Main Threads of ICT Innovation in Oulu in 1960—1990

Henry Oinas-Kukkonen[1], Jouni Similä[2] and Petri Pulli[2]
[1] Department of History, P.O. Box 1000, FIN-90014 University of Oulu, Finland; OASIS research group, Department of Information Processing Science, University of Oulu, Finland
[2] Department of Information Processing Science, P.O. Box 3000, FIN-90014 University of Oulu, Finland
Email: Henry.Oinas-Kukkonen@oulu.fi, Jouni.Simila@oulu.fi and Petri.Pulli@oulu.fi

Abstract
The purpose of the paper is to find and map the matters running through as the main threads of the information and communication technology (ICT) innovation in Oulu, Finland during the years 1960 – 1990, not to extensively draw all perceptible connecting links between all possible companies or parties that operated in the area during nearly a third of a century neither cover a complete and detailed 30-year-history of individual links.

Introduction

A market research company Taloustutkimus Oy researched images of Finnish cities and municipalities in 2003 and named top 100 locations in Finland. A year later a weekly supplement *NYT* of the biggest daily subscription-based newspaper in Scandinavia and Finland's leading national paper *Helsingin Sanomat* picked Oulu from these top 100 locations as the best place in Finland. Oulu's extraordinary innovative and economic success was one the major reasons for the choice.[1]

At the turn of the millennium the Oulu region was the second most important information and communication technology (ICT) and software industry center in Finland. High technology products in question were mainly sophisticated mobile phones which need software to function. High technology production meant directly nearly 10,000 ICT jobs and indirectly ICT employment of 15,000 people for a city of 117,680 inhabitants.[2] Even the strong Oulu dialect took a new loan-word *haitekki* from the expression high tech in English, which has not been shamed to repeat.[3]

---

[1] Mikko-Pekka Heikkinen, "Oulu – ei mikään paska kaupunki." *Viikkoliite NYT, Helsingin Sanomat*, Number 1, 2005, pp. 8 - 11; "About Helsingin Sanomat." *Helsingin Sanomat International Edition*, http://www.hs.fi/english/about/; Henry Oinas-Kukkonen, "Moderni ja monipuolinen 'haitekkikaupunki'." *Oulun vuosisadat 1605—2005* (Rovaniemi: Pohjois-Suomen Historiallinen Yhdistys, 2005), p. 197.
[2] "ICT-alan työpaikat Oulunseudulla 1993 – 2004." *Statistics Finland*, http://tilastokeskus.fi/tup/seutunet/download/ouluseutu/ict_tyop.ppt; "Informaatiosektorin työpaikat

Oulu reached the position of the sixth largest city in Finland in 1990. It became the fastest growing region in the 1990s in Finland. At the end of the decade among its people was the second largest section of population, right after the Capital region, who earned over 42,000 Euro in annual income. In 2003 there were even proposals about getting a "second capital" for the country. No wonder that instead of seeing a well-known "must" for a Soviet leader, Lenin Museum, Soviet president Mikhail Gorbachev chose to visit Oulu Technology Park (*Oulun teknologiakylä*) in October 1989[4]. Numerous heads of states, delegations and journalists[5] from different parts of the world followed his example and flocked to figure out what the mysterious "Oulu Phenomenon" (*Oulu-ilmiö*) is all about.[6]

What was Oulu like?

Oulu is a city in Northern Finland that has a history of long duration as a location for business and export industry. In the Middle Ages especially fish, butter, train oil, furs and hides were exported to the European market. Oulu was only the ninth location in Finland that got city privileges from the Swedish king in 1605, but in the next century it became the third largest city in a country, which was part of the kingdom of Sweden. Tar export, shipping and shipbuilding became significant in the 17th and 18th centuries, leather industry in the 19th century and forest and chemical industries in the first half of the 20th century. International and domestic reasons pushed Oulu into a serious period of recession and unemployment in the 1970s.[7]

Oulun seudulla 1993 – 2004." *Statistics Finland*, http://tilastokeskus.fi/tup/seutunet/download/ouluseutu/info_tyop.ppt; "Oulu 1960 – 2000". City of Oulu, http://www.ouka.fi/historia/1960.htm; Oinas-Kukkonen, p. 177.

[3] Oinas-Kukkonen, p. 176.

[4] "Gorbatsovin yllätysvierailun syyt. Oulun teknologia kiinnostaa Tampereen museota enemmän." *Kaleva*, 27.10.1989, p. 24.

[5] See e.g. "Hot Tech Cities." *BerliNews*, 31. March 2000, http://www.berlinews.de/archiv/928.shtml; Carol J. Williams, "A Wireless Wake-Up Call for Finland; The mobile communications industry has reinvigorated the country, changing the way Finns work, play and see their place in the world." *The Los Angeles Times*; November 8, 1999.

[6] Oinas-Kukkonen, pp. 179, 180, 185, 188.

[7] Matti Enbuske, "Oulu 1600-luvulla: perustamisesta isoonvihaan." *Oulun vuosisadat 1605—2005* (Rovaniemi: Pohjois-Suomen Historiallinen Yhdistys, 2005) pp. 29, 35; Jouko Vahtola, "Oulujokisuun keskusasema 1500-luvulla," *Valkean kaupungin vaiheet: Oulun historiaa* (Rovaniemi: Pohjois-Suomen Historiallinen Yhdistys, 1987), pp. 65-70; Eino Siuruainen, "Talouselämä Oulussa." *Valkean kaupungin vaiheet: Oulun historiaa*, pp. 200-207; Turo Manninen, *Oulun kaupungin historia*, Volume VI (Oulu: Oulun kaupunki, 1995), p. 79.

Later, declining and unemployment-ridden Oulu was seen to get lift from trough of a wave by a break-through of electronics and its innovations. A lot of emphasis was placed on local links and connections enabling innovativeness.[8]

Education and innovation

There is an old saying in Finnish ”*Ouluun kouluun*”, which roughly means ”go to a school, go to Oulu”. At the beginning of this millennium over 60 % of people older than fifteen had either secondary level degrees or bachelor's degrees in Oulu. In 2002 8,8 % of people living in Oulu had master’s degrees. Oulu is a city holding ninth position among cities of 15 older European Union countries, when college educated people are calculated. At the end of 2003 there were 86,000 pupils and students enrolled in educational institutions in Oulu.[9] Yet, Oulu does not have an old university city status.

Even though Oulu was known as a school city at least from the 17th century onwards,[10] the University of Oulu was established as late as 1958, as the most northern university in the world. The Department of Electrical Engineering was established in 1965 and the Department of Information Processing Science in 1969.[11] The University of Oulu is a multidisciplinary university, which is typically stated to have created an innovative base and have been network linked to local production and economy.[12]

---

[8] Comp. e.g. Mika Kulju, *Oulun ihmeen tekijät* (Helsinki: Ajatus, 2002), passim; Matti Otala, *Uskalla olla viisas* (Helsinki: Ajatus kustannusosakeyhtiö, 2001), passim; Manninen, pp. 127-128; *Experts trust Oulu: the secret of the “Oulu phenomenon”* (City of Oulu, Economic affairs office, 199-?), passim.
[9] Oinas-Kukkonen, p. 189.
[10] Enbuske, p. 40.
[11] Liisa ja Kyösti Julku, *Oulun yliopiston perustamisen historia* (Rovaniemi: Pohjois-Suomen Historiallinen Yhdistys, 1983), pp. 274; 294 (Summary in English); Matti Salo, *Pohjoinen Alma mater. Oulun yliopisto osana korkeakoululaitosta ja yhteiskuntaa perustamisvaiheista vuoteen 2000* (Rovaniemi: Pohjois-Suomen Historiallinen Yhdistys, 2003), pp. 15, 252.
[12] See e.g. Henry Oinas-Kukkonen, Jouni Similä, Pentti Kerola, Petri Pulli and Samuli Saukkonen, ”Development in the Growth Base of the 'Oulu Phenomenon'. The role of systems/software methodologies”. *History of Nordic Computing*. IFIP WG9.7 First Working Conference on the History of Nordic Computing (HiNC1), June 16-18, 2003, Trondheim, Norway. Series: IFIP International Federation for Information Processing, Vol. 174. Bubenko, Janis; Impagliazzo, John; Solvberg, Arne (Eds.), (New York, N.Y: Springer, 2005), pp. 435, 436, 445.

