DEVELOPMENT IN THE GROWTH BASE OF THE 'OULU PHENOMENON'

The role of systems/software methodologies

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Abstract: Oulu has been a place for business and export industry in Northern Finland. In the 1970s began a difficult period of recession. Then, declining and unemployment-ridden Oulu seemed unexpectedly to start to boom. High technology products were being produced in the city and these products were sold more and more in international market. The main contribution of the paper is to provide a more thorough view of the multi-scientific expertise apparent in the gradual building of the growth base of the 'Oulu phenomenon'. The analysis shows the crucial role of system-theoretical and software-oriented expertise and complements earlier views.

Key words: Systems software, Oulu, computing history, Finland

1. INTRODUCTION

Oulu has a long history as a place for business and export industry in Northern Finland. In the Middle Ages especially fish, butter, train oil, furs,

and hides found their ways to the European market. Later, important were tar export, shipping, and shipbuilding in the seventeenth and eighteenth centuries, leather industry in the nineteenth century and forest and chemical industries in the first half of the twentieth century. In the 1970s, due to international and domestic reasons, began a difficult period of recession and unemployment.[1]

Then, declining and unemployment-ridden Oulu seemed unexpectedly to start to boom. The city began producing high technology products with embedded software and sold these products more and more in international markets. Local people and authorities seemed to believe again in progress and improvement on their life conditions and economy in the region. This overall change was and is an unanticipated and astonishing "jackpot" — the term Oulu phenomenon (*Oulu-ilmiö*) soon appeared. This major change was not ignored abroad either. Various kinds of delegations from different parts of the world flocked to estimate the situation in Oulu and to learn from it. Others wanted to have their success story realized,. too. Foreign and domestic journalists wrote their wonder stories.[2]

We often view the Oulu phenomenon as a triumph of electronics. However, nobody has unambiguously defined the duration or actual content of the Oulu phenomenon.[3] Here, the first basic idea is that the life span of the Oulu phenomenon has not come to its end. Second, existing high technology products in question such as sophisticated mobile phones need software to function. These products contributed to the development of systems, the software industry, and information processing science in the Oulu region even when we consider the period preceding 1985. Furthermore, the Department of Information Processing Sciences (*Tietojenkäsittelyopin laitos*, later *Tietojenkäsittelytieteiden laitos*, TOL) in Oulu University was not a concrete outgrowth of the Oulu phenomenon. Why is this so? Has the department, contrary to the general assumption, actually had essential but more abstract and infrastructural effects on the growth of the Oulu phenomenon?

[1] 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.

[2] 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.

[3] 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.

To the main question, we seek answers through variety of sources. As a starting point, the major newspaper in the Oulu region, *Kaleva*, has actively taken part in the discussion concerning the Oulu phenomenon. This and the published literature concerning high technology and its research in the large do not solely form the source base. Most of the authors of this paper have experience of different kind of scientific backgrounds, paradigms, and even practical careers in computing. In the following chapters, we first describe the birth of the 'Oulu phenomenon' as portrayed in the *Kaleva* newspaper. Then we present the University of Oulu from the viewpoint of computing and analyze the role of TOL as a source of basic research in information systems (IS). Then we describe and discuss the major relationships and co-efforts with other faculties, the City of Oulu, the Technical Research Centre of Finland (VTT, *Valtion teknillinen tutkimuskeskus*), and local industries. Finally, we make significant conclusions with some lessons learned for the future benefit of Nordic computing.

2. THE BIRTH OF THE 'OULU PHENOMENON' IN KALEVA

In order to provide the background for the analysis of the factors behind the growth of the 'Oulu phenomenon,' we provide here a brief account of the chronological flow of events based on the articles published in the local *Kaleva* newspaper between the years 1969 and 1985. The role and importance of the influence of the Department of Electrical Engineering (later electrical and information engineering) on the growth of the Oulu phenomenon has been recognized repeatedly in the public and is clearly supported by historical evidence. Matti Otala[4] and Seppo Säynäjäkangas[5] as professors and directors of the department publicly spoke and wrote about the importance of electronics research and industry for the future of Oulu and the whole of Northern Finland numerous times during the late 1960s, through the 1970s and early 1980s. In addition, Professor Pentti Lappalainen after his appointment in 1974[6] and later as the director of the department continued the theme. VTT came to support the idea.

[4] "Elektroniikan tutkimustyötä Oulun yliopistossa" (Research work in electronics at the University of Oulu), *Kaleva,* 13.9.1969, p. 4; "Elektroniikan teollisuus on hyvässä myötätuulessa" (Electronics industry in good downwind), *Kaleva,* 10.8.1971, p. 3.

[5] Professor Seppo Säynäjäkangas, "Elektroniikka muuttaa maailmankuvaamme" (Electronics will change our world view), *Kaleva,* 12.6.1976, p. 2.

[5] Professor Pentti Lappalainen, "Helmitaulusta tietokoneeseen" (From an abacus to a computer), *Kaleva,* 12.5.1976, pp. 2, 4.

After the planning[7] and finally the establishment of the Laboratory of Electronics in Oulu in 1974[8], the directors of the Oulu branch came to support the creation of electronics industry in Oulu. Again, we see in the articles the promotion by Otala[9] in his new role as the director of the laboratory and the active role of Martti Karppinen[10] as vice-director as well as Jarmo Karvonen[11]. Later during the 1980s, Samuli Saukkonen[12], in his role as the director of the laboratory (established in 1983), continued the support of computer technology.[13] Additionally, on a general level, the University of Oulu actively supported the promotion of electronics industry in the 1970s and thereafter. The active roles of Rector Markku Mannerkoski[14] (in the context of adp education[15]) and of Olavi Jakkula[16] already emerge from *Kaleva* during mid 1970s. VTT and the University of Oulu established an advisory board led on the university side by Professor Juhani Oksman, who at that time was the dean of the technical faculty and later the rector of the university. The advisory board formed a general cooperation agreement in 1974[17] that was the basis of the common public support for electronics industry. After the polemical public appearances of Antti Piippo in 1979[18] and 1980s[19] as executive director of Aspo Electronics,

[7] "Tutkimusta lisää Pohjois-Suomeen? VTT:n haaraosasto perusteilla Ouluun" (More research in Northern Finland? VTT's branch office to be established in Oulu), *Kaleva,* 4.2.1972, p. 11.

