Triple Helix Collaboration for eCare in the 1970s

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Abstract. The Elema project at Uppsala Academic Hospital, Uppsala Data Center and Uppsala University in collaboration with the industry (Siemens and Elema-Schönander) during 1968 and until 1984 had tremendous success and influence on quality of clinical work and practices to improve patient care, as well as commercial products, which e.g. led to total worldwide sales within Siemens exceeding 5 billion Swedish Kronor. A number of spinoff companies were also launched within the Nordic cluster (CART).

Keywords: computers, software, user interface, radiation therapy, cancer, clinical physiology, Triple Helix[1], eCare[2], cluster, CART, treatment planning, scintigraphy, pattern recognition, decision support.

1 The Emergence of Data Processing in Uppsala

The need for computers in the field of natural sciences was seen early by several heads of institutions, who made numerous requests to the Swedish Government for funding from the mid-50s. It was not until Werner Schneider, associate professor of Physics, engaged himself by presenting proposals and taking numerous personal contacts, that the Swedish Government decided to finance one computer at each Swedish university, starting with Uppsala University in 1965. The Uppsala Data Centre (UDAC) was formed and became the focal point

[1] Triple Helix was a successful partnership concept between academia, industry and government.

[2] eCare means here: support and improvements in medical care using computers and communication technologies.

for supporting computer activities at universities and within the public sector.

During this era, computer technology became increasingly open for decentralized support, and the Swedish state formed the Swedish Planning and Rationalization Institute of Health and Social Services (SPRI). An early and important SPRI project was 4005, with the purpose to create a normative, basic system for data processing within the health sector. Patient administration routines were to be combined with software systems for Bacteriological and Clinical Chemical Laboratories and stored in separate hierarchical databanks.
W. Schneider argued for an expanded concept, the Multi-Satellite System (MMS), in which the central and regional mainframes would coordinate administrative systems and databases (Fig. 1). The mainframes would then interact with decentralized computers, with the main task to process and store data of local character, e.g. data from the signal processing of clinical and laboratory computers. Eleven application areas within the hospital were judged to be candidates for computerization.

2 A Collaboration Project Emerges

The MMS philosophy aroused the interest of the management of Siemens Medical Engineering Group in Erlangen, Germany. An internal conference was organized at Siemens, and W. Schneider was met with a hugely positive response. The idea of a collaboration project between UDAC, Siemens and the University Hospital in Uppsala, Sweden (UAS) emerged.

The initial enthusiasm at Siemens was followed by a battle for computer equipment. It soon became clear, that the project required a well-equipped process computer with A/D and D/A converters, digital I/O channels, relay control and graphic display in addition to the usual peripherals such as line printers, punch card readers and tape drives. This was rare and expensive equipment. The project's first process computer, a Siemens 305, included 28 pcs 19 inch racks with a footprint of about 80 sqm, at a price in 1970 of almost 3 million Swedish kronor (SEK).

Börje Rudewald, CEO of the Swedish Siemens-owned company Elema-Schönander AB (ES), understood, that an Uppsala-based project could only be realized if the responsibility and cost were managed fully by ES. A staff of six people was recruited and lead by Sune Karlsson, who reported directly to the CEO. UDAC recruited two computational physicists, Bengt Olsen, at the time an associate professor at Chalmers University in Gothenburg, Sweden, and Hans Dahlin, master student in computational physics at Uppsala University.

Karlsson and Olsen were given joint responsibility for project management and Dahlin´s task was to enhance activities within the field of radiotherapy. Over time, approximately 40 people plus several students became involved in the project.

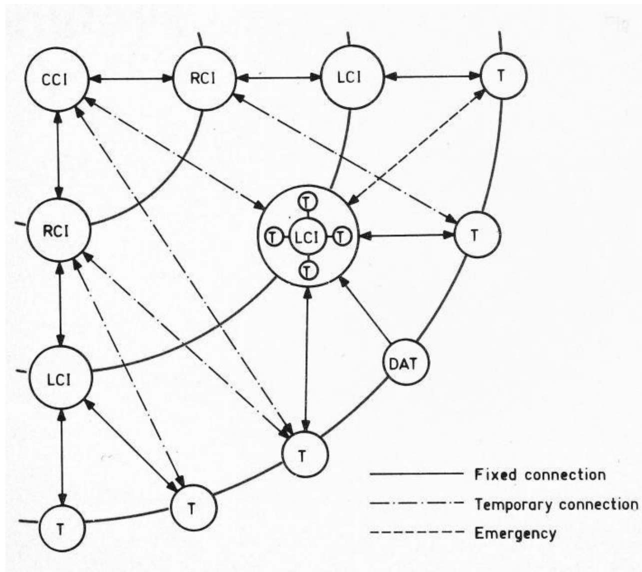

Fig. 1. The Multi-Satellite System (MMS) was a concept for a nationwide data system. CCI: central computer installation, RCI: regional computer installation, LCI: local computer installation, T: terminal, DAT: data acquisition terminal.

