Petru Golanovi
se srdečnými
pozdravy

Jan G. Oblonsky

Eloge: Antonin Svoboda, 1907–1980

JAN G. OBLONSKY

Antonin Svoboda in 1970.

When the Fourth IEEE Symposium on Computer Arithmetic assembled in Santa Monica in October 1978, the following note was attached to the foreword of the proceedings:

> With the consent of the Program Committee, we wish to dedicate these Proceedings . . . to Professor Antonin Svoboda on the occasion of his retirement from active academic life which has spanned a half century of creative activity in Europe and in the United States. Among his varied interests in computer science and computer engineering, Tony's continued contributions to computer arithmetic have inspired many of us by their originality, rigor, and by the infectious enthusiasm of his personal presentations.

Computer arithmetic was just one of the many fields of interest of Antonin Svoboda, who pioneered the use of analog computers in fire-control devices, who worked on fault tolerance in digital computers, and whose creativity astounded all who had the opportunity to work with him.

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Antonin Svoboda was born on October 14, 1907, in Prague, Czechoslovakia, where his father was professor of Czech language and literature. After obtaining his electrical engineering degree in 1931 from the Czech Institute of Technology in Prague (České Vysoké Učeni Technické), he studied theoretical and experimental physics at Charles University, also in Prague. There he met an astronomy student, Miluna Joanelli, whom he married in 1936. In the same year he submitted a thesis on the application of tensor calculus to electric power distribution and obtained the Doctor of Technical Sciences degree from the Institute of Technology. His early interests were in physics—extensions of relativity theory and X-ray spectroscopy, which he pursued at the institute of Professor Dolejšek in Prague. As a hobby, he published a book, *New Theory of Bridge*, which presented a scientific approach to a bidding strategy in bridge. He also became a successful musician, which provided additional support during his studies. He was the pianist of the Prague Wind Quintet, founded by the renowned conductor Václav Smetáček, his lifelong friend. Occasionally, Svoboda played percussion with the Czech Philharmonic Orchestra.

Svoboda intended to follow a career in basic research and teaching. His plans, however, were severely affected by the events of world politics. His native Czechoslovakia had become more and more threatened by its neighbor—Nazi Germany. In the fall of 1936, Svoboda was called to active duty for two years in the Czechoslovak army. He was assigned to a unit that was testing new antiaircraft fire-control equipment developed by the Czech armament factories. Svoboda not only significantly improved the testing methods then currently in use, but was also involved in improving the equipment itself. He soon acquired a leading role in that field in Czechoslovakia, submitting his proposals through regular army channels. After his return from service in the fall of 1938, he resumed the position of assistant professor of mathematics at the Czech Institute of Technology.

His tenure there did not last long. Immediately after the occupation of Czechoslovakia by the German army in March 1939, the former officials of the Czechoslovak Ministry of Defense encouraged him to leave Czechoslovakia and go to Paris, officially for a prolonged scientific visit. He took with him the most advanced fire-control equipment, which he made available to the Allied war efforts. Accompanied by his wife, he settled in Paris, becoming a consultant to the French Ministry of War and working on designs for La Société d'Application Générale d'Electricité et de Méchanique (SAGEM). He was soon joined by his friend Vladimir Vand, a physicist who had also escaped from occupied Czechoslovakia. Together, they finished the design of their first analog computer—the antiaircraft gunfire director—based on the use of a mechanical integrator invented by Vand. Of course, Vand was not aware that a similar device had been invented by Lord Kelvin about 100 years earlier.

While in Paris, Svoboda's wife Miluna gave birth to twins, of which only one, Tomas, survived. Soon thereafter they had to leave Paris for southern France because of the approaching German army. As there was no regular transportation available, they had to use bicycles: one tandem ridden by Vand and Miluna, carrying the documentation of their fire director inside its frame, and the other ridden by Svoboda, carrying his newly born son in the basket. After covering several hundred miles through war-torn France, they reached a port in southern France where they were supposed to be evacuated on a British destroyer. This plan failed because of some misunderstanding between the British and French authorities securing the evacuation, and the Svobodas had to spend several months in Marseilles, hiding from agents of the Gestapo and trying to find a way to escape. Eventually Vand managed to get to England. Miluna, with the baby, secured passage to the United States via Lisbon through an American charity. Svoboda himself got to the United States via Casablanca with the help of a local store manager of the Czech shoe factory, Bata. The family was reunited in New York City in January 1941. In the United States, Svoboda continued the development of antiaircraft defense gear, and in 1943 he was invited to join the Radiation Laboratory of MIT, where secret work on radar was under way. There he further refined his original methods for the synthesis of computing linkages and applied them in the design of a mechanical analog computer that became part of the Mark 56 antiaircraft defense system for heavy guns (Figure 1). Svoboda concluded his stay at MIT in 1946 by writing a book, *Computing Mechanisms and Linkages*, as part of the Radiation Laboratory Series dedicated to documenting the results of the radar development efforts during the war. The book provides comprehensive analysis and synthesis methods for bar-linkage analog computing devices. It is a fundamental work in its field; it has been translated into Russian, reprinted in England (by Dover Press), and even reprinted in China. In appreciation of his contribution to the war effort, the United States presented the Naval Ordnance Development Award to Svoboda in 1948.

