A Slice of Norway’s Computing History

Yngvar Lundh was instrumental in the development of some of Norway’s earliest digital computers, having started his investigation of digital electronics in the 1950s. He continued his involvement with digital computers and digital communications for the next 40 years. A 10 April 2017 article about Lundh in the Norwegian online information and telecommunications newspaper digi.no quotes another pioneer of Norwegian computing, saying, “Yngvar Lundh is the most important person in Norwegian IT ever.” The pioneering digital work at the Norwegian Defence Research Establishment is the focus of Lundh’s report here, particularly the hardware development activities and early involvement with internetworking.

As a university engineering student in the spring of 1956, I came across some articles on “electronic brains” in the library. I had been intensely interested in electronics for several years and had built my ham radio equipment of parts from old German military radios—pretty much the only available parts then, shortly after World War II. When I asked my professor if my master’s thesis could be about electronic brains, the answer was that, regrettably, nobody at the Technical University of Norway knew enough to offer that. That summer I stopped by a center for technical and industrial research in Oslo to see a computing machine that they had built there, named Nusse. However, what I saw and the limited explanation they gave me did not tempt me to ask to do my thesis work there.

In the early fall I was relieved to learn that Karl Holberg, a researcher at the Norwegian Defence Research Establishment (NDRE), had heard of my wish. He proposed a thesis project and offered me a place in NDRE’s laboratory at Kjeller, about 20 kilometers from Oslo. I went to Kjeller and did my thesis work there during the fall term 1956 (see Figure 1, left). At the end of that year, I received my Sivilingeniør (siv.ing.) degree—the five-year degree given by the Norwegian Technical University and roughly equivalent to an MSc. My thesis was entitled “Investigation of an Operational Digital Computing Technique.”1 After that NDRE employed me, and I continued there as a researcher for 28 years.
For the first few years at NDRE, my supervisors gave me a rather free hand investigating computers in general. Several large computing engines using vacuum tubes were being built in laboratories around the world; machines employing up to 50,000 tubes were in use for military purposes. Because of the limited lifetime of tubes, a main problem was to keep the machines running reliably in spite of the need for frequent tube replacement. Therefore, I spent most of my time studying other possible devices to replace vacuum tubes, including various magnetic devices. The transistor, invented in 1947, was another promising possibility. It soon became clear that much of the work in this area was going on in laboratories in the United States. Therefore, I applied for and was awarded, by the Norway’s Technical Scientific Research Council, a research fellowship to the Massachusetts Institute of Technology (MIT).

Figure 1. A binary multiplier (left) was one of several modules I built as part of my thesis work using traditional electronic circuits—vacuum tubes (top) and discrete resistors and capacitors (bottom); the TX-0 at MIT (right) that I learned to program.

GUEST AT MIT

In the fall of 1958, I began a year as guest researcher at MIT. I attended a few classes there besides studying various ongoing projects. I especially became interested in a little computer called the TX-0 (see Figure 1, right—Ralph Scheidenhelm is standing, and I believe I am the young man sitting at the console). That machine had been built using transistor logic circuits. I understood that a larger computer called TX-2 was already being developed for military use. I spent much time on the backside of TX-0 with an oscilloscope learning details of how the computer was built using registers, arithmetic, and logic functional units, and how these again were composed of individual gates and flip-flops from transistors and passive components. I began to suspect that much other interesting work was going on in other laboratories around the US, and I obtained a travel fellowship that allowed me to visit many US laboratories during the summer of 1959. That gave me insight into many other approaches to digital electronics and computer design as well as a network of contacts of digital electronics researchers and engineers. I had a particularly good opportunity during that fall term to study the emerging technology of computers and transistor circuits.

I also taught myself to program the TX-0. One needed to keep track of every bit of the program—the ones and zeroes that were read into the computer from punched paper tape. In those early days, even the tiniest show of what an electronic brain could do was impressive. My simple program enabling TX-0 to play tic-tac-toe via the screen and light pen became a favorite for demonstration to visitors and was mentioned in the 1 May 1959 issue of a Boston Herald newspaper story covering an MIT Open House event. The caption of the newspaper’s photo says

**SCIENTIFIC WONDER that will be among the exhibits open for inspection by the public tomorrow at the Massachusetts Institute of Technology. This is a TX-0 computer, and while it looks frightening, it will be shown to be highly entertaining as it plays “tic-tac-toe” on the television screen with the operator.**

Computer screens and interactivity were new and nearly unknown at the time.
While at MIT, I also had the opportunity to meet with Ken Olsen, who I understood had been a key person in developing the TX-0. He had now started a company, Digital Equipment Corporation. I met him at a modest exhibition in Boston when he showed DEC’s first computer, the PDP-1. The era of minicomputers had begun. While being much smaller than the first “electronic brains,” minicomputers outperformed them.

