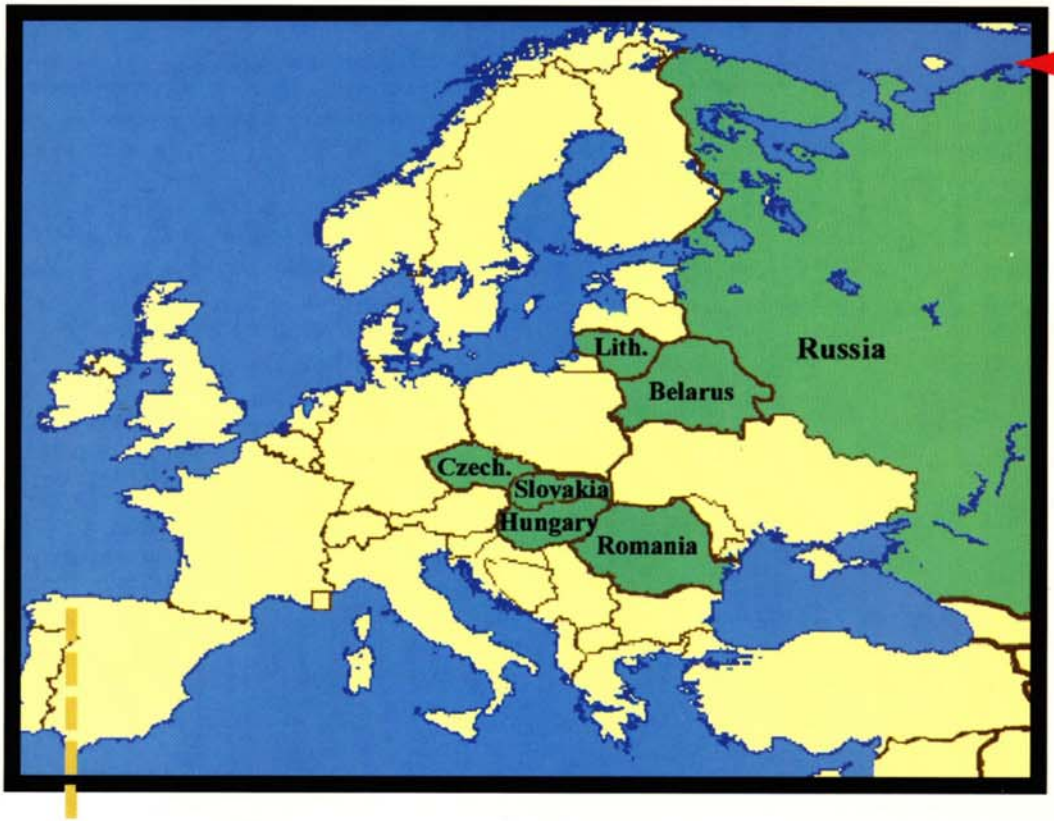
IEEE
Annals
of the History of Computing

Volume 21 Number 3 July–September 1999

21/3



Special Issue on Central and Eastern Europe

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Computers in Lithuania

LAIMUTIS TELKSNYS AND ANTANAS ŽILINSKAS

Computers, computer science, and computer engineering have more than 50 years of history in Lithuania. We describe the main directions of research and industrial applications. Also, we present the development of education in computer science and engineering, called informatics in Europe and Lithuania.

Introduction

The idea of computer applications arose in Lithuania 55 years ago. Physicist Adolfas Jucys, an alumnus of the Vytautas Magnus University (in Kaunas, Lithuania)[10] and an assistant in the Physics Department of this university, brought the idea to Lithuania from the United Kingdom. In 1939 and 1940, Jucys studied at Manchester and Cambridge universities. There he meet Professor Douglas Hartree, who designed an integrator—a modern computer at that time—and used it for solving problems in atomic physics. Jucys, during his study and research period in the United Kingdom, started investigating the Hartree equation, which was important in the theory of the atom. These investigations impressed Jucys, and, after his return to Lithuania, he decided to continue the research and wanted to implement the methods of integrating Hartree equations by means of computers.[2]

However, the outbreak of World War II and the subsequent Soviet occupation of Lithuania postponed the realization of this idea for two decades. Cybernetics—and the field of computers that was related to it (until the middle 1950s)—was claimed as "a pseudo science." In the *Short Philosophy Dictionary*, Rozental and Judin[8] wrote: "Cybernetics is a pseudo science that sprang up in the USA after the Second World War and became widespread in other capitalist countries" (p. 236).