After concluding his activities at MIT, Svoboda returned to Czechoslovakia with the idea of building a "mathematical machines" industry in his native country. His dream was for Czechoslovakia to become in computers what Switzerland once was in watchmaking. While his wartime activities had been mostly in the field of mechanical or electromechanical analog devices, he soon recognized the emerging importance of digital techniques. While still at MIT, he had become familiar with the work of his friend Howard H. Aiken on the Mark I computer at Harvard. In 1947, Svoboda visited the leading centers of digital computing research in the Western world. He met with Alan M. Turing at NPL, Teddington, Maurice V. Wilkes at Cambridge, Herman H. Goldstine and A. D. Booth at Princeton, and, for the second time, Aiken at Harvard. He also visited the EDVAC project at the Moore School in Pennsylvania. Svoboda brought back to Czechoslovakia a wealth of valuable reports and the friendships of many outstanding pioneers in digital computer technology. As a first step in the realization of his computing plans in Czechoslovakia, he entered into an agreement with a manufacturer of punched-card equipment in Prague (which later became National Enterprise Aritma). He founded a development laboratory there, where several models of his projects were built. These included a series of electromechanical computers from a simple four-function desktop calculator to a programmable computer with punched-card constant and program step memories. The most important product of Svoboda's laboratory was the calculating punch (Figure 2). This was a relay computer performing four arithmetic functions with punched-card input and output and plugboard programming. This calculating punch became the key component of the punched-card machine assortment manufactured by Aritma. Several hundred

Jan G. Oblonsky was born in 1926 in Czechoslovakia. He received an MSEE degree with honors from the Czech Institute of Technology in Prague in 1949 and a Ph.D. in computer science from the Electrotechnical Institute of the Czechoslovak Academy of Sciences in Prague in 1955. Between 1953 and 1967 he was with the Research Institute of Mathematical Machines in Prague, first in charge of the digital computer research department and finally as scientific advisor to the director. In 1969 he joined the IBM Corporation in Gaithersburg, Maryland. His current interests include computer architecture, performance evaluation, and human-machine interfaces.

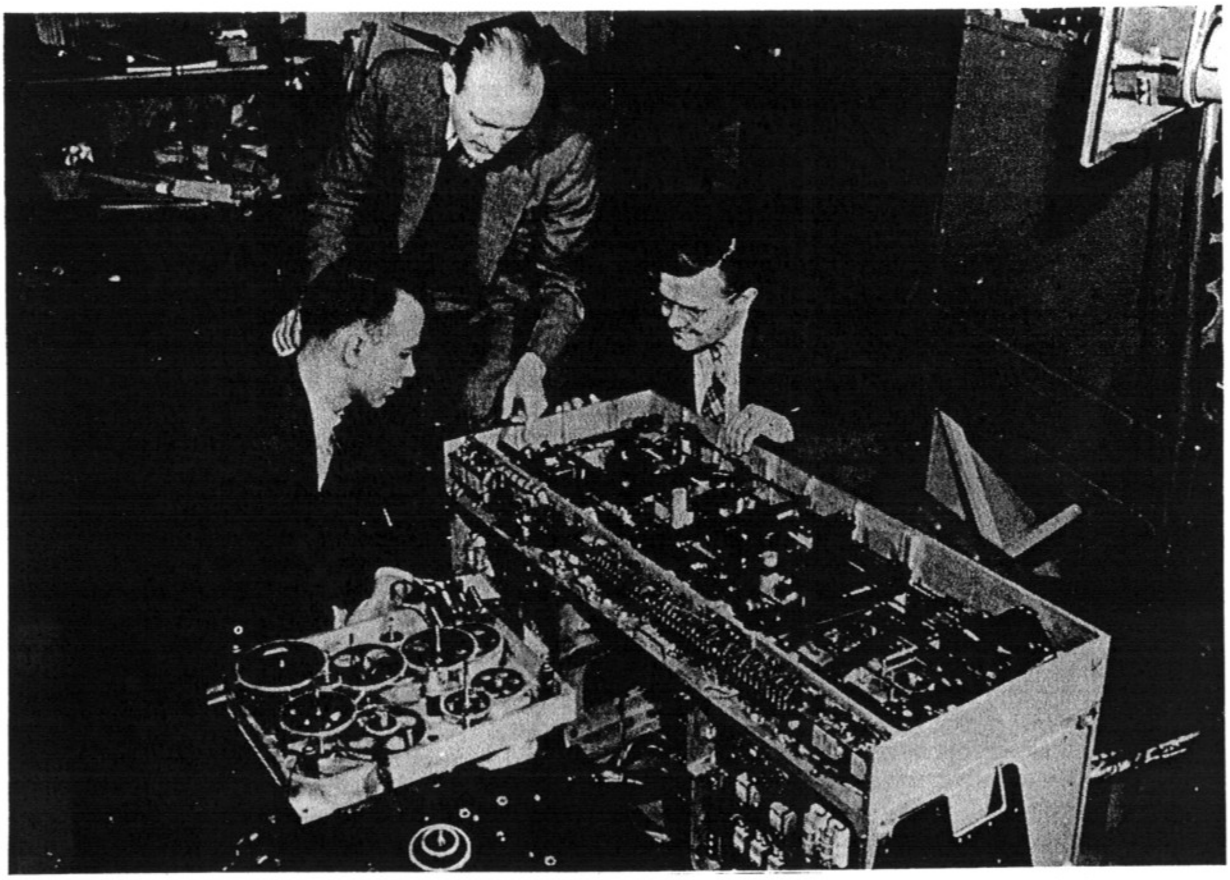

Figure 1. Antonin Svoboda (right), Robert L. Kenngott (center), and Carl W. Miller (left) checking the linkage computer part of Mark 56 at MIT. (Radiation Laboratory, MIT.)

