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CREATING A NETWORK: ADVANCED TECHNOLOGY OR PRIMITIVE NEEDS?

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INTRODUCTION[1]

In 1966 two different groups were trying to establish themselves as suppliers of industrial automation systems in Norway. The first group had its base at the Automation Laboratory at SINTEF (The Foundation for Scientific and Industrial Research at The Norwegian Institute of Technology) and was in the forefront in the field of advanced industrial automation in Norway.[2] The other was Noratom, a firm in Oslo with strong linkages to The Institute for Nuclear Research (IFA) and the activities that were carried out by the Norwegian civil nuclear research program. Noratom was a well established firm, selling medical equipment to hospitals, pneumatic and electromagnetic automation devices to industry.

In 1967 the firm Comtec was established when seven researchers from the first group left their jobs to set up a new firm. Comtec was to be financed and owned by Nobø, another Trondheim company which produced office furniture and electrical ovens. At that time Comtec seemed to be a strong competitor to Noratom because the researchers from SINTEF were the same persons that had been responible for the development of new and more advanced technological solutions in automation. Besides, they already had several contracts with Norwegian industrial companies on automation tasks.

Five years later, in 1972, Noratom and a few international companies had most of the Norwegian market for automation systems. Comtec had surrendered and moved to other high-tech areas. In the seventies it was a successfull supplier of automation systems for graphical industry and newpapers. A decription of this development, the rise and fall of Comtec, can be told in different ways: As a history of commercial success or as an analysis of failure, according to time span and focal point. Here I will concentrate on Comtec as a failure and leave out the firm's more successful aspects. I will look at some important factors with regard to technology transfer, innovation and technological change. The question I am adressing in this article is quite simple: Why was it Noratom and not Comtec with it's more advanced automation systems that became the dominant supplier of automation systems to Norwegian industry?[3]

Previous research activities and literature related to these issues can be divided into several broad categories. One category is dealing with managerial dispositions, organizational structure of the firm, the research institutions or the industrial branch in question. Examples of this type of literature are Abernathy's, *The Productivity Dilemma*, Burns and Stalker's, *The Management of Innovation*, Williamson's, *The Economic Institutions of Capitalism: Firms,*

Markets and Relational Contracting, and Tushman and Moore's, *Readings in the Management of Innovation.*[4]

Another group consists of macro-oriented, economic studies designed to improve our understanding of the market and evaluating the needs of the user. To get an idea of this type of literature one can read Dosi's: "Sources, Procedures and Microeconomic Effects of Innovation" in *Journal of Economic Literature.*[5]

A third category has focused on questions of technology policies and strategies at a governmental level. Examples from this category are Freeman's book *The Economics of Industrial Innovation*, Freeman and Lundvall: *Small Countries Facing the Technological Revolution*, and Rothwell and Zegveld: *Industrial Innovation and Public Policy.*[6]

New historical and sociological studies in the STS-field (Science, Technology and Society), both Norwegian and international ones have rejected these models as beeing to broad and structural.[7] A main claim is that technology transfer is more complex and more dependent on actor-oriented factors than most of these descriptions show. The new technological studies have identified elements at micro level that are crucial to the success and effect of technology transfer. I would like to mention Ørstadvik's *Engineers as Master-builders of Society*, Hatling's, *Entreprenør eller leverandør - Om teknologiske FoU-institutt sine relasjonar til industribedrifter* and Overbye: *Fra forskning til industri - Utviklingen av industribedriften Norcontrol* as Norwegian examples of this new type of studies.[8] In my paper, actor-oriented explanations are emphazised, but I am not going to leave out issues on other levels.

A main point is that technology transfer could be seen as creation of networks. This stands in contrast to the all too common view of technology transfer as linear, one-way activities, the transport of readymade or nearly finished technological solutions and products.

Another aspect and a consequence of this claim is that the networks in question are built through translation of interests. By that I mean that new technological solutions are not fixed, but open to change and negotiations between the various actors that participate in the development and transfer process. During all stages, technological solutions are constantly adjusted to the participating actors, financial sources, political decisions, social situations and cultural trends. The adjustment and changes in the technological solutions are made to make possible supporters interested, secure economical funding and to keep the actors and elements of networks in place.