Towards diversification and free trade

After the Second World War, Finland was obliged to pay severe war indemnity to Soviet Union. The industrial policy was oriented towards promoting heavy industry and exports. Finland suffered seriously from the lack of capital, since the war had destroyed much of the infrastructure and much mobile capital left the country due to geopolitical uncertainty after the war.[13]

The industrial policy was oriented to encourage heavy industry investments. There were three main mechanisms in place. (1) Allocation of loans: The Bank of Finland was in charge of reviewing all major investments involving loan based capital. (2) Industry profits were waived for government tax if they were used for investments to build new capacity. (3) Inflationary fiscal policies were followed: for example, Finnish Mark was devaluated four times during 1977—1979.[14]

General economic conditions were very turbulent: high inflation and energy crisis by oil embargo caused dynamic changes in society and economy in the 1970s. Important had also been a favorable commercial and political development towards European Free Trade Area[15] (EFTA). In June 1961 an interim agreement for the formation of a free-trade area by an EFTA-Finland Association Agreement (FINEFTA) entered into force. Finland gave the same customs benefits to the Soviet Union as to the EFTA states.[16] In 1973 an EEC-Finland Agreement on Free-trade area covering of European Coal and Steel Community products was signed and it came into force during 1974-1975. This was followed also by admitting similar customs benefits to the Soviet Union and free trade agreements with the Soviet satellite states Bulgaria, Hungary, Czechoslovakia, German Democratic Republic and Poland.[17]

During the late 1960's and early 1970's it became fashionable for industry to diversify. The basic underlying idea was that of a conglomerate, i.e. a large, diversified company with a wide array of businesses. It was thought that many

[13] See e.g. Erkki Pihkala, *Suomalaiset maailmantaloudessa keskiajalta EU-Suomeen* (Helsinki: Suomalaisen Kirjallisuuden Seura, 2001), pp. 177 – 180.
[14] Pihkala, pp. 184, 185, 193, 196, 207, 208, 235-239, 367.
[15] European Free Trade Association (EFTA). http://www.efta.int/.
[16] Pihkala, pp. 201, 203, 206.
[17] Pihkala, pp. 213 – 219.

businesses would reduce the sensitivity to economic cycles because the economic conditions would be asymmetric in different businesses of the conglomerate and would thus smooth out the sensitivity overall. However, unfortunately for the conglomerates, the energy crisis in 1974-1976 treated all businesses symmetrically and forced many of the conglomerates into a crisis and to spin off non-core businesses.[18]

The ICT industry pioneer companies in the Oulu region prior to 1972 had mainly their origin as diversification business within a conglomerate "wannabe" company. After 1973 many of these companies were objects of reorganization through mergers and acquisitions. These issues are discussed in chapters one and two.

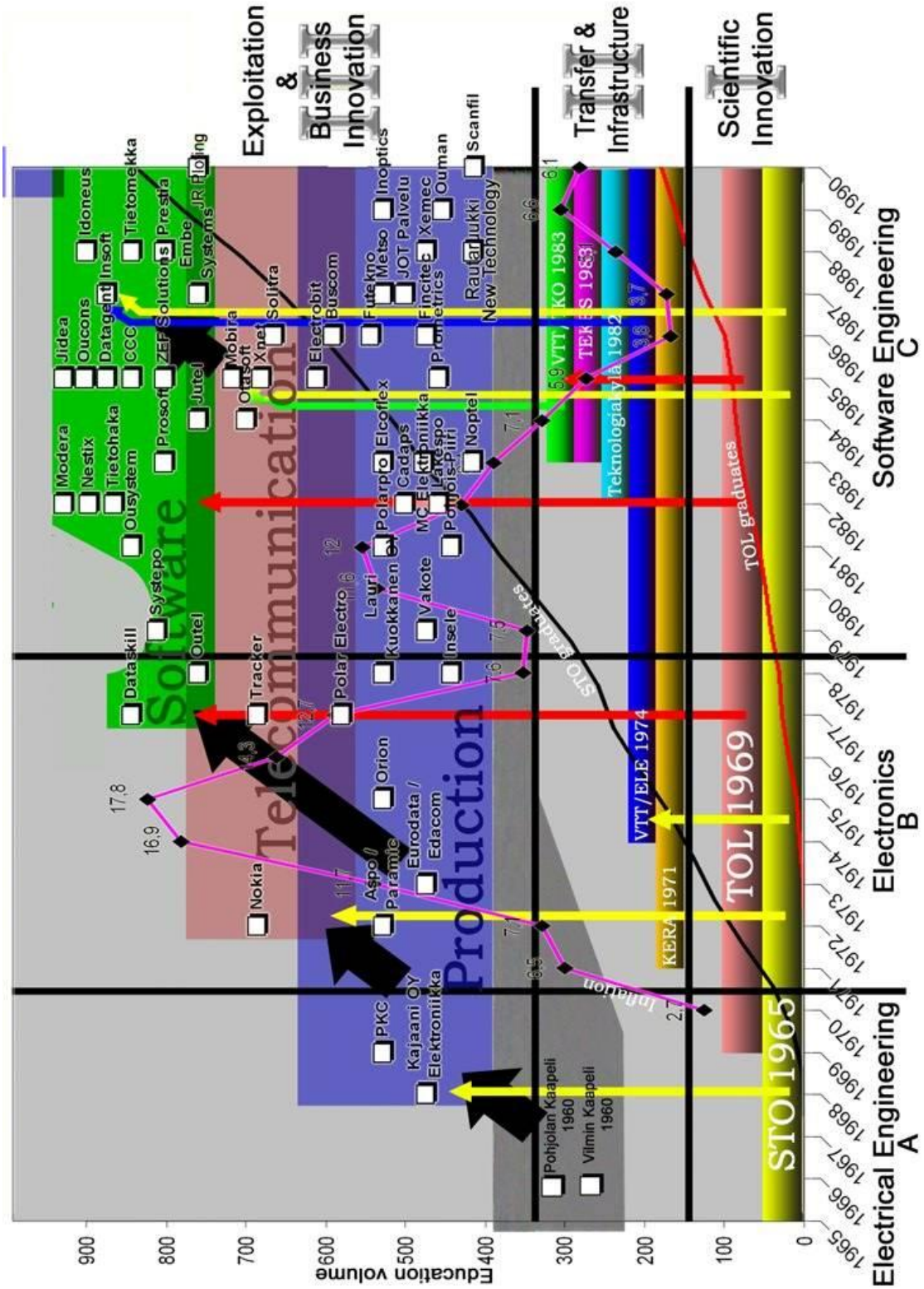
The Threads diagram

The key idea to understand as described in the diagram[19] (see Figure 1) is the thread thinking: matters running through the whole course. These matters connect successive parts of ICT innovation in Oulu.

[18] See e.g. Henri Servaes, "The Value of Diversification During the Conglomerate Merger Wave." *The Journal of Finance*, Vol. 51, No. 4. (Sep., 1996), pp. 1201-1225 comp. Vincenzo Aliberti and Milford Green, "Canada's International Merger Activity for the Period 1971 to 1991: A Developmental, Geographic and Historical Dimension." *Geography Online: Geographic Research on the Web*, http://www.siue.edu/GEOGRAPHY/ONLINE/aliberti.htm.

[19] We are grateful for Mr. Jussi Autio for collecting the company data and drawing the diagram for us. Sources of the Threads diagram: Kaupparekisteri (Trade Register of the National Board of Patents and Registration of Finland, in Finnish). CD-KATKA 1/03 (Helsinki: Patentti- ja rekisterihallitus, 2003); An email message from the Managing Director of Dataskill Oy Seppo Koivumaa, 25.5.2006; Ilkka Heikura, Sähkötekniikan ensimmäiset vuosikymmenet Oulun yliopistossa (Oulu: Avanti Management Oy, 2005); Mika Kulju, Oulun ihmeen tekijät (Helsinki: Ajatus, 2002), Mika Raunio, Luova kaupunki, inhimilliset voimavarat ja kaupunkiseudun kehitys (Tampere: Tampereen yliopisto, 2005); Eino Tunkelo, Oulun teknologiakylä 1980—1988. Miten syntyi Oulu-ilmiö? (Oulu: Suomen Itsenäisyyden Juhlavuoden 1967 rahasto, 1988);"CCC - Finding Solutions", http://www.ccc.fi/1.htm; "Insoft Oy - The visualizer of software development", http://www.insoft.fi/eng/pr2About.htm; "MCon Partners OY", http://www.mconpartners.com/tiki-index.php?page=Partnerit; "Meet Oulu Hightech – teknologiavierailut", http://www.congressoulu.fi/meetouluhitech/hitechyritykset.html.

Figure 1. The Threads diagram



The Threads diagram presents four basic general-level aspects to the Oulu phenomenon. First there are three line diagrams that provide you a quick information on facts that affected all high-tech business in the Oulu region. Two of the line diagrams tell you the cumulative workforce that had been educated at the Department of Electrical Engineering (STO) and the Department of Information Processing Sciences (TOL) and was potentially available in the area. The cumulative workforce created by the Department of Electrical Engineering is marked with a black line and the Department of Information Processing Sciences' workforce with a red line. Third, a pink line diagram shows the yearly inflation and inflation percentage in Finland which obviously had a serious impact on all business.

The thread thinking is a key issue in the diagram. You can see that the timeline has been divided into three categories (A, B and C) depending on which technological innovation was the most essential during the different periods. This horizontal thread is the technological thread in the diagram. During the years before 1972 electrical engineering (A) was the technology that built the foundation from where others could continue. From about 1972 until about 1978 electronics (B) provided the breeding ground for new companies and made it possible that in the 1980s software engineering (C) would grow to a substantial industry. Each period was built on top of the previous one, which was a prerequisite for the following.