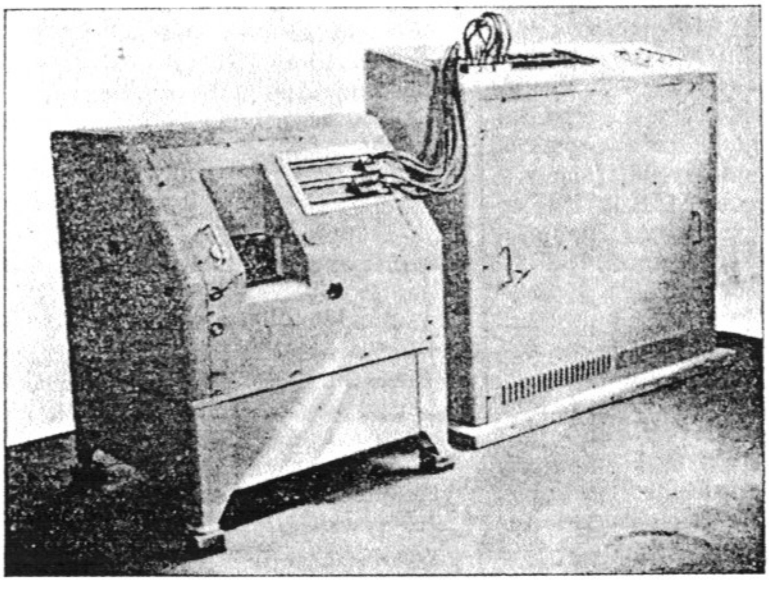

Figure 2. Calculating punch Aritma designed by Svoboda in 1949–1950. (*Stroje na zpracovani informaci.*)

were manufactured during a 15-year period. For this work, Svoboda was awarded a state prize by the Czechoslovak government in 1953.

In 1948, Svoboda habilitated (qualified) as a docent at the Czech Institute of Technology in Prague, and introduced a two-semester course called "Mathematical Machines" for advanced students of electrical and mechanical engineering. During later years, this course became an important source of young enthusiasts for the development of computers in Czechoslovakia.

In 1950, Svoboda accepted a position in the newly established Central Institute of Mathematics in Prague. There he started to build up a department of "Mathematical Machines," which eventually became the Research Institute of Mathematical Machines of the Czechoslovak Academy of Sciences in Prague. This organization has been the focal point of computer research in Czechoslovakia, covering both analog and digital computer design and theoretical research in related fields. A regular three-year Ph.D. study program was also conducted there under Svoboda's direction. A yearly publication, "Information Processing Machines," has been published regularly since 1952. The story of the institute is described on pages 294–298 of this issue of the *Annals* in an article reprinted from the publication.

I was lucky to be one of the few students who chose to attend Svoboda's lectures beginning in 1948. I joined the institute in 1950 as one of the first two doctoral candidates. This started the fourteen years of my close working association with Svoboda. After finishing my Ph.D. program, I became head of the digital computer department of the institute in 1953. Svoboda remained with the institute, first as executive director, later as director of research, and finally as a member of the scientific advisory board, until his second departure from Czechoslovakia in 1964. While the original department in 1950 consisted of Svoboda, two other employees (Václav Černý and Jindřich M. Marek) and two students (František Svoboda and myself), the institute's head count in 1964 was about 900, including over 30 Ph.D.'s and several hundred engineers.

Svoboda's diverse research activities in this period included:

1. Computer architecture: computers M 1, SAPO, EPOS 1, and EPOS 2.
2. Numerical analysis: development of methods suitable for digital computers.
3. Arithmetic codes and algorithms: development of the numerical system of residue classes; fast-division algorithm; high-speed adders.

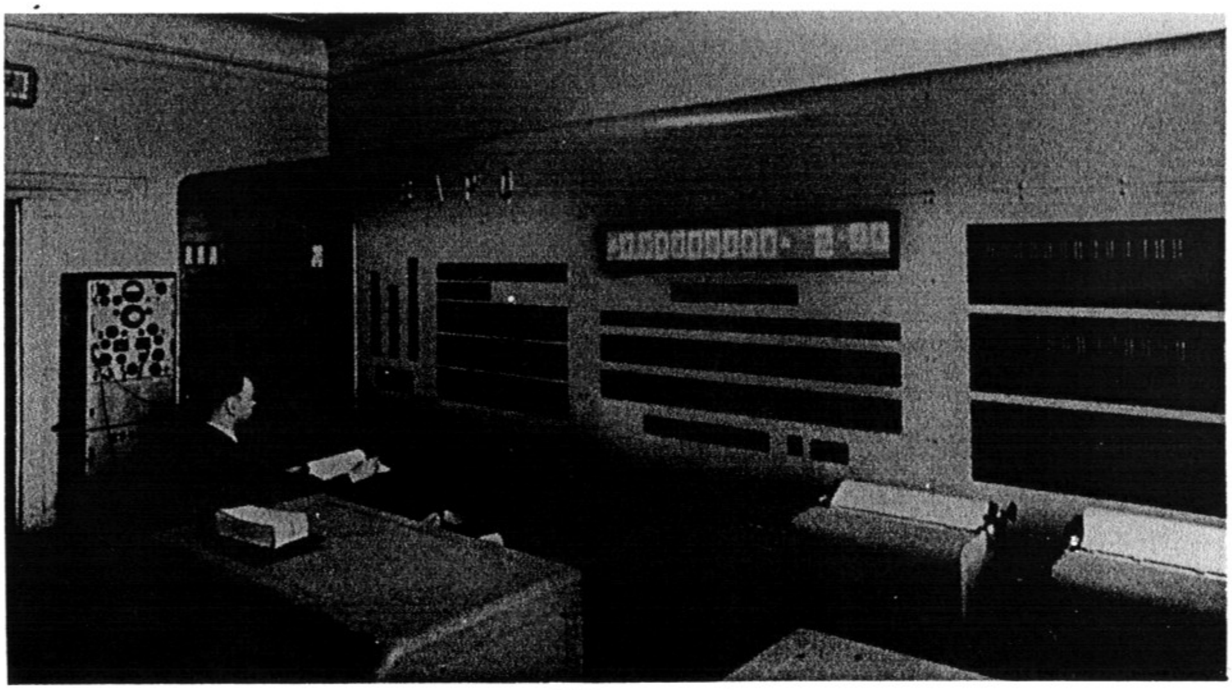

Figure 3. SAPO fault-tolerant computer at the Academy of Sciences, Prague.

Figure 4. EPOS 1 computer under construction.