In this connection I am widening the use of the concept "actor" and give it a broader and more unconventional interpretation than we are used to in history and sociology. Examples of actors in the actor-network approach are: Persons, social groups, institutions, politicians and technical devices. That does not imply that artifacts have a will of their own, but that technical solutions have certain functional limitations and that technology are woven into social, political and cultural forces in a more fundamental way than we usually think. The point is to establish a kind of interpretative symmetry between the social and the technical in explanations. This strive for symmetry is the metodological attempt to overcome the explanatory traps of technological determinism and

"the social shaping of technological explanations". This is expressed by John Law this way:

> *"Rather than treating, for instance the social in one way and the scientific in another, one seeks instead to follow the fortunes of the network in question and consider its problems, the obduracy of the elements involved in those problems, and the response of the network as it seeks to solve them".*[9]

This interpretation breaks with the usual historical and sociological use of the concept where technology is an outcome of social forces. The concept actor should in many ways be regarded as the French twin concept "actand", an actor without intentions. For me as a historian, intention is central in explanations. When I use this grip, it is an extra tool and an abstraction like other historical abstractions (ideal type and class as two examples) to overcome the misunderstanding of technology as determined by the social.

Using the actor-network approach, the understanding of the rhetoric used to enroll new actors and supporters for a research project or a technological solution becomes vital. Bruno Latour describes five main enrollment techniques in his book *Science in Action*: One way is to tailor the research program or the technological concept in such a way that it fits another person's or groups goal's. The second method to secure support or funding is to redefine others goals to make them fit your own. A third possibility is to enroll the potential supporters by doing "a short detour", convincing them that if they take your way it will take them the right way to their own goal. The fourth method of translation is different tactical movements to keep the enrolled actors in place in the network. A fifth method for translation of interests is to be indispensable, with other words to make oneself a nessesary element in others activities.[10] All these translations can be used in combination with the others, and there are also many posssible variations of these main methods.

Another important point in the actor-network approach is the element of conflict. Both within themselves and in relation to their surroundings, networks are subject to conflicts and hostility. Networks may be also be in conflict with other networks. The success achieved by one network related to other networks is a function of the relative strength of the components in question, some connections are more durable than others.[11]

"A FIRM THAT CAN CONNECT SCIENCE AND INDUSTRY"

In 1966 the staff at the Automation Laboratory at SINTEF/NTH was filled with excitement. The researchers working in the laboratory were eager to get a new concept for advanced automation, into industry. An automation concept that was the result of over ten years intensive work in the field. Jens G. Balchen, professor and the leader of the NTH/SINTEF Laboratory, had been the driving force behind this effort. Balchen was a dynamic and charismatic person, sometimes more of a missionary. He had started his work on auto-

mation problems in the early fifties when this was a new and unknown field in Norway. In 1953 he had built an analog computer, and this work had directed his attentions towards the field of industrial automation. Analog computers were fast but with low numerical accuracy. This made them suitable for regulation, but not for calculation. Both because of his personal qualities and his insight, he was soon accompanied by a rapidly growing staff of researchers.

The analog computer, called DIANNA, was followed by an analog registrator called ISAC in 1960. This machine could registrate, record and draw graphical pictures of variables in industrial processes. The equipment was used in industry and in nuclear reactors. The rights to ISAC was bought by Noratom and sold to process plants, mostly abroad.[12] In the early sixties the laboratory also created four different types of electronic regulating mechanism for milling machines and developed methods for automation of ships. But the Laboratory's main ambition was to develop methods and equipment for industrial automation with computers. In 1963 the institute recieved it's first digital computer, a Danish machine called GIER. The Automation Laboratory now made tests where they simulated industrial processes with DIANNA and controlled these processes with GIER.

In 1965 the Automation Laboratory announced that they had come up with a new system for industrial automation. The concept was a combination of software and hardware, data programs and technical equipment. The automation system was, according to the researchers at the laboratory, able to record, evaluate and control comprehensive industrial production processes at high speed and in a very reliable way. The main target for a commercial exploitation of the system was Norwegian process-industry, a vital part of industry. The concept was also adapted to other tasks, as automation of ships and automation of graphical industry. It is important to know that all these projects were financed by the Royal Norwegian Council for Scientific and Industrial Research (NTNF). Most of the research in this field, also at other institutes was paid for by NTNF.

The automation concept used an American minicomputer as its system brain. The computer, PDP-8, was relatively simple, cheap and small, and it was crucial for concept.[13] There were two main reason for the central role of this machine: The first one was that the size and economic situation of the average Norwegian corporations in the sixties did not permit any expensive data equipment. Only a few Norwegian corporations could afford to buy and maintain expensive and large computers. In addition, mainframes were constructed for calculation tasks and not to regulate industrial processes. The second reason was the rough environment into which the artefact should be placed. The machine had to be simple and robust.

