the controls'. We met with a certain amount of resistance from the machine suppliers, but our differences were sorted out, and this meant that we had gained control over all of the drilling parameters*".

Before the introduction of the new integrated control systems, there was usually a driller on deck, and a derrick man in the drilling derrick 30 metres above the deck. The derrick mans work was manual vertical pipe handling and to monitor the operations. The communication between the driller and the derrick man, which was by hand signals or telephone, was a potential source of safety issues. In addition, the job in the drilling tower was ergonomically unfortunate, as the derrick man had to spend hours staring down. When automated pipe handling (the Star Racker) and CCTV technology was introduced, the cameras took over the monitoring tasks previously performed by the derrick man. Furthermore, the drilling cabin had two control/operation stations (one for the driller and one for the assistant driller). During our interviews, Mcgill referred to the producer of CCTV systems, HERNIS, as "the camera

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[14] Major remote control equipment includes Drawworks, Rotary Table, Top Drive, Slips, Elevators, Mud Pumps, Catwalk Machine or Pick-Up Machine, Vertical Pipehandler, Fingerboard, Iron Roughneck, Thread Dope Machine and Mud Bucket (Mcgill 1991).

guys". The drillers' cabin was designed with ergonomic in mind and provided direct communications between the two main persons operating the rig.

A next step on the way towards integrated and remote-controlled drilling operations was Hitec's creation of the Cyberbase drilling control system, which collected all the control functions for the drilling operations and later digitalized them. Initially, Cyberbase did the same as all the stand-alone systems, but integrated into one, based on electrical cables; later these were replaced with integrated fibre cables. From then on, the large number of electric cables between controller and machinery would be replaced by a few dual fiber Ethernet network cables connecting the drilling control PLCs. Rather than using meters, indicators, or gauges, drillers would take their cue from software-generated instrumentation on the Cyberbase monitors located in the Driller's Cabin. According to Amin and Mcgill (1996), an emphasis on safety and work environment concerns, including ergonomics, was a major factor in the development of Cyberbase and a way to go in the future. One of the main functions of the PLC system is to coordinate different actuators so that they simultaneously produce the desired movement of a particular piece of machinery. Connecting the drilling controls and the data acquisition into a network results in the following features (Mcgill and Watson 1995):

- Processing of information from all pieces of drilling equipment to all operators
- Data exchange between drilling instruments and drilling equipment
- Logging is performed for well comparison purposes
- All available information can be collected into a shared data base
- High-speed communication to/from all PLCs
- Ergonomically designed displays and indicators which can easily be modified to accommodate technological changes
- Total rig alarm system

Cyberbase was created in the 1993-1995 period. Gjedebo described it as a significant departure from the previous thinking about the human-process interface: abandoning the traditional approach of human adaptation to the processes, Cyberbase took the human terms – human data processing on the drilling deck – as their starting point, and adapted the processes to these. According to Mcgill, the German Siemens company was an important resource for Hitec in the digitalisation of Cyberbase. Siemens was already in Stavanger, working with the oil industry, and the firm represented essential competence in industrial PLC control and programming. Furthermore, as mentioned, one of Hitec's pioneers, Sætre, had previously worked for Siemens. Gjedebo underlines that the key feature of Cyberbase is not the software, but the thinking, pointing to the fact that Hitec has replaced its software several times. Apart from Cyberbase, the drilling cabin consists exclusively of hardware.

Furthermore, the research institute Ullrigg Drilling and Well Centre in Stavanger was important to Hitec, Mcgill recounts: "The first Cyberbase was developed for the research rig and I think we received some research money from Shell." Gjedebo reports that Hitec received an additional 2 million Norwegian kroner from the Research Council of Norway for the purpose of developing Cyberbase, and channelled a corresponding sum of the firm's own resources into the project. According to Mcgill, Gjedebo did not patent Cyberbase, which is now used by "everyone". The Ullrigg Drilling and Well Centre[15] confirms that Cyberbase is now the industry standard.

It emerges in Keilen (2005) that Rogaland Research launched a project in 1981[16] called "Integrated safety evaluation of drilling operations". The vision was to create an ideal rig with automated drilling operations operated from a centralised integrated control room. Furthermore, it emerges from the same source that Hitec commercialised Rogaland Research's IDS technology in their SDI – Smart Drilling Instrumentation – and Cyberbase product lines.

On the drilling side, Mcgill emphasises that Hitec also made an important innovation with their improvement of the drilling rig drive systems, replacing DC electrical motors with AC motors on drilling rig drive systems. This has, for example, made operations control easier, in that separate breaks and flexible speed control are now redundant (Mcgill and Watson 1995). The scale of this innovation is daunting, as a drilling rig tends to have drilling rig drive systems consisting of 10 motors, each with an effect of some 1,000 Hp. AC motors have become the industry standard in drilling rig drive systems. They were first installed at the Troll rig by Hitec-Dreco with great success 1994/1995, according to Mcgill. Conversion from DC to AC for drilling rig drive systems has also sparked off significant innovations on drilling machinery as Top Drives.

Hitec constructed their first pipe handling machine, the "Star Racker", for the research rig (the Ullrigg Drilling and Well Centre). Soon after the contract from the research rig, Hitec

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[15] In Norwegian Academy of Technological Science (NTVA) in Co-operation with Offshore Media Group and INTSOK (2005), *Norwegian Petroleum Technology. A success story.* Trondheim.

[16] See the previous reference.

received the Draugen drilling contract including a Star Racker. The Star Racker to the research rig was delivered and tested before the Draugen version was supplied offshore.

Hitec represented Varco in Norway at the time, and supplied control systems for Varco's pipehandling machines. Mcgill confirms that know-how from Varco was incorporated into the pipehandling machine, the Star Racker, which was designed by Hitec and constructed by Varco. Varco's version of pipehandling machine had a control system which did not work to well and Hitec supplied their system to Varco's machine, which was sold world wide by Varco. According to Gjedebo, it was Phillips that partly financed the Star Racker to the research rig. He identifies Phillips as a good customer.