When, in 1956, computers became legal and research in theoretical physics became a high priority, Jucys, now director of the Institute of Physics and Mathematics of the Lithuanian Academy of Sciences,[4] started to systematically utilize computers in scientific research. Three scholars of the Institute of Physics and Mathematics (graduates of the Physics Department of Vilnius University[11]) studied computers and programming in the Computing Center of the Soviet Academy of Sciences. They learned how to use Strela-3, Ural-2, and BESM-2 computers, which at the time were the newest Soviet machines. They participated in maintenance of the computers and learned how to utilize them. They even made several proposals to improve the computers. These circumstances made it possible to realize Jucys's aspirations. On 14 July 1962, a BESM-2M (serial number 14) computer was installed in the Institute of Physics and Mathematics of the Lithuanian Academy of Sciences.

The computer industry began in Lithuania in the late 1950s. The Vilnius Computer Factory (VCF) and the Special Computer Design Bureau (SCDB) started to function in Vilnius in 1959. At the same time, teaching computer hardware engineering started in the Kaunas Polytechnical Institute[3] in 1958; teaching of programming courses in the Vilnius University began in 1959. Almost 100 Lithuanian mathematicians, physicists, and engineers were sent for intensive 18-month computer science courses to the Institute of Energetics in Moscow and the Polytechnical Institute in Leningrad.

At the end of the 1950s, the first Lithuanian experts received the degree of candidate of sciences (similar to the U.S. PhD degree) in subjects related to computer science from the prominent scientific centers of the Soviet Academy of Sciences:

- J. Mockus from the Institute of Energetics in 1958 and
- L. Telksnys (the first author) at the Institute of Automation and Remote Control in 1960.

Upon their return to Lithuania, the critical mass had accumulated for starting a serious effort in scientific research and studies of computers and related fields and for developing the corresponding industry.

Computers and Research

During the Soviet occupation, fundamental research was mainly concentrated in the institutes of the Lithuanian Academy of Sciences. The fundamental and applied computer-supported research was concentrated during the 1960s in the Institute of Physics and Mathematics of the Lithuanian Academy of Sciences (the Institute of Physics and Mathematics was reorganized into the Institute of Mathematics and Cybernetics in 1977 and into the Institute of Mathematics and Informatics in 1990).

The first computer used for scientific research purposes in Lithuania was the BESM-2M (see Fig. 1) that was installed in the Lithuanian Academy of Sciences. It was the most powerful Soviet computer at that time. The computer had the following characteristics: 2,047 words of 39 bits of RAM, two magnetic drums of 12,290 words, and four drives of magnetic tapes (each of 131,000 words). The computer consisted of 3,000 electronic tubes and 10,000 diodes and consumed 43 kW of electric power. The programmers had to code their algorithms using computer machine language instructions. Only 50 percent of computer time was productive; the other half was spent performing preventive maintenance or repairs.

The second computer installed in the Institute of Physics and Mathematics in 1968—a BESM-4—was more reliable and more powerful than the first one: It could perform 2,000 instructions per

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second, had 4,000 words of 45 bits of RAM, had a magnetic drum of 64,000 words, and had four drives of magnetic tapes. The programmers now also used the language Algol. Since the Algol compiler made the development of the algorithms much easier, many scientists started developing original software. To manage this development, the Lithuanian Fund of Algorithms and Programs was established in 1969.

Fig. 1. Computer BESM-2M at the Institute of Physics and Mathematics of the Lithuanian Academy of Sciences. (Left) Prof. Vytautas Statulevičius. (Right) Prof. Adolfas Jucys.