To demonstrate and to evaluate their automation concept, the laboratory installed and demonstrated their system at Dalen Portland Sementfabrikk (a cement-mill) in Brevik in 1966. The PDP-8 computer in connection with measurement devices and regulators controlled the rotation speed, the temperature and the duration of the cement production process. In the autumn of 1966 over 100 Norwegian industrial leaders and technical staff were gathered at Dalen Portland for a demonstration of the system. Accor-

ding to the periodical *Teknisk Ukeblad* the audience found it interesting and a promising basis for better methods for production in the future.[14]

Even if the coporation leaders found the concept exciting, they had no hurry to try it in their own factories. No contracts were entered at that time. The automation system at Dalen Portland was then derigged and transported back to the laboratory, and the SINTEF-people continued their search for someone that would produce and sell these systems. The researchers soon realized that if their automation ideas were to become a viable product, they would have to see to it themselves. For them the next logical step was to get economical support to finance their own firm. Plans for such a firm were made, and in December 1966 the researchers at the laboratory wrote to SINTEFs administration:

> *"It may be known that we have been working with the idea of a firm that could offer the Norwegian and other markets advanced automation techniques. Up till this day no such firm has been established. Now SINTEF's and NTH's engineers have taken an initiative."*[15]

According to the plans outlined in the letter, capital for the firm should come from different sources. One third of the stock would be owned by different companies in the Trondheim area, one third by the researchers themselves or other persons at SINTEF, and the remaining from wherever it could be mobilized. In this way the engineers could keep control of the firm themselves and not surrendering management to external groups.

Balchen's announcement of plans for a new firm in industrial automation sector came very inconvenient for Noratom. At the time of the announcement, Fredrik Møller, the managing director of Noratom, had taken the first steps to go into and secure the seemingly promising field of industrial automation for his company. He now planned to further develop and broaden these activities. Møller knew that SINTEF's automation concept opened new perspectives and possibilities in this field.

To get a picture of the firm Noratom and it's position it is necessary to have a brief look at the expensive and extensive adventure of nuclear energy research i Norway, a development that had as one of its consequences the establishment of Noratom.

THE CIVIL NUCLEAR-ENERGY PROGRAM: BIG SCIENCE AND TECHNOLOGY

In 1947 a Norwegian physicist, Gunnar Randers was trying to set up a Norwegian civil nuclear-research program. To start this type of costly research was difficult in the first post-war years because of the country's difficult financial situation. The shortage of foreign currency made the government restrict all kinds of investments that were not absolutely neccesary. But Randers found an ally in The Minister of Defense, Jens Christian Hauge of the Social Democratic Party. It is difficult to judge Hauge's motives for cooperation with

Randers: Was it the promising new source of energy or rather the potential access to nuclear weapons? Anyway, it is clear that Hauge was powerful enough to secure the necessary funding for the nuclear program by supplying capital from the military budgets.

The initiative from Hauge had the important effect that the project received political support and, compared to other research activities, generous economic funding. The Institute for Nuclear Research (IFA) was established in 1948, financed by The Norwegian Institute for Military Research (FFI). A description of the nuclear initiative is given by Gunnar Randers himself in his book, *Lysår*. Here, the author stands out as a classical entrepreneur, very concerned with doing the right thing at the right time, connecting the right persons and institutions, associating all types of actors and elements to make a supporting network for the nuclear energy program. The "social" activities can be judged as important as the activities in the technical field. In June 1951 the first Norwegian reactor, Jeep 1 was in operation.[16]

The nuclear program had an annual budget of 20 million Norwegian kroner (3 mill. dollars). To secure future funding, its management found it neccesary to provide the research activities with a strong industrial legitimization. To start a firm that should link the nuclear program to the industrial world was a natural continuation of IFA's ideas, and an ideal way to justify their work. The potential link between research and industry, Noratom, was started in 1957.

If we look at the methods of translation described in my introduction, the nuclear-energy program may be considered a classical example of networking by such processes. By using technological and political rhetoric, creating attractive scenarios for the future, Randers could enroll actors from different sectors to support his ideas. A report from 1953 is a farfetched but not untypical example of the kind of rethoric Randers used to secure political and economical support. In the report he argued for the necessity of a nuclear program by the following statement:

> "*The use of energy and the level of living-standard is closely linked. We can see the end of the world's energy sources.*"[17]

In my opinion the Civil-Nuclear Program should also be interpreted as an alliance between the Sosial Democratic Party leadership with their visions of a highly effective and productive industrial state, and the researchers with visions of their science as the prime solver of future human problems. By translating the politicians' ideas of productivity and efficiency into support of "the new clean energy source", Randers secured backing for his project. In short he used classical enrollment techniques to make the political leadership. "Your goals are the same as mine. Why not support mine to reach yours"?[18]