Alliances and drilling rig projects

Hitec produced no mechanical parts in-house (apart drillers cabin) and needed partners for mechanical work and machinery in order to realise their vision of integrated remote drilling control. Mcgill relates in an interview that the only two companies he wanted to cooperate with on this project were the Canadian company Dreco and the American company Varco. Dreco designed and constructed drilling rigs, and Varco designed and produced vital drilling equipment such as pipe handling machinery and top drives. Mcgill was familiar with both companies from his previous job. He worked with Moran drilling contractors on Ekofisk when Dreco built the lightweight drilling rig Phillips Rig 50 – which has been identified as a very successful piece of work (McBean 1997). Mcgill soon contacted both Dreco and Varco, seeking to arrange for Hitec to become the agent or representative of these companies in Norway. McBean (1997, 177) writes that Mcgill's approaches met deaf ears in the former company, "as Dreco continued to 'smart' from its Phillips 50 ordeal".

When Mcgill joined Hitec in late 1987/early 1988, one of his first tasks was to prepare the conceptual design for a lighter-weight drilling rig for Norsk Hydro's Sleipner gas drilling facility. He successfully sought assistance from Dreco's London office to improve the concept for the rig; however, Hydro concluded that "*the concept was too revolutionary to warrant further evaluation*" (McBean 1997, 177).

On Gjedebo's initiative, contact was resumed between Dreco and Hitec in late 1988. He argued that Hitec and Dreco should pool their resources to tackle the drilling rig planned by Shell for the Draugen platform. Gjedebo had great confidence in their joint ability to realise a turnkey derrick package (EPC-contract) for Draugen. During this process, Maritime

Hydraulics, Kristiansand[17], made a complaint to the Norwegian Oil Ministry about Shell's plans for a 'single source', or non-competitive, bid approach to the design and construction of the new Draugen offshore drilling rig.

This resulted in a new round of preparations, this time for a public tendering process. McBean (1997) writes that Hitec and Dreco were aware that Shell was under time pressure, and they quickly prepared a preliminary rig design for a complete lightweight rig package. In this process they encountered the argument that even when pooling their resources, they were too small for the task, and their financial muscles were dismissed as less than impressive. Nevertheless, the financial team of Shell Norway subsequently accepted Hitec-Dreco as a qualified supplier. The Kvaerner Rosenberg shipyard in Stavanger was Shell's main contractor. The Hitec-Dreco joint venture was soon formalised. In the autumn of 1990 it was announced that Hitec-Dreco had been awarded the Draugen job, and they were told to expect confirmation of a purchasing order for the drilling equipment system from the general contractor. The production of the rig started in January 1991, in Canada. By the end of October, the process of testing the rig was completed, in Haugesund, two months earlier than scheduled. It was now ready to be disassembled and taken to the Rosenberg shipyard in Stavanger, where the work of constructing the platform on which the rig was to be mounted was nearing completion. At a subsequent party arranged by Hitec-Dreco, the president of Shell Norway expressed his confidence in the new drilling rig design: "*Shell Norway is overwhelmed and very pleased with the results of this drilling rig. Although our next project, Troll, appears to be going in another directio, I personally hope that Shell will go with the Hitec-Dreco concept*" (McBean, 1997, 184). It is part of this success story that during Hitec-Dreco's work on this project, the Norwegian Petroleum Directorate carried out a full audit of the firm. The audit included quality assurance, quality control documentation, engineering calculations, and planning and manufacturing procedures. No negative findings were reported.

Engineering and construction of a drilling rig for Shell's Troll platform was the next major rig commission for Hitec-Dreco. The outcome this time was disappointing, involving financial loss and considerable turbulence in the customer relation (McBean 1997). McBean (p. 226) describes the problems on this project as "the Troll contract battle". Mcgill characterized it as a "*fight*" and recounts: "*We ran into problems with the specifications*". When Mcgill is asked to specify the problems at Troll he emphasises that whereas Shell's practical drilling people at

[17] The present company Aker MH, which is a subsidiary of Aker Solution.

Draugen and Hitec-Dreco worked in close collaboration to find solutions, the contractors hired in to look after Shell's interests at Troll showed no interest in new technology and innovation. Implementation of new technology requires flexibility from the client's side, and close collaboration to find the best solutions. Shell's contractors were adamant about the specifications, and forced Hitec-Dreco to use specifications prepared for large rigs, although the Troll platform rig was a particularly compact one. The rig was delivered on time, but with a large cost overrun, and the venture brought both Dreco and Hitec within the brink of financial ruin. In the early phase of Troll, Shell' drilling people also took part on site, but they withdrew when the problems start to pile up.

Because of the problems on the Troll project, Hitec-Dreco lost a contract with BP that involved constructing a drilling rig for the British sector. However, Hitec-Dreco's engineering was used in the construction. The rig was delivered by Christmas 1995, well within the cost framework and 6 months ahead of the time schedule. Hitec-Dreco's engineering input attracted much praise (ibid.).

Phillips Petroleum was the first oil company to buy a drilling control system based on Cyberbase. The negotiations between Hitec-Dreco and Phillips regarding the construction of a workover drilling rig for the development drilling platform 2/4X (Ekofisk) virtually coincided with the Troll negotiations, and bids were tendered for both projects in April 1992. Like other companies, Phillips was bound by the increasingly strict safety regulations for operations in the North Sea. However, according to McBean (1997), Phillips enjoyed greater freedom and independence in the design, construction and operation of drilling and workover rigs in the North Sea than any other operator, Shell included. He attributes this to the fact that Phillips was the only operator not partnered with Statoil; and also that the company was the first to make a commercially viable discovery of oil, thus enabling it to establish oil production in the Ekofisk field before the creation of Statoil. McBean ascribes the more sympathetic ears lent to Hitec-Dreco's innovative rig design by the project teams at Phillips than by their counterparts at Shell to the fact that Phillips had more leeway than the rest.

However, Mcgill reports that Phillips, too, rejected Hitec-Dreco's proposals initially. It was only when Hitec-Dreco managed to convince Phillips that the proposed technology – which was based on PLC operation control – was state of the art, and in widespread use for production control in other industries – such as at the brewery in Stavanger (Tou) – that this opposition was overcome. Mcgill's general experience is that conservatism is commonplace in the industry. More often than not, the oil companies prefer proven technology.