3 Activity Areas

In January 1969, UAS received a formal proposal from ES and UDAC offering to place personnel and computer resources at the disposal of the hospital for a period of two years in order to develop medical-technical data routines. The work in this connection would be conducted at the Department of Clinical Physiology, the Radiation Physics Department and the Radiotherapy Clinics under the leadership of the respective professors.

The proposal was accepted and the development project (Elema project) was launched. The project activities were mainly to coincide with the following requests: electrocardiography, cardiac catheterization, radiotherapy, scintigraphy, library programs, software systems, experiments and education [1].

The process computer (Siemens 305) was installed - with considerable delay in November 1970, which meant, that for almost two years the project´s focus was to practice and train participants, and to concentrate the development activities to the UDAC computer CDC 3600, in order to prepare program blocks and subroutine libraries for all areas of the project. These preparatory activities proved to be significant for the success of the project, since it laid a solid framework for the whole Elema project.

4 Scintigraphy and Pattern Recognition

In the Elema project's initial phase, various image processing algorithms for scintigrams were developed and tested with computer simulated phantoms. After the computer installation and connection to a scintigraph, SCINTIMAT2, increasing clinical reality could gradually be introduced.

The national gynaecological health screening program at the beginning of the 1970s at UAS, led by Dr. Inge Hesselius and Dr. Björn Stenkvist, was desperately searching for digital technology to analyse the cell samples, and experience from the scintigraphy project could be used for the purpose. This new project under the lead of Ewert Bengtsson was welcomed as an add-on to the Elema project. Siemens designed an interface so that a microscope, CLASSIMAT donated by Ernst Leitz GmbH, could be controlled by the process computer [2].

Methodologies to optically distinguish cancer cells from normal cells were prepared. The new project was successful and initiated new fields of activity in image processing and pattern recognition [3].

These activities resulted in a "world patent" in 1975 based on a method for automatic focusing of optical instruments, widely used without permission of the inventors. Today, most cameras and many other optical instruments use the patented method.

The company IMTEC was later formed to commercialize automatic cell analysis.
Unfortunately, the microscope was ahead of its time and never became cost effective, so activities were closed at the end of the 1980s, although further contacts for manufacture and research were pursued. The National Institutes of Health (NIH) engaged three scientists in the Uppsala project and ,subsequently, the current Centre for Image Analysis (CBA) was founded under the professorship of Ewert Bengtsson, who formerly completed his thesis work in the Elema project.

The Scintigraphy project, led by Hans Lundqvist, resulted in developments in the area of Positron Emission Tomography (PET), which led to the development of a commercial PET camera by an Uppsala company Scanditronix AB later acquired by General Electric.

5 ECG and Cardiac-Catheterization

In the general health screening X71 within Gävleborg county in Sweden, approximately 5 000 twelve-channel ECG exams on men of ages 40+ were recorded in analogue fixed format on a Siemens ECG magnetic tape recorder. Minnesota code was used for ECG characterization and refined progressively during the experiment.

Not all activities within the Elema project were equally successful. Although an ECG interpretation package was developed and abandoned due to a marketing decision, Siemens transferred the responsibility for the world market of Electrocardiography and Cardiac Catheterization to ES in 1977.

ES introduced its first computer supported cardiac catheterization lab in 1975. About 150 systems were sold during the next 11 years and a total of approximately 3000 cardiac catheterization units were sold by the year 2003. The total sales amounted to several billion SEK.

Between 1988 and 2002 about 5500 ECG devices with integrated interpretation of resting ECG were sold. The software was based on criteria and programs by Peter W Macfarlane University of Glasgow and adapted with experience from the Elema project.

6 Experiments and Software Systems

Experimental research work was also very important for the project. About 50 university students made various thesis contributions and UDAC's development of an interactive LISP led by Erik Sandewall, prof. of Artificial Intelligence (AI), provided important results. Various attempts were also made with AI to gather useful knowledge about ECG interpretation from clinicians. Siemens Interactive Compiler SIC, which was developed in collaboration between UDAC and Siemens, was an attempt to replace a Desk calculator via a simplified FORTRAN compiler.

7 International Eyes on the Elema project

The Working Group on Radiotherapy was inspired by the conference report of the Second International Conference on Computers in Radiotherapy (ICCR) in Paris in 1968. Groups that developed software in the field were contacted and asked to contribute knowledge and software. The Elema project was presented at the third conference in Glasgow in 1970 [4-5] and made such a positive impression on the program committee, that they decided to hold the next ICCR meeting, U72, in Uppsala, Sweden, in 1972. A huge effort to engage all participants in preconference work gave the conference a unique atmosphere of collaboration.