4. Switching theory: synthesis of relay networks; graphic means and methods for switching circuit design.
5. Cybernetics: model of instinct of self-preservation; medical treatment with automata.

The M 1 computer was a special-purpose unit built for the Institute of Physics in Prague in 1950–1952. It is of some interest because it includes probably the first known use of a pipeline arithmetic unit, implemented here with electromechanical relays. The arithmetic unit of the M 1 was built to evaluate the expression

$$\left[\sum_{n=1}^{N} \psi_n \sin (hx_n + ky_n + lz_n)\right]^2 + \left[\sum_{n=1}^{N} \psi_n \cos (hx_n + ky_n + lz_n)\right]^2$$

for a large number of input variables. While implemented with electromechanical relays, it produced one complete summand per one relay action. This was achieved by splitting the computation into simpler steps (partial additions, table lookups, etc.) performed concurrently on different consecutive sets of input variables in assembly-line fashion (Černý and Oblonsky 1955).

SAPO was the first full-scale automatic digital computer built in Czechoslovakia from 1950 to 1956 (Figure 3). It was a relay machine with magnetic drum memory, five-address instructions, and floating-point 32-bit binary arithmetic. The poor quality of available components combined with political conditions in Czechoslovakia provided the motivation for SAPO's creators to take special measures to assure its successful operation. Thus SAPO became the first fault-tolerant computer ever built. It had three CPUs operating concurrently on identical data, two voting units to select the correct result, immediate reread and compare to check the memory-write operations, parity for checking the memory-read operations, and single-instruction restart if any of the previous measures failed (Oblonsky 1962, Avizienis 1978).

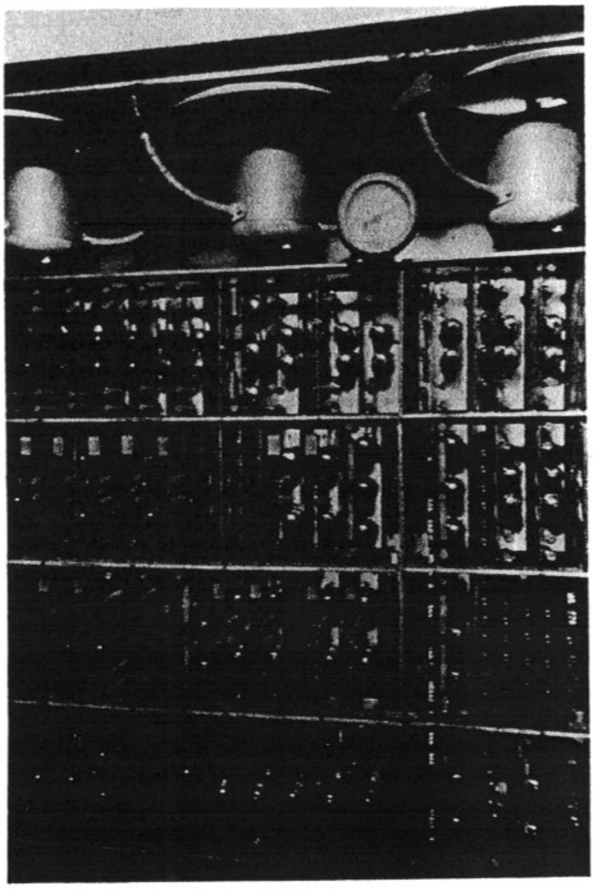

Figure 5. Circuits of the EPOS 1 computer.

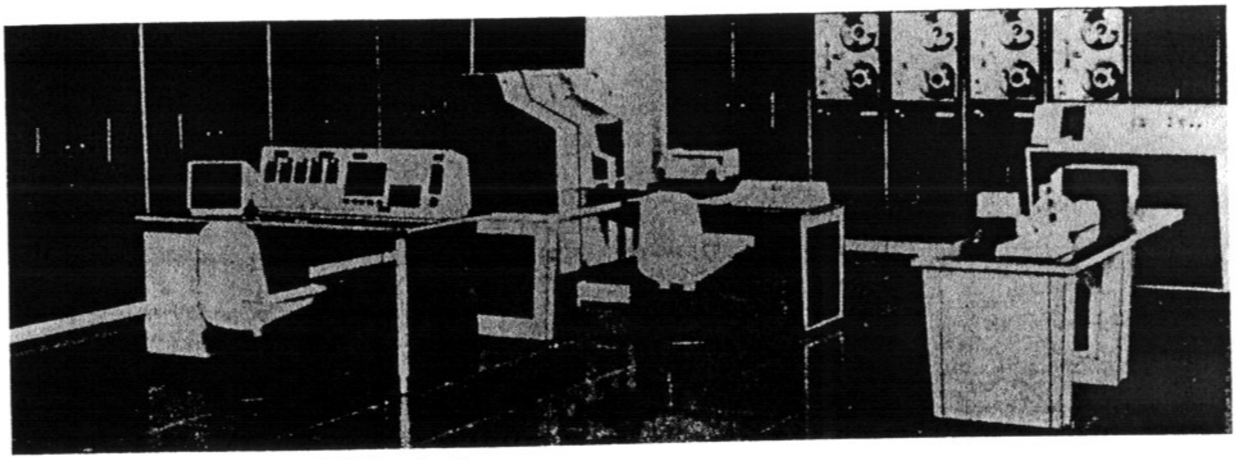

Figure 6. EPOS 2 computer. (Jiri Chocolac.)

EPOS 1 (Figures 4 and 5) was a next-generation computer (1958–1963) with vacuum-tube amplifiers, germanium-diode logic, nickel-delay line registers and buffers, and ferrite core memory. It was a decimal machine, also with very complete fault-tolerance features. The CPU used the residue class number system to perform decimal addition and multiplication, while Svoboda's new algorithm was used for division (1963*d*). Its control provided for hardware-managed task switching between five instruction streams, thus allowing the overlapping of the CPU and I/O functions. EPOS 2 (Figure 6) was a transistorized version with only minor architectural modifications.