A vertical thread, the innovation thread - which is the focus in this research - is divided into three parts or categories. In the bottom you see the Scientific Innovation (I) thread that presents the basic research done in the university. In the middle there is Transfer & Infrastructure (II) thread that smoothes the path for product development. Particularly small companies could not afford to spend money on R&D and this thread shows organizations such as VTT or KERA that either directly helped companies develop their own products or helped them with monetary issues. On top of the diagram is the Exploitation & Business Innovation (III) thread that presents the industry itself. The companies are placed there according to the year they were founded, and most of them continued to function throughout the examined timescale.

Companies are divided into four groups: pre- 1965 cable industry, Vilmin kaapeli and Pohjolan kaapeli, is marked with gray field at the most bottom field, production marked as a field with blue color, telecommunication as a field in pink color and software as a field in green color. Companies are placed in the diagram horizontally depending on the year they started in Oulu. Vertically they are placed on the field they mainly operate.

As we are interested in innovation transfers that leaves us with the fourth aspect in the diagram. The large black arrows show a major impact that one field has started to have for another one. In all but one case it also means that one particular field has been crucial in giving birth to the new field. Instead of drawing separate arrows from scientific innovation (I) up to each company, an arrow describing an innovation thread is drawn from one innovation level (I or II) to a specific field (i.e. production, telecommunication, or software). The vertical, small arrows thus represent a start of a close connection and innovation transfers between the connected entities. They are either spin-off projects or people that transfer their know-how to another place. The color of the arrow is the same as the innovation provider (i.e. yellow for Department of Electrical Engineering, red for Department of Information Processing Sciences, blue for VTT/ELE and green for VTT/TKO).

1. Cable industry and growth expectations since 1960

In the Oulu region cable industry represents growing electrical engineering industry and can not be ignored due to its links to later major operators in Oulu. Finnish cable industry primarily exported to the Soviet Union. In 1960 the company T:mi Vilmin Kaapeli was established in Oulu (see Figure 1). An older Finnish cable factory Suomen Kaapelitehdas Oy which operated in Helsinki was not enthused to have a new northern competitor. As a response, it established an affiliated company Pohjolan Kaapeli Oy in Oulu in the very same year (see Figure 1). Cable factories increased their production in Oulu and tried to crush each other in market competition. Suomen

Kaapelitehdas was merged to Oy Nokia Ab[20] in 1966. Vilmin Kaapeli was bought by Sähköliikkeiden Oy and AEG and named as Kaapelitehdas Oy. Later, it first became SLO-Kaapeli Oy which then was acquired in 1986 by Nokia.[21]

Electronics industry had a narrow base in Finland, and in addition to cable industry most of the activities in electronics meant building radios and televisions, but those activities were not located in Northern Finland. However, a period of growth was on the threshold in Finnish electronics: expectation of a sevenfold growth and 30,000 jobs during the 1970s and 1980s.[22]

Especially Northern Finland and Oulu in that region were regarded as an area for a potential growth in electronics. The basic infrastructure which the industry needed did exist, costs were lower than in Southern Finland, government subsidies for developing areas could be obtained and labor was available, however skilled people specialized in electronics were needed. These aspects were outspoken by Professor Matti Otala from the Department of Electrical Engineering at the University of Oulu.[23] He stated in the main newspaper in the Oulu region, *Kaleva*, in September 1969 that electronics industry would be established in Oulu within a couple of years.[24]

2. Threads towards electronics industry in 1970s

Cable production boomed and a new university was functioning in Oulu. Both phenomena may be linked to hydro-electric power stations. In the Oulu region there were several hydro-electric power stations and many more in Northern Finland.

When the Department of Electrical Engineering was established in 1965, the plan was that it would serve the needs of personnel for hydro-electric power stations and their

---

[20] Later Nokia affiliated company Pohjolan Kaapeli Oy became a base to a PKC Group. “Historia.” http://www.pkcgroup.com/index.
[21] Juhana Aunesluoma, “Sähköistämisen alkuvuosista sodanjälkeiseen idänkauppaan – kaapeli 1922—1966.” In Martti Häikiö, *Nokia Oyj:n historia, 1. Fuusio. Yhdistymisen kautta suomalaiseksi monialayritykseksi 1865—1982* (Edita: Helsinki, 2001), pp. 77 - 79; Heikura, pp. 67, 155.
[22] Heikura, p. 148.
[23] Interview, Professor Seppo Leppävuori, conducted by Ilkka Heikura, 14.4.2004; “Elektroniikan teollisuus on hyvässä myötätuulessa”, *Kaleva*, 10.8.1971, p. 3; Heikura, pp. 20, 148, 149.

construction in Northern Finland.[25] However, signs of academic innovations directed towards this sector have not been presented in a way that any significant innovation thread could be drawn from the department to the hydro-electric power sector.

There was an important development impact from outside. U.S. license manufacturing of military radiophones allowed companies in the Oulu region access to newest electronics components. [26] Important components were Transistor Transistor Logic gates (TTL) that allowed construction of digital electronics products, analog microcircuits such as Operational Amplifiers allowing construction of analog electronics products, and microprocessors allowing construction of embedded computer products.[27]

During 1970 – 1975 research activities at the Department of Electrical Engineering in the University of Oulu had concentrated on High-Fidelity[28] (HiFi) audio electronics, most notably low-distortion[29] amplifier designs. Professor Matti Otala was the premier figure who became internationally well-known in this field as he was invited to work for the U.S. Harman-Kardon company.[30] Also his research paper related to Transient Inter-Modulation (TIM) distortion[31] became legendary within the HiFi world and was highly visible also in marketing worldwide.

In the Finnish industry of the 1970s Kajaani Oy Elektroniikka, Aspo Oy Paramic Ab, Oy Nokia Ab Elektroniikka and Polar Electro found their place in Oulu,[32] as well as did Eurodata[33] (see Figure 1). In addition there was the VTT Technical Research Centre of Finland which began to operate in the city (see Figure 1). These were linked

---

[24] "Elektroniikan tutkimustyötä Oulun yliopistossa", *Kaleva*, 13.9.1969, p. 4.
[25] Interview, Professor Juhani Oksman, conducted by Ilkka Heikura, 15.12.2003; Heikura, p. 9.
[26] Dan Steinbock: "What next? Finnish ICT Cluster and Globalization", Sisäasiainministeriön julkaisuja 38/2004, p. 49.
www.intermin.fi/intermin/biblio.nsf/461584FDBB699A17C2256F24004D60EE/$file/382004.pdf
[27] http://smithsonianchips.si.edu/augarten/index.htm
[28] High Fidelity is used to describe recordings and audio equipment which were intended to provide faithful sound reproduction.
[29] Distortion means here alteration of the original shape (or other characteristic) of sound, waveform or other form of musical information or representation.
[30] Interview, Professor Matti Otala, conducted by Ilkka Heikura, 13.10.2003; Kulju, p. 54.
[31] Matti Otala, "Circuit design modifications for minimizing transient intermodulation distortion in audio amplifiers". *Audio Engineering Society Journal*, Volume 20, Number 5, June 1972, pp. 396 - 399.
[32] Oinas-Kukkonen-Similä-Kerola et al., p. 429; Heikura, pp. 111, 140.

to the operations of the Department of Electrical Engineering and in the case of Eurodata also to the Department of Information Processing Science. Thus innovation threads can be found to lead from academia to electronics industry.

Starting thread to Kajaani Oy Elektroniikka

Quite often the beginnings of actual electronics industry in Northern Finland have been linked to the paper mill Kajaani Oy's steps to establish its electronics department in Oulu in 1968 in co-operation with Professor Matti Otala and the Department of Electrical Engineering. A "code name", Oy Jänkä Electronics Ab, was used for the affiliated company that was established in 1968**.** Two years later Kajaani Oy Elektroniikka was established (see Figure 1).[34] In practice research and development was carried out at the Department of Electrical Engineering until 1977, when these were transferred to the Kajaani city some 150 kilometers away from Oulu. Kajaani Oy Elektroniikka invented a CORAM-meter to measure lightness of cellulose or chemical pulp. At the end of the 1970s Kajaani Oy Elektroniikka had tested products for telecommunication and dairy automation, farming and forestry automation, audio and educational electronics, audio electronics and metallurgy. Taximeters for cabs and radio mixing desks or consoles for Finland's national public service broadcasting company Yleisradio were in production. In 1977 Kajaani Oy Elektroniikka bought Eurodata Oy and got hold of cash register technology. In addition to Kajaani Oy a large company which took early steps in electronics was the steelworks company Rautaruukki Oy.[35] A thread from the Department of Electrical Engineering to Rautaruukki can be found. For example, Jarmo Karvonen worked four years for developing instruments for Rautaruukki in Oulu.[36]