The demand for computing power grew very rapidly in the 1970s and 1980s because of an increase in the number of users and the complexity of their problems. The most rational way to satisfy the growing demand was installation of the most powerful computer available, the BESM-6, which also had the most advanced, scientifically oriented software. The first BESM-6 was installed in 1972 and a second one in 1976. The performance of BESM-6 was 1 million instructions per second; it had more memory than the BESM-4 and had removable disks. The most important feature of the new computer was its advanced software and multiuser mode. The latter made possible the start of development in 1974 of the multiaccess computer system MOKSLAS for the research institutes of the Lithuanian Academy of Sciences. In 1976, two BESM-6 computers were connected into a system working under one operating system and using the same disk storage. Hungarian Videoton 340 monitors were used as terminals. The engineers of the Institute of Physics and Mathematics, cooperating with the experts of the Department of Communication Systems of the Kaunas University of Technology, developed a system by which remote terminals were connected to the system via leased intercity telephone lines.

Starting in 1979, the BESM-6 computer, which was in the Institute of Mathematics and Cybernetics, was accessible by means of a remote terminal in the Institute of Physiology and Pathology of the Cardiovascular System situated in Palanga 350 kilometers from Vilnius (see Fig. 2).

The BESM-6 computer system operated 24 hours per day, had a RAM of 192,000 words of 50 bits, had 24 drives of exchangeable drums of 512,000 words, and had 20 magnetic tape drives. Apart from the usual I/O devices, the system had digital-to-analog and analog-to-digital converters. The system could run up to six batch jobs and 10 terminal tasks. Algol, Fortran, and Lisp compilers and several assemblers were available. The net of terminals was managed by the KRAB system, which supported:

- the creating and editing of files;
- running of tasks;
- displaying of the results; and
- drawing of graphs on special graphic terminals and plotters.

Fig. 2. The first remote terminal in Lithuania was in Palanga at the Institute of Physiology and Pathology of the Cardiovascular System, 350 kilometers away from the mainframe in Vilnius. The engineer team after successful tests are (from left to right): Vitalijus Pikelis, Kęstutis Juškevicius, Aleksandras Žukauskas, and Jonas Kaukenas.

Almost 70 percent of the tasks were created via terminals, and the time of debugging codes was decreased up to 10 times as compared to the work in batch mode. At the end of the 1980s, 25 scientific and industrial institutions were users of the computer system known as MOKSLAS. Almost 200 users logged into the computer system daily. In the 1990s, microcomputers (e.g., Elektronika 60) became available and were connected to the system as intelligent terminals. The users of such workstations could run simple tasks or use them to code programs in Pascal, Fortran, Basic, MODULA-2, Algol, and C and in a macroassembler. Several database management systems were available, e.g., MINI SETOR and KVANT-M. The compatible microcomputers were DVK-2, DVK-3, and Elektronika 60.

In 1987, the computer system MOKSLAS consisted of:

- two BESM-6 mainframes;
- an ES-1045 mainframe;
- an ELBRUS-1 mainframe; and
- 115 terminals.

Magnetic tapes were used for data exchange among the computers. The system was available to researchers and technical personnel of 10 institutes of the Lithuanian Academy of Sciences and 16 other institutions 24 hours a day, 365 days per year. More than 90 percent of the tasks for computing or debugging were controlled via terminals.

Computations became an important part of the research in many institutes of the Lithuanian Academy of Sciences.[4] Computers were used in these fields:

1) theoretical physics (computation of spectra of atoms and molecules);

2) physics of solids (features of semiconductors in conditions of high-frequency electromagnetic radiation of submillimeter range);
3) heat physics (heat conductivity processes in thermal and nuclear electric power plants);
4) energetics (control of technological processes in nuclear electric power plants);
5) chemistry and technology (electrochemical coating); and
6) statistical problems of control, recognition, and optimization.

Computers were intensively used for data analysis in the following fields:

- laser spectroscopy;
- photometry of stars;
- spectroscopy of molecules;
- dendrochronoclimatology;
- cardiology; and
- oncology.