The development of the residue class system, which was on Svoboda's mind for an appreciable time, is an interesting story in itself. The original impulse came from Svoboda in his computer course in 1950 when, while explaining the theory of linkage multipliers, he noted how in the analog world there is no structural difference between an adder and a multiplier (the difference being only in applying proper scales at input and output), whereas in the digital implementations the adder and multiplier are completely different structures. He challenged his students to try to find a digital implementation that would perform both multiplication and addition with comparable ease. Some time later, one of the students, Miro Valach, approached Svoboda with the idea of digital encoding, which became known as the numerical system of residue classes. Of course, it took many years of research effort by Svoboda, Valach, and others (Szabo and Tanaka 1967) to develop the theory and arrive at a practical application, as in the arithmetic unit of the EPOS computers (1962*a*).

Svoboda's extensive research in switching theory was stimulated by the requirements for developing methods for design of logic circuits for the computer projects of the institute. One distinct feature of these methods was the application of graphic-mechanical means to visualize the responses of logic circuits and to expand the scope of problems that could be handled with the limited computer support of those days (Figures 7 and 8).

In 1957, Svoboda was invited to present a course in logic design at the Chinese Academy of Sciences in Peking. He also lectured in Moscow, Kiev, Dresden, Cracow, Warsaw, and Bucharest. His visits to Western countries were much more limited. He managed to attend the Darmstadt (1956), Madrid (1958), and Namur (1958) conferences, but was not permitted to attend Cambridge (1959) and many other significant scientific meetings. He also was not allowed to accept the invitation to join the Department of Applied Mathematics of the University of Grenoble (France) in 1963. Eventually, in 1964, Svoboda, his family, and a few friends managed to escape from the stifling conditions of communist-controlled Czechoslovakia, and in 1965 they arrived in the United States to find their ultimate home.

In 1966, Svoboda joined the faculty of the University of California in Los Angeles, becoming professor in 1968. He taught courses in logic design, computer architecture, and computer arithmetic. Also in 1968 he received the IEEE Fellow Award for "his contributions in logic design, mechanical design, and his fundamental work on residue class number system."

His main research activities continued in expanding his logic design methods. He exploited the didactic advantages of his graphic-mechanical aids to logic design. He conceived the idea of a Boolean analyzer to facilitate the solution of some fundamental problems in advanced logic design. He developed the methods for finding optimal solutions into an APL

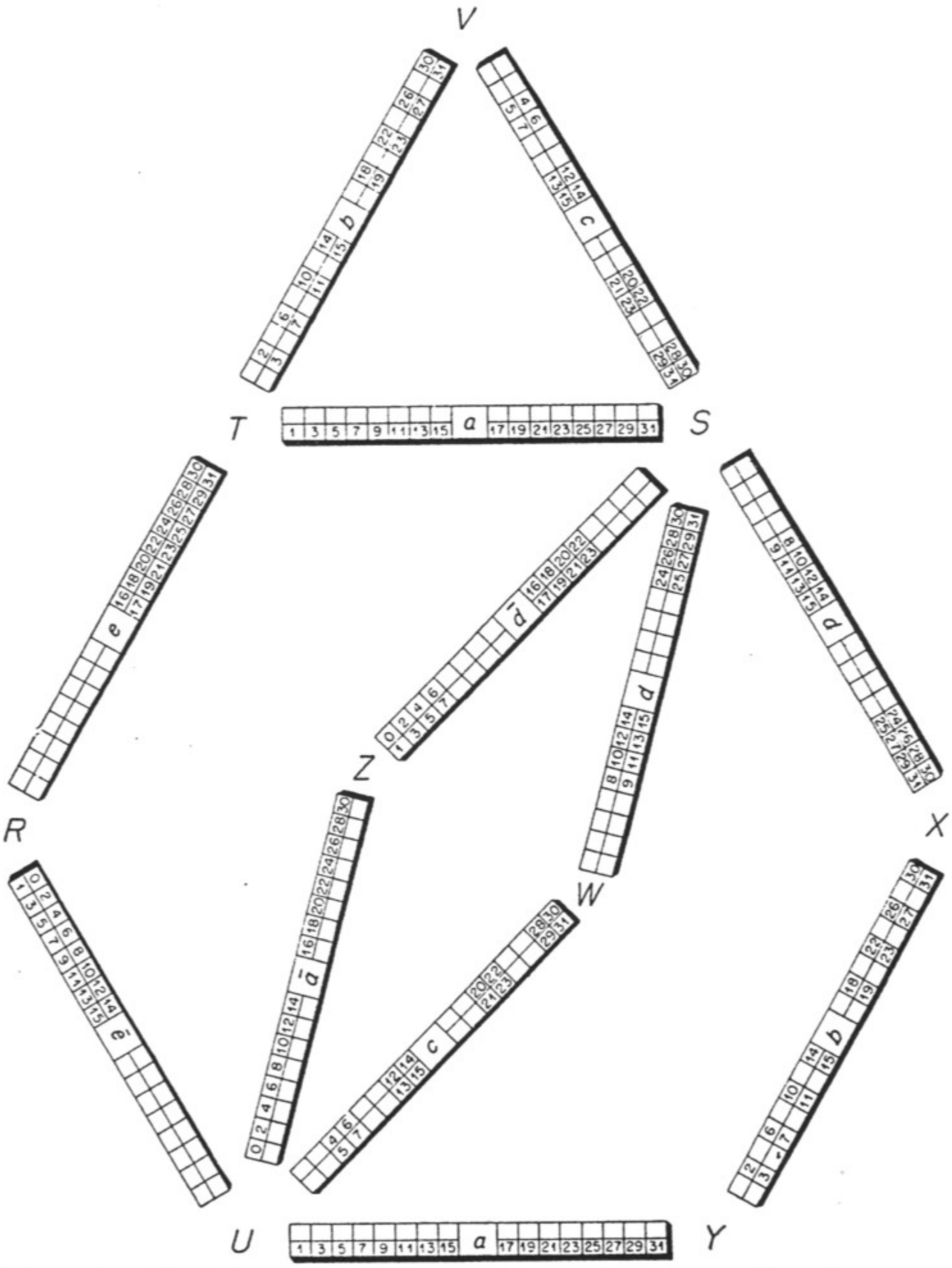

Figure 7. "Bones" used by Svoboda to model relay networks. (*Stroje na zpracovani informaci.*)