The negotiations with Phillips dragged out. One of the reasons was that the new investments depended on Philip's licensing period, due to expire in 2011, being extended. It was eventually extended to 2035 by the Storting. Hitec-Dreco then encountered problems in connection with Troll, and there was an internal tug of war in Phillips about which drill supplier to choose. Gerald Berk from Phillips, who was positive to the new design, interviewed people from Shell who had worked with Hitec-Dreco on the Draugen and Troll projects, and found two diametrically opposed stories about Hitec-Dreco's performance. When it was clear that the job on the Phillips rig would be done by the same team who designed and built Draugen, he was prepared to put his reputation on the line to give Hitec-Dreco the job, according to McBean (1997).

Hitec-Dreco had to prepare a new scope of work, contract terms, and equipment specifications based on the lessons they had learned on the Shell Troll project. In addition to protecting Phillips from any problems that Hitec-Dreco might face in the final settlement of the Troll project, it was decided to define Hitec as the prime contractor, and to use Hitec-Dreco as a subcontractor to Hitec. The contract was finalised in January 1995, and in October 1996, drilling operations started at the Phillips 2/4-X platform. The engineering and construction work went as anticipated. Phillips employee Croucher (1998) later presented the paper "An integrated team approach to the design, construction, start-up and operation of the world's most modern drilling rig" to an offshore technology conference in Houston. Croucher's descriptions of the drilling rig (p. 86) – where most of the operations use a combination of remote control and automation – focuses in full on the Cyberbase control system: "[There is] no external control/instrumentation. The Cyberbase man-machine interface allows the driller to control all drilling equipment/systems via a 'drill by wire' digital control system". Furthermore, Croucher writes that the rig contains a "low noise Driller's cabin" and "fully integrated four stage pipe handling system (pipe deck to derrick)". He leaves no doubt that this design was innovative: "The 2/4 X platform rig was so original in terms of its advanced level of technical complexity, it logically follows that the supplier of the rig had little experience of the actual operation of such a drilling unit. The supplier was offering a solution which, despite being a natural development of previous automated rigs, was untried in an operating environment. A success factor in the Phillips project was "the combination of proactive and empowered customer representatives and willing and receptive suppliers [, which] combined to make a highly effective supplier organisation" (ibid., 88). Later, Hitec entered into cooperation with Smedvig Shipowners on rig commissions for floating rigs[18] (*Stavanger Aftenblad* 24th December 1996). Hitec also acquired joint ownership of several companies in the oil and gas sector, such as Multi-Fluid (*Stavanger Aftenblad* 4th March 1999), to take one example. In our interviews, Mcgill described Smedvig as an important participant and a major investor in the offshore supply industry in Stavanger. Peder Smedvig and Gjedebo knew each other from their school days.

In addition to producing drill solutions, Hitec was also active in a series of other product areas. The firm became involved in a string of companies within oil and gas, but also within property and other trades – partly by founding new companies, and partly through takeovers. Gjedebo seemed to recall that they were, or had been, involved in a total of 26 companies. Among the better known of these are APL (Advanced Production Loading), and Remora. The latter is still part of the Hitec group. While APL focuses on buoy loading for oil tankers, Remora produces advanced technological solutions for the transferral of oil from one vessel to another. When Hitec entered the stock exchange in 1993, Statoil's then CEO Arve Johnsen was elected to the company board. The annual purchases of goods and services from Hitec by Statoil were in the order of some 60,000 NOK during this period. According to Gjedebo, Hitec enjoyed a good relationship with Statoil's laboratories and operations, although the data indicates that Statoil was not among the firm's most important customers. Statoil and Hitec were joint majority owners of APL during a period in the 1990s. The relationship was not without its frictions, and Hitec disposed of its shares. However, at a later date, shares were again acquired in the same firm – but these, too, were subsequently sold. APL was a "money-making machine", according to Gjedebo,.

The parts of Hitec not included in the drilling industry section acquired by National Oilwell in 2000 (370 employees[19]) were incorporated into HitecVision (550 employees[20]), whose business idea is to purchase companies and develop them for resale. National Oilwell had previously been used by Hitec as a subcontractor of drilling equipment (*Stavanger Aftenblad* 22nd September 1999). HitecVision owns a portfolio of firms worth some 4-5 thousand million NOK, according to Gjedebo. Meanwhile, National Oilwell has acquired both Dreco and the Norwegian company Hydralift in Kristiansand (October 2002), merged with Varco

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[18] Drilling ships and semi submersible rigs

[19] *Stavanger Aftenblad*,12th October 1999.

[20] See footnote 19.

(2005). The company name is now National Oilwell Varco, and the Norwegian main office is in Kristiansand. Kristiansand is also the location of the company's production of drilling equipment such as top drives, iron roughnecks, power slips, pipe-rack gantry cranes/horizontal pipe handling systems, riser-tensioning systems, passive and active drill string compensator systems (crown mounted), and derricks. The firm also produces cranes and winches. This production takes place in Molde on the premises of the former company Stålproducter AS, which was acquired by Hydralift in 2001.

Gjedebo emphasises that their primary motivation for selling to the Americans was a combination of the market prospects and the fact that they had become so heavily dependent on the oil industry. However, it is also a fact that a fair amount of money changed hands in this transaction. Both Gjedebo and Mcgill followed the firm into National Oilwell. Gjedebo worked as R & D manager and second in command at the headquarters in Houston for four years. The job description was related to transmission of technology and technological expertise. It belongs to the story of the transaction with National Oilwell that Gjedebo pledged to refrain from competitive activities (*Stavanger Aftenblad* 11th October 1999). In Mcgill's experience, National Oilwell was an oversized and bureaucratic organisation that lacked entrepreneurial spirit. There was little concern for development of new ideas, as the company was primarily interested in selling the existing technology already in its possession. Mcgill left National Oilwell after some 12 months. Gjedebo has been awarded the title "Norwegian Entrepreneur of the Year", and he was also identified as Norway's "Oilman of the Year" in 1997. In May 2007, Gjedebo received the *OTC Heritage Award* for his contributions to technological development within the petroleum industry.