The main result of my stay at MIT was to decide that back home I would build a computer to beat both TX-0 and PDP-1. I now knew how to do it. During that fall, Karl Holberg from NDRE stopped by during a trip in the US. He shared my enthusiasm and supported my work very positively during the coming years.

LYDIA SIGNAL PROCESSOR

Back at Kjeller in January 1960, I had hoped to build a computer to rival those that I had seen. However, that had to wait awhile. Higher priority at NDRE was a project to recover signals that were obscured by noise. My colleagues Helge Ekre and Finn Bryn had presented elegant theoretical methods showing that it could be done; however, they knew of no machine that could perform their signal processing in real time.

While I had been at MIT, a big commercial computer had been installed at NDRE. It consisted of several large cabinets and required a new addition to the house. Jan Garwick, astronomer and head of NDRE’s mathematics section, was the force behind the “Mercury” computer, bought from Ferranti in Manchester, UK. That machine became important in many of the tasks of the mathematics section in the following years. However, it was far from being able to solve our signal-processing tasks in real time.

Fortunately, I was able to come up with a way to build a special digital system that could perform the signal processing fast enough, and I was trusted to do it. Two new siding engineers, Lars Monrad-Krohn and Per Bjørge, had now joined NDRE. Together we began implementing the signal-processing machine (other engineers joined the group over time). Five or six types of modules were designed and fabricated within the group (for the assembly we hired a woman, experienced in soldering, from a radio manufacturer in Oslo). We had read all we could find in the literature about practical problems and took special care to ensure reliable operation. That involved worst-case electrical design as well as special highly accurate all-gold-plated connectors (Figure 2). Typical card modules were flip-flop or dual inverter. Several hundred cards were required, filling four large cabinets. The completed machine, named Lydia, was installed in the fall of 1962. It performed as predicted, and our transistor circuits were quite reliable. No replacements were ever needed.2
The Lydia computer became a great success, and we were ready to realize our dream of developing a general, programmable computer. We began to consider the details of the new generation of logic circuits. Much improved transistors were now becoming available. However, again, another project needed to be tackled first.

An aside: We continued module development over quite a few years. The first two series of modules (one for Lydia and the other for the later SAM computer) were fully compatible mechanically. The SAM modules were 250 times faster than the Lydia modules. Later, in the 1970s, we employed the emerging integrated circuit technology for modules. They were assembled on cards with similar mechanics, a little further developed.

SATELLITE COMMUNICATIONS

In January 1963, a technical committee from the telecom administrations of Denmark, Sweden, and Norway contacted NDRE. Two telecommunication satellites, named Telstar and Relay, had been launched into orbit. They would enable intercontinental transmission of full TV signals. However, that would require ground stations with antennas large enough to handle those weak broadband transmissions. It would require approximately 30-meter dish antenna disks and steering to follow predicted trajectories with accuracy of several seconds of arc. Such ground stations were being built in the US and in England, and powerful computers were used to steer those antennas. Such stations were beyond budgetary possibilities in Norway, but the Scandinavian Tele Satellite Committee (STSK) had agreed with radio astronomer Olof Rydbäck at Chalmers University in Gothenburg, Sweden, to use his new large radio telescope at Råø, south of Gothenburg. We were then asked if we could find a way to steer that antenna (Figure 3).

Jan Garwick proposed a way to approximate the satellite track with second-order functions, and I proposed a way to build a special digital device that could generate such second-order polynomials. We used the same type of modules that were employed in Lydia. Predicted satellite orbit data was received for a few days at a time (I forget from whom we received the data—perhaps NASA). Lennart Hansson at the Swedish Televerket (national telecommunication monopoly in those pre-privatization days) converted the predicted satellite track into a format that I could use. Einar Evensen of NDRE built the powerful servos to steer the antenna according to the real-time azimuth and elevation angles that my digital device generated. Thus, a Scandinavian ground station was established. It was completed and allowed direct TV transmission from California starting in November 1964. Soon afterward communication satellites were placed in high orbits to make satellites appear stationary, and steering was no longer necessary. But the Scandinavians had been able to join the new satellite technological race.3
THE SAM COMPUTER

Finally, we would be able to develop a general-purpose computer (Figure 4).