[8] "VTT aloittaa Oulussa 1.3" (VTT starts in Oulu 1.3), *Kaleva,* 16.2.1974, p. 1.

[9] Professor Matti Otala, VTT, "Elektroniikassa kaikki mahdollista" (In electronics everything is possible), *Kaleva,* 15.9.1975, p. 5.

[10] "Tuotekehittelyn merkitys kasvaa" (Importance of product development grows), *Kaleva,* 2.3.1978, p. 13.

[11] "Yritysten syntymistä tuettava tehokkaammin" (Birth of companies should be supported more effectively), *Kaleva,* 25.2.1980, p. 10.

[12] "Elektroniikan ohjelmakehitys keskittymässä Oulun seudulle" (Electronics program development concentrating in Oulu area), *Kaleva*, 19.5.1984, p. 20.

[13] "Tietokonetekniikan laboratorio Ouluun" (Laboratory of computer technology in Oulu), *Kaleva*, 4.3.1983, p. 15.

[14] "Oulun yliopisto avasi ovensa: Mannerkoski uskoo teknologiakylään" (University of Oulu opens its doors: Mannerkoski believes in technology park), *Kaleva*, 2.9.1982, p. 6.

[15] "Lisää atk-opetusta: Automaattinen tietojenkäsittely laajenee nopeammin kuin jähmeä koulutus- ja työllisyyssuunnittelu" (More adp education: Automatic data processing expands faster than sluggish education and employment planning), *Kaleva,* 3.11.1982, p. 2.

[16] "Mallia brittien tukitoimista: Elektroniikka-alan kehittämistä tutkitaan" (Model from Brittish support actions: Investigation of development of electronics industry), *Kaleva,* 6.10.1976, p. 6.

[17] "VTT ja Oulun yliopisto aloittavat yhteistyön" (VTT and University of Oulu start cooperation), *Kaleva,* 31.8.1974, pp. 1, 2.

[18] "Komponenttituotanto tulossa elektroniikkateollisuuteemme" (Component production coming into our electronics industry), *Kaleva,* 15.10.1979, p. 9.

the City of Oulu[20] also actively and massively started to promote the electronics industry, especially the establishment of an electronics park in Oulu that finally came about in 1982.[21] We did not observe a public link regarding the role of TOL to the growth of the Oulu phenomenon and we will investigate that later, largely based on the connections made in the chronological analysis of events in this section.

2.1 Two technological tracks apart

Looking at the historical evidence through the *Kaleva* newspaper articles between the years 1969-1985 there seem to be two parallel but separate technological tracks. One points to the growth of the electronics industry and includes the starting of the Eurodata company in Kempele in 1973,[22] the establishment and enlargement of the Nokia electronics factory in 1974[23] and the Aspo electronics factory in 1975[24] both in the Rusko area, and the establishment of Polar Electro in Kempele in 1977.[25] The electronics track led finally through several growth years to the establishment of the electronics park initially as a haven in the centre of the city[26] for several small companies in various industrial and service areas and later in the Linnanmaa area in 1986 as a real technology park[27] (called later as Technopolis) for future global telecommunication companies. Mobira, which was to become Nokia Mobile Phones, started its operations in the

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[19] Antti Piippo, Aspo, "Oulu ei oivalla missä mennään" (Antti Piippo: Oulu does not realize where we are going), *Kaleva,* 25.2.1980, p. 10.

[20] "Elektroniikkakylästä vauhtia" (Momentum from electronics park), *Kaleva,* 25.2.1980, p. 10; Oulusta on päätetty tehdä Suomen elektroniikkateollisuuden keskus (Oulu has been decided to become the centre of electronics industry in Finland), *Kaleva*, 2.2.1981, p. 10.

[21] "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.

[22] "Eurodatan elektroniikkatuotanto uusilla urilla" (Eurodata's electronics production in new tracks), *Kaleva,* 10.8.1975, p. 2.

[23] "Elektroniikkatehdas vihittiin" (Electronics factory inaugurated), *Kaleva,* 4.5.1974, p. 7.

[24] "Ouluun lisää elektroniikkateollisuutta" (More electronics industry in Oulu), *Kaleva,* 4.7.1975, p. 1.

[25] "Oulun teknologiakylän toimintaidea palkittiin" (Business idea of Oulu technology park awarded), *Kaleva*, 8.4.1984, p. 7.

[26] Pekka Siltanen, "Korkean teknologian tyyssijaa synnytetään Oulun keskustaan" (Stronghold of high technology in centre of Oulu), *Kaleva*, 19.10.1982, p. 10.

[27] "Oulun teknologiakylän osakkeista yleisöanti: Varoilla siirto Linnanmaalle" (Public issue of shares of Oulu technology park: funds used for transfer to Linnanmaa), *Kaleva*, 23.11.1984, p. 3; "Teknologiakylä aloittaa rakentamisen Linnanmaalla" (Technology park starts building in Linnanmaa), *Kaleva*, 26.9.1985, p. 18.

technology park in 1986 and was later followed by globally successful companies though on a clearly lower scale.

The other track follows the 'normal' development of automatic data processing (adp) which the Institute of Information Processing Science (the name Department of Information Processing Science was adopted in 1987) was identified with during the 1970s and early 1980s. This includes the establishment of the yearly Blanko conference series in 1973 and the founding of the first systems and software companies in the late 1970s - among others Dataskill in 1976, Systepo in 1979[28], Modera in 1982[29], and CCC in 1985. Computer manufacturers established also offices in Oulu, for example Nixdorf in 1979[30] and HP in 1981[31]. According to *Kaleva* the Finnish adp industry passed the era of 'quiet life' in 1979[32] and the adp processing association[33] called for more education in all levels at that time. The Adp-82 days in Helsinki[34] repeated this call in 1982 and estimated next year the need of new employees in the industry to be between 1500 and 2000.[35] Even later public calls for increase in adp education[36] were not realized in the yearly student intake of the department which slowly rose from the first 10 in 1972 to the level of 25 in 1985 – later the intake again

[28] "Atk palveluyritys käyntiin Oulussa" (Adp service company starts in Oulu), *Kaleva,* 3.3.1979, p. 12.