The CCTV supplier

In the autumn of 1981 Jon Are Nor started to discuss the idea of establishing a company with a work college, Arild Hammer, and a neighbourhood friend, Erik Ellefsen. This was in the small town of Tvedestrand, Aust-Agder Country, some five hours' drive from Stavanger. Nor was a trained electrical engineer, and had worked as an electricion both in the merchant navy and on an oil rig in the North Sea. Up to the founding of HERNIS, he and Hammer also worked together within ventilation, which uses PLC control technology. Hammer and Ellefsen were mechanics and had expertise in the area of machining of steel. The three entrepreneurs quit their jobs and established HERNIS in May 1982. Soon, Sigmund Rudnes also joined the company as a partner. His background was from electronics, and he brought some emergency light systems business with him into the company. This was vital for the company's survival in the fist two years of its existence. Rudnes had an important business connection with a local shipowner and investor. "*Rudnes was a great talker, and was made general manager*", Hammer relates. In the early period of their business venture, camera inspections of sewer systems for municipalities in the region added to the income and helped sustain the company.

The business idea was inspired by the introduction of remote control vehicles (ROV) to monitor sub-sea blow-out-valves in connection with the oil and gas explorations in the North Sea. 27 years later, Nor described the idea in terms of providing an "*extension of the human eye for monitoring and inspection purposes in hazardous environments*". Turn-key systems including explosion proof (EX) camera stations supplied to the oil and gas industry are at present a core product for the company.

In 1983, the HERNIS company attended the international oil exhibition in Stavanger for the first time. Later in the same year, they received a request from National Electro[21] to deliver explosion proof cameras[22]. "*After studying the requirements and regulations for such equipment, we decided to go for it. The price we offered was, however, taken out of the blue.*" Time passed, and one day HERNIS received a phone call from National Electro. It transpired that the Norwegian government had introduced new regulations requiring that for the Gullfaks oilfield, a minimum 25 % of the total supplies (in terms of value) had to be bought from Norwegian firms. The HERNIS entrepreneurs then contacted Astrid Gjertsen, a local representative to the national parliament, the Storting. According to information gathered by two of the entrepreneurs, there could be "*no doubt that she had pulled some strings in our favor*". Licences for drilling and exploitation of oil in the promising Gullfaks field were allocated in 1978 to three Norwegian companies, namely Statoil, Norsk Hydro, and Saga Petroleum, with Statoil as the operator. This was the first time Norwegian authorities opted for an exclusively Norwegian group of licensees[23].

HERNIS's competitor for the EX cameras was an Italian-owned plant with operations in the United Kingdom (80 employees). Ready-made EX-CCTV camera equipment was already part

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[21] The name was later changed to EB and then ABB.

[22] An EX-camera is designed not to explode when gas leakage occur to protect surrounding environment and people. There are built in mechanisms to press possible entering gas out of the camera. Hence, the camera also retains its functionality when gas leakage accidents happen.

[23] www.statoil.com

of this company’s portfolio, whereas the HERNIS entrepreneurs only had a few drawings and specifications for such cameras at this stage. However, whereas the competitor’s equipment was made in cast-iron, and characterized as huge and heavy (80-90 kg), the camera designed by HERNIS weighed a mere 35 kg, replacing cast-iron with acid proof steel as the main material basis for the camera houses. Hence the specified equipment was within manhandling size. Another improvement made by HERNIS – and one that is still considered a competitive advantage – was to integrate the cables within the construction. In the harsh North Sea climate, this offered important protection, extending the life cycle of the cables and lowering the maintenance cost.

National Electro won the supply contract for the Statoil Gullfaks A rig, and HERNIS signed a subcontractor deal with National Electro worth 2 million NOK for the delivery of 25 EX cameras. “Then the job began”, according to one of the entrepreneurs. A prototype was made in a garage rented locally, and according to the respondent, the entrepreneurs worked really intensely to achieve the necessary EX-certification. The certification body, NEMCO, had no prior experience in testing and issuing certificates for such equipment, but “they were cooperative”. “*We made many trips to Oslo. Testing in Oslo during the day and making adjustment at night back in Tvedestrand*”. Tvedestrand is located south of Oslo, and the drive takes some 4-5 hours by car. “*All the time, we had to face problems head-on and solve them, and working on the prototypes proved particularly challenging*”. One of the entrepreneurs describes the early stages of their effort as a period of “*trial and error*”.

The deliveries fulfilling the Gullfaks A contract were completed in 1984, and HERNIS experienced a sharp rise in demand for the company’s services as problem solvers (engineering) and in orders for EXE-equipment, both during and after the production period. A considerable share of the extra work commissioned for Gullfaks was supplied directly to Statoil, not via the principal company for the first contract.

Knowledge of other actors was crucial in the early development phase. “We had to go where the knowledge was to be found. One challenge was to adapt the large video cameras of that time to pipes, where low weight was essential. We moved components around to accommodate the physical constraints, but some sizes and connections could not be altered, such as cathode ray tubes (CRT). Things are much easier today, with cameras the size of a lump of sugar available for sale.”

Moreover, the entrepreneurs lacked basic knowledge about video technology, but in this context National Electro was an important resource. National Electro was the agent of an

American video camera producer, and possessed the necessary skills. As a supplier of video cameras, National Electro transferred knowledge to the studied company, but the fact that the entrepreneurs were acquainted with employees at National Electro also played a role. According to one of our respondents, "*the larger companies of that time were eager to outsource work to smaller companies like HERNIS*". An academic from Agder University College assisted in developing video matrixes and a fibre optic link. Other resources mentioned by the entrepreneur informants in connection with video matrixes were Moland Automasjon (located in Aust-Agder County) and Sandar electronics (Sandefjord). During these early days, the company Norsk Kabel produced the cables designed by HERNIS. The machining of acid-proof steel was outsourced to the Sandvik company in Sweden when initial in-house attempts at such manufacturing proved unsuccessful.

The development of the first EXE camera was part-financed by a government agency providing risk capital for emerging businesses, Industribanken. One of the entrepreneurs argued during our interview that the company should have applied for more money: "W*e frequently had to make sewage inspections to survive the first years*", he explains. "W*e were always financially behind*". The local bank took their private houses as collateral for the loan financing the company's first lathe.

The entrepreneurs encountered scepticism towards their business project from financial institutions in general, as well as from the local authorities. For instance, when they needed a new location for capacity reasons in the process of switching from prototyping to industrialization, the elected business committee in the municipality of Tvedestrand had nothing to offer, even though vacant production sites were available. "*When we had a 1000 things to do in connection with the prototyping for the first contract, the necessary relocation became an extra burden,*" one of the entrepreneurs recalls. In 1983, the company issued new shares, and a local shipowner and investor bought shares worth almost 50% of company total. Consequently, its activities were moved to a production facility owned by this investor in a neighbouring municipality. In a second equity dilution move somewhat later, another local investor also acquired a significant ownership share.