Karl Holberg now had a leading role in the Penguin missile program, which would need a minicomputer for handling experimental data. Instead of purchasing a minicomputer, we decided that we could develop a suitable computer for a similar budget. New faster transistors were coming on the market from competing companies. While each new transistor type initially commanded a very high price, prices fell fast as competitors caught up. That especially was the case for those components that were produced by the silicon planar method. We acquired three each of a couple of new transistors for our first designs. Fortunately, we selected a winner whose price fell. Therefore, by the time we needed to purchase 2,000 of them, we could. We built a few new modules, functionally similar to the old ones and mechanically identical. The new set of modules turned out to work 250 times faster! It is interesting to note that development did not stop there. Very large improvement of performance factors have prevailed with new generations of semiconductor devices to this day. One wonders if there are other areas of comparable technological development in history.

Figure 4. The SAM operator’s desk. From the left: punched paper tape reader, Flexowriter, control panel, and display screen. The computer circuits with our card modules filled four large cabinets.

Figure 5. The SAM computer (left) had a memory of 64x64 25-bit words. Each bit was stored in a toroidal core of magnetic material (top right of left image). Circuits for writing and reading had to be very precise. The display (right) was effective but expensive.

We produced several hundred new cards to implement a programmable computer. It also needed a memory. A promising technique had now been invented. It used small magnetic cores that were magnetized one way for representing one and the other for zero. We were able to purchase from Philips a memory array consisting of 24 planes. Each plane had 64x64 cores already wired. Olav Landsverk got the task to design driver circuits. They worked reliably, and SAM had a memory of 4,096 24-bit words (Figure 5, left). We also developed a small index memory using thin film components, but that never became important. For a while I
considered possibilities for an associative memory using multi-aperture magnetic cores, but we soon realized that we would not be able to make it efficient.

I had learned with the TX-0 that a display screen and a light pen would be desirable. We purchased a Charactron shaped beam tube. Knut Korsvold designed the very special driving circuits for it. A light pen with its driver electronics was designed by Per Bugge Asperheim. These devices (Figure 5, right) were both integrated with the SAM computer and turned out to be quite useful. But they were far too expensive. Another 20 years went by before CRT displays became common, and then as simple terminals at first.

SAM was used for many purposes from the fall of 1963. Some additions were made. After 10 years of service SAM was donated to the Norwegian Technical Museum, where it is still exhibited.

SIFFERGRUPPEN

After Lars Monrad-Krohn and Per Bjørge joined NDRE for the Lydia project, we began referring to ourselves as Siffergruppen (the digital group, Figure 6). The group grew to eight to ten young engineers over the following few years. They were recruited more or less directly from their respective engineering schools, and first the Lydia project and the SAM computer were important in attracting them. They were creative and enthusiastic about digital computing.

Programming methods and languages became very important fields of development. One of my students, Martin Vånar, developed a programming system for SAM called Samba. It was inspired by Jan Garwick’s ideas about data structures and was quite sophisticated for its time. Lars Monrad-Krohn spent a fellowship year at MIT and came back full of ideas about programming and languages. He developed a much simpler assembly program for SAM called Asem. It became the most used system for programming SAM.

Siffergruppen then went on to develop smaller yet more powerful minicomputers. Two were built—for Nordlysobservatoriet in Tromsø and Christian Michelsens Institute in Bergen. Thought was also given to building a computer to handle the sophisticated methods used by field artillery. A one-week seminar on the methods developed by clever artillerists over centuries was arranged for a handful of research engineers in the summer
of 1965. Siffergruppen then set about creating such a machine. (Some members of Siffergruppen were also looking at the possibility to start a company; I touch on this in the last section.)

After finishing my five-year administrative assignment, I wished to get into technical work again. I was aware of the steady and rapid technological development, and I was permitted a sabbatical year. I was pleased to receive an invitation to spend that year at Bell Labs in the US. Starting in the fall of 1970 I worked for a year with its semiconductor memory department. The previous year an integrated circuit had been developed that could store 64 bits. At Bell we were now given the task to make one that stored 256 bits. That year made me aware of many sides of integrated circuits. I decided to develop the capability of NDRE to design its own specialized application-specific integrated circuits, and I still had ideas about very powerful computers. One application that had caught my attention in the early 1960s was seismic signal processing. One powerful application was detection of underground nuclear tests. I had to drop that idea when two American companies were given contracts in that area.

MARTINUS

Instead my colleagues at NDRE came up with even more demanding signal-processing problems. That eventually led me to develop a powerful multi-computer (Figure 7). It consisted of 30 programmable computers, each quite powerful. They could exchange data via a system of wide buses. They were programmed and controlled by a master computer—actually a minicomputer—that we purchased from Norsk Data. The finished multicomputer, called Martinus, was put in experimental operation to find weak signals that had been deeply buried in noise.