The time-consuming computations were performed on two- and three-dimensional semiconductor structures and in designing radio electronic, electrographic, and vibromechanical equipment. Original packages working in dialog mode were available, e.g., for solving elliptic differential equations, system identification, multiextremal optimization, analysis and synthesis of stochastic processes, computation of spectra of atoms and molecules, recognition of objects moving in the atmosphere and hydrosphere, scheduling and control of research and development projects, and CAD software. The creation of databases was begun based on an investigation of Lithuanian environmental pollution, sociological research, medical data (e.g., oncological and heart rate), dendrochronoclimatology, fresh water fishing, and others.

When IBM PCs appeared in the research institutes in 1987, they very soon dominated all applications. In comparison with PCs, the old-fashioned mainframes were slow, expensive, and not user-friendly. Therefore, it was decided to dismantle ELBRUS-1 on 30 December 1989 and ES-1060 in May 1992.

The new stage of computer networking started after the restoration of Lithuanian independence on 11 March 1990. The activity in computer science was implemented by the Institute of Mathematics and Informatics in cooperation with Lithuanian universities. The development of the Lithuanian Academic and Research Computer Network (LITNET), based on Internet TCP/IP technology, was started. The computer network has been expanded through active cooperation with Estonian and Latvian academic and research computer networks. A large amount of support, by both equipment and practical experience, has been received from the computer network of the Nordic countries, NORDUnet, as well as from Internet specialists from the United States and other countries. The cooperative project of the three Baltic states (Estonia, Latvia, and Lithuania) to implement a backbone (64 kbps) connecting Vilnius and Kaunas in Lithuania, Riga in Latvia, and Tallinn and Tartu in Estonia was supported by UNESCO with licenses for Cisco routers donated by the United States.

Norway's help has been of particular importance. Thanks to Norway, LITNET established computer connections with the world's computer networks through NORDUnet on 10 October 1991. At that time, the Norwegian government donated a satellite channel of 64 kbps to protect Lithuania from possible Soviet information blockade. A 9.6-kbps digital satellite channel was dedicated to help LITNET to maintain contact with European and U.S. computer networks through the NORDUnet. Moreover, the Norwegian government, the University of Oslo, the Norwegian–Lithuanian association, and various other Norwegian organizations have donated NORSK Data computers for LITNET to create a computer network, X25 software to maintain connections, and an X400 to maintain email connection.

At present, NORSK Data computers are not being used in the LITNET. Using NORSK Data computers as the operating system, SINTRAN has been able to perform only part of the Unix function. That has prevented LITNET from utilizing all of the Internet possibilities. For that reason, these computers were replaced with Unix-based computers in 1993.

On 14 March 1994, the LITNET became a member of the Internet computer network. Now the users of the LITNET have access to the whole Internet.

Today, the LITNET has three main nodes. They are at the Institute of Mathematics and Informatics, Kaunas University of Technology, and Vilnius University. LITNET is connected to the NORDUnet through two 64-kbps satellite TCP/IP links. There are now 1,600 PCs and hosts in the LITNET with more than 10,000 LITNET users from 130 organizations: 10 universities and academies, 14 research institutes, and 106 other nonprofit organizations (schools, libraries, health services, and other governmental groups). The LITNET uses information and teleworking services for research institutes and universities.

Computer Industry

The building of a cash register manufacturing facility in Vilnius in 1957 meant the beginning of the history of the computer industry in Lithuania. The facility had manufactured only one batch of cash registers in 1958 before production was stopped because of insufficient demand, and the plant was modified for manufacturing computers. The SCDB was established in 1959 to support the production. The Lithuanian computer industry passed all typical stages of design, technology and production: from electromechanical card punchers and computers based on vacuum tubes to LSI technology and distributed systems of data processing.

In 1959, the manufacturing of 80-column punched-card peripheral devices was started: card punches (PI 80-1), card readers (PS 80), and reproducers (PR 80-2). Similar 45-column devices (PI 45, PI 45U, and PR 45) were manufactured starting in 1960. Card sorters (RPM 80-2M) were manufactured starting in 1961.