1989 was a turning point. A collapse in the property market and huge interest rates provided the backdrop. HERNIS relocated to its present location (Hisøy in the Arendal municipal area). Its first customer in the oil and gas industry, National Electro, had some 40,000 square metres of unoccupied production facilities at Hisøy. HERNIS's largest investor went bankrupt in the crisis, and a UK-based firm acquired the company in the same year for a very small sum of money, according to our respondents. A local investor, Ugland, also expressed interest in buying HERNIS, but the sellers' suspicions that this would mean a relocation of the company's activities to Ugland's shipyard in Grimstad made this a less interesting alternative. The entrepreneurs came out of the transaction with a net dept and no ownership in the company. The other investors also lost most of their invested money. The company which bought HERNIS – later named HERNIS Scan Systems – is still the owner; however, the name has been changed to the Vislink Group, and its capital has been somewhat restructured. According to the entrepreneurs, their market knowledge and financial management skills may have been too weak. "W*e were too engineering-minded*", they conclude. In 2010, HERNIS Scan Systems appears to be a thriving company, with about 200 employees.

Analysis

Hitec's successor, NOV Stavanger, and HERNIS are both part of the Norwegian oil and gas clusters centred on Stavanger. This is confirmed by their products and their lists of customers. In terms of exogenous shocks, the fundamental shock in this context was the discovery of commercially exploitable oil and gas reserves in 1969. Attracting international oil companies to Stavanger and Norway with the purpose of exploratory drilling, development, and exploitation/operation on the oil and gas fields, this generated market opportunities for the supply industry in Norway. Measures introduced by the Government as part of a policy of Norwegianising oil and gas exploitation on the Norwegian section of the Continental Shelf helped strengthen Norwegian supply industry opportunities even further.

Exogenous shock

In the cases of both Hitec and HERNIS we may talk of an exogenous shock in the shape of technological opportunities. For Hitec, the challenge was to improve underdeveloped American technology by integrating the operation and monitoring of various drilling machinery and data logging into a drillers' cabin, and of maximising operational automation and remote control in the process. These innovations, achieved through the application of state-of-the-art technology, typically helped make redundant dangerous manual tasks on the drilling deck and in the drilling tower. The technological opportunity grasped by Hitec has become a pull factor and market opportunity for HERNIS, as Hitec's vision depends completely on well-functioning CCTV systems. The products of the two firms are complementary. Perhaps the most striking example is that explosion-proof CCTV cameras have replaced the manual monitoring tasks which used to be performed by the derrick man, who was perched 30 metres above the drilling deck. The Bravo accident, followed by stricter government offshore oil industry legislation, was an additional shock which led to an increase in the demand (and stricter legal requirements) for safer drilling operations. HERNIS experienced this shock indirectly through further increases in the demand over time. HERNIS saw the technological possibility of developing an explosion-proof CCTV camera which was both lighter and easier to handle than the cameras available at the time, while also connecting the cameras into an integrated data network system which could be remote controlled from a single location. With steadily increasing safety demands, the use of CCTV cameras has exploded.

Governmental oil and gas industry policies

Norwegian governmental policies directed at increasing offshore safety was an important precondition for the journey of technological innovation undertaken by Hitec from the late 1980s up to its acquisition by NOV in 1999/2000. Our data indicates that the costs and risks of failure contained in the relatively large steps of innovation taken by Hitec during the 1990s would not have been accepted by the oil companies had it not been for the absolute safety requirements imposed by the Government. Thus the safety legislation imposed on the Norwegian Continental Shelf by the authorities created an important impetus for technological innovation, allowing small companies such as Hitec and HERNIS to fill the technological gap.

The customer side and the policy of Norwegianisation

On the customer side, Shell (Draugen and Troll) and Philips (2/4X) were the companies to take on the risk of building drilling rigs according to the new concept developed by Hitec and Dreco. A conceptual proposal made for Norsk Hydro in the late 1980s was rejected on account of being too revolutionary. Our data indicates that it is difficult to succeed with innovative proposals in this industry, which seems to prefer proven technology. Furthermore, our data shows that Hitec was the driving force in the uptake of these new ideas, through a consistent effort to sell its product – possibly with one exception: landing the Troll contract was an easy match due to the company’s successful Draugen venture. AC-powered drilling rig drive systems were first introduced at Troll. However, the problems encountered by Hitec-Dreco on the Troll project injured the company’s reputation, and they also lost the construction part of a contract with BP on the British sector. The possibility of securing a contract for Philips’s 2/4X platform was also seemed to be in jeopardy, but in this case, Hitec-Dreco was given the commission in the end. One of the factors in the latter case was that central individuals at Philips believed firmly in Hitec-Dreco's concept, and knew what they had managed to achieve at Draugen. Cyberbase was first used in the operations of the 2/4X platform, and has since then become the industry standard. Furthermore, Philips also financed the Star Racker pipe handling machine, developed by Hitec in collaboration with Varco and included in the drilling package for 2/4X.

Whereas Statoil and the Norwegianisation policies of the Norwegian Government seem to have been unimportant factors in Hitec's customer relations, the opposite was the case for HERNIS. Precisely the government-imposed requirement that Statoil's Gullfaks used Norwegian suppliers enabled HERNIS to enter the business of supplying CCTV camera systems. The intervention of a local member of the Storting was probably also instrumental in getting the venture off the ground. At this stage, HERNIS had never made a single CCTV camera. The company managed to develop an EXE certified prototype in time, winning the first contract, and proving that it was capable of making explosion-safe CCTV cameras which were far superior to anything already on the market in terms of weight, and with regard to the ability to withstand the rough climate of the North Sea during the autumn and winter seasons. Subsequently, orders were received on a large scale.