[29] "Yliopistomiesten atk-yhtiö tarjoaa tietoa yrityksille" (University men's adp company offers know-how to industry), *Kaleva*, 6.11.1982, p. 16.

[30] "Uusi tietokoneyhtiö perustettu Ouluun" (New computer company established in Oulu), *Kaleva,* 4.9.1979, p. 10.

[31] "Atk-ala uskoo kasvun jatkuvan" (Adp industry believes growth to continue), *Kaleva*, 22.10.1981, p. 15.

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

[33] "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.

[34] Robert Brantberg, "ATK-82: Toimistoautomaatio, ATK ja tietoliikenne yhdistyvät" (ADP-82: Office automation, ADP and data communication converge), *Kaleva*, 4.3.1982, p.14.

[35] "Atk-ammattien veto jatkuu voimakkaana" (Pull of adp professions continues strong), *Kaleva*, 19.12.1983, p. 8.

[36] 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.

slowly increased to 45 by 1996 wherefrom it dramatically expanded to the present 250-300 level in only six years.

Looking at the Blanko conference themes (see footnote)[37], we notice that despite the fact that in the first Blanko conference in 1973[38] both professor Matti Otala from the Department of Electrical Engineering and professor Pentti Kerola from the Institute of Information Processing Science presented their respective education curricula and despite the fact that electronics was one of the main themes in Blanko in 1981[39], the Institute of Information Processing Science as well as the Blanko conference series profiled themselves mainly in basic research of information systems. It emphasized the human and organizational aspects especially through Professor Kerola's articles and presentations[40] in the 1970s and early 1980s. This profile

[37] "Tietojenkäsittelyn käytäntöön perehdytään" (Data processing practices discussed), *Kaleva,* 1.11.1975, p. 5; "Blanko-75 Oulussa – ATK-opetus palvelee käytännön työelämää" (Blanko-75 in Oulu – ADP education serves practical working life), *Kaleva,* 28.11.1975, p. 2; "Oulun Blanko-päivät: Kotimainen tietokone 'täysin mahdollinen'" (Oulu's Blanko days: Domestic computer "fully possible"), *Kaleva,* 29.11.1975, p. 4; "Tietojenkäsittely inhimillisemmäksi" (Data processing more humane), *Kaleva,* 25.11.1977, p. 11; "Tietojenkäsittely tulee yksilölliseksi" (Data processing becomes more individual), *Kaleva,* 3.10.1978, p. 1; Professor Yrjö Neuvo, "Automaatiokeskustelu Suomessa hakoteillä" (Discussion on automation in Finland off the track), *Kaleva,* 2.10.1979, p. 13; "Blanko-päivät tulossa: Atk:n käyttäjä vahvasti esillä" (Blanko days coming: Adp user strongly on view), *Kaleva,* 16.9.1980, p. 14, "Blanko-81: Atk-järjestelmä ei ole valmis ensi yrittämällä" (Blanko-81: Adp system is not ready on first try), *Kaleva,* 17.9.1981, p. 15; "Blanko-81: Käyttäjä oppii systemointia" (Blanko-81: User learns systemeering), *Kaleva*, 18.9.1981, p. 13; "Blanko-81: Nyt atk tulee konttoreihin" (Blanko-81: Now adp comes to office), *Kaleva*, 19.9.1981, p. 6; "Blanko-päivät kansainvälistyvät" (Blanko days becoming more international), *Kaleva*, 2.11.1982, p. 13; "Blanko osoitti jälleen elinvoimaisuutensa" (Blanko shows again its vitality), *Kaleva*, 13.11.1982, p. 18; "Uutta tietotekniikkaa puntaroidaan Oulussa" (New information technology deliberated in Oulu), *Kaleva*, 9.8.1985, p. 14; "Helsingin keskityspyrkimykset torjutaan: Blanko-näyttelyllä vakaa asema tulevaisuudessakin" (Helsinki's centralization efforts countered: Blanko exhibition has a strong status also in the future), *Kaleva,* 27.9.1985, p. 8; "Tietotekniikkapäivät: Suomalaisella tietokonetekniikalla 'ruusuinen tulevaisuus'" (Information technology days: Finnish computer technology has a "rosy future"), *Kaleva,* 28.9.1985, p. 18.

[38] "Blanko -73 kertoo tietojenkäsittelystä Pohjois-Suomessa" (Blanko-73 tells about data processing in Northern Finland), *Kaleva,* 8.10.1973, p. 3.

[39] "Blanko-päivät laajenevat: Elektroniikka-ala mukaan" (Blanko days expand: Electronics industry joining), *Kaleva*, 19.6.1981, p. 14.

[40] Pentti Kerola, "Tietokone ihmisen auttajana" (Computer as man's assistant), *Kaleva,* 18.12.1977, p. 2; Pentti Kerola, "Tietokone on nopea idiootti" (Computer is a fast idiot), *Kaleva,* 19.12.1977, pp. 2, 12; "Atk-suunnittelu kuin arkkitehdin työtä" (Adp design similar to architect's work), *Kaleva*, 30.9.1980, pp. 1, 5; Robert Brantberg, "Ihminen on tärkein tietojenkäsittelyssäkin" (Human is most important also in data processing), *Kaleva,* 12.4.1981, p. 9; "Tietotekniikalle otetaan uutta suuntaa: Ihmiskeskeisyys valttia

emphasized general system-theoretical deep structures in the departmental curriculum as can be seen in a later section.

2.2 A pivotal change

A change came in the early 1980s.[41] VTT opened a new research program in software engineering environments in 1981[42] and cooperation between TOL and especially the local computer technology laboratory was started in 1983 in the form of common research projects especially in embedded software. This led to the establishment of a new software engineering study alternative in the TOL's curriculum in 1986.

The Oulu phenomenon appears to have two faces – the public face is the growth of the electronics and telecommunication industry and the lesser publicized the growth of the software industry. The relevance and importance of the cooperation between VTT and TOL in the transfer of methodological knowledge and expertise to the electronics and telecommunication industry will be analyzed more deeply in two later sections. The role of TOL in the growth of the software industry is more direct.

If we look at the companies operating in the adp industry during the 1970s and 1980s it is noteworthy that the adp companies were mainly established and managed by the graduates from the Institute 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[43]. Of these only CCC grew later to a nationally sizable company employing more than 500 persons presently. It seems that most graduates from TOL 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[44]. Very few, it seems, worked in the electronics industry.