Logic Design Laboratory, as published in his last book, *Advanced Logic Design Techniques*, written with his student, Donnamaie E. White. While on a sabbatical leave in early 1975, Svoboda gave a course in Boolean switching circuits at the Université de Paris, France. Svoboda became professor emeritus in 1977, the same year in which he suffered his first heart attack. After recovering, he moved to Oregon, where his son Tomas Svoboda, a gifted composer and outstanding chess player, is professor of music at Portland State University. Antonin continued his activities there, consulting, writing, and lecturing.

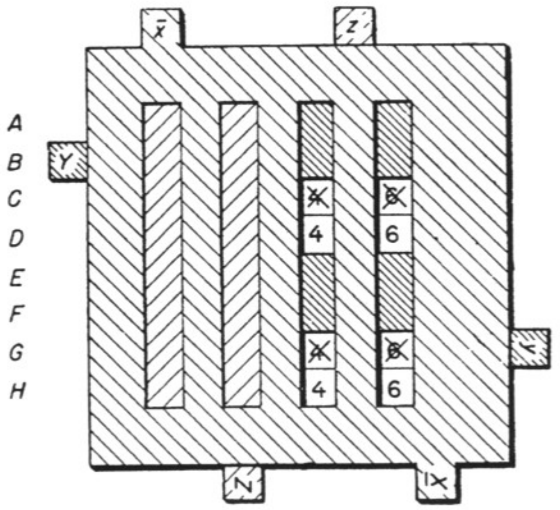

Figure 8. "Logical grids" for representation of Boolean functions. (*Stroje na zpracovani informaci*.)

I felt exceptionally happy when, on Christmas 1967, my family and I joined the Svobodas for a reunion celebration in Santa Monica, California. While our paths diverged from that point, we stayed in close contact, paying visits to each other whenever an opportunity arose. I was on my way for one such visit when I phoned Tony from Los Angeles on Sunday morning, May 18, 1980. We had made final arrangements for my arrival the following Friday, as he had a lecture scheduled at Berkeley for Wednesday of the same week. We both felt very happy about our upcoming meeting. Two hours later I received a call from Miluna with the tragic news of Tony's sudden death. His family, friends, and colleagues will miss this great, noble man for a long time to come. Tony was not only an extremely gifted scientist, teacher, and fighter for his ideas, but also a very warm and gentle human being. He possessed the rare gift of inducing friendship in most people who came in contact with him. He loved his family, friends, students, and work. Many of his pupils, myself included, regarded him as their best personal friend.

Tony enjoyed playing chess, playing card games, playing piano both solo and four-hands with friends, and recording his son's concert performances and compositions on tape. He was an enthusiastic photographer, accumulating thousands of negatives, prints, and slides during his eventful lifetime. Later he found great pleasure in the company of his grandson, Martin, who shows mathematical predispositions close to his own.

Svoboda left a legacy of well over a hundred patents, scores of papers, research reports, class notes, and books. A bibliography of his books and published papers is attached. A list including patents and other materials is in the General Systems Depository at SUNY Binghamton.

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Editor's Note: On the following pages we are reprinting two articles about early computer work in Czechoslovakia—both pertaining to Antonin Svoboda. The first article was written by Nelson Blachman in 1959. The second was published without attribution in 1964; it was written by Jan G. Oblonsky.

Czechoslovak Automatic Digital Computer, SAPO

(*European Scientific Notes*, No. 13-7, July 1, 1959, pp. 150–151)[1]

About a year and a half ago, the Vyzkumny Ustav Matematickych Stroju (Research Institute of Mathematical Machines) in Prague completed Czechoslovakia's first stored-program digital computer, SAPO (*Samocinny Pocitac* = automatic computer). The machine, whose design dates from around 1951, uses a magnetic drum for storage and relays for logic. Among its unique features are the triplication of the arithmetic unit (along with duplication of other facilities) and the method of identifying storage locations on the drum. Both arithmetic and storage units operate in the parallel mode, achieving a speed of three operations per second. Because of its high redundancy and its extensive correcting features, SAPO is able to compute for long periods without stopping, and there is no routine maintenance or marginal checking.

The drum, 14 cm in diameter and 16 cm high, stores 1024 32-bit words. Communication with the drum takes two revolutions (40 ms), one for address selection and one for reading or writing. Timing information is obtained from a single track (punched into a disk that rotates with the drum) on which a "Korobov sequence of binary digits" is stored. It is read (photoelectrically) by ten heads spaced at intervals of 101 bits. The sequence is such that all 2^{10} possible combinations of bits are read out some time during a drum revolution. (Evidently, van Brijn in 1944 antedated Korobov's later study of such sequences.) Thus, successive addresses are located in almost unpredictable positions on the drum, and minimum-latency programming would be infeasible; in fact, the design of the computer precludes it.

Numbers are represented in the floating-point mode with 25 bits for the factor, six for the exponent, and one for a parity check. Instructions incorporate five addresses and fill two words; the fourth and fifth addresses denote the locations of alternative next instructions, selected according to the sign of the result. There are two operation codes in each instruction, the second one controlling the input/output equipment. The execution of each instruction requires eight drum accesses—seven for reading and one for writing—thus taking 320 ms altogether. In addition to the usual arithmetic and logical operations, binary-decimal conversion and certain shifting and substitution operations are available in SAPO.