There was a clear thread from the Department of Electrical Engineering to Kajaani Oy Elektroniikka. For example, already in 1971 a memorandum of the Council of Oulu Region (*Pohjois-Pohjanmaan maakuntaliitto)* declared optimistically that "already

---

[33] "Eurodatan elektroniikkatuotanto uusilla urilla." *Kaleva*, 10.8.1975, p. 2.
[34] Heikura, pp. 140, 147.
[35] Kulju, pp. 60 - 61; Heikura, pp. 134-136, 147.
[36] Interview, Jarmo Karvonen, conducted by Ilkka Heikura, 28.11.2003.

now it can be claimed that the university has had remarkable influence due to the fact that industry of this sector *(i.e. electronics,* italics ours) has arrived to the region".[37]

Thick film hybrid circuit thread - Aspo Oy

In the early 1970s research and development in various fields of microelectronics and production was carried out in both thin and thick film hybrid circuit[38] production, and the latter had industrial significance in Finland. Since 1971 thick film hybrid circuits had been used for designing microchips. The production technology of thick film hybrid circuits and applications were being developed by Oy Paramic Ab and the University of Oulu. The research and development effort was given a major boost in 1972 when the Department of Electrical Engineering where thick film hybrid circuit technology was taught got better equipment. Professor Matti Otala's substitute Seppo Leppävuori, who had published the first research article on thick film hybrid circuits in Finland in 1970, began at the University of Oulu in 1972 a research effort which led to the production of the first thick film hybrid circuits in 1973. This research covered production, its processes and applications. Oy Paramic Ab had been established with the aid of the Department of Electrical Engineering, and Leppävuori was the chairman of the board. A project funded by The Finnish National Fund for Research and Development (Sitra) was important for Paramic.[39] A thread from the Department of Electrical Engineering to Paramic was remarkably strong (see Figure 1).

In the electronics industry hybrid circuits were needed especially for communications equipment. Hybrid circuits increased reliability but enabled smaller size and lighter weight. In instrumentation where stability and accuracy were crucial various measuring and controlling circuits and amplifiers used the new technology. For consumer electronics like television and synthesizers hybrid circuits cut production costs.[40]

---

[37] "Jo nyt yliopistolla voidaan sanoa olleen suurta merkitystä sille, että alueelle on hakeutunut alan teollisuutta." (in Finnish). Heikura, p. 151.
[38] See "Research and Technology Development: Glossary." www.aspocomp.com/technology/sanasto.html.
[39] Interview, Professor Seppo Leppävuori, conducted by Ilkka Heikura, 14 April 2004; Heikura, pp. 40, 119, 120, 123.

The first hybrid circuit microelectronics factory began to operate on October 18th in 1975 in the Rusko suburb in Oulu, and Oy Paramic Ab was merged into Aspo Oy during the same year. Thick film hybrid circuit production of Aspo Oy Elektroniikka was based directly on the groundwork of the Department of Electrical Engineering. Together approximately one million circuits of 60 types were produced for domestic and foreign customers needs, also electronic equipment was produced. Even though Aspo Oy produced nearly 100 percent of hybrid circuits sold in Finland there were two other companies, which produced hybrid circuits at the end of 1970s: Oy Nokia Ab and Salora Oy. The latter was a television factory in Salo which hired many Oulu University research students and thus obtained more know-how on hybrid circuits, which were used in televisions. A Salora affiliated company Salcomp Oy in Kemijärvi also received know how; for example, ex-University of Oulu student Jorma Terentjeff[41] entered into Salcomp in 1979.[42]

As a highlight of the Aspo operations in Oulu we have seen the establishment of the new factory on February 25th in 1980. In addition to an increase in competitiveness its importance has been emphasized because Aspo's director of consumer electronics Antti Piippo stressed the need to establish a high technology park in Oulu.[43]

Thread to radiotelephones - Nokia

Oy Nokia Ab established a small electronics department in Kaapelitehdas in Helsinki in 1960 that was developing industrial and radio electronics starting in 1962.[44] In the company there was an Oulu-born radio link section manager Matti Otala who was said to be "a raising star in electronics". He was invited from Nokia to a professorship in the Department of Electrical Engineering in 1967. For a short while he had a position both in Nokia and in the Department of Electrical Engineering, but the main point was that he had straight links to the electronics business.[45]

---

[40] "Mikroelektroniikkatutkimus ja –teollisuus Suomessa", *Kaleva*, 26.2.1978, p. 2; Heikura, p. 121.
[41] Later the managing director, among others, of Salcomp, Aspocomp, Eurodata and JOT Automation. Kulju, pp. 183 - 186.
[42] Interview, Professor Seppo Leppävuori, conducted by Ilkka Heikura, 14.4. 2004; "Ouluun lisää elektroniikkateollisuutta". *Kaleva*, 4.7.1975, p. 1; Heikura, pp. 120, 121, 123, 125, 149.
[43] "Antti Piippo Aspo: Oulu ei oivalla missä mennään." *Kaleva, 25.2.1980, p. 10;* Interview, Professor Seppo Leppävuori, conducted by Ilkka Heikura, 14.4. 2004; Heikura, pp. 15, 149.
[44] Heikura, p. 157.
[45] Interview, Professor Juhani Oksman, conducted by Ilkka Heikura, 15.12.2003; Heikura, pp. 54, 55, 68, 142.

In 1972 Finnish Defense Forces made a remarkable order of military radiotelephones. There was a condition to the manufacturer: production was to be carried out in a developing industrial area within Finland. Oulu was placed in a secondary category of developing areas and in the first category there was the Kajaani area, which was proposed by Nokia's competitor Kajaani Oy Elektroniikka as a location for the production. However, Nokia already had cable production in Oulu, and it was emphasized especially to the Finnish government that Nokia would also co-operate with the Department of Electrical Engineering at the University of Oulu. Oulu won the competition. Military radio telephones that were produced were based on an American license and mainly on modules made elsewhere, but the Department of Electrical Engineering at the Oulu University may be said to have supported Nokia's chances to develop in Oulu even though Oulu educated engineers were not largely employed at the beginning.[46]

Oy Nokia Ab Elektroniikka established a military radio telephone factory in Oulu in 1973 (see Figure 1). Civilian production of radiotelephones and other communication equipment was promptly transferred to Oulu, because there were capacity and government subsidiaries available. In October 1973 Nokia electronics production employed approximately 200 people. Nokia established a new electronics factory in Oulu in 1974. Nokia's research and development stayed in Helsinki at the beginning, but already in 1976 a Nokia production manager Aarne Soikkeli stated in *Kaleva* that the University of Oulu has significance for educating people for the development.[47] Later the University of Oulu was often named as the first "University of Nokia".[48]

Thread to ADP cash registers - Eurodata

At the end of 1973 a company called Social Automation Oy was renamed as Eurodata Oy. During the next year it got funding from Sitra to develop a new automatic data processing (*ADP)* cash register EDA-10 aimed mainly for hotels and restaurants. Also

---

[46] "Oulun elektroniikkatehdas aloittaa jo tänä syksynä?" *Kaleva*, 8.8.1971, p. 12; Heikura, pp. 67, 68, 156, 157, 163; Häikiö, *Nokia Oyj:n historia, 1*, p. 154.
[47] "Elektroniikkatehdas vihittiin." *Kaleva*, 4.5.1974, p. 7; "Elektroniikkaa vientiin Oulusta." *Kaleva*, 8.4.1976, p. 1; Heikura, pp. 118, 148, 156, 160; Martti Häikiö, Nokia *Oyj:n historia,1* , pp. 122, 154.
[48] Martti Häikiö, *Nokia Oyj:n historia, 2. Sturm un Drang. Suurkaupoilla eurooppalaiseksi elektroniikkayritykseksi 1983—1991* (Helsinki: Edita, 2001), p. 98.

the first Finnish computer displays were claimed to be produced. However, the main target was to produce electronic equipment for self-service in gas stations. Eurodata got two thirds of the share of the Finnish market by the year of 1975. The engineers for research and development in the company came from the Department of Electrical Engineering and the Department of Information Processing Science at the University of Oulu.[49] Thus a thread from both of the departments to the company can be found.

A heartbeat thread - Polar Electro

The first student to graduate from the Department of Electrical Engineering was Seppo Säynäjäkangas. He became first an assistant to professor Juhani Oksman and then since 1976 a professor in electronics when Matti Otala left the department. In the leadership of Säynäjäkangas meters for measuring heartbeat were developed. Several innovations were achieved in the measurement of heartbeat: measurement of heartbeat on skin using the body's electric fields and wireless transfer of heartbeat pulse data using analog electromagnetic field. The latter invention was patented[50]. Also construction of heartbeat monitoring devices was researched actively by professor Seppo Säynäjäkangas. Two models of heart rate monitor resulted from two diploma theses in 1976.[51]

In 1977 Säynäjäkangas established Polar Electro (see Figure 1) and first commercial products entered markets in the next year. Polar Electro carried out research concerning electronics as well as physiology. Several patents were achieved: in 1977 a meter for continuous heartbeat monitoring. Also a system to measure heartbeat from the fingertips and a computerized and wireless heartbeat monitor were developed.[52]

[49] "Eurodatan elektroniikkatuotanto uusilla urilla". *Kaleva*, 10.8.1975, p.2.
[50] US Patent 4,625,733, Säynäjäkangas, teaches a wireless and continuous heart rate measurement concept consisting of a measuring belt to be positioned on the chest by means of an elastic band and a heart rate receiver worn on the wrist like a watch.
[51] Heikura, pp. 111, 113.
[52] Heikura, p. 111.