NORATOM - IFA'S LINK TO INDUSTRY

The firm Noratom was started in 1957, financed by 78 different companies, a cross-section of the most influential industrial enterprises, banks and in-

surance companies in Norway. The initiative must be seen as an attempt to reap the fruits of the nuclear energy program, and a way to legitimize the huge governmental spendings in this field. I think that central actors, both on the political and the scientific side, in the years up to 1965 believed in the practical use of and a future of nuclear energy. A conference in Oslo in 1956 with participants from the Social Democratic Party, from the scientific institutions and the trade unions, praised nuclear energy and industrial automation as the future and as neccessary to a modern society.[19]

After the start Noratom got several contracts in connection with the building of Norwegian nuclear research reactors. The firm also made contracts abroad doing similar work in the civil nuclear field there. More interesting to us is the fact that Noratom gradually developed a competence in the automation field and became a supplier of control instruments and systems for industry. This was not so strange when we think of the kind of work carried out at IFA. Building efficient and reliable control mechanisms was one important part of the nuclear activities. This was a conventional type of automation with hydraulic and pneumatic equipment, mostly control of single processes.[20]

In the middle of the sixties, Noratom experienced economic stagnation that called for a shift in the firm's business strategy. One of the attempt to do this was that Noratom together with Kongsberg Våpenfabrikk and Norsk Hydro started a new firm in 1965. The firm, Norcontrol, would develop automation systems for ships. This work was carried out in co-operation with the Automation Laboratory at SINTEF. The principles that were applied in industrial automation were to be applied for automation of ships and vica versa. In 1967 Noratom and Norcontrol merged to secure the competence they had acquired in automation. Their new plan were to be a stronghold in the potential field of industrial automation.[21]

The reason for moving into another field than the nuclear sector was not only the stagnating economy. By the middle sixties it was obvious that the Nuclear Energy Program was loosing support, and that nuclear energy would have no role as a source of energy in Norway for at least two decades, maybe not at all. The base for the firms activities was in other words eroding.[22] In addition to the bleak future of nuclear energy, both political and industrial leaders wanted to move the economic resources used on the Nuclear Energy Program to more industry-related research projects. This demand was most strongly expressed by The Norwegian Industrial Federation (Industriforbundet).

A committee was set up to evaluate the work of IFA. The report was presented in 1965 and was followed by a new statement from The Industrial Federation that found the critique of the nuclear activities too weak. The Nuclear Energy Program was discussed in the Norwegian Parliament, and everybody saw this as a signal to the nuclear sector that the good times might be ending. From 1967 the funding of IFA was to be kept at a fixed sum.[23]

In the middle of the sixties IFA had a large staff (approx. 500 persons), and had spent 350 million Norwegian kroner on nuclear energy research. Of this 238 million kroner was funded by the Norwegian govern-

ment. This was a substantial part of the resources used on research activities in this period.[24]

If we apply the network metaphor on this development we can say that the Noratom initiative was one way to expand IFA's network. The Norwegian research sector has always been dominated by federal funding. As a consequence, the guiding principles for research activities have stressed the importance of having industrial results as a result of the research activities. On that background the Noratom initiative was one way to legitimize the research activities at IFA and to keep on to federal support for IFA. The weakening of the nuclear vision threatened the IFA vision. From Noratom's management's point of view they feared that if IFA had to cut down or even stop their activities, this would also threaten the existence of their firm. The need for new elements to replace the weak parts of the network were therefore pressing. By using the expertise they had acquired in nuclear research in other fields, such as the automation of ships or in industrial automation, the failure for the nuclear program need not be a disaster. In addition this new field seemed a promising way for Noratom, which with a new base would continue to get customers and secure work for their staff. But there were others trying to set up commercial activities in this field.

CONFLICT

In 1966 professor Jens G. Balchen wrote to the managing director of NTNF Robert Major:

> *"We hope that our new firm will be established soon. I have noticed, several of our friends in the industry think that this is an unfriendly action. We don't think of it that way, and we hope that we can co-operate with firms that until now have had the results of the Norwegian research institutes at their disposition."*[25]

Even if Noratom had experience in this field, as a result of the work in the nuclear sector and with ship automation projects, they knew that the Automation Laboratory in Trondheim had developed better and more promising methods for automation. To understand the conflict between the Oslo and the Trondheim initiatives it is also important to understand the difference between these two types of technology.

When I refer to conventional automation I mean feedback-mechanisms based on pneumatic, hydraulic or simple electromechanical principles. Very simply, we can say that each conventional piece of automation was able to measure, evaluate and control one process at one time in an industrial production system. In a factory equipped with conventional automation mechanisms there had to be several automation loops for each stage of production. This was the type of equipment the average Norwegian industrial plant used in the sixties.