We noted earlier that the two tracks were separate. This is not completely true but to a large extent and a bit surprisingly this seems to be true and is evidenced by the *Kaleva* articles as well personal experiences of the authors. There are exceptions and these are worth telling about. The

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järjestelmäsuunnittelussa" (New direction for information technology: human centredness trump in systems design), *Kaleva*, 30.4.1984, p. 5.

41 "Ohjelmistoteollisuus kasvamassa Suomessa" (Software industry grows in Finland), *Kaleva*, 3.6.1982, p. 5.

42 "VTT:lle uusia tutkimusohjelmia" (New research programs in VTT), *Kaleva*, 15.10.1981, p. 15.

43 "Atk-alan palvelujen kysyntä voimistunut" (Demand for adp services strengthens), *Kaleva*, 31.3.1984, p. 17.

44 Comp. Manninen, p. 127.

best case is Eurodata, which Kajaani Electronics bought in 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[45]. Nowadays, Fujitsu owns the company and operates it in Oulu mainly in its original application area: service station automation. The first system developed by Eurodata was, in fact, mainly subcontracted in 1977-1978 from Dataskill. Both companies had close ties to TOL. Eurodata's system group was managed by Timo Korhonen, a graduate from TOL, who later managed Edacom's system development activities until 1985 when he together with one of the authors, Jouni Similä and some other persons started the CCC companies. Another interesting fact is that the founding of CCC was based on a project contract and project personnel bought from Tietoseppo where another one of the authors, Pentti Kerola was involved for a brief period as research director at that time. Jouni Similä and Juhani Iivari from TOL were also members of the Dataskill development group. Later Jouni Similä worked on several occasions with Edacom and CCC. The product at that time was called super cash register – a clear case of embedded software. Later another one of the authors, Samuli Saukkonen also worked in Edacom in the late 1980s. One of Insele's[46] chief software designers in the early 1980s was also a graduate from TOL. Undoubtedly, there are other cases, too, but smaller ones.

The gap between electronics and information processing science remained however wide until the 1990s when Nokia in fact became a software house. This naturally led to the merging of the two technological tracks - as an example CCC became one of the most important software technology partners of Nokia even on a global scale. The seeds for the growth and the merging of the two technological tracks were sown in the 1970s and early 1980s and the fruits we are enjoying now.

2.3 Questions of size and focus

One of the reasons why the TOL institute had such a small publicly known effect in the growth of the Oulu phenomenon in the 1970s and the early 1980s is of course a question of sheer size. Seppo Säynäjäkangas reported in 1978 that during the first ten years 251 diploma engineers and 4 doctors had graduated from the Department of Electrical Engineering. Of the graduates, an essential percentage (60-70) majored in electronics[47]. In

[45] "Edacomille Ouluun suunnitteluyksikkö" (Edacom's development unit in Oulu), *Kaleva*, 8.12.1983, p. 19.

[46] "Tietokone panee lämpölaskut kuriin" (Computer clamps down on energy bills), *Kaleva,* 6.2.1979, p. 1.

[47] Professor Seppo Säynäjäkangas, "Elektroniikkainsinöörien koulutus Oulun yliopistossa" (Education of electrical engineers in University of Oulu), *Kaleva,* 7.10.1978, p. 2.

the case of TOL, the numbers of the first five years were 32 masters of science degrees and four licentiate degrees. The Department of Electrical Engineering had about 400 students in electronics by 1978; TOL had about 80 students. The trend continued all the way to the late 1990s – only now in 2003, the student admissions are on the equal scale. TOL has been, however, already from the beginning actively involved in the offering of courses as secondary subjects to students in other fields of sciences – the role of TOL in the society can be seen as larger than merely in the number of graduates.

Another reason that was already briefly mentioned was the different focus that the departments/institutes had especially before software engineering became a study alternative in TOL. While it can be argued that the education offered at TOL was a viable one (also for a career in the software development sector in electronics industry and personal experience confirms this), it seems clear that when graduating students were not given contacts through the education to the electronics industry in the same scale as to the adp industry, their primary choice for career was for adp industry. Another argument is that simply there were not as many job opportunities in the electronics industry as in the adp industry for graduates from TOL at that time – electronics and software did mix but not in the scale as now. The late 1990s have changed this completely – one can claim that Nokia is indeed a software house and the mobile phone is 90% software nowadays in terms of R&D effort.

2.4 Early role of Technopolis

The role of Technopolis has perhaps been a bit overplayed by the media throughout the years. Out of the companies mentioned here, only Modera[48] and Mobira were directly connected to the technology park. The case of Mobira[49] and its start-up in 1986 in the technology park[50] is of course an important one as it did lead through the growth of Nokia, to the establishment of numerous companies around Nokia and to the growth of the technology park. This however happened only in the 1990s. If we look at the companies that started in the technology park in 1983 none of them has grown to a nationally sizable company except those involved closely with Nokia in the 1990s. The idea that the technology park would act as a

[48] "Oulun seutu voimistuu atk-ohjelmien tuottajana" (Oulu regions grows stronger as adp software producer), *Kaleva*, 30.12.1985, p. 9.

[49] "Mobira hajasijoitti ohjelmistoryhmän Ouluun" (Mobira decentralized software group to Oulu), *Kaleva*, 12.10.1985, p. 20.

[50] "Huipputekniikan yritykset kilpailevat menosta Linnanmaalle" (High technology companies competing about moving to Linnanmaa), *Kaleva*, 23.11.1985, p. 22.

'hatchery' for new companies seems a bit over-reaching. The park has however played a major role in the growth of the Oulu phenomenon, has offered affordable rental office space, and has responded to growth needs in an admirable way.

3. MULTIDISCIPLINARY RESEARCH AND HIGHER EDUCATION OF COMPUTING IN THE OULU UNIVERSITY

3.1 Organizational and research paradigmatic context

Previous analyses agree that the University of Oulu, which was established in 1958, had a significant influence on the growth base of the Oulu phenomenon.[51] The Institute of Information Processing Science was established 1968 and it began to operate as a separate and faculty-independent unit in 1969. It had responsibility for research and education of information processing (computing), and in addition for computer and systems/software services for the whole university. As most students came to TOL from the Faculty of Science, where information processing science could be a major subject, ties to this faculty became close. Education of information processing science was coordinated in the Faculty of Science and professor Pentti Kerola became its member in 1973.[52] In Kerola's leadership research concentrated on philosophies and theories of information systems. This and the special organizational structure that forms the broad arena for information processing science in Oulu should be born in mind, when one examines the topic more closely.