Intermediary thread - VTT

In Jorma Terentjeff's opinion companies concentrated on development not in research for which they did not have enough money nor educated staff in the 1960s and the 1970s.[53]

Major research and development of thick film hybrid circuits had taken place nearly solely at the University of Oulu in 1972-74. In addition to electronics industry, i.e. Aspo Oy and Salora, the university, Academy of Finland and the Ministry of Trade and Industry had invested in this activity. However, research and development entered into a new phase, when VTT established the Laboratory of Electronics in Oulu in 1974 (see Figure 1). Even though there were five considerable research and production laboratories in Finland concentrating on thick film hybrid circuits, teaching, research development and industry heavily centered in Oulu which already had international significance. Organizational change created a close network enabling information exchange. Professor Matti Otala and his research group left the Department of Electrical Engineering for the VTT. Also responsibilities were divided: the Department of Electrical Engineering concentrated on materials and components while VTT focused on industrial applications of the thick film hybrid technology and new production processes. Even though responsibilities were divided VTT and the University of Oulu agreed on co-operation.[54] The laboratory started to grow and specialize in various electronics design skills. One of the specialization areas selected was low power consumption Complementary Metal-Oxide Semiconductor (CMOS) digital electronics, microprocessors and memories that constitute building blocks for mobile embedded[55] computer systems. Another important relevant research field was opened during 1974-1980 in software engineering tools and methods for embedded microprocessors.

VTT became a new companion for the Department of Electrical Engineering in innovation. However, it can also be seen as an intermediary thread of ICT innovation in Oulu (see Figure 1).

---

[53] Heikura, p. 128
[54] "VTT aloittaa Oulussa 1.3." *Kaleva*, 16.2.1974, p. 1; "VTT ja Oulun yliopisto aloittavat yhteistyön" *Kaleva*, 31.8.1974, p. 1; Heikura, pp. 118, 120, 122, 124, 149.
[55] Embedded computer means that the computer is hidden inside a product.

3. Software engineering threads in late 1970s and 1980s

Emergence of the software engineering threads to the ADP industry

During the years 1979 – 1983 there seems to have been a slow-growing period in the Oulu region: ICT companies appear to have been established sparsely (see Figure 2).

This was probably caused by a severe lack of capital due to changes in the fiscal policy to fight inflation (see Figure 1). Changes in the fiscal policy were a global phenomenon highlighted by the USA Federal Reserve chairman Paul Volker's tough interest rate policy to curb inflation[56]. By mid-1980s a new industrial policy was formed in Finland that provided capital[57] and state support for research and development[58] for industrial companies (see also Figure 1).[59]

It seems that the "slow lane" of the early 1980's caused the Oulu region to think about how to support new businesses and find new threads for success. Oulun teknologiakylä or Oulu Technology Park[60] was established in 1982[61]. Improved economic conditions for small and medium sized enterprises started to pay off and the number of companies during 1984 – 1990 started to show new vigorous growth (see Figure 2).

---

[56] Carlos Capistrán-Carmona, "Bias in Federal Reserve Inflation Forecasts: Is the Federal Reserve Irrational or Just Cautious?" *Computing in Economics and Finance 2005*, Number 127. http://repec.org/sce2005/up.23079.1106776160.pdf.

[57] Government-backed funds (Kehitysaluerahasto and Sitra) were allowed to inject capital in small and medium sized industrial companies in the forms of loans and equity.

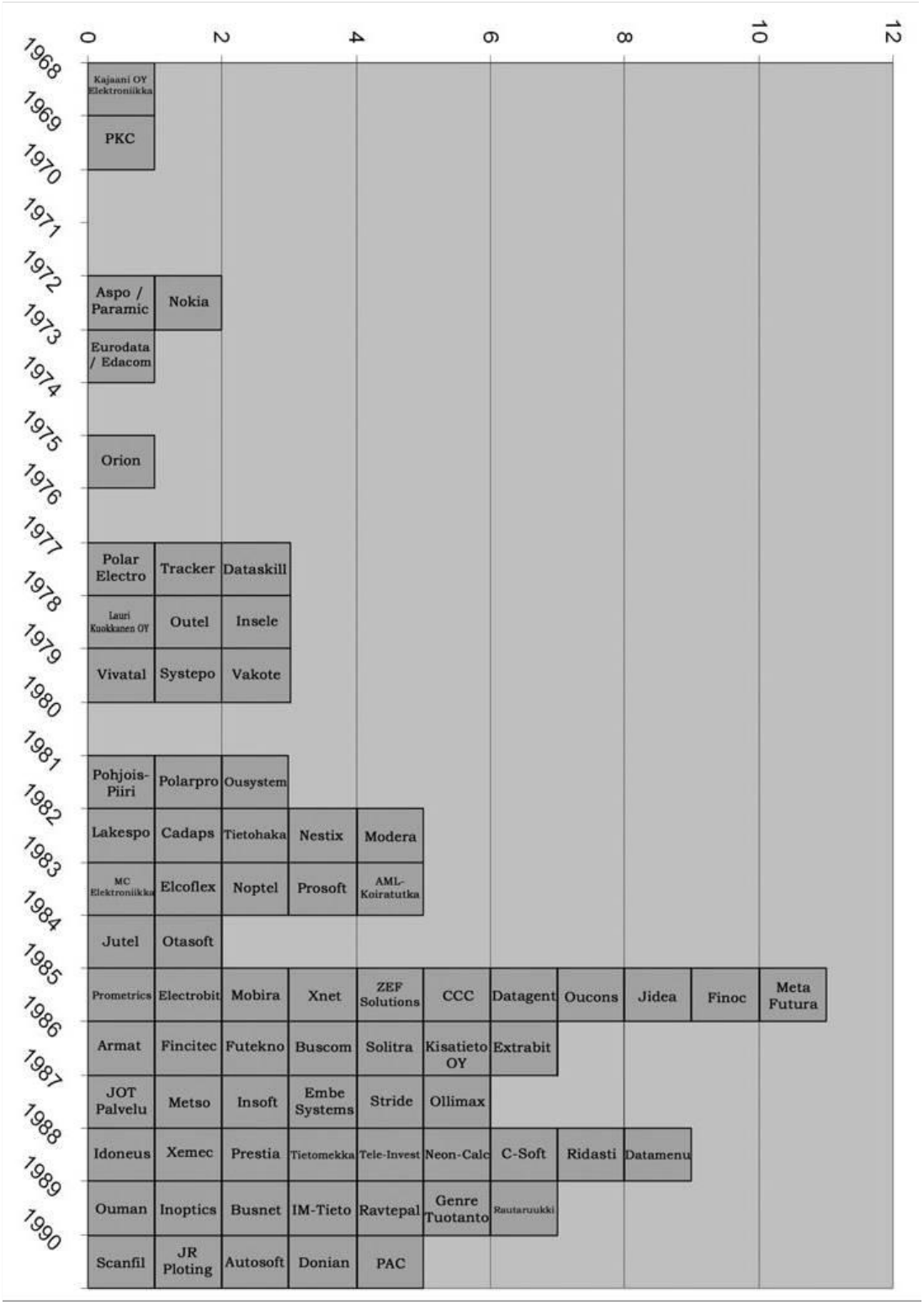
[58] Government research and development subsidies were reorganised from "politically" controlled ministry of industry favouring heavy industry into a separate agency (TEKES) that allocates subsidies based on the proposals foreseen innovation and economic merits favouring small and medium sized industry.

[59] Häikiö, *Nokia Oyj:n historia, 2*, 82 – 85.

[60] An area for high-tech industry following the example of Silicon Valley, known for explosive growth of electronics industry there.

[61] "Keskiviikkona perustettu Oulun Teknologiakylä Oy selvä osoitus: Oulun elinkeinopolitiikkaa kehitetään nyt tarmokkaasti" (Oulu Technology Park established on Wednesday a clear sign: Oulu's industrial policy is developed vigorously), *Kaleva*, 1.4.1982, p. 18; Eino Tunkelo, *Oulun teknologiakylä 1980—1988. Miten syntyi Oulu-ilmiö?* (Oulu: Suomen Itsenäisyyden Juhlavuoden 1967 rahasto, 1988), p. 1.

Figure 2. The Company diagram



Sources as for the Threads diagram. See note 19.