Figure 7. The Martinus multicomputer.

KNUTEPUNKTSTEKNIKK

The progress in digital techniques had great influence on methods in telecommunications. In Great Britain and in France some powerful digital telephone systems had been developed using switching systems controlled by minicomputers. It was suggested to me that NDRE might possibly develop our own digital switch. That was in the early 1970s. Around 1970–71 the first computer on one silicon chip—a microcomputer—had become available from the leading company Intel in California. It had a word length of four bits only. I thought it might be possible to make a computer-controlled digital switch if I had an 8-bit microcomputer. I had frequent contact with Intel and other semiconductor companies and got the feeling that an 8-bit processor would become available soon. They gave me some preview information but no supporting software or specimens. Therefore, I gave one of my students, Peder Emstad, the thesis task to write simulation and support software, and in anticipation of such a microprocessor becoming available, we started the fall of 1973 developing a microprocessor-controlled switching office. It turned out that we could do that as a very compact and competitive unit using the newest components including an 8-bit microprocessor. The switch could handle...
only 30 subscribers. But we had designed it to enable any number of switches to be plugged together to automatically collaborate in networks consisting of those compact switches as the network nodes. The system was called knutepunktsteknikk. We collaborated with Standard Telefon og Kabelfabrik AS, which developed the system further for both military and civilian use. It put it in production and marketed it with great success both in Norway and internationally for many years.

Figure 8. Microprocessor control permitted a very small switching unit, here represented by circles with four "ports" each. A port could be connected to a digital multiplexer (triangle) handling 30 individual phone lines or to a port on another switch. Such interconnections could be made directly or via a two-way microwave link (squares).

INVolVEMENT WITH THE INTERNET

We started our involvement with development of the Internet by getting a connection to the ARPANET, precursor to the Internet. The US Advanced Research Projects Agency (ARPA) began implementation of the ARPANET in 1969. The network consisted of packet switches called IMPs that formed a communications subnetwork using leased communications circuits between pairs of IMPs. Computers from various vendors at universities, military locations, and companies were connected to a nearby IMP and communicated with each other across the IMP subnetwork. Some ARPANET sites had only terminal connections to the ARPANET; this was done with the addition to the IMP of terminal concentrator hardware and software. The augmented IMP was called a TIP.

Following initiation of the ARPANET, US and international interest in packet-based computer network grew quickly (except with telephone companies and computer vendors promoting propriety network architectures). In 1972 Lawrence Roberts and Robert Kahn of ARPA began investigation of extending the network across international borders. They visited Peter Kirstein at University College London (UCL) and the Norwegian Research Administration. The latter was their partner in the project that had established a seismic system in Norway with a processing center, Norsar, at Kjeller, next door to NDRE. That project got a leased data line from Kjeller to an ARPANET IMP in Virginia transmitting 2.4kbs of seismic data.

Also in 1972, Roberts and Kahn organized a big public demonstration of the ARPANET technology at the International Conference on Computer Communication (ICCC) conference held in Washington, DC. I attended this demonstration at ICCC and found it interesting. I met with Roberts and Kahn told them I would like to participate, but that it might take some time to obtain support at NDRE. I kept close contact with Roberts and Kahn, and in 1973 they installed a TIP in Norsar’s building in Kjeller, close to the NDRE location. We wanted it outside NDRE’s military premises, and that was where the existing leased phone line terminated. We did not otherwise interfere with Norsar’s operation. We were able to increase the capacity of the...
2.4kbs leased line to 9.6k/s by using improved modems. Multiplexers gave us 7.2k/s for connecting us independently to ARPANET while leaving the 2.4k/s for the seismological connection. Because of the relatively short distance between UCL in London and Kjeller, Peter Kirstein was able to fund a connection to the ARPANET via Kjeller (right side of Figure 9). The next group after UCL and us to have an ARPANET connection from outside the US did not happen until 1980.

Figure 9. In 1974 the ARPANET extended from Honolulu to London via Kjeller, comprised of 40 research and other establishments.

The TIP made it possible for me to have a TIP terminal installed in my office and at a few other places; I was hoping to generate interest in networking with students and others.