The resource perspective

Hitec's core competence was machinery instrumentation and control. Realising the idea of integrating and standardising the operation of different types of machinery involved changing the present order of things for the machinery suppliers. They were used to supplying machinery where each unit had separate systems of operation and control. The basis for contracts had to be altered to open the competition for complete packages containing integrated control and operation systems. This would make Hitec a connecting link between the machinery suppliers for the rig (the mechanical construction) and the main contractor. The main contractor is often one of the former shipbuilding yards, but often, the oil companies are also strongly involved in the choice of suppliers. An obvious approach in this situation was to seek to get into a position of being able to offer complete drill rig packages, which would allow Hitec to make demands of the machinery suppliers in terms of interfaces between machinery equipment and operation control. Realising this ambition required external expertise and technology, and the Canadian rig constructor Dreco gradually became a partner in Hitec-Dreco for delivery of complete drilling packages, where Hitec supplied the operation control and the instrumentation for Hitec-Dreco. Mcgill had worked with Dreco in his previous job, and held the firm's level of competence in high esteem. Furthermore, an alliance was established with the American drilling machinery firm Varco. Know-how from Varco was important when Hitec-Dreco developed its own pipe-handling machine, the Star-Racker. Conversely, Hitec supplied control technology for Varco's own version of pipe-handling machines, which were sold world wide. Moreover, know-how and resources from Siemens were central when the operation control systems were digitalised (PLC) as a part of Cyberbase.

The problems encountered by Hitec-Dreco in connection with the Troll rig serve as confirmation of the IMP network theory in the sense that increasing the resources in relations between firms requires close cooperation and mutual orientation when the products are as integrated and as complex as in this case, involving a great degree of reciprocal interdependency (Kalsaas 2010). The strategy of keeping the supplier at an arm's length, which seems to have been pursued by Shell's contractor at Troll, is a recipe for failure in the context of innovation in value chains, as it leaves out an important condition for resource transmission.

HERNIS also had in-house knowledge on operation and monitoring of cameras and steel machination, but it lacked video competence, for instance. Our data shows that HERNIS acquired resources and competence formally from other companies, but also through informal networks in the local community, across the boundaries between different companies. One of HERNIS's major challenges early on in the process was to fit existing video cameras into relatively small cylindrical pipes. Gradually, the firm adopted the strategy of maximising its in-house control over both engineering and production. However, some components – such as the inner components of video cameras and standard monitors – have always been purchased from external suppliers, and lately, the company has also started to outsource more of the component production in order to handle the growth in business. Printed circuit boards are for example to a great extent produced by the company Kitron, which is located in the neighbouring building at Hisøya in Arendal.

The institutional perspective

Hitec received funding from the Norwegian Research Council to develop Cyberbase. Shell contributed financially to the implementation of the first Cyberbase at the Ullrigg Drilling and Well Centre (the research rig) in Stavanger. Mcgill confirms that the research rig was important for Hitec, and the first "Star Racker" was constructed for the research rig and tested out before delivery of a corresponding machine to the Philips rig 2/4X. According to a secondary source, Rogaland Research initiated research as early as 1981 on concepts and ideas which were later commercialised by Hitec. However, from our interviews with the entrepreneurs, we are left with an impression that these were their own ideas, and that most of the development work was done in-house. Neither the then University College in Stavanger nor the College of Engineering seems to have represented a significant resource for Hitec. Instead, things seem to have worked the other way round. For example, the then University College commissioned a PVT lab from Hitec, and was on its customer list throughout the Hitec period, according to Gjedebo. In 2007, the Gjedebo family donated 50 million NOK earmarked the establishing of an innovation research centre at the University of Stavanger[24].

When Gjedebo established the forerunner of Hitec, there were no contributions from external sources of finance. The venture started very modestly, and investments were financed from expansion of the firm's business, according to Gjedebo. Gradually, the company started to receive some contributions from oil companies for development work, however; but this money was not easily released, Mcgill recalls: "We often felt as if we were begging for money and spending too much time doing so". In 1993 Hitec was listed on the Oslo Stock Exchange, and remained so until the takeover by NOV.

HERNIS also had modest beginnings. Upon being rewarded the contract with Statoil, its founders managed to borrow 0.5 million NOK in the State-run Norwegian Bank for Industry to finance the development of the prototype of an explosion-proof camera. One of the company's founders comments that they were *too* modest in their borrowing: "*We should have borrowed more; if we had, we might have been the owners today*". In a yet earlier phase, the interviewed founder borrowed 50,000 NOK from a local bank to buy a lathe, using his private home as equity. During the negotiations, the bank manager referred to a conversation with a representative of the then Regional Development Fund, who is reported to have remarked that "*this will probably be yet another bankruptcy*". The company met little sympathy in the local bank, and the municipal authorities were indifferent, rejecting the application to rent a vacant industrial plant.

It was critical for the further development of the company that a local investor acquired partial ownership at an early stage. The then Agder University College (HiA) was not of any significance as a resource for HERNIS either, but a HiA employee (Ola Thorkel Aas) made a contribution to HERNIS early on by developing video matrixes and a fibre-optic link. Since

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[24] The University College was awarded university status in 2004.

then, HiA (and from 2007 the University of Agder) has become the supplier of trained engineers for HERNIS.

The entrepreneurial perspective

Both companies were originally founded by entrepreneurs with a strong local connection. They thus confirm the theory that entrepreneurship is inherently a local phenomenon. HERNIS was started in a garage, and Gjedebo started out in the basement of the family home. When the Gjedebo family left Bærum, in the Oslo region, to move home to Stavanger three years after Phillips had confirmed the first large discovery of oil at Ekofisk, it had nothing to do with the oil industry. It was all to do with pull factors: the family members were homesick, and the family had managed to get a place to moor a boat at Lake Hillevågsvannet. In other words, it was not the exogenous shock of the growing oil activities that triggered the origin and developmental path of Gjedebo styringssystemer and the successor Hitec. The ambitions increased gradually. In contrast, the oil industry was clearly the shock that triggered the establishment of HERNIS.

Both companies were based on their founders' expertise and experience with regard to the primary technology, but neither firm had any experience of "its" slice of the oil industry – and HERNIS even lacked experience with CCTV technology when the firm started out. Gjedebo had a network of contacts to draw on, but HERNIS had to start more or less from scratch in this respect too.