Pioneering events for software industry birth in Oulu region the 1970's were annual conference series "Blanko" started in 1973, and the founding of the first systems and software companies in the late 1970s - among others the first software house Dataskill in 1976 and Systepo in 1979 (see Figure 1). Early 1980's brought forth Modera in 1982, and CCC in 1985 (see Figure 1). Computer manufacturers established also offices in Oulu, for example Nixdorf in 1979 and HP in 1981.[62]

The Finnish ADP industry passed the era of 'quiet life' in 1979[63]. Calls for more ADP education came from several directions, for example the ADP-82 days in Helsinki estimated the need of new employees in the industry in 1983 to be between 1500 and 2000.[64] Even later public calls for increase in ADP education[65] were not realized at those times in the yearly student intakes of the university in ADP related education. For example the yearly student intake of the Department of Information Processing Science slowly rose from the first 10 in 1972 only to the level of 25 in 1985. This trend can also be seen in the cumulative number of MS degrees in Figure 1. The student intakes of the department continued to grow quite slowly for a decade until the late 1990's when a dramatic increase from 45 to the present 250 took place between 1996 and 2002 in only six years.[66] The increase in the student intakes of the

---

[62] "Atk palveluyritys käyntiin Oulussa" (ADP service company starts in Oulu), *Kaleva*, 3.3.1979, p. 12; "Uusi tietokoneyhtiö perustettu Ouluun" (New computer company established in Oulu), *Kaleva*, 4.9.1979, p. 10 ; "Atk-ala uskoo kasvun jatkuvan" (ADP industry believes growth to continue), *Kaleva*, 22.10.1981, p. 15; "Yliopistomiesten atk-yhtiö tarjoaa tietoa yrityksille", *Kaleva*, 6.11.1982, p. 16.

[63] "Suomen atk-teollisuus ohittanut hiljaiselon" (Finnish ADP industry passes era of quiet life), *Kaleva*, 9.1.1979, p. 10.

[64] "Tietojenkäsittelyliitto koolla: Atk-oppia pitäisi lisätä keskiasteella" (Data processing association convenes: ADP education should be increased in middle level), *Kaleva*, 29.3.1979, p. 5; Robert Brantberg, "ATK-82: Toimistoautomaatio, ATK ja tietoliikenne yhdistyvät" (ADP-82: Office automation, ADP and data communication converge), *Kaleva*, 4.3.1982, p.14; "Atk-ammattien veto jatkuu voimakkaana" (Pull of ADP professions continues strong), *Kaleva*, 19.12.1983, p. 8.

[65] Tuulikki Ukkola, "Tietotekniikkaa: Joko lopultakin saadaan vauhtia tietotekniikan opetukseen?" (Do we finally get into stride in information technology education?), *Kaleva*, 23.3.1985, p. 2; "Tietotekniikan koulutusmäärät eivät juuri nouse" (Level of information technology education does not rise), *Kaleva*, 19.5.1985, p. 7; "Tietotekniikan ammattilaisista yhä suurempi pula" (Even stronger shortage of information technology professionals), *Kaleva*, 24.5.1985, p. 19; "Oulu tarvitsisi lisää teknologian koulutusta" (Oulu needs more technology education), *Kaleva*, 24.8.1985, pp. 3, 4; Rector Markku Mannerkoski, "Tietotekniikan merkitystä aliarvioitiin" (Importance of information technology was underestimated), *Kaleva*, 3.9.1985, p. 2.

[66] Oulun yliopiston hallituksen pöytäkirjat (The minutes of the administrative board of the University of Oulu), for the years 1995-2006 http://www.hallinto.oulu.fi/hallitus/paatos/index.htm, for earlier years the archives of the University of Oulu.

department in the 1990's happened in conformance with national level increases in ICT education[67].

The ADP companies in the industry during the 1970s and 1980s were mainly established and managed by the graduates from the Department of Information Processing Science – this is true in the case of Dataskill, Modera and CCC as well as Tietoseppo which was established in Kajaani in 1981.[68] Of these only CCC grew later to a nationally sizable company employing about 400 persons presently. Most graduates from the Department of Information Processing Science in the 1970s and early 1980s either worked in these companies, or in ADP departments of large industrial companies, or in ADP departments in public administration. Quite a few also moved to Southern Finland in search of a job.[69]

The two tracks – electronics (or microchips) and software - were during that period largely separate. There are exceptions and the best case is Eurodata (see Figure 1), which Kajaani Electronics bought in the late 1970s and moved to Kajaani, simultaneously only to open an office in Oulu in 1983 as well as to change its name to Edacom.[70] Nowadays, Fujitsu owns the company and operates it in Oulu mainly in its original application area: service station automation.

Eurodata sought actively expertise from companies and people related to the university. The first system developed by Eurodata was, in fact, mainly subcontracted in 1977-1978 from Dataskill. Both companies had close ties to the Department of Information Processing Science. Eurodata's system group was managed by Timo Korhonen, a graduate from the Department of Information Processing Science. Dataskill had very strong links with the Department of Information Processing Science. Nearly all of the persons involved in the development of this pioneering

---

[67] Opetusministeriön julkaisuja – Työryhmämuistiot 1997, 25, Tietoteollisuuden koulutustarvetyöryhmä, Tietoteollisuuden koulutuksen lisätoimenpideohjelma 1998 – 2002 (A supplementary measures program of education for information technology industry), ISBN 952-44-2000-7.
[68] "Atk-alan palvelujen kysyntä voimistunut" (Demand for ADP services strengthens), *Kaleva*, 31.3.1984, p. 17.
[69] Comp. Manninen, p. 127.
[70] "Edacomille Ouluun suunnitteluyksikkö" (Edacom's development unit in Oulu), *Kaleva*, 8.12.1983, p. 19.

embedded cash register system – Juhani Iivari, Seppo Koivumaa, Jouni Similä - had some form of departmental background.

During this period the average annual master's degree completion from the Department of Electrical Engineering was 40 - 50 and from the Department of Information Processing Science 5 – 10 (for cumulative numbers see Figure 1). Most of the graduates of the departments had to go to work in Southern Finland because there were not enough qualified job offers available in Oulu region. The situation started to improve in the early 1980's and many of the expatriates came back with a lot of knowledge they gained from their jobs and companies in the south. However, important is that in the late 1970s and early 1980's i.e. approximately after ten years of history of the Department of Information Processing Science in Oulu, there had emerged a software engineering thread to the ADP industry.

Cooperation thread in software engineering research

In 1974, VTT established the Laboratory of Electronics in Oulu. The new laboratory got a full mandate to implement VTT's general mission in all of Finland – to help industry to develop its competitiveness. This meant that the laboratory services had to be marketed in the whole country, not only in Northern Finland. The laboratory interpreted this general mission with the goal of creating new industrial and commercial business by positioning its role as an applied research partner between basic research and industrial product development.[71]

During the 1970s and early 1980s, professor Veikko Palva was the director of VTT's Division of Electrical and Nuclear Technology. Professor Palva encouraged the new laboratory to strengthen its relationships with the University of Oulu in software related issues.[72] He had a vision to develop the VTT Oulu competence on embedded software engineering and this was crucial to the growth of software engineering skills in Oulu area. Eventually this led to an increasing amount of cooperation with the Department of Information Processing Science.

[71] Kulju, pp. 63-69.
[72] Martti Karppinen, Minutes of a telephone call, 21.2.2003.

Internally financed research projects were started with main objectives to develop the laboratory's own competence to help companies in developing software components and production as part of electronic products. Basic skills in software engineering were developed by implementing the first post-graduate course in software engineering[73] followed with regular courses in software engineering for electrical engineering students at the University of Oulu. This constituted a basic seeding of potential growth on software engineering knowledge base with the hope of hiring qualified employees to VTT and industry in the future. National information technology conferences like Blanko and Elkom were participated by giving presentations on software engineering.[74] One aim with these activities was general marketing of VTT as a product development partner in software engineering.