At U72 the results of the Radiotherapy development of the Elema project, implemented in clinical routines at the Hospital, were presented to the delegates [1], [6]. The new inventions of interactive dose-planning, using a unique Rho-Theta table (Fig. 2) and automatic radiation control, were recognized as the most outstanding innovation in radiotherapy in the world.

8 Radiotherapy Field Development

The Elema project had a vital role as a catalyst for worldwide research and product development in the radiotherapy field regarding dose-planning, image handling and quality assurance from the early 1970s to late 1990s [7-13].

Fig. 2. The original man-machine radiotherapy interface with the Rho-Theta unit.

8.1 Commercial Cooperation and Market Penetration

The results presented in the project report in 1972 encouraged the radiology and radiotherapy divisions at Siemens UBMed to establish a close cooperation with Uppsala University and its Data Centre, UDAC. The long term development program was to focus on commercializing of the results from the radiotherapy part of the Elema project.

The Division for Medical Computer Physics, led by Hans Dahlin, was established at UDAC to cooperate with Siemens. The office for the new division was located at the oncology department at UAS in order to incorporate the knowledge of the daily routine and its personnel into the development work.

The project was named SIDOS-U (Siemens Dose Planning System version Uppsala) and was successfully in operation for almost ten years. The resulting products for so-called external and gynaecological radiotherapy became an international success for Siemens, who sold more than 500 individual systems worldwide with a total value exceeding 2 billion SEK.

A strong relation between the US company Digital Equipment (DEC) and UDAC was established towards the end of the Elema project and became extremely effective in transferring the results from the Elema project into small computer systems for hospital laboratories.

The cooperation with DEC also had a major impact on Siemens decision to exchange their own lab computers to DEC computers for applications in the biomedical field. In the 1980s and 1990s Siemens became DEC´s largest customer for medical computer applications.

A popular movement to close down all nuclear power stations, due to the risk of radiation damage to nature and mankind, spread after the accident at

Three Mile Island, USA, in 1979. These circumstances also had a strong negative effect on the use of radiation in the healthcare sector.

After the announcement of new, more effective cytostatic drugs for cancer treatments by the end of the 1970s, the industry's interest for radiotherapy technology faded.

By the end of the 1970s, UDAC and its special division for medical computer physics had developed unique knowledge and an international network on how computer technology and software development could be used for safe and accurate radiation therapy in cancer care. This led to a spin-off project using the 305 computer at UAS for the development of a dose-planning system for the Gammaknife product.

The project was led by the special division at UDAC as a cooperation between the Institute for Physical Biology and professor Börje Larsson, the Neurosurgical department at Karolinska Hospital and professor Lars Leksell, and the Radiophysics department at Radiumhemmet in Stockholm and professor Rune Walstam. The first software implementation was carried out at the Gammaknife unit at Radiumhemmet in 1975 [14], which later led to the commercialization of the results by Scanditronix AB and later by Elekta AB at the beginning of 1980s. Elekta is today a world leading company in radiation oncology with over 4000 employees.

8.2 Changing View on Radiotherapy – the CART Development

A workshop on Computers in Radiotherapy was organized at the Nordic Radiology Congress in Åbo, Finland 1981, where Hans Dahlin presented a challenging paper on how computers and intelligent software development could make radiation therapy an important complementary discipline to the cytostatic drug treatments.

The same year a group of Nordic physicists and doctors came together in Uppsala to discuss requirements and recommendations for computer aided radiotherapy. The meeting resulted in a two year pre-study project and was financed by Nordforsk and the Nordic Industrial Fund. The group consisted of clinical experts (physicists and doctors) from Sweden, Finland, Denmark and Norway. H. Dahlin at UDAC became the operational manager of the project together with Jan Törnqvist who represented Nordforsk.

The resulting work, *User requirement on CT based computer dose-planning systems*, was presented in 1984 and pointed out necessities and possibilities to make radiation therapy both safe and accurate in a future perspective [15].

The pre-study project encouraged Nordic oncology clinics, cancer research institutes and Nordic medical companies to join and establish a new non competing project to develop technology and software.

In 1985 the Nordic Computer Aided Radiotherapy project (CART) was launched and comprised of members from the Nordic Industries, research institutes and oncology clinics [16]. Half of the total budget of 30 MSEK came from the Nordic Industrial Fund, and the other half came from the Nordic Industries, mainly as equipment for the developing sites (the Demonstrators).

Demonstrators were set up: one in Uppsala, Sweden, with focus on Image Handling and Man- machine Communication, one in Tampere, Finland, with focus on 3D treatment modelling, one in Rejkavik, Island, with focus on Oncological Databases, and one in Oslo, Norway, with focus on Simulators and CT imaging.