In the Faculty of Science the Department of Mathematics directed by professor Paavo Turakainen was interested in theories of formal automata and languages as one subarea of mathematics. The higher education in mathematics was utilized in the master level curriculum of information processing science, partially as obligatory studies of mathematics and partially the theoretical computing courses were utilized on the voluntary basis of students.[53]

[51] *Experts trust Oulu: the secret of the "Oulu phenomenon"* (City of Oulu, Economic affairs office, 199-?), pp.6-7; Manninen, p. 274.

[52] Matti Salo, "Yliopiston kokonaiskehitys," *Oulun yliopiston historia, 1958* – 1993, pp. 109; Matti Salo, "Luonnontieteellinen tiedekunta," *Oulun yliopiston historia, 1958* – 1993, pp. 434, 435. Cooperation with the Faculty of Science was continuation to Kerola's cooperation with the Faculty of Philosophy begun already in 1971.

[53] Salo, "Yliopiston kokonaiskehitys, " p. 109; Salo, "Luonnontieteellinen tiedekunta," pp. 428, 430, 435.

In the Faculty of Technology information engineering and telecommunication research and higher education as one subarea of electronics were started in the beginning of 1970s under the direction of professor Pentti Lappalainen. A technology driven curriculum "Information Engineering" was developed for engineering students. They interacted and cooperated with TOL on the same voluntary basis, as did students of mathematics.[54]

3.2 "To better theories for best practice" – A guideline in TOL

During 1970-75 Kerola and professor Pertti Järvinen from the University of Tampere started their regular research co-effort on the basis of their practical experiences in the sixties in Finnish wood and metal industry. The main messages of practical experiences were ambiguity and high variety of successes and failures in the utilization of computing facilities and tools. Deeper awareness and understanding was clearly needed.

Kerola and Järvinen utilized philosophies and theories of prominent system theorists Ackoff and Emery, Churchman, Lange and Mesarovic, and more specifically Swedish professor Börje Langefors' core concepts of information systems[55]. Juhani Iivari and Kalle Lyytinen describe the pioneering research results as follows:

> "... The key contributions of the PSC[56] model[57] were the distinction between pragmatic and semantic level, which refined the infological realm of Langefors into two, and the formulation of a set of complicated process equations which challenged the linear lifecycle of model of IS development (sc. Waterfall model, added by us) by suggesting a dynamic and hierarchical process model for IS. The model argued that different design aspects (or levels of abstraction) such as the infological and the

[54] Salo, "Luonnontieteellinen tiedekunta," pp. 435; Matti Salo, "Teknillinen tiedekunta," *Oulun yliopiston historia, 1958* – 1993, pp. 535-537.

[55] Börje Langefors, *Theoretical Analysis of Information Systems,* (Lund: Studentlitteratur, 1966).

[56] P stands for pragmatic, S semantic and C constructive main points of view or aspects of systems analysis.
These aspects concern the efforts to answer into 'why', 'what' and 'how' questions of the information system/software to be developed and used.

[57] Pentti Kerola and Pertti Järvinen, *Systemeering II—system theoretical and cybernetic model of IS development and use*, in Finnish, (Helsinki: Gaudeamus, 1975); Pentti Kerola and Peter Freeman, "A comparison of life cycle models," *Proceedings, 5th International Conference on Software Engineering, March 9-12, 1981. San Diego, California*, (IEEE Computer Society Press, 1981), pp. 90-99.

> datalogical design aspect can and most often do proceed **concurrently**, the process is not closed to one process trajectory but may vary due to local contingencies, and that the process model is **recursive** in nature..."[58] (boldfacing ours)

The fundamental ideas of the PSC model were further elaborated into PIOCO models in Oulu, especially by Professor Juhani Iivari and Erkki Koskela.[59] This gradually extended during eighties and early nineties into the sociocybernetic approach. In it IS design is analyzed as human action, modeling it in terms of the sociocybernetic theory of acts[60]. Also, the model was extended to capture principles of object-oriented analysis and design.[61]

This research has especially influenced on the doctoral education of Information Systems Science, not only nationally in Finland, but also on the Nordic level of cooperation by special IRIS doctoral seminars, established by Järvinen and Kerola in 1978.

3.3 Interaction of theories and practice in curriculum of information systems architects and software engineers

From the early beginning of the seventies different philosophies and theoretical approaches for IS development and use have had influence on the master level education at the University of Oulu. This has been recognized by the international committee, which in the evaluation report about the Finnish research and education of computing says:

[58] Juhani Iivari and Kalle Lyytinen, "Information Systems Research in Scandinavia—Unity in Plurality," *Scandinavian Journal of Information Systems,* Vol. 10, No. 1&2, 1998, pp. 135-185.

[59] Juhani Iivari and Erkki Koskela, "The PIOCO model for IS design," *MIS Quarterly,* Vol. 11, No. 3 1987, pp. 401-419. The PIOCO models were developed on the basis of the PSC approach, especially utilizing socio-economic background theories. The PIOCO includes three metamodels of IS/SW, its development (including requirements, specification design, implementation and use) and the choice/quality criteria integrated as a hierarchical and dynamic whole.

[60] Yrjö Aulin-Ahmavaara, "A general theory of acts with application to the distinction between rational and irrational 'social cognition'," *Zeitschrift fur allgemeine Wissenschaftstheorie*, Vol. VIII, No. 2, 1977, pp. 195-220.

[61] Juhani Iivari, "Object-oriented design of information systems: the design process," in *Object oriented approach in information systems*, Proceedings of the IFIP TC8/WG8.1 Working Conference on the Object Oriented Approach in Information Systems, Quebec City, Canada, 28-31 October, 1991, edited by F. van Assche, B. Moulin, C. Rolland. (Amsterdam; New York: North-Holland; New York, N.Y., U.S.A.: Distributors for the U.S. and Canada, Elsevier Science Pub. Co., 1991), pp. 61-87.