Advanced automation on the other hand used a computer to record, evaluate and control the automation processes. The result was a faster, more flexible and more precise process. Each system could control all or several processes simultanously. It represented a qualitative increase in the automation possibilities and a radical break with conventional methods for automation. In comparison with such systems Noratoms methods were old-fashioned and far less effective.

As we can see, a pressing problem for the Noratom group was to obtain knowledge of advanced automation from SINTEF. A second problem was to stop the SINTEF people from starting their own firm. Noratom's director, Fredrik Møller, wrote to the Automation Laboratory and asked for trained researchers for their project. If the laboratory not could spare some of its researchers, Møller wanted to have some of Noratom's own engineers at the laboratory to upgrade their knowledge of automation.[26]

When Balchen announced his plans for a new firm, he was entering the same field as Noratom. This made it more difficult for Noratom to get researchers and expertise from SINTEF, and it was also the signal from a potential competitor. To stop or to control the inititive taken by the Trondheim group, Balchen was invited to Oslo, officially to give more information about their plans. It was obvious, as Balchen had stated in his letter to Rovert Major, that key personalities in NTNF and in the industrial environment of Oslo regarded Balchen's initiative as disobedience and Balchen himself as a nuisance. It is also clear that they regarded the research results from the NTNF-financed research in the field of automation as more or less their own property. But this was a claim they could not express officially.

In addition to Noratom's wish to be the central automation firm in Norway, several of the owners of Noratom were corporations involved in the process industry field. The management of these corporations wanted to have control over the development in this field themselves. These influential and heavy actors wanted no aliens in what they considered their own back yard.[27]

The competence accumulated by the Automation Laboratory had been financed by government funding, and the ideal and official objective for NTH/SINTEF was to serve Norwegian industry. This was a central point, and it was used by both groups. In his statements and in letters Balchen especially focused on the national importance of the activities in this sector of industry and the importance to create a firm that could link research and industry.

As an answer to the spinn-off attempt in Trondheim and as a means to solve the conflict between the two groups, Noratom's board of directors proposed that the Balchen-group should be a local branch of a central automation firm in Oslo.

This points out several interesting elements in the conflict and competition between the two firms. First there was a struggle to secure the technological expertise, secondly it was a conflict between the large established corporations and a new unestablished competitor. It can also be seen as a struggle to establish a network or to keep up already establish networks against the creation of a competing networks.

A SOLUTION

In the spring of 1967, Balchen, his staff and SINTEF's administration negotiated with a company in Trondheim that was interested in buying the automation concept. The company, Nobø, was a producer of electrical ovens and office furniture. In the early sixties they had experienced increasing sales. Now they wanted to use the advantageous financial situation to renew their spectrum of products and production methods. At the time when Balchen was called to Oslo, the negotiations between SINTEF's and Nobø's administration on the economical and legal terms for the spin-off were more or less settled.

On that background the managing director of Nobø, Kåre I. Torp and professor Balchen came out strongly against the idea of starting a firm that would end up as a subsidary branch of Noratom in Trondheim. Their conclusion was to proceed with their plans for an independent firm.

In May 1967, the leaders of the Norwegian research institutes were gathered in Oslo to discuss the different plans for establishing automation firms in Norway. At this meeting Balchen announced that a firm that would exploit the competence accumulated by the staff at the Automation Laboratory already had been established in Trondheim. This was not exactly true, but it was not so far from the truth. Balchens statement at the meeting put an end to the struggle between Noratom and SINTEF about the rights to the research results of the Automation Laboratory at SINTEF.

The anouncement of the establishment of an firm in Trondheim made the Noratom people furious, and Balchen was summoned to a meeting at Elektrokemisk A/S where the more influential people behind Noratom were assembled to discuss the new automation firm in Trondheim. The industrial managers expressed their irritation. In their opinion, this was to be a strategically placed firm. Therefore it should be located in Oslo where the most important industrial companies and research institutions were placed. Balchen's and Torp's firm was percieved as an act of "war" for them. As a kind of revenge they declared that they from now on would go abroad to buy automation services. Late in the spring of 1967 the negotiations between Nobø and SINTEF were completed, and in May Computer Techniques A/S, later called Comtec was started. From 1967 Noratom and Comtec worked as competitors in this sector.[28]