As the new electronics products increasingly included embedded software parts, the VTT laboratory in Oulu started to pay attention to this technology area as well. During the spring cooperation with the Department of Information Processing Science had already been started with one student project. A further change came in the early 1980s.[75] VTT started a new research program in software engineering environments in 1981[76]. With the emphasis in software engineering in mind, VTT hired its first scientist with a post-graduate degree in technical physics and electronics, Samuli Saukkonen - later since 1990 one of the professors of the Department of Information Processing Science - to develop the laboratory's competence in the field of software engineering.[77]

---

[73] M. Pietikäinen, H. Hakalahti (eds.), *Ohjelmointitekniikka* (Software engineering, in Finnish), (Oulu: University of Oulu, Department of Electrical Engineering, 1979).
[74] S. Saukkonen, *Mikrotietokonesovellusten kehittäminen* (Development of microcomputer applications), in Finnish, Blanko '79, 1.10.1979, Oulu, 4 p; S. Saukkonen, "Ohjelmistotekniikka mikrotietokonesovelluksissa," *Mikrotietokoneiden ohjelmointi*, osa 3, ("Software engineering in microcomputer applications", Programming microcomputers, part 3), in Finnish, (Helsinki: Insinööritieto, 1980), pp. 155-80; S. Saukkonen, *Ohjelmoinnin apuvälineet* (Programming tools), in Finnish, Blanko '81, Oulu, syyskuu 1981, 3 p; S. Saukkonen, *Mikrotietokoneiden uudet tehokkaat ohjelmointiympäristöt* (New efficient programming environments for microcomputers), in Finnish, ELKOM '81, Helsinki, 12 p; S. Saukkonen, *Ohjelmistoinsinöörin työkalut* (Software engineer's tools), in Finnish, Elektroniikkapäivät '85, Helsinki 13.-15.3.1985, 7 p.
[75] "Ohjelmistoteollisuus kasvamassa Suomessa" (Software industry grows in Finland), *Kaleva*, 3.6.1982, p. 5.
[76] "VTT:lle uusia tutkimusohjelmia" (New research programs in VTT), *Kaleva*, 15.10.1981, p. 15.
[77] Martti Karppinen, Minutes of a telephone call, 21.2.2003.

In the beginning of 1983, the Laboratory of Computer Technology of VTT (TKO) was established by taking the Computer Technology section out of the Electronics laboratory (see Figure 1). Samuli Saukkonen became the first director of this laboratory. He continued and deepened the cooperation with the Department of Information Processing Science in software engineering research. Cooperation between the Department of Information Processing Science and the new laboratory at VTT was started in 1983 in the form of common research projects especially in embedded software. The Tekes (*Teknologian kehittämiskeskus*, the National Technology Development Centre) funded research project focused on software requirements and specification methods for embedded software and a subproject on conceptual models of embedded systems describing the fundamental elements of embedded systems and their development from the software point of view.[78] The forerunning and fundamental project opened the eyes of many technically oriented engineers to see the importance of a wider systems perspective to software development. Eventually this effort also led to the establishment of a new software engineering study alternative in the Department of Information Processing Science's curriculum in 1986.

During 1981-1985 VTT Electronics laboratory started also developing a general purpose Software Engineering Environment for industrial microprocessor software application development. By 1982 the term embedded software was launched to denote microprocessor based applications. Key persons behind the initiative at VTT were Samuli Saukkonen, Pekka Kemppainen and Tuomo Tuomikoski – who all had educational.backgrounds in electronics. The project's funding came from process automation, machine building, and telecommunication companies in Finland. A very advanced toolbox of software engineering methodologies supporting the so called "Waterfall" process model[79] was constructed. Explicit support for requirements specification[80], version control and configuration management, code size, labor, and

[78] J. Iivari, E. Koskela, M. Ihme, I. Tervonen, *A Conceptual Model for Embedded Software and its Production*, (University of Oulu, Institute of Information Processing Science, Research papers series A7, 1986, 184 p).
[79] W. Royce, "Managing the Development of Large Software Systems: Concepts and Techniques," *Proceedings*, WESCON (1970).
[80] SADT (Structured Analysis and Design Technique).

schedule effort estimation using Boehm's approach[81], and use of email as communication media in software development projects constituted the main results of the project.

Research on software engineering environments was influenced by the theoretical research on software development methodology for information processing systems carried out at the University of Oulu, the Department of Information Processing Science. Retrospectively one of the most important contributions was the thinking in *abstraction layers*, which dates back to the research by Professor Pentti Kerola and Juhani Iivari in the 1970s[82]. The main penetration of abstraction layer thinking reshaped the traditional Waterfall process model based on sequential tasks and milestones. This novel thinking and interpretation allowed early adoption of Ward & Mellor Structured Analysis for Real-Time Systems (SA/RT) methodology[83] when it was launched in USA in 1984-1985. This methodology was highly superior to earlier specification and design methodologies because it provided explicit support for real-time embedded software development via the mechanism of finite state machines, and precise semantics of modeling language elements[84]. Later research at the department led to a software engineering process model and methodology, Bootstrap[85], which gave increased support to project management and process improvement. Another noticeable development took place in 1987 by a startup company Insoft[86] who developed a computer-aided software engineering tool "Prosa" . The Insoft founders were Dr Mikko Tervonen and Hannu Lehikoinen whose backgrounds were University of Oulu Electrical Engineering department and VTT Electronics. Prosa tool advanced adoption of SA/RT methodology in Oulu region companies.

---

[81] Barry Boehm, *Software Engineering Economics* (New York: Prentice Hall, 1982).
[82] Juhani Iivari, "Taxonomy of the experimental and evolutionary approaches to systemeering." *Proceedings of the IFIP TC 8 Working Conference on Evolutionary Information Systems*. (Amsterdam: North-Holland, 1981), pp. 261-277.
[83] P.T. Ward & S.J. Mellor, *Structured Development for Real-Time Systems*. Vol. 1-3. (New York: Yourdon Press, 1985).
[84] P.T. Ward "The transaction schema: en extension of the data flow diagram to represent control and timing," *IEEE transactions on Software Engineering* 12. 2.1986, pp. 198-210.
[85] P. Kuvaja, J. Similä, L. Kraznik, A. Bicego, S. Saukkonen & G. Koch, *Software Process Assessment & Improvement – The BOOTSTRAP Approach* (Oxford: Blackwell Publishers, 1994).
[86] http://www.insoft.fi/

The cooperation with the Department of Information Processing Science influenced also the first PhD thesis on software engineering in VTT and the University of Oulu[87] by giving grounds for the development of a design approach for real-time embedded software. International research cooperation was started with the help of Professor Pentti Kerola's widespread networks in research community. Veikko Seppänen, a graduate from the Department of Electrical Engineering and later in the 1990's one of the professors at the Department of Information Processing Science, was the first PhD student to be sent abroad to the well-known software engineering research group of Professor Peter Freeman, University of California at Irvine. The visit abroad led to Seppänen's PhD at the Department of Electrical Engineering on software component reuse[88]. PhD training and implementation of industrial projects with applied research in focus were significant in growing a group of professional PhD level researchers. Also the VTT initiated possibility for persons with a background in electronics to partake in the research with the Department of Information Processing Science and later to join the department had a remarkable role in the evolution of software engineering research and education at the University of Oulu.[89]

Large research projects were also carried out emphasizing development of new practices and software engineering environments for electronics companies. Major technology transfer projects from the early 1980s were the development of product configuration management practices for Telenokia Oy (later Nokia Networks) and software project planning and management practices for Mobira Oy (later Nokia Mobile Phones)[90]. One of the largest efforts (tens of man-years) was the development of an expert system generating customized software packages for elevators manufacturer Kone Oy. VTT Oulu laboratories' focus on embedded software engineering research made possible a further growth of a critical mass of researchers.

---

[87] Samuli Saukkonen, *A Constructive Method for the Architectural Design and Correctness Verification of Real-Time Programs*, (Acta Polytechnica Scandinavica, Ma 40, ISBN 951-666-170-X, 1983, 122 p. PhD thesis).
[88] Veikko Seppänen, *Acquisition and Reuse of Knowledge for Directing the Construction of Embedded Software*, (Technical research Centre of Finland, Publications 66, Espoo, 1990. 218 p. Ph.D. thesis).
[89] In the beginning of the 1990's one third of the professors at the Department of Information Processing Science had a post-graduate degree closely related with electronics. Presently the percentage is about 26% and 37% if graduate degrees are taken into account. Since the late 1980's all students in electrical engineering have taken their introductory courses in programming, algorithms and data structures from the Department of Information Processing Science.
[90] P. Kemppainen, *Mobira Oy:n ohjelmistotyön käsikirja (Manual for software engineering at Mobira OY)*, in Finnish, V1.1 7.5.1984. 97 p.

This was only possible due to the close cooperation with the University of Oulu and especially with the Department of Information Processing Science where the culture of internationally respected basic research on information systems was highly developed.

Thread to Mobira, later Nokia Mobile Phones

Due to reorganization of several Finnish companies in telecommunication and television production a new company, Mobira Oy (see Figure 1), was formed on operations based in Salo, southern Finland, in 1979. Nokia Oy and Hollming shipyards, which had to Nokia's surprise succeeded to buy Salora Oy just few months earlier, established Mobira as a joint venture.[91] Significant were Nokia's organizational changes in 1979. As a result Nokia's civilian radio telephone factory was transferred to Mobira Oy.[92] In the next phase during late 1980s, Nokia finally bought Hollming out after some bitter in-house conflicts. Later, in the beginning of 1990s Mobira's name was changed and it became nowadays so well-known Nokia Mobile Phones[93] – birth of a giant[94]. Of course, none of this was seen in those days when Mobira was established. It was just a wobbling company with only 200 employees spun out of a big industry reorganization.