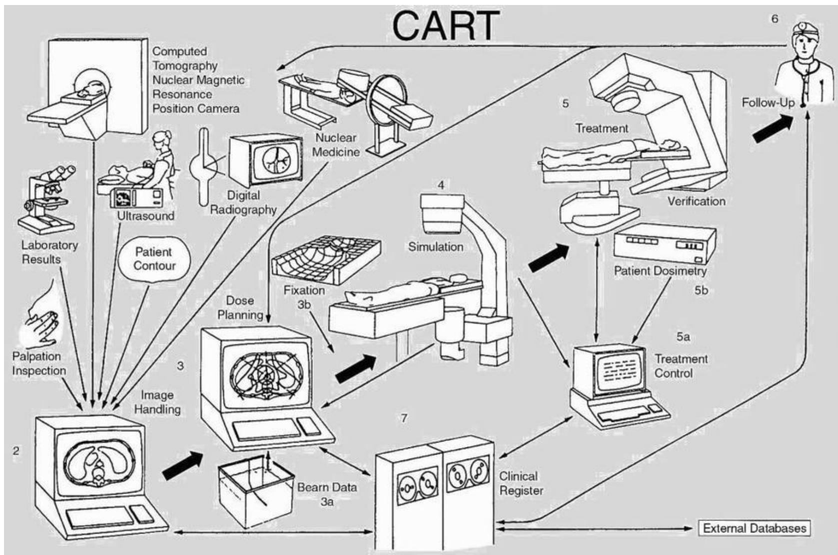

Fig. 3. The Computer Aided Radiotherapy (CART) Project

The CART program became known internationally and was referred to as the "Nordic Wonder", which resulted in a collaboration with the Radiophysics Department at the University of Chapel Hill in North Carolina.

In 1998 an international seminar on *The accomplishment and future directions of the Scandinavian Program CART* (sponsored by National Cancer Institute, as part of the World Congress on Medical Physics and Biomedical Engineering in San Antonio) gave a broad international understanding of the CART mission [17]. This encouraged many companies to develop new products based on the CART results with the purpose of improving the integration and use of clinical and technical information from early diagnoses in order to follow up individual patients in cancer care.

Radiotherapy in cancer care today involves precision and treatment quality and so improves the quality of life for today's cancer patients. The Elema project and the resulting activities in the 1970s and 1980s contributed much to this success, thanks to the structured and targeted cooperation between research, industry and clinical activities. Similar project collaboration today in other areas of cancer care, such as tumour diagnostics, screening and drug use would benefit more patients in the early stages of their disease and increase the quality of life for those patients where cure is not possible. This is particularly important in less developed countries, where today more than half of all cancer cases and deaths due to cancer occur.

9 The Effects of the Elema project after 1972

- Knowledge and experience from the Elema project was applied immediately in the clinical operations at UAS. Siemens 305 was used even a few years after 1972, until it was replaced by more compact and yet more powerful computers.
- Early on a DEC PDP11 was installed in Clinical Physiology for continued cardiac catheterization and ECG development.
- The radiation therapy segment was further developed and expanded world-wide through a 10-year collaboration with Siemens.
- Imaging became an academic institution under the leadership of a former project member.
- Spin-off companies influenced by the project were started.
- ES introduced early microprocessor control and complete computerized products to the market.

The Elema project was characterized by freedom with responsibility, by non-bureaucratic allocation of resources from forward-thinking leaders, by a dedicated staff under flexible working conditions.

10 Conclusions

Some important elements remain from the experience of the Elema project. To-day's projects that support organizations, such as Vinnova in Sweden and similar organizations in other Nordic countries, should possibly revise their definition of project conditions. This may provide the opportunity to regain an international front position regarding skills in the Nordic countries and strengthen long-term economic and enterprise development.

Nordic cooperation could be based on the following:

- Principals should only specify general conditions and allow freedom for project leaders to develop an innovative and creative environment for project participants.
- The main goals must be clear and the results evaluated by decision makers with knowledge and emotional ability to cope with future assessment and with understanding of how the desired results could be achieved. The budget should provide space for spinoff effects.
- Allow projects a start-up phase where tools and aid for the work ahead could be created.
- Install the development tools, e.g. computers, as close to the clinical

environment as possible in order to take advantage of a direct contact with the staff and the environment to which the project relates.

- Make sure that management actively supports the project. Give the medical staff that are directly and indirectly "affected" by the project a commitment under their own responsibility. Organize project meetings at times when all involved can participate.
- Use a development method based on interactive and incremental development. Collaborate tightly with cross functional teams. This encourages rapid and flexible response to requested changes, using tight iterations throughout the development cycle. This method has come to be called agile development in 2001.
- Conduct early international "state of the art" research, to map out unknowns and alternatives.
- Allow the students and project workers involved in specific project issues an adequate remuneration and adequate access to common resources.
- Ensure that the participating clinics receive a refund for the work done by accessing produced results and products under economically favorable terms.

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