The production of the first electronic calculator, EV 80-3, was started in Vilnius in 1960. These first-generation computers (clones of the IBM 604) were designed by the Institute of Computers (Niischetmach) in Moscow. The computer consisted of two devices: CPU (1,620 vacuum tubes) and an I/O punched-card unit. The CPU operated at the rate of 2,000 instructions per second and had 48 bytes of RAM. The set of instructions included four arithmetic operations and some logic instructions. The computer consumed 8.7 kW of electric power, weighed 1,700 kilograms, and occupied 25 square meters.

The SCDB designers created the first Lithuanian original computer—the EASP-S computer (see Fig. 3)—for correlation and spectral analysis of stochastic processes of optical and magnetic records in 1962.[1] Its production continued from 1964 to 1967. This specialized computer was designed for statistical analysis of

stochastic processes that might be represented by electrical signals or by graphs drawn on paper. The important innovation was an automatic device for the input of graphical data. The device created in the SCDB operated several hundred times faster than the standard devices. The designers of the computer earned the Academician S. Vavilov Prize, which was awarded for outstanding results in creating equipment and systems for scientific research.

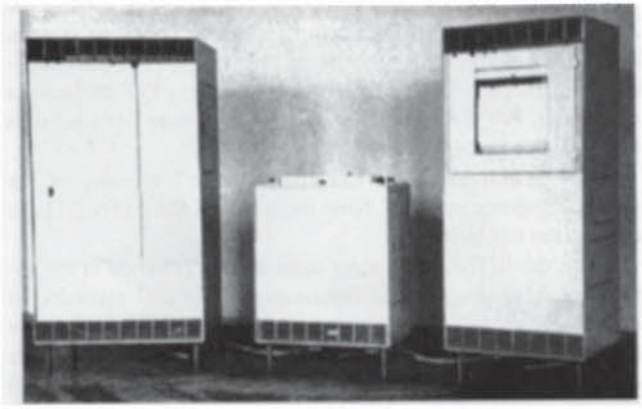

Fig. 3. The EASP-S computer for correlation and spectral analysis of stochastic processes of optical and magnetic records.

In 1963, the engineers of the SCDB designed a specialized computer for the location of atomic explosions. The new ferrotransistor elements enabled it to have high speed and reliability. The VCF manufactured the computers.

The engineers of the SCDB also designed an original second-generation computer—the EVT 80-2 Rūta—in 1963 (see Fig. 4). The local engineers designed new ferrotransistor elements especially for this computer. The production of this computer continued from 1964 to 1974. The CPU operated at the rate of 2,500 instructions per second and had 50 bytes of RAM. The new computer was oriented to solve management problems and was more reliable than the previous EV 80-3M, for which manufacturing was stopped in 1964. In the same year, 1964, the manufacturing of magnetic drum storage devices and of magnetic read/write heads started in Lithuania as parts for another computer: the ATE80-1. The production of this machine was to be started in Vilnius, but the computer and the drum devices were designed in the Institute of Computers (Niischetmach) in Moscow.

The growing computer production caused the establishment, in 1965, of the organization known as Sigma, which united the main activities of design and manufacturing of computers in Lithuania. The activities in industry influenced research in these areas. Research in the area of CAD and of diagnosis of chips and computer devices started at the Kaunas University of Technology.

The production of the Rūta 110 computer, designed by specialists of the SCDB, was started in the VCF in 1969. The computer was meant for processing large data arrays in automated management systems. It had advanced I/O devices, removable disk drives, magnetic tapes, an adapter for 30 Teletypes, and 228 data collectors. The staff of the SCDB designed two original advanced peripheral devices for the Rūta 110 computer: the removable disks (R401) and the optical character reader for printed and hand-written texts (Rūta 701, see Fig. 5). The Lithuanian removable disk drive (R401) was the first such device in the former Soviet Union. The information density was 30 bits per square millimeter, the size of storage was 1 MB, and the access time was 0.2 second. The VCF and the Plant of Precise Mechanics in Panevezys, Lithuania, manufactured these drives.