The situation in 1967 can be seen as the organization of two competing networks. The Comtec network was built around the concept of advanced automation technology. This attempt was supported by SINTEF that wanted a research-initiated firm in Trondheim to show that the NTH/SINTEF system worked according to their claims about spin-offs. Another important element in the formation of this network was the ambitious group of researchers headed by Balchen. They defined their project in such a way that they they were able to interest and later win financial support from Nobø. An invisible, but important actor was NTNF, even if this institution offered only passive support. To enroll and to secure support from NTNF the researchers labeled their potential firm as "a link between science and industry". By that they hooked their project onto vital and central statements given by the NTNF-system. In the evaluation of the research system made in 1964 NTNF

had stated that they would increase the support to spin-offs. By using NTNF and NTNF's new policy as a part of their network the Comtec-group made it difficult for the Noratom-group to utter official claims to the rights to the research-output from SINTEF.[29]

In contrast, the Noratom network was built on conventional automation, the firm's own financial resources, the connection to IFA and several years of experience dealing with projects in industry. When we look closer at at it, we also discover Social Democratic leaders whispering in the corners. Several of the large companies that had interests in Noratom were partly owned by the state. Noratom's Board of Directors was also an impressive list of the more influential leaders of Norwegian industry.[30]

A STRONGER NETWORK

At the start, in 1967, Comtec seemed to be supported by the strongest network. They had central researchers from the Automation Laboratory at SINTEF in their staff. The same researchers had created the new automation concept and now they brought their expertise with them. In addition Comtec had contracts with four Norwegian process plants to deliver automation equipment to sections of their production. Noratom on the other side had experience with conventional automation, their old customers and all the "good friends" in industry.

In 1968 and 1969 Comtec delivered automation equipment to Drammens Glassverk, STK, Emmaboda Glassverk (Sweden) and Christiania Spigerverk. The construction and installation of these systems caused massive problems for the Comtec-staff, and the payment for the contracts did not even cover expences. After having completed these projects Comtec only got minor jobs of this type.

In contrast to the slowdown of Comtec Noratom had more success. In 1969 Noratom delivered its first automation system to Elkem. After that they had deliveries of such systems to Bremanger Smelteverk, Christiania Spikerverk and Norsk Hydro. In 1977 the periodical *Norges Industri* wrote in relation with a delivery to UNIONs new pulp mill in Skien that Noratom in the last years had made three similar deliveries, and was the only Norwegian producer of modern computer-systems for automation in the process industry.[31] An analysis of the development of Noratom and Comtec reveals interesting differences that can explain the contrasting trajectories of the two firms. The cause of the difference can be explained by several factors, but to simplify the analysis I will restrict myself to some elements.

For Comtec one obvious problem was the economical result from constructing and installing the automation systems. Comtec lost money on most of its automation contracts. This could easily be explained as an expected problem for a pioner firm. But such an explanation will cover important details. One is what caused the bad economical result?

What appeared when Comtec constructed and installed the systems, was a mismatch between their systems and the existing production equipment in the factories. The equipment in Norwegian companies was based on pneu-

matic and hydraulic regulation. Whole families of equipment compatible with each other dominated, in addition to this problem, many companies were not even at this stage of automation. Norwegian industry was, by comparison to the computer systems, to primitive and simple. To link the existing equipment with advanced automation was a difficult and time-consuming job.

Another problem for Comtec was the computer they used, PDP-8. It had the advantages of being small and cheap, but the computers memory was only 4K. To store all the necessary information and the regulation programs for comprehensive automation processes became impossible. To overcome this problem, they used assembler program codes and simplified the regulating operations. Using this type of primitive data-programs, to make new programs or to change old ones was difficult and time-consuming. Consequently, advanced automation was no longer so advanced.

These problems came in combination with the different cultural background and experince of the industrial leaders and the researchers working for Comtec. The technical staff and the leaders of Norwegian industry were trained and used to convential automation. The researchers working for Comtec had their background from the scientific laboratory. The gap between these two groups was not bridged, and the neccesary confidence and trust, built on understanding each others goals, was not achieved.

An important and crucial element in the supporting network for Comtec, Norwegian industrial production equipment, was difficult to link to the advanced automation network. In addition to these difficulties, also the social actors, the leaders and engineers in industry were reluctant to the new soulutions for automation.[32]

Noratom started their activities in the other end. The firm had for some time sold equipment that measured and regulated industrial processes based on pneumatic and hydraulic principles. They had done this with simple instruments and gradually increased the complexity of the tasks and equipment. In doing so they had achieved two things. They had learned about industrial processes from the bottom, and they had established confidence and contact with the industrial leaders. Automation was not, as the Comtec-people believed, a general commodity and could not be sold as such. Not as an act of policy, but because the problems involved in obtaining knowledge about advanced automation forced them to move gradually from conventional to advanced automation, enrolling in the process an important new actor, the Norsk Data computers. These computers were not as cheap as PDP-8, but they were much better for automation operations because of their higher capacity. Owing to that they could use progamming techniques that were more flexible and with more options. [33]

By 1972 Comtec had more or less given up the field of industrial automation.[34] They had difficulties with their technological solutions, but in addition there was another problem that caused more worries. They got very few new contracts, and they certainly got no contracts from what we must call Noratom's industrial friends. That left very little for Comtec. Their brash behavior had destroyed the possible goodwill from vital and central interests. They had lost the possibility of enrolling potential customers. Norwegian process industry by and large used Noratom to modernize their factories. When

the Norwegian process-industry bought automatic equipment in the seventies and eighties they got it from Noratom/Norcontroll or from abroad.