> "TOL research group has a strong cross-disciplinary approach to information processing covering aspects of social science and computer science. The group is especially strong in IS methodologies and philosophical issues in relation to IS. It is regarded as one of the leading centres in this respect. Over and above the research topics mentioned above, significant research has taken place during seventies and eighties in the group on IS curriculum[62] ...the ideas emanating from this research have been utilized in the design of the curriculum in Information Processing Science[63]. As far as the Committee could judge, the teaching programme seemed to be a comprehensive, well-balanced IS curriculum, covering theoretical as well as applied subjects."[64]

This essential IS theoretical base has at TOL been merged to the software engineering (SE) curriculum in a balanced and synergetic manner. One interactive and cooperative subfield of this curriculum has been from the early 1970s in project/team efforts between practice organizations (local industry, communal depts. etc.) and TOL personnel and students.

An essential amount, at least some hundreds, of IS and SE professionals and managers from the late 1970s have been educated into the multiscientific and integrative worldview on computing and its utilization with human, organizational, technical and formal features in the theoretical and practical integration.

4. SYMBIOSIS OF VTT AND TOL

In 1974, VTT established the Laboratory of Electronics (VTT/ELE) in Oulu. The new laboratory got a full mandate to implement VTT's general

[62] Risto Nuutinen, Erkki Koskela, Juhani Iivari and Pentti Kerola, "Design and implementation experiences of a curriculum for the information systems architect (ISA) reflected on the IFIP/BCS curriculum," in R. A. Buckingham, R. A. Hirschheim, F. F. Land and C. J. Tully (eds.), *Information Systems Education —recommendations and implementation*, (British Computer Society—Monographs in Informatics, 1987), pp. 179-203.

[63] Pentti Kerola, Erkki Koskela, Risto Nuutinen and Tuomo Riekki, *Tietojenkäsittelyn perustutkinnon kehittämisestä Oulun Yliopistossa* (On Development of Master Level Curriculum for Information Processing Science (Information Systems Architects), in Finnish), Publications of Institute of Information Processing Science A10, (Oulu: University of Oulu, 1979).

[64] International Committee, "Evaluation of Research and Teaching in Computer Science, Computer Engineering and Information Systems," (Helsinki: Publications of the Academy of Finland, 1990), pp. 31-33.

mission in the whole country – to help industry to develop its competitiveness. This meant that the laboratory had to market its services all over Finland, not only in Northern Finland. VTT/ELE interpreted this mission with the goal of creating new industrial and commercial business by positioning its role between basic research and industrial product development.[65] In the beginning, VTT operated mainly as a product development partner with industrial companies. As the new electronics products increasingly included software parts, VTT/ELE started to pay attention to this technology area as well. With this in mind, VTT hired its first scientist with post-graduate degree, Samuli Saukkonen to develop the laboratory's competence in the field of software engineering.[66]

Internally financed research projects were started with main objectives to develop VTT/ELE'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[67] followed with regular courses in software engineering for electrical engineering students at the University of Oulu. This was 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. As there was wider need for software engineering education for engineers working in industry, many short courses were implemented in Helsinki together with INSKO (Continuing Education Centre for Engineers). National conferences like Blanko and Elkom were participated by giving presentations on software engineering.[68] One aim with these activities was general marketing of VTT as a product development partner in software engineering.

During the 1970s and early 1980s, professor Veikko Palva was the director of VTT's Division of Electrical and Nuclear Technology, where VTT/ELE was one laboratory. Professor Palva advised the laboratory to strengthen its relationships with the University of Oulu in embedded

[65] Kulju, pp. 63-69.

[66] Martti Karppinen, Minutes of a telephone call, 21.2.2003.

[67] M. Pietikäinen, H. Hakalahti (eds.), *Ohjelmointitekniikka* (Software engineering, in Finnish), (Oulu: University of Oulu, Department of Electrical Engineering, 1979).

[68] 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.

software related issues.[69] He had a vision to develop the VTT Oulu competence on embedded software engineering and this was crucial to the growth on software engineering skills in Oulu area. Very soon, this led to an increasing amount of cooperation with TOL.

Cooperation was started with one student project during the spring of 1979, followed with a Tekes (*Teknologian kehittämiskeskus*, the National Technology Development Centre) funded research project focusing on software requirements and specification methods for embedded software and a subproject CONSE on conceptual models of embedded systems describing the fundamental elements of embedded systems and their development from the software point of view.[70] This forerunning and fundamental project opened the eyes of many technically oriented engineers to see the importance of a wider systems perspective to software development.

The TOL cooperation influenced also the first PhD thesis on software engineering in VTT and the University of Oulu[71] 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 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, leading to Seppänen's PhD on software component reuse[72]. From these series of actions, we can conclude that VTT Oulu had found its natural role between basic research and industrial product development by strengthening its role in applied research as software engineering technology transfer partner for electronics industry. PhD training and implementation of industrial projects with applied research in focus were significant in growing a group of professional PhD level researchers. Again, TOL had a remarkable role in this evolution.

In the beginning of 1983, the Laboratory of Computer Technology of VTT (VTT/TKO) was established by taking the Computer Technology section out of the VTT/ELE. Samuli Saukkonen was the first director of this laboratory, continuing and deepening the cooperation with TOL in software engineering research. Large research projects were carried out emphasizing

[69] Martti Karppinen, Minutes of a telephone call, 21.2.2003.

[70] 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).

[71] 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).

[72] 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).

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)[73]. One of the largest efforts (tens of man-years) was the development of an expert system generating customized software packages for elevators. The goal was to get a system where the sales people just specify the properties of a lift by filling a standard sheet and the expert system then combines the software components and its parameters according to the order. With this system, Kone Oy could dramatically decrease the delivery time of customized elevator software. VTT/TKO's mandate inside the VTT to take responsibility on embedded software engineering research made it possible to grow the critical mass of researchers. This was only possible due to the close cooperation with the University of Oulu and especially with TOL where the culture of internationally respected basic research on information systems was highly developed.