Aritma punched-card equipment (resembling Remington-Rand) is used for input and output and can fill the memory in ten minutes. SAPO uses 8000 relays and 350 tubes, all of the latter being associated with the drum.

Actually, the drum has two address-selecting devices; the second one uses a Korobov sequence which is the complement of the first, checking it against a separately generated complement of the address to be selected. Everything written on the drum is immediately read back for checking. The outputs of the three arithmetic units are compared in two separate but identical devices to ascertain how many agree. If there is any disagreement or failure in any check, 128 bits are printed out to indicate its nature. In case only two arithmetic units agree, the computation continues, but in other cases the last operation is repeated, and it usually succeeds on the second try; otherwise the machine stops. Each operation is begun only after the preceding operation has been found to be correct.

SAPO was built under the supervision of Dr. Antonin Svoboda, who is a member and former director of the Institute and is a docent at the Technical College in Prague. Jan Oblonsky designed SAPO's logic. Recently Svoboda delivered a series of lectures on digital computers in Peking during a two-week visit. He lectured in English to a class of ten, and in addition delivered some public lectures which were translated into Chinese. There are three separate computer groups in Peking, one building a BESM, one building an M-3. and one building a Mark III (a parallel drum machine), all with Chinese components though Russian designs. One of these groups is the Institute of Mathematical Machines of the Chinese Academy of Sciences; its director is Mr. Wu. Other computers are being built in Shanghai. The U.S.S.R. has sold and will soon deliver an URAL digital computer to Prague.

The Research Institute of Mathematical Machines in Prague employs about a hundred people and has, in addition to SAPO, a large number of Aritma punched-card machines. Svoboda was involved in the design of some of them, and some of the designs were German, having been taken over as war booty.

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Personnel of the Institute are doing and publishing a considerable variety of work on computer design and utilization.

Thought is being given to the design of a faster machine than SAPO, which will have only two arithmetic units, since it suffices to repeat an operation in case of disagreement. The new machine will have a word length of 65 bits including check digits. A "residue-class number representation" is to be used, with the base 2, 3, 5; i.e., numbers will be represented by their residues modulo 2, 3, and 5. Numbers larger than 29 are to be handled by some sort of repeated use of the base. Since in residue-class arithmetic there is no carry from one residue to another, a certain economy of equipment may be attained. The computer is to be serio-parallel with drum storage and a 1-mc clock, achieving a speed of 110,000 operations per second (6000 multiplications/sec). Drum timing will not involve a Korobov sequence. Fixed-point arithmetic and one-address instructions will be used.

It is evident that Czechoslovakia is capable of a large and high-grade effort in the computer field, and it is regrettable that she is cut off by the lack of foreign currency and travel from contact with other groups. Visitors will find a friendly welcome and easy communication in English. —*N. M. Blachman*

The Development of the Research Institute of Mathematical Machines in Prague (*Information Processing Machines*, No. 10, 1964, pages 15–24)[1]

The publication of the 10th volume of "Information Processing Machines" stimulates the recollection of the development of its publishing organization, which is closely related to the development of the whole discipline in Czechoslovakia.

In 1946 a small group of individuals interested in information processing machines gathered at a series of lectures given by Antonín Svoboda at the Technological Institute in Prague (Česke vysoké uceni technické v Praze). This group consisted of students as well as of some members of the development department of the Zbrojovka factory in Prague. This factory, which produced mechanical punched-card machines, later became the National Enterprise Aritma.

In the above-mentioned department, under the leadership of Antonín Svoboda, the first research was undertaken resulting in the construction of the *calculating punch* T50 [1]. In this relay machine, which with slight modifications has been and is in production up to now, new logical principles and algorithms were applied.

In 1950 the basis of research in Czechoslovakia was expanded and the Central Institute for Mathematics was established under the direction of Academician Eduard Čech. In 1952 the Czechoslovak Academy of Sciences was founded incorporating the above-mentioned Institute. The department for the research of mathematical machines, headed by Antonín Svoboda, was a part of this Institute from its very beginnings. This department developed rapidly into an independent Institute of Mathematical Machines of the Academy. In this connection the name of the later Professor Václav Hruška, the first scientific editor of the Symposia, should be mentioned as a man who rightly grasped the importance and significance of the field of information processing machines, and gave it all his support. When the significance of information processing machines as an industrial branch was realized, the Institute was transferred to the Ministry of General Engineering in 1958.

The Institute of Mathematical Machines has been active in the following four directions:

1. Design of computers, both digital and analog.
2. Theoretical research, especially in the switching theory, algorithms, and related fields.
3. Research in methods of application of computers, including advanced programming techniques, etc.
4. Propagation of the information processing field through organization of scientific conferences, lectures, seminars and courses, publication of its symposia, etc

During the existence of the Institute many computer projects have been designed. Some of these should be mentioned explicitly.

Special-purpose relay computer MI [2] which performs a three-dimensional Fourier synthesis. This machine was designed for the investigation of crystal structures by the trial-and-error method. Its general conception was set up in October 1950 in cooperation with the experts of the Central Institute for Physics and realized by Aritma in 1951–1952. This parallel working relay machine with a binary code and built-in algorithm performed about 40 operations/second. Its capacity was sufficient for a calculation of a 60 atom's structure.

General-purpose computer SAPO [1, 4–7, 98, 99] is a five-address parallel binary computer with magnetic drum storage for 1024 words. A word contains 32 bits. A system of floating point is applied. Punched

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cards are used for input and output. The algorithms for arithmetic operations were made up in such a way (including multiplication and division) that all operations are performed in six relay actions. A threefold arithmetic unit secured the computer against errors. Statistics of parts failures were recorded by an electric typewriter. The building unit of SAPO was relay analogous to that used in the above-mentioned calculating punch [3].