VTT Electronics laboratory in Oulu had employed a brilliant hardware designer, Lauri Vatjus-Anttila. He had specialized in design using low-power consuming CMOS[95] logic circuits. Vatjus-Anttila had also become an expert in RCA[96] 1800 Cosmac 8-bit CMOS-processor.[97] During the early 1980s it was the only proper general-purpose CMOS processor. In 1983, Vatjus-Anttila started an important project for the then little known Finnish company Mobira, and the project's goal was to design the processing and memory unit for new generation NMT[98]/TACS[99]/AMPS[100] cellular car

---

[91] Häikiö, *Nokia Oyj:n historia, 1*, 228, 276 – 278; History of Hollming. http://www.hollming.fi/history_business.html#.
[92] Heikura, pp. 148, 149, 156, 157.
[93] "Suomalaisen sähkö- ja elektroniikkateollisuuden laajentuminen 1980-luvulla" (Expansion of Finnish electrical and electronics industries during 1980's), in Finnish. http://www.info.uta.fi/winsoc/ajankohtaista/hist.htm#9.
[94] Nokia is currently the leader in mobile phone manufacturing and sales in the world measured in global market share.
[95] Complementary Metal-Oxide Silicon.
[96] Radio Corporation of America.
[97] RCA 1802 Processor. http://www3.sk.sympatico.ca/jbayko/cpu2.html#Sec2Part1.
[98] Nordic Mobile Telephone – analog cellular phone system standard in Scandinavian countries.

telephone. He ended up designing a radical architecture, which introduced two CMOS processors including Cosmac for the radio unit and Hitachi 4-bit processor[101] for handset user interface. A serial link enabled the radio unit to communicate with the handset processor: a breakthrough in convenience of use was done, as now the thick parallel signal "bullworker" cable could be replaced with thin flexible cable.

Mobira's engineers planned to build the software for the cellular car telephone by themselves, but they soon realized that the aggressive schedule agreed with the contract of the UK TACS system version ordered by Vodafone UK[102] could not be met. At that time Vodafone was just a little known startup operator[103]. Mobira's desperate move was to order the TACS version software development project from VTT Oulu. This was a realistic move since they already knew the VTT Oulu people from the hardware development. The VTT Oulu people were confident that they could tackle and accomplish any software project. This self-confidence was based on the new methodologies which they had acquired within the software engineering environments research. The radio unit software project was led by two Oulu university educated engineers, Jukka Korhonen and later by Erkki Veikkolainen, and Handset unit software project by one of the authors, Petri Pulli - a graduate and later a doctor from the Department of Electrical Engineering and since 1999 one of the professors of the Department of Information Processing Science. This again clearly highlights threads from these University of Oulu departments continuing via the VTT intermediary thread to the ICT industry. Also, it points out how innovation threads connected university departments with each other. By 1984 the software projects for both processors were completed a few months overtime after typical struggling with software errors and performance optimization. However, when all other parts of the Mobira's project were significantly late, and the Oulu based TACS part was just a little late, competence found in Oulu became visible and it achieved an excellent reputation.

---

[99] Total Access Communication System - U.S. analog cellular phone system standard.
[100] Advanced Mobile Phone Service - U.K. analog cellular phone system standard.
[101] HMCS40 Series 4-bit microcontroller able to drive liquid crystal display directly.
[102] Vodafone. http://www.vodafone.com/.
[103] Vodafone started in 1982 as a subsidiary of Racal Electronics bidding for the private sector UK cellular license. Vodaphone is currently world's biggest mobile operator by number of subscribers.

Mobira hired Erkki Veikkolainen to set up a software development unit based in Oulu[104]. He used his links and experience, and effectively hired the first employees from the VTT and the University of Oulu. Software developers as well as hardware and integrated circuit designers were hired. One of his major recruitments was University of Oulu educated Juha Rapeli[105], who had a major role in development of Mobira's first "one piece" cellular phone, the legendary Mobira Cityman 450/900.[106] Rapeli became later one of the key architects for the 2nd generation cellular phone system GSM[107].

This new Mobira (or Nokia) software development unit received software engineering expertise, which was carried over from VTT Oulu in "leather folders", i.e. in the heads of the key persons hired by Erkki Veikkolainen. The new Mobira unit was also to supervise R&D projects within University and VTT[108]: the connection between VTT and Mobira stayed very close and trustworthy, and the innovation thread clearly visible.

Successful Mobira Oulu software unit turned out capable of cranking out software projects very reliably and in time. It gained respect and credibility inside Mobira, which consequently allocated more project responsibilities to Oulu. This meant growth also for the hardware and application specific integrated circuit design (ASIC) personnel. Soon Oulu was exporting software engineering know-how, which remarkably resulted from the main ICT innovation threads in Oulu. These Oulu-originated innovative threads did lead to other Mobira mobile phones sites in Finland and abroad. Mobira later in the beginning of 1990s changed its name. The Oulu Mobira software unit became Nokia Mobile Phones Oulu.

---

[104] "Mobira hajasijoitti ohjelmistoryhmän Ouluun," (Mobira decentralized a software group into Oulu), *Kaleva,* 12.10.1985, p. 20.
[105] Juha Rapeli. http://www.ee.oulu.fi/~rapeli/
[106] Mobira Cityman. http://www.rigpix.com/mobphoneana/mobira_cityman.htm.
[107] Global System for Mobile Communications – digital mobile communication standard.
[108] Nokia in Finnish Innovations system.
http://www.etla.fi/english/research/publications/searchengine/pdf/dp/dp811.pdf.

Innovation threads that spun clusters

Clearly there were matters running through the ICT innovation in Oulu in 1960—1990. The Scientific Innovation thread deriving from the university departments runs stable through the time period and through its phases of Electrical Engineering, Electronics and Software Engineering. The Transfer and Infrastructure thread did cover the period quite well even though it did not do that in the absolute sense. The Exploitation & Business Innovation thread can be divided into main groups or clusters: 1) a cluster of Production of electrical engineering and electronics including also the cable industry which created an important "prehistory" in Oulu, 2) Telecommunications cluster and 3) Software cluster. There also appear to be companies which are part of more than one cluster. We name these as polycluster companies.

Innovation threads to the companies within clusters have specific features which enable their naming: e.g. a pioneer position reveals a starting thread to Kajaani Oy Elektroniikka. Innovation threads can also refer to a technology or a methodology: e.g. thick film hybrid circuit thread – Aspo Oy. Innovation threads can as well refer to certain consumer goods or products: e.g. thread to radiotelephones – Nokia.

Innovation threads clearly had an effect vertically outside of the university, but it is interesting to note that they also had an influence horizontally between the departments of the university. The effect could be direct, but it could be also indirect due to an intermediary. This is understandable as most of the time co-operation was the key word and together main innovation threads spun new entities or clusters.

As shown in Table 1, we have found four major industrial clusters which have contributed strongly to the growth in Oulu region[109]. Further, we explain birth of each cluster to have been launched from the underlying cluster by innovations breaking out of the technological envelope of the underlying cluster.

[109] Our analysis is retrospective, so these clusters may not have been so obvious to the contemporary observers.

Industry Cluster	**Birth Innovation**	**Growth Envelope**	**Breakout Innovations**
Electrotechnical 1960-1970	Electric Power Distribution Network	Cables and Wiring	Electronics
Electronics (1968-)	Thick-Film Hybrids	Electronics Manufacturing	Low-Power Electronics Sensors
Telecommunications (1972-)	US Military Radio License	Wireless Telecommunications	Software Production Production Testing
Software (1974-, 1982-)	ADP Systems	Software Projects	Embedded Software Software for Mobile Phones

Table 1: Detailed industry cluster table derived from innovation threads analysis

The innovation threads were noteworthy factors to be traced as themselves, but when connected to the clusters they spun, their value as research objects gained further weight. Also, when they are interpreted, a theoretical but empirically observed growth pattern can be proposed on the basis of this historical analysis:

Our interpretation of the “success formula” for Oulu region has been the following:

1. (a) Leading-edge academic research on a diverse portfolio of industry-relevant topics and dissemination of research results to the industry. Research precedes industrial take-up by at least 5 years in time horizon. (b) Academic researchers becoming entrepreneurs and bringing their innovations to existing companies or new start up companies (Cycle ~5... 15 years)
2. (a) Profitable industrial cluster that wishes to expand, diversify and renew its product portfolio using new opportunities provided by innovations coming within the industry and from academic research. (b) Restructuring of industry

where new products or product lines are spun-off from the mother company for faster growth. (c) Fast growing companies form a cluster that becomes a new industrial base for diversification. (Cycle duration ~ 5 - 10 years)

3. (a) Attraction of company subsidiaries by availability of educated human resources for hiring, knowledge and critical mass of infrastructure, industrial base and relevant services. (b) Attraction effect takes 5 – 10 years to propagate to companies outside the region.

The ICT innovation threads beginning in Oulu were, of course, significant for the region, but they did not just limit their influence to the region of origin. Due to advancing free trade, globalization and world economy the threads and their traces, if followed beyond the region of origin, could be spun together with other threads.