CONCLUSION

The two firms, Noratom and Comtec, are by no means chosen at random. Both had strategic positions in the Norwegian industry in the sixties; and the development of both these firms reveal interesting elements in connection with problems involving technology transfer and technological change.

In the start Comtec had the technological advantage. What changed the situation and tipped the balance in favor of Noratom could be explained by two main factors. First the problem connecting new technological solutions to older systems. The other important factor was the problem linking a new firm to the established network of corporations.

Comtec's technological system for automation was different from the the existing systems. In addition, the firm tied itself to the cheap, but primitive PDP-8. Noratom's solution for process industry automation was in the start relatively simple, easy to use and to connect with existing machinery. After some years Noratom developed these systems and in the seventies Noratom's network no longer consisted of outdated conventional automation, but advanced automation with new *Norsk Data* computers.

The second main point was that Noratom was owned by the large industrial corporations and financial institutions, a strong and mighty alliance indeed. Comtec's network was built on support from SINTEF and Nobø. Owing to the conflict with the financial supporters of Noratom in the initial phase, Comtec was unable to to access the most vital and important parts of Norwegian industry. When Noratom became skilled in advanced automation, they already had the necessary contacts and confidence from industry.

What comes out of this analysis is the importance of doing micro-level studies of technology transfer and technology change. The reason for this is obvious, important aspects of such processes are first detected at this level. Another interesting point is the neccessity to look at all types of elements, also the technological solutions. What can be seen is that the technological problems were connected to the social problems and vica versa. That opens for a more untraditional treatment of such elements as technology. Technology encompasses a heterogeniety of elements. The successful entrepreneurs or "heterogeneous engineers" consider all types of elements, both social and technical and tries to connect them. In studies of technology transfer one must try to make no distinction between social, economical, political and technological explanations. In contrast to many of the one-dimensional explanations and models in this field, the use of the actor network approach treat such comprehensive developments as totalities. This gives historical analysis a tool, among other tools to look into such processes.

The conflict between Comtec and Noratom give an indication of the difficulties encountered by small companies attempting to break through and into the established industrial firm structure in small states as Norway. The Comtec/Noratom case also points at a general element of conflict. To estab-

lish new technological methods or to create new firms may end up as a competition between different networks.

NOTES:

1. A previous version of this paper was presented at the International Conference on **Technology Transfer and Innovation in Mixed Economies** in Trondheim 27.-29. of August 1990.

1. The Automation Laboratory was an loosely knit and cooperative unit between The Institute for Automation, NTH (The Norwegian Technical University) and The Division for Automation, SINTEF. This colloboration between a research institute (SINTEF) and a technical university was an unique combination, also according to international standards. This integrated unit is called The Automation Laboratory in this paper, the Norwegian name was Institutt for reguleringsteknikk/Avdeling for Reguleringsteknikk or Department 48. It was directed by professor Jens Glad. Balchen. Other important researchers at the Laboratory in this connection was Hans Levold, Ole Hestvik, Jens Moe, Knut Grimnes, Per Tore Jacobsen and Inge Mohus.

3. A more comprehensive analysis of this development of Comtec can be found in Per Østby: *Tilfellet Comtec - Fra Forskning til Industri*, STS-report 8/90, Trondheim 1989.

4. Abernathy, W.: *The Productivity Dilemma*, Baltimore 1978. Burns, T. and Stalker, G. M.: *The Management of Innovation*, London 1961. Oliver E. Williamson: *Markets and Hierachies*, New York 1975 and *The Economic Institutions of Capitalism: Firms, Markets and Relational Contracting*, New York 1985. Michel L. Tushman and William L. Moore(Eds): *Readings in the Management of Innovation*, London 1982.

5. Giovanni Dosi: "Sources, Procedures and Microeconomic Effects of Innovation", *Journal of Economic Literature*, Vol. XXVI, September 1988, page 1120-1171.