SAPO was the first operating automatic computer in Czechoslovakia. Its construction and exploitation enabled the Institute to obtain the first practical experience in the field of automatic computing. This experience was used in the construction a whole *family of relay computers*. There was, for example, a model of *E1a computer* finished in 1960 with punched-tape control and a ten-word relay storage using polarized relays of a new type.

Computer E1b, finished in 1962, has a drum storage of 1000 words, punched-tape input and output, and an electric typewriter. This computer operates in the decimal number system with floating point.

As an experimental model, the *Computer MNP10* was finished in 1962 using a relay control and a serial arithmetic unit with ferrite cores and diodes.

As a new line of work, a project of small, transistorized *Computer MSP* was initiated in 1960. This computer, which is now in a state of being assembled, used a ferrite core storage of 2500 words. It operates in the decimal system with alphanumeric data. It is fitted with up to ten punched-tape photoreaders, tape punch, and electric typewriter. Its operating times are 140 μs for addition, 980 μs for multiplication, and 3570 μs for division, with twelve-digit words.

Later a project of a special punched-card (transistorized) *Computer DP100* was designed in cooperation with Aritma. Variable-length instructions and a special logical circuit for nonaddress reading of instructions are used in the computer.

The main efforts of the Institute in the last several years have been concentrated on the design and construction of the *Universal Data Processing System (EPOS)* [8–13].

EPOS is primarily intended for data processing applications. It has a modular design consisting of a basic computer, which may be fitted with different inputs, outputs, and storage units, according to the needs of its individual users. The system has a built-in facility to time-share five quite independently prepared programs.

The basic computer of the EPOS system is a decimal one-address series-parallel computer operating with words of twelve decimal digits. It may be fitted with an arithmetic unit with floating-point operations. The set of storages contains the expandable ferrite core storage, the basic capacity being 2000 words, a magnetic drum storage of up to 50,000 words [11], and an adequate number of magnetic tape storage units. Punched-card units or punched-tape units, electric typewriters, and line printers may also be included into the system in adequate numbers. The system is equipped with automatic error detection and correction in its main parts.

The existing EPOS 1 system using tubes performs addition in 52 μs, multiplication in 208 μs, and division in 1196 μs, including access times. A transistorized version EPOS 2 is under construction.

Since 1957 independent work on numerical-control contouring systems has been carried out in the Institute. In this line four types of *linear interpolaters*, from the NLI-1 with relays up to the NLI-4 with ferro-transistor circuits, have been designed and produced. *A continues-path system (quadratic interpolater)* DAPOS with transistors has also been developed. For more general applications in automation, a *modular system of logical building blocks* LOGIZET was developed.

With regard to analog computers the following should be mentioned as examples.

Small differential analyzer MEDA [14], in serial production since 1958, and a *large-scale differential analyzer* ANALOGON [15], completed in 1961. Both these machines are the result of a research group that joined the Institute in 1960. Before this time, the *electromechanical differential analyzer* EMDA [16], and several small special-purpose analog machines [17–20, 100] were developed in the Institute.

In the theoretical line of work the main effort in the first years was on *switching theory* [21–33, 105, 106]. For analysis and synthesis of switching circuits a system of graphical and mechanical means was developed. Various models (not only algebraic) were used for design of combinatorial switching circuits. The method for the solution of systems of Boolean equations was later developed [25] and used for the analysis and synthesis of sequential switching circuits [46, 106].

In the *theory of coding*, codes for different purposes were investigated [34–41]. An important result was the discovery of advantageous qualities of the *system of residual classes* and the thorough elaboration of its application for digital computers [41–44, 101–104].

With the work on different computers, *research on algorithms* was closely connected [45–48]. The speed of operations, detection of errors resulting in the use of imperfect elements, and economy in quantity of elements result from these theoretical works. This applies also in the case of numerical-control contouring systems, where a new algorithm for quadratic

Year	Number of discus-sions	Average number of partici-pants	Number of lectures	
			From the Instutute	Guests
1953	21	17	49	6
1954	28	32	59	4
1955	27	33	44	5
1956	28	29	42	14
1957	22	31	40	3
1958	8	39	18	0
1959	20	35	32	7
1960	10	38	10	7
1962	7	56	10	3
1963	13	61	20	1

interpolation was discovered. Remarkable results were also achieved in the field of algorithms for decimal computers.

In parallel with the development of computers, the work on programming methods is carried out. Programming methods were elaborated and practically verified for each individual computer developed in the Institute [52–78].

In recent times the aim has concentrated on automatic programming systems [66–72]. The ALGOL 60 language is used as a basis. *Compilers for the system* EPOS1 *and for the computer* MSP *are in the process of development.*

Different languages suitable for the programming of data processing problems are being studied [73]. Due attention is paid also to the *problems of language translation* [77, 78] *and real-time process control.*

The research work of the Institute is periodically presented to the public by means of *symposia* where individual papers are discussed and later appear in *print.*

The first symposium was organized in 1952. At this symposium the construction of SAPO, the methods of its applications, and the use of punched-card machines for scientific computing were the main topics.

Similar themes were also discussed at the second symposium in 1953 with some international participation. The fourth symposium in 1955 deserves special mention owing to the fact that papers on two computers from the U.S.S.R., two from Poland, and one from Germany were presented by their respective designers.

The last symposium organized in 1962 covered quite a broad field of topics in information processing theory and practice.

In order to maintain constant contact between individuals interested in information processing, the Institute organizes *fortnightly public discussions* where two topics are presented and discussed. This also represents a forum for occasional guests from other institutes at home and abroad. The scale of attendance at these discussions may be seen from the accompanying table.

During the existence of the Institute quite a number of scientific research workers and specialists of all grades in the field of information processing have been educated.

This short report endeavors to show the scope of the efforts of the Research Institute of Mathematical Machines to cope with the dramatic development in the field of information processing machinery in the last decade.

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