4.1 Software engineering environment research

During 1981-1985 VTT Electronics laboratory launched a research project on developing a general purpose Software Engineering Environment (SEE) 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. The project did receive funding from process automation, machine building, and telecommunication companies in Finland. This project effectively collected then a very advanced toolbox of software engineering methodologies supporting the so called "Waterfall" process model[74]. Especially worth mentioning was explicit support for requirements specification[75], version control and configuration management, code size, labor, and schedule effort estimation using Boehm's approach[76], and use of email as communication media in software development projects.

SEE research was influenced by the theoretical research on software development methodology for information processing systems carried out at

[73] P. Kemppainen, *Mobira Oy:n ohjelmistotyön käsikirja (Manual for software engineering at Mobira OY)*, in Finnish, V1.1 7.5.1984. 97 p.

[74] W. Royce, "Managing the Development of Large Software Systems: Concepts and Techniques," *Proceedings*, WESCON (1970).

[75] SADT (Structured Analysis and Design Technique).

[76] Barry Boehm, *Software Engineering Economics* (New York, Prentice Hall, 1982).

University of Oulu Department of Information Processing Science. Especially important in retrospect has turned out the thinking in *abstraction layers*, which dates back to the research by Professor Pentti Kerola and Juhani Iivari in the 1970s[77]. The main penetration of abstraction layer thinking was via the CONSE project, which 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[78] 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[79]. Later research at the department led to a software engineering process model and methodology, Bootstrap[80], which gave increased support to project management and process improvement.

5. FROM MOBIRA R&D PROJECTS TO NOKIA MOBILE PHONES OULU

Mobira was a new company formed in 1979 on operations based in Salo, southern Finland, as a result, of reorganization of several Finnish companies in telecommunication and television production. Mobira was a joint venture of Nokia Corporation and Hollming shipyards[81]. During late 1980s, Nokia bought Hollming out after some bitter in-house conflicts. Mobira later in the beginning of 1990s changed its name and became Nokia Mobile Phones[82] – birth of a giant[83]. Of course, none of this was seen when Mobira was

[77] 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.

[78] P.T. Ward & S.J. Mellor, *Structured Development for Real-Time Systems*. Vol. 1-3. (New York: Yourdon Press, 1985).

[79] 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.

[80] P. Kuvaja, J. Similä, L. Kraznik, A. Bicego, S. Saukkonen &G. Koch, *Software Process Assessment & Improvement – The BOOTSTRAP Approach* (Oxford, Blackwell Publishers, 1994).

[81] History of Hollming. http://www.hollming.fi/history_business.html#.

[82] 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.

[83] Nokia is currently the leader in mobile phone manufacturing and sales in the world measured in global market share.

established. It was just a wobbling company with about 200 employees spun out of a big industry reorganization.

VTT Electronics laboratory had a brilliant hardware designer, Lauri Vatjus-Anttila, who had specialized in design using low-power consuming CMOS[84] logic circuits. He had also become an expert in RCA[85] 1800 Cosmac 8-bit CMOS-processor,[86] which was the only proper general-purpose CMOS processor during early 1980s. In 1983, he started an important project to design the processing and memory unit for new generation NMT[87]/TACS[88]/AMPS[89] cellular car telephone for the then little known Finnish company Mobira. He designed a radical architecture introducing two CMOS processors, Cosmac for the radio unit and Hitachi 4-bit processor[90] for handset user interface. The radio unit was communicating with the handset processor with a serial link, which produced a breakthrough in convenience of use, since the thick parallel signal "bullworker" cable was replaced with thin flexible cable.

Mobira aimed to build the software for the phone themselves but they soon found out that they were not capable of meeting the aggressive schedule they had agreed with the contract of the UK TACS system version ordered by Vodafone UK[91], which was then a little known startup operator[92]. As a desperate move, Mobira ordered the TACS version software development project from VTT Oulu, since they already knew the people from the hardware development. The laboratory was confident that they could tackle and accomplish any software project with the new methodologies they had acquired within the SEE research. The radio unit software project was lead by Jukka Korhonen and later by Erkki Veikkolainen, and Handset unit software project by Petri Pulli. By 1984 the software projects for both processors were completed a few months overtime after typical struggling with software errors and performance optimization. Although the Oulu based TACS part was a little late, all other parts of the Mobira's project were late much more, which brought Oulu in very good light.

[84] Complementary Metal-Oxide Silicon.
[85] Radio Corporation of America.
[86] RCA 1802 Processor. http://www3.sk.sympatico.ca/jbayko/cpu2.html#Sec2Part1.
[87] Nordic Mobile Telephone – analog cellular phone system standard in Scandinavian countries.
[88] Total Access Communication System - U.S. analog cellular phone system standard.
[89] Advanced Mobile Phone Service - U.K. analog cellular phone system standard.
[90] HMCS40 Series 4-bit microcontroller able to drive liquid crystal display directly.
[91] Vodafone. http://www.vodafone.com/.
[92] 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.

5.1 Birth of Nokia mobile phones Oulu

Veikkolainen was hired by Mobira to set up a software development unit based in Oulu[93]. He effectively hired the first employees from VTT and University of Oulu. Besides software developers, he also hired hardware and integrated circuit designers, where especially one of his major recruitments was Juha Rapeli[94], who had a major role in development of Mobira's first "one piece" cellular phone, the legendary Mobira Cityman 450/900.[95] He then later became one of the key architects for the 2nd generation cellular phone system GSM[96].

The software engineering expertise for this new Nokia software development unit was carried over from VTT in "leather folders", i.e. in the heads of the key persons hired by Veikkolainen. Also included into the role of this new Mobira unit was to supervise R&D projects within University and VTT[97], so the connection between VTT and Mobira stayed very close and trustworthy.

The Mobira Oulu software unit turned out capable of cranking out software projects very reliably and in time, gaining respect and credibility inside Mobira. Consequently, Mobira allocated more project responsibilities to Oulu growing also the hardware and application specific integrated circuit design (ASIC) personnel. Soon Oulu was exporting software engineering know-how also 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.

6. MAIN CONCLUSIONS

Specifically in addition to the electronics and telecommunication expertise offered as the core of the growth base, a more balanced analysis shows also the crucial role of system-theoretical and software-oriented expertise. When sufficient explanations are given to the growth base of the Oulu phenomenon, it is necessary to take into account development of systems and software industry and information processing science in the Oulu region. Then, what kind of major conclusions could we derive from

[93] "Mobira hajasijoitti ohjelmistoryhmän Ouluun," (Mobira decentralized a software group into Oulu), *Kaleva,* 12.10.1985, p. 20.