6. Christopher Freeman: *The Economics of Industrial Innovation*, London 1982. Christopher Freeman and Bengt-Åke Lundvall: *Small Countries Facing the Technological Revolution*, London 1988. Rothwell, P. and Zegveld, W: *Industrial Innovation and Public Policy*, London 1982.

7. Bruno Latour: *Science in Action*, Milton Keynes 1987. Michel Callon: "Society in the Making: The Study of Technology as a tool for Sociological Analysis", page 83 and John Law: "Technology and Heterogenous Engineering: The Case of Portuguese Expansion", page 111, both in Wiebe E. Bijker, Thomas P. Hughes and Trevor Pinch (Eds): *The Social Construction of Technological Systems*, London 1987.

8. Finn Ørstadvik: *Engineers as Masterbuilders of Society*, Oslo 1989. Morten Hatling: *Entreprenør eller leverandør - Om teknologiske FoU-institutt sine relasjonar til industribedrifter*, Trondheim 1989. Signy Overbye: *Fra forskning til industri - Utviklingen av industribedriften Norcontrol*, Oslo 1989. Two thesises in history dealing with related matters are to be finished spring 1991. Anne Kristin Børresen: *Utdanning of forskning innen elektronikk ved NTH og SINTEF, 1945 - 1965* and Stig Kvaal: Drømmen om kontroll. *Automatisering, forskning og ideologi i Norge 1945 - 1965*.

9. John Law, page 114 in Bijker, Hughes and Pinch 1987.

10. Latour 1987, page 108 - 121.

11. Latour 1987, page 129.

12. Bjørn L. Basberg: *Analoge maskiner i en digital tid? Noen iaktagelser om analoge regnemaskiners plass i norsk forskning og industri i 1950- og 1960-årene.* NAVF/NTNF's project on history of technology analyzing the Norwegian electronic industry from 1945-1970, paper no. 29, 1987 (On the Norwegian development of analog calculators in research and industry in the 1950ies and 1960ies.)

13. DEC's PDP8 had an internal memory of 4Kb, later this was increased to 8Kb. The initial prize was 18000 dollars.

15 *Teknisk Ukeblad* nr 25, 29.juni 1967.

15. Draft for a letter made for SINTEFs administration. The letter was written by Jens G. Balchen in cooparation with Hans Levold and Ole Hestvik. 27.Desember 1966. Translated by the author.

16. Gunnar Randers: *Lysår*, Oslo 1975, page 155-157.

17. Gunnar Randers: *Atomenergi som industriell kraftkilde*, Oslo 1953.

18. Latour 1987, page 108-115.

19. *Teknikken og framtiden (The Technology and The Future)*, a collection of articles from the conference with the same name, held by the Norwegian Federation of Trade Unions and The Norwegian Social-Democratic Party in Oslo, in February 1956.

20. *Noratom-nytt*, March 1965, page 7, Jette Flagestad: *Historien om Noratom*, Oslo 1988, page 4ff. Overbye 1989, page 120-125.

21. Ibb Høivold: *Mine engasjementer i norsk elektronikkvirksomhet*, Paper at a seminar on Sørnesset, 5. Oktober 1985. Page 8. Ibb Høivold was the managing director of Norcontrol.

22. Stortingsmelding nr.22 (1966-67).

23. Noratom-nytt, March 1967, page 2-8. *Norges Industri* nr. 15, September 1966, page 401-406. Astrid Forland: *Atomer for krig eller fred?*, Oslo 1988.

24. Stortingsmelding 22, 1966-67), page 16.

25. Letter from professor Jens G. Balchen to Robert Major, 18. November 1966.

26. Letter from Fredrik Møller, Noratom A/S, to Eiliv Sødahl. 19. Desember 1966.

27. Interview with Hans Levold the 12. and 17. of August 1987.

28. Note from a meeting at Elektrokemisk A/S 5. Mai 1967. Letter from professor Jens G. Balchen to Karl Lorck 10. Mai 1967. Letter from Karl Lorck to Jens G. Balchen 13. Mai 1967.

29. NTNFs forskningsutredning, Oslo 1964.

30. *Noratom-nytt*, March and June 1965.

31. *Norges Industri*, No. 21, 1977, page 33.

32. A description of the Norwegian industry and the situation for automation is given by the director for Årdal and Sunndal AluminiumVerk, Haakon Sandvold in *Teknisk Ukeblad* no. 14. 4. April 1964, page 329-338.

33. Also Comtec had negotiations with Norsk Data to change computers for their systems. One reason for not changing was the problem maintaining two different types of computers.

34. To avoid the picture of Comtec as a failure I will add that Comtec in the seventies had success with their datasystems in printing industry, newspapers and publishers. At one time they had 60% of the market for professional word-processing systems in Europe.

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