Fig. 4. The Rūta EVP 80-2. An original second-generation computer developed at the Special Computer Design Bureau in Vilnius and produced by the Vilnius Computer Factory. (From left to right) Members of the design team: Bronislovas Bieliauskas, Gediminas Zdanys, Jonas Puodžius, Regina Valatkaite, Stanislovas Girlevičius, and Alfonsas Lipnickas.

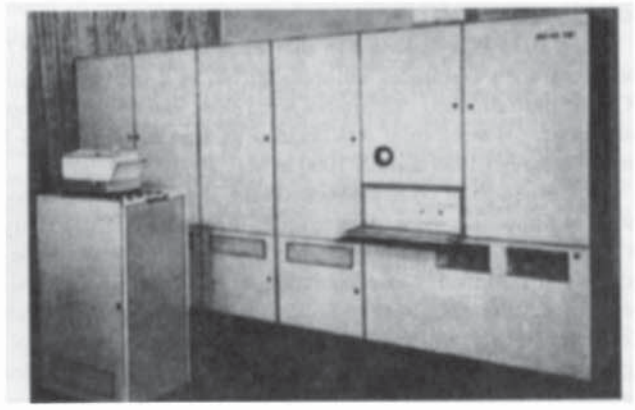

Fig. 5. The Rūta 701 computer. The hand-printed optical character reader was developed at the Special Computer Design Bureau in Vilnius and produced by the Vilnius Computer Factory.

The optical character reader Rūta 701[6,7]—the other peripheral device designed by Lithuanian engineers in the SCDB—could read printed and hand-printed numbers and four special characters from paper sheets (210 × 140–297 mm). The results could be stored in RAM or written to the tapes or punch cards. The reading rate was 200 characters per second. In cases in which the device could not recognize a pattern, it was shown to a human operator, who made the final decision. The failure probability was 2.6×10^{-5}, and the probability of refusal of recognition was 1.5×10^{-4}

for bad-quality printed text. For hand-printed characters, these probabilities were equal to 5.8×10^{-6} and 3.8×10^{-5} correspondingly. Rūta 701 was the first industrial hand-printed optical character reading machine in Europe.

Several innovations of the Rūta 701 were patented in the United States, Japan, the United Kingdom, France, the German Democratic Republic, the Federal Republic of Germany, and Czechoslovakia. For this optical reader, the designers earned the Lithuanian State Science and Engineering Prize (1967), the Academician S. Vavilov Prize (1968), and the Great Gold Medal of the International Leipzig Fair in the Germany Democratic Republic (1969). The Japanese firm of Toshiba as well as French specialists were interested in cooperating with the Lithuanians in the development of the device, e.g., replacing transistors with integrated circuits. The organizers of the International Osaka Fair proposed to demonstrate the Rūta 701 in Osaka, Japan. However, Soviet authorities vetoed all these interesting proposals.

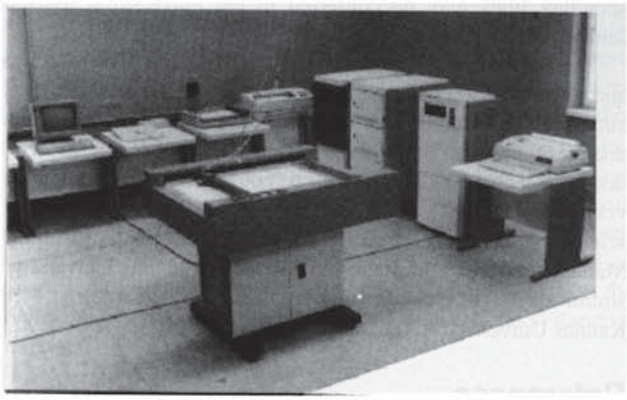

Fig. 6. The computer SM 1700, a VAX 730 clone, developed at the Special Computer Design Bureau in Vilnius and produced by Vilnius Computer Factory in 1986–1990.