Generating interest was a very slow process. I kept going to ARPA’s meetings. To make that possible, ARPA paid for my travel expenses. My boss Karl Holberg accepted my activities, and I kept him fully informed. I was engaged full time directing two development projects during that time—knutepunktsteknikk and another project. I had one thesis student working on ARPANET protocol issues. It took more than two years before I had two serious physicists made available to me because they had become superfluous in their prior project, and their specialty of nuclear physics was not needed in other groups. They started by learning Fortran programming.

Much active development of the internetworking concepts and technology took place in the period 1974 to 1981, and there were fairly regular meetings (led first by Bob Kahn, and later joined by Vint Cerf) of representative from 10 or so institutions and companies participating in internetworking experiments. At the first several meetings, before 1974 and with a somewhat wider participation, important ideas were discussed about the desirable properties of a network beyond what had already been demonstrated in ARPANET. I participated in these meeting from 1972, but I had great difficulties in recruiting interested persons except one thesis student. It took almost three years before I had a team that later became active in the collaborative development of what became the Internet.

During the following years, intensive development was carried out by the group of institutions and companies. My NDRE team came to consist of Pål Spilling, Åge Stensby, Finn Arve Aagesen, and Øyvind Hvin-den. Along with the teams from the other places, we used the ARPANET and other small networks as a laboratory for experimentation with internetworking technology. The goals were to make internetworking more efficient and robust and to be capable of using all available carrier channels efficiently for applications with various requirements for capacity and for error control. Central to this effort was the TCP protocol (later TCP/IP) originally codified by Cerf and Kahn. Over time, the technology was perfected in practical terms, and more people began to use it. By 1981 the methods had become stable and ARPANET became just another network on the Internet.

Extensive computer networking research was also undertaken in Norway during the 1970s and 80s by the universities in Oslo, Trondheim, and Tromsø. They established a network called Uninet. Rolf Nordhagen at Oslo University was especially active. But we were unable to make those groups interested in collaborating
in the Internet development. In the mid-1990s, the Internet was becoming increasingly important for several establishments in Norway and elsewhere internationally; then they connected. Since then Uninett has been important for the operation of the Internet in Norway.

COMPUTER INDUSTRY CONNECTIONS

During the 1970s and 80s a significant computer industry grew in Norway. The main three companies were each led by a core of earlier members of Siffergruppen, and they derived much of their initial and decisive knowledge from projects undertaken by that group.

Lars Monrad-Krohn, Per Bjørge, and Rolf Skår, another Siffergruppen member, started a minicomputer company in 1967, Norsk Data Elektronikk AS (ND). They were motivated by the good reactions in Norway to the SAM-2 computer, and their first computer, the Nord-1, was a continuation of NDRE design work for a follow-on machine to the SAM-2. Until minicomputers were supplanted by workstations and personal computers, ND was a great success by Norwegian standards.

The possible military application for field artillery work done in Siffergruppen attracted the interest of the old Norwegian company Kongsberg Våpenfabrikk AS (KV). It enhanced its electronics activity, and its data division acquired some members of Siffergruppen. Olav Landsverk was one of them. A competitive situation developed between KV and ND for this market, but KV succeeded in becoming the manufacturer of a specialized computer making modern field artillery more powerful. They also made minicomputers for the general market.

AS Informasjonskontroll (IK) was a powerful Norwegian consulting company. One of the first students I recruited from the University of Oslo was Martin Vånar. He started his major studies in 1960, and I was his supervisor. I believe he spent almost two years before graduating. I then had him employed and join Siffergruppen working on software for the SAM computer. Some years later he left NDRE to start IK. Some years after that he hired Knut Korsvoll, one of the young engineers in Siffergruppen.

ND and KV both made successful series of minicomputers, mostly catering to different markets. IK was important in that same period of so much technology change. From establishment in the late 1960s it was very active and expanded for two decades. (Unfortunately, ND did not survive the minicomputer crisis around 1990 and went out of business in 1992.)

CONCLUSION

I see digital computing development in Norway as having significantly started at NDRE and the knowledge and activity then moving out into Norwegian industry. Those developments in the 1970s and 1980s provided a strong base for flourishing Norwegian computing activities today.

REFERENCES


ABOUT THE AUTHOR

Yngvar Lundh is retired and living in Tønsberg, Norway, after a career that included: research engineer at Forsvarets forskningsinstitutt (National Defence Research Establishment), professor of informatics at the University of Oslo, and chief engineer at Televerket (the Norwegian state-owned telephone authority). After leaving Televerket he started a small business called Vista Telematikk from which he did consulting for a few years. During his career he also served on a variety of official advisory committees. Lundh was appointed to the Norges Tekniske Vitenskapsakademi (Norwegian Technical Academy of Sciences) in 1963.