In terms of the theory that individuals start companies in the location where they have formed business networks and have access to resources, a more nuanced picture therefore emerge. Gjedebo had a certain network in local and national industry with regard to control technology; he was able to draw on this network, and gradually started to make a good living. By his own account, he did not initially wish to expand his activities into a larger venture, but the localisation of his firm and the uniqueness of its product – automation and remote control of production equipment and tools – gradually attracted more and more business with the oil companies, and "in many respects, the path emerged along the way". In the early stage, Gjedebo had a competitor in Stavanger, but this firm disappeared from the market after a while. The critical turning point in the development seems to be the establishing of Hitec; and it was probably crucial for the firm's future that Sætre (1986) and Mcgill (1988/89), and eventually Ertvaag (1990), came onboard. This meant that Hitec had in-house technological top competence within drilling, and operation and control systems; competence within salesmanship; competence in the management of complex drilling construction projects; and competence within economy, financing, and management. And based on our primary material, these four individuals were exceptional both in terms of their strong motivation and their entrepreneurial spirit. This factor needs to be given considerable emphasis in the endeavour to understand the course of events. Moreover, we see from the period leading up to the Draugen contract that not only did the Hitec entrepreneurs draw on international resources, as exemplified by Dreco and Varco; they also, through hard work and relation-building, created the conditions which enabled them to realise their innovative ideas by impacting changes to the way development projects were organised in terms of the division of labour and the distribution of responsibility in the value chain. This was a considerable achievement, since the changes meant that some participants, often powerful international corporations, were demoted from the being first-tier suppliers under the traditional way of doing things, to becoming second-tier suppliers in the new order.

In HERNIS's case, the entrepreneurs can hardly be said to have had any business network to build on. Such a network was built later, during the work with the prototype for the first camera, and industrial production of the camera and the system components involved began. The external resources available in this case were activated through the work on the prototype. We can perhaps also see it as typical of HERNIS's evolution that when its founders submitted the bid for the first Gullfaks contract, the price tag was chosen at random. The localisation of the firm (in Tvedestrand) also does not seem particularly favourable with regard to establishing a new enterprise aimed at supplying goods and services for the oil and gas activities on the Norwegian continental shelf. There was no industrial network in the vicinity whose resources might have been drawn on. Today, this localisation may be seen as a relative advantage, as there seems to be a smaller turnover of expert employees compared to the situation experienced by NOV Stavanger (Kalsaas 2010).

HERNIS's founders did not acquire professional competence in economy and financing during the early phase, and this may be part of the explanation why the original owners failed to weather the crisis in 1989 and were sold out to a British investment company for very little money. And whereas the founders of Hitec were left with considerable resources as a result of their innovations when the drilling activities were sold, the founders of HERNIS were left with net debts.

The founders of both companies took great risks. This is exemplified by the fact that HERNIS was partly financed with security in the founders' private homes. Dreco-Hitec was close to financial ruin in connection with the commission for the Troll rig, and in connection with the delivery of Philips's 2/4X, Hitec was the contractual partner. In connection with being appointed Norwegian Entrepreneur of the Year, and going to Monaco for the international final, Gjedebo was interviewed on 30th May 2008 by the regional newspaper *Stavanger Aftenblad*. He was asked what he did with all his money: "*You look at it, but then you throw it all into the fire again and want to start something bigger. That's the psyche of the entrepreneur*." The difficulties Hitec-Dreco encountered during the Troll commission also exemplifies how difficult life can be for a relatively small company in this trade, where problems with one job can be enough to jolt one out of business.

The theory above stresses that successful entrepreneurs tend to become serial entrepreneurs. This is to a great extent the case for those involved in the Hitec milieu. They have shown great creativity as capitalists in the Stavanger area, where many of the technology firms they have initiated within oil and gas – but outside drilling – live on, and where they continue to make new investments. For example, *Stavanger Aftenblad* reports the following news on 18th September 2010: "*Hitec daughter landed prestige commission in Gulf of Mexico*". HERNIS is different in this respect, and is characterised by frugality and a lack of new ventures, apart from its offshoots in Houston and Singapore. Nevertheless, the company represents world class within its niche, as confirmed by NOV Stavanger.

Local buzz

In Mcgill's experience, informal professional networks mean "*a lot*": "*I have many friends in the oil and gas business in Stavanger and we talk a good deal about activities and projects, and if I'm pondering an idea I ask my friends what they think of it*." This can be tied to the phenomenon of "local buzz". Gjedebo is cited in Reve et al. (2001) as saying that the localisation in Stavanger has provided access to cooperation partners within technology/product development, as well as to important and demanding international customers. In our primary data, Gjedebo confirms the vital importance of Hitec being located in Stavanger, although he adds that it would have made no difference if it had been localised in the neighbouring municipal area of Sola.

In the late 1990s Hitec built the drilling vessel "Navis Explorer" on its own account, but in the name of a company (Navis) established for this purpose. Hitec assumed that this represented the future, according to Gjedebo; and this has been confirmed since, in the shape of the tendency to replace large and heavy installations with more flexible ones. *Stavanger Aftenblad* (28th December 1999) reported that the drilling vessel had been given a large drilling commission in Brazil, and shortly afterwards, Navis was bought by Fred. Olsen Energy (*Stavanger Aftenblad* 7th July 2001). Mcgill tells us that Maritime Hydraulic in Kristiansand developed a floating rig at the same time as Hitec, and that there "*was a lot of copying*" in the 1990s. This can be understood as a buzz-phenomenon, where knowledge and ideas are "*floating*" around in the oil milieu in Southwest Norway. Mcgill did not perceive of copying as negative, and expressed a firm belief in competition as an enabler for innovation: "*It brings things forward*", he asserted.

Moreover, Mcgill emphasised the arena "International Association for Drilling Contractors" (IADC) as a very important forum for exchanging knowledge and ideas[25]: "*I have experienced that there is a free flow of information in the IADC conferences and meetings*", he told us; see for example the IADC-papers Mcgill (1991, 1994); Mcgill and Watson (1995); Croucher (1998). IADC seems to function as an arena for global pipeline processes. Gjedebo was awarded the prize OTC Heritage Award in Houston in 2007. He comments in an interview with *Stavanger Aftenblad* (30th May 2008) that he has a mixed feeling about such awards, but that it is important in relation to his professional activities: "*You gain access to many additional places when you've received such a stamp*." The award can therefore be understood as an enabler giving Gjedebo access to additional resources in the global pipeland, in addition to its function of strengthening his reputation.