The design of a new optical character reader (Rūta 711) was started in cooperation with Germany Democratic Republic specialists in the second half of the 1960s. The device was to be used in banks, insurance companies, and post offices to read printed and hand-printed numbers and several characters. The design was a joint project with several institutions of the Germany Democratic Republic. The staff of the SCDB created the units to read and recognize the characters, while the German experts designed the mechanisms for transporting and sorting the documents. Two experimental versions were produced in 1973. They operated at the rate of 1,000 characters per second. The failure probability was 0.8×10^{-6}, and the probability of refusal was 10^{-6}. However, Soviet ministries prevented joint production with the German Democratic Republic. However, the activities of Lithuanian industry on optical character readers stimulated the research projects on recognition theory at the Kaunas University of Technology and the Institute of Physics and Mathematics of the Lithuanian Academy of Sciences.

Since 1969, the main goal of Sigma was to design and produce third-generation minicomputers: the M 5000 in 1973–1979 and the M 5010 in 1975-1981. They operated at the rate of 14,000 instructions per second and had 32 kb of RAM. A later version, the M 5100, which was manufactured from 1978 to 1984, was capable of 33,000 instructions per second and had 64 kb of RAM.

Another minicomputer—the SM 1600, oriented to solving problems of management and statistics—was manufactured during 1982–1988. The computer contained two processors. One was a clone of the PDP11/34A. The machine was capable of 30,000 instructions per second and had a memory of 256 kB expandable to four MB. A special removable disk drive (SM 5048) was designed, using LSI technology, with an information density of 1,200 bits per square millimeter, a capacity of 16 MB, and an access time of 0.038 second.

In the beginning of the 1980s, the Moscow authorities ordered the start of the design and preparation of technology for producing clones of DEC computers. The computer (SM 1700), a VAX 730 clone, was manufactured in 1986–1990 (see Fig. 6). It was used for engineering calculations and as a CAD workstation.

The explosive development of PC technology in the West demanded an attempt to start the production of PCs in Lithuania. The Nuklonas plant in Šiauliai for the making of microelectronics circuits started the manufacturing of a personal computer called the BK-0010. The BK-0010 was planned to be used for the computerization of high schools. However, the characteristics of available chips were not sufficient to produce PCs comparable with those produced in the West or in the Far East. Therefore, production was stopped. The same reason was behind the 1992 stopping of preparations to produce PCs at the VCF.

At the end of the 1980s, the Lithuanian computer organization Sigma united seven plants—two located in Vilnius and one each in Kaunas, Panevėžys, Telšiai, Pabradė, and Tauragė—and several design bureaus. About 18,000 people worked in the production and management areas and 2,000 worked in the research and development area.

In 1990, the independence of Lithuania was restored. A bit later, the Soviet Union fell to pieces, and the situation in the computer industry changed drastically. The Soviet market was lost. The Lithuanian consumers bought cheaper and better computers from the West and from Southeast Asia. These circumstances caused the Sigma organization to disintegrate. Some departments went bankrupt, and others were drastically reduced. Similar changes affected the design and research institutions. The Vilnius Sigma plant, organized on the basis of the VCF, now produces telephone equipment. The staff of about 100 people of the State Institute of Information Technologies is designing the information systems for transportation and petroleum companies and for the administration of atomic energy. The small company Sigmanta, in cooperation with IBM, started the development and production of software for the RISC Power PC and Pentium. The Lithuanian–French joint venture NERISENA developed a project for the Lithuanian State Communications and Informatics Program: Lithuania 2000. About 200 small and medium size companies sell computers and software, prepare computerization projects, propose services, and train computer users in Lithuania. At present, the Intel-based PCs are dominating the market, while the richest or largest users, e.g., banks and ministries, own Unix-based computer systems.

Academic Studies

The beginning of the development of computer science and engineering during Soviet occupation was difficult because of the

hostility of political and ideological leaders of the country to the so-called bourgeois pseudo science of cybernetics. Therefore, it was especially dangerous if such a subject was taught to Lithuanians—all of whom were under suspicion of being nationalists. It was only at the end of the 1950s and the beginning of the 1960s that Lithuanian students and engineers gained access to computers in Moscow, Leningrad, and Minsk.