[94] Juha Rapeli. http://www.ee.oulu.fi/~tsuutari/Rapeli_pages/rapeliindex.html.

[95] Mobira Cityman. http://www.rigpix.com/mobphoneana/mobira_cityman.htm.

[96] Global System for Mobile Communications – digital mobile communication standard.

[97] Nokia in Finnish Innovations system.
http://www.etla.fi/english/research/publications/searchengine/pdf/dp/dp811.pdf.

the development of the Oulu phenomenon, and with which kind of reasoning? We have found three different, but interacting, growth sub bases:

- personal educational knowledge base with high individual variety
- team/project/social knowledge base, where early awareness about cooperation has existed
- systems/software methodological knowledge diffusion and transfer

In the young and fast growing university with its cooperating parties, the mental climate locally was empathic and auspicious for a variety of different scientific paradigms and approaches in research and higher education of computing. The intellectual liberalism and open-mindedness was generally prevalent and needed when fundamental theories were searched for the best practices. Of course, individual preferences varied and challenged each other. During the first years those influenced on varied, more individualistic efforts. Rather soon, however, the needs and value of cooperation were recognized.

The mental climate within the university, and its faculties with partially different research cultures, as well as the Oulu region in general showed clear signs of collaborative open teamwork from early on. Partners with different vested interests worked together setting aside their differences.

As the most factual and significant result of this historical analysis we present the systems and software methodological knowledge diffusion and transfer which has happened at Oulu area. This fundamental, as we claim it, was part of the growth base and can be visualized by Figure 1.

The described growth has happened through a value chain where the basic and applied research results from TOL were transferred to other organizations either directly by individual professionals or through the organizational actions with VTT and IS/SW service companies. During the time period being analyzed (1969-1985) the methodology transfer culminated in the case of Mobira and several software companies.

This paper has concerned the birth and early development of computing in the Oulu area. Actually, it was concurrently a start for an "industrial explosion", especially concerning software development and their embedded use during the last twenty years. The software technological 'explosion' will be the next phase and object of a longer historical analysis which is implemented in near future.

Overall, the early experiences of the 'Oulu phenomenon' have shown to us that the potential integration of technological, mathematical, and humanistic competence can be a probable oasis of success, if the liberal and broadminded intellectualism is prevalent. The co-effort between different kind of researchers, research mediators, and professionals and managers of industrial and community organizations is challenging, but not easy co-effort. However, the scientific and professional 'ecumenism' would be necessary. Various aspects on computing differ quite much, but they are

also complementary at the same time. In integration, the 'unity in plurality' is sought.

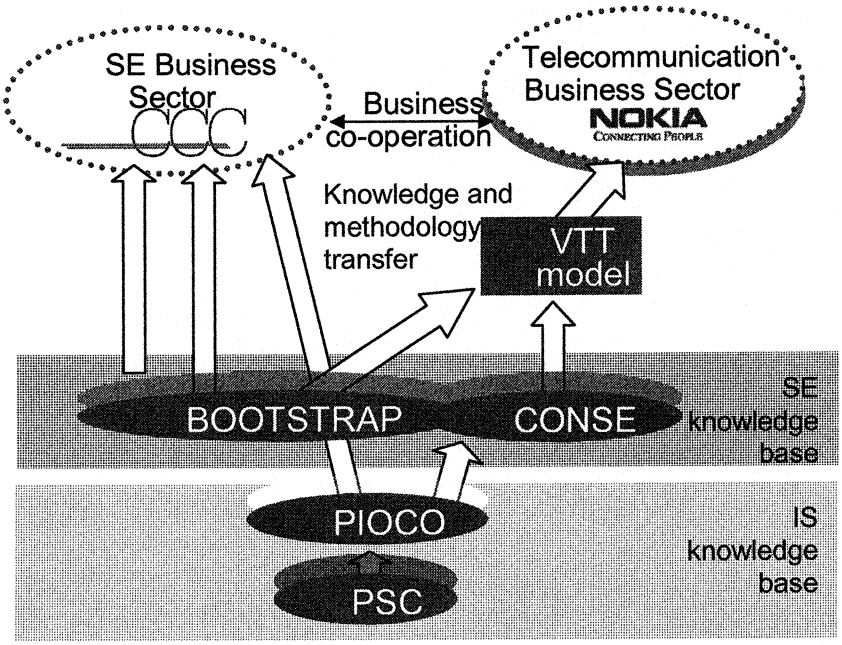

Figure 1. Growth Base of systems and software methodological knowledge in 'Oulu phenomenon'.

7. DISCUSSION AND COMMENTS FROM THE CONFERENCE

Question 1: How big is Oulu and University of Oulu and how many high tech jobs there are?

Answer 1: In the Oulu region there are nearly 200,000 inhabitants, in the University of Oulu there are about 15,000 students and there are more than 10,000 high tech jobs in the region.

Question 2: What are the total yearly intakes of new students for the curricula of informatics (including information processing science and information technology), and correspondingly the total yearly outputs of master level degrees during the last years?

Answer 2: The student intakes at the Department of Information Processing Science have increased from the level of 45 in the late 1980's and early 1990's (until 1996) to the level of about 300 in the last few years. The acceptance percentage of applicants has remained during these years around 25-30%. Presently, the number of master level degrees is rapidly growing and the expected number for 2003 is more than 50, while it has earlier been between 25-30 students.

The total student intake at the Department of Electrical and Information Engineering has increased likewise but not in the same scale. During the early 1990's until 1995, the student intake was around 150 to rise all the way close to 400 in 2001, during the last two years the student intake is around 320. The acceptance percentage has varied between 40-60% in the early 1990's, and between 70-90% later. The number of master level degrees has been around 60 in the early and mid 1990's and about 85 during the last four years.

Question 3: What kind and how large basic education is given about the development methodologies of embedded systems?

Answer 3: Both the Department of Information Processing Science and the Department of Electrical and Information Engineering have significant amounts of education in this topic of studies. The individual amounts in total are varying because of the distribution between the compulsory and voluntary studies. The embedded system studies usually taken are about 5 study weeks at the Department of Information Processing Sciences and about 20 study weeks at the Department of Electrical and Information Engineering.

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