No buzz has been uncovered in relation to HERNIS. However, the internet is evidently important as a global pipeline and a source of ideas and improvements. This is according to one of the company's software experts, who devote his spare time to keeping himself updated. Furthermore, the company upgrades its knowledge about what is moving in the market and what is new within technology among other things through the regular customer contact of its network of agents and sales staff. The customers often "leak" information about what offers they have received in terms of technology from the competitors. HERNIS employs a significant number of staff whose brief is development and innovation work.

If we consider important relations in the two company histories on the personal level, this aspect should not be underestimated in Hitec's case. Gjedebo met Sætre through his customer relationship to Siemens. Gjedebo and Mcgill filled the roles of supplier and customer, and met

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[25] www.iadc.org

when Gjedeo sought Mcgill's advice on drilling before Mcgill was invited to join Hitec. They also lived in the same neighbourhood in Stavanger. Mcgill knew Dreco and Varco employees from former customer-supplier relations through the drilling contractor company Moran at Ekofisk, where he used to work. In HERNIS's case, the friendship relation between the four founders is prominent.

Both local buzz and global pipeline seem to have been significant factors for Hitec's innovations within drilling, although one can of course not generalise on the basis of single cases. A survey study by Fitjar and Rodrígues-Pose (2010) seeking to find out why companies in Southwest Norway (covering cities like Stavanger, Kristiansand and Haugesund) are so innovative despite little investment in R&D, does not find the answer in cluster theory. Rather, the authors conclude that the most successful firms with regard to new products are the ones which look outside the region, and build international relations. However, the study is based on data covering all of the industrial activities in the region, and a survey study based on data gathered only from the companies' CEOs can easily miss nuances about what is actually going on.

Conclusion

Both of the studied companies were establish as a result of exogenous shocks which opened possibilities for potential entrepreneurs. Shocks experienced by Hitec can be said to have been transmitted, in turn, to HERNIS. HERNIS delivers a product which is an important complementary component in a state-of-the art drilling package, in a setting where safety has become more and more important. CCTV technology can help reduce the number of people on the drilling deck; at the same time drilling machinery is increasingly becoming remote controlled and partially automated. The latter is within the core area of Hitec's competence. Both companies have been innovative, each in its own field, and above all Hitec has taken several large steps in terms of altering the way drilling operations are controlled and logged today. Both companies have employed synthetic knowledge, or experience-based engineering know-how, which includes trial and error. Hitec managed to convince some oil companies to change the way the construction of drilling rigs is organised in such a way that the company's ideas for a shared control system for all of the machinery could be realised.

A fundamental ingredient in Hitec's successful venture of shared and remote control systems seems to be the Norwegian government's increased safety requirements for offshore activities. A significantly stricter safety regime seems to have been introduced after the Bravo accident.

Both companies had modest beginnings. Hitec started out in a basement, and HERNIS in a garage. Oil and gas did not generate the creation of Hitec's predecessor; rather, its market idea and product was automation of traditional industries, especially the canning industry. Developments in Stavanger and its environs, as well as the resource areas of the individuals who joined the company along the way as owners and co-responsible for its operation, had sent Hitec head-on into the drilling control systems area by the late 1980s. HERNIS became a CCTV systems company as a direct consequence of the Norwegian government's policies of Norwegianising the oil and gas industry connected to the Norwegian continental shelf. However, a local member of the Storting also seems to have used her influence to further the company's cause.

Hitec built alliances with Canadian Dreco and American Varco in order to be able to offer turnkey rig packages to the oil companies. Expert knowledge from Varco contributed in the building of Hitec's first pipe handling machine, "the Star Racker". The research rig at Ullandhaug in Stavanger has been an important resource for Hitec in the testing of new equipment. Siemen's resources were absolutely essential when the control system was digitalised in the shape of the product "Cyberbase", and based on PLC controlling. The Norwegian Research Council helped finance Cyberbase, and several oil companies have contributed financially to the development of innovative solutions.

The founders of HERNIS lacked video competence when they developed the prototype for their first EXE camera. They acquired this competence formally through company relations within and beyond the region, but also via informal channels consisting of helpful individuals. What was then National Electric – the first customer for a Gullfaks contract – seems to have played a cardinal role in the transferral of video-related technology to HERNIS. HiA in Grimstad played a role through an individual employed by the institution, but generally speaking, the local public institutions of education and research do not appear to have played much of a role in the early stages of either of the two companies.

For both Hitec and HERNIS, it was the founders and early pioneers of the companies who with their enthusiasm, creativity, and willingness to take risks took advantage of the opportunities and partly created some of the conditions which enabled them to succeed. In HERNIS's case, there was little in the way of business networks to build on. Hitec's predecessor, on the other hand, had a few business relations from the very beginning, and more were to come with Mcgill, bringing his expert knowledge and experiences about drilling, joined the company, and the firm was augmented with professional expertise in the areas of salesmanship (Sætre), and of economy and finance (Ertvaag). The Hitec founders/pioneers also stand out as serial entrepreneurs, and have demonstrated great creativity as capitalists. The founders of HERNIS lost ownership of the company during a crisis in 1989 due to liquidity problems, and the sale of the company left them with a net debt.

Local buzz connected to the oil industry in the Stavanger district has clearly been important for Hitec's evolution and development, in combination with transmission of tacit knowledge in global pipelines. Being located in the periphery of the oil and gas cluster, HERNIS does not seem to have been able to take advantage of the cluster to the same extent. The internet appears to be an important source of new ideas for improving the product at HERNIS.

Personal relations, on the other hand, seem to have been of great importance for both companies. For example, what would have become of Hitec, had it not been for Gjedebo and Mcgill coming to know each other, and Mcgill presenting his ideas to Gjedebo? For HERNIS, the relation between a few workmates and neighbours was a crucial factor in sparking the venture.

Acknowledgements

I would like to extend my sincere gratitude to the HERNIS founders Erik Ellefsen and John Are Nor, as well as to the founder of Hitec, Jon Grude Gjedebo, and the Hitec pioneer John Mcgill, for their contributions to the data used for this article. I would also like to thank the many individuals in NOV and HERNIS who have previously contributed with data which sheds light on today's interactions between NOV and HERNIS.

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