The first Lithuanian candidate of sciences thesis (similar to a U.S. PhD) in computer research was prepared outside Lithuania. J. Mockus did his thesis about computer-aided modeling of high-voltage circuit breakers[5] in 1958 in the Energetics Institute of the Soviet Academy of Sciences. L. Telksnys produced a candidate of sciences thesis about computer-aided statistical analysis of automation control systems[9] in 1960 in the Institute of Automation and Remote Control of the Soviet Academy of Sciences.

As mentioned in the introduction, one of the most influential Lithuanian physicists from the early 1950s—Jucys—demanded the installation of a computer in Vilnius. In 1955, as support from the center to the provinces, Vilnius University got a donation from Moscow University of an integrator (analog computer) ELI-12 capable of solving linear differential equations up to the 12th order.[12] Although the integrator was not helpful in solving Hartree-Fok equations, which were the subject of Jucys's research, in the following years it was used to teach students at Vilnius University. The attempts to get a real computer did not cease until the BESM-2M was installed in the Lithuanian Academy of Sciences in 1962, as mentioned earlier. Another brand of Soviet computer, the Minsk, was oriented more to economic computations. In 1963, a Minsk-14 was installed in Vilnius University and in the Kaunas Polytechnical Institute (now Kaunas University of Technology). The producers of these computers organized special courses in Minsk, which many Lithuanian engineers and programmers attended.

Various ministries and other institutions organized their own computing centers. In 1970, there were 16 centers with 21 computers in Lithuania. The first program in computer engineering started during the 1958–1959 academic year in the Kaunas University of Technology. Several undergraduates of electrical engineering studied the new disciplines of analog and digital computers, programming, and simulation. They graduated a year later than normal, in 1961, but got a new diploma degree: engineer of computing devices and equipment. In 1961, a Chair of Computing Devices and Automatics was established in the Department of Electrical Engineering. The first dissertation for the degree of a candidate of sciences in computer engineering was defended in Lithuania in 1966. After many reorganizations of departments and chairs, in 1990 a Department of Informatics was established.[3]

The first courses on computer programming were introduced into the curriculum of mathematical students at Vilnius University in 1959. Since no computer was available in Lithuania at that time, the students had to go to Riga, Latvia, for computing practice. This situation lasted from 1960 until the installation of the first computer in Vilnius in 1962: the BESM-2. Many alumni of the Mathematical Department of Vilnius University worked as programmers at various computing centers and did research in computer science; however, Vilnius University had not set up a Department of Computer Science (informatics). One chair of the Mathematical Department (its name changed repeatedly) was responsible for studies of computer science. In 1999, the Mathematical Department was renamed the Department of Mathematics and Informatics.

Computer science and computer engineering are divided into two areas in Lithuania. Theoretical foundations are called Informatics (Informatika) and ascribed to the area of physical sciences. Technological aspects and technical applications are named Informatics Technologies and ascribed to the area of technological sciences. The degrees are conferred according to this classification, e.g., doctor of physical sciences in informatics.

After the restoration of independence, the universities of Lithuania were reorganized (in 1991), introducing the U.S. pattern of degree programs:

- bachelor's degree, four years;
- master's degree, two years; and
- doctor's degree, five years.

However, as in Germany, the highest scientific degree is doctor habilitus, which is indispensable for candidates to get a position of full professor. The following positions are available and corresponding titles may be conferred in the universities: assistant, senior assistant, docent (associate professor), and professor.

The association of the Institute of Mathematics and Informatics and Vytautas Magnus University and Vilnius University are authorized to organize doctoral studies and confer the degree of doctor of physical sciences in informatics. A similar degree of doctor of technical sciences may be conferred by the Kaunas University of Technology. The degree of doctor habilitus of physical sciences may be conferred by the Association of the Institute of Mathematics and Informatics and Vytautas Magnus University. A similar degree of technological sciences may be conferred by the Kaunas University of Technology.

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