Vadim KOTOV

BRIEF HISTORY OF COMPUTERS IN RUSSIA

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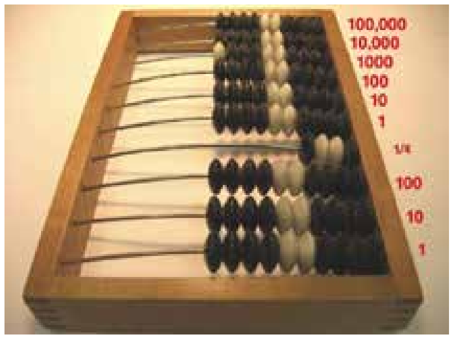
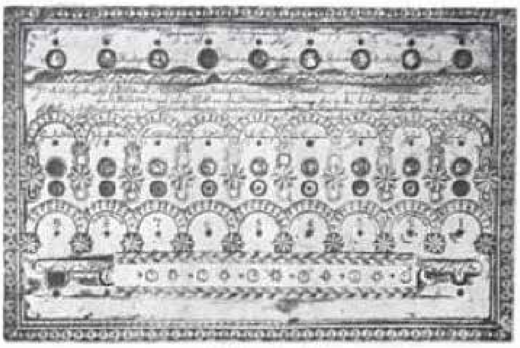
Before Computers: Mechanical Arithmetic

Time Frame



In 18th and 19th centuries, Russia was emerging from the self-isolation of the past. Peter the Great “cut the window into Europe”, started domestic manufacturing, and founded the Russian Academy of Sciences with strong mathematical bias (Euler, Bernoulli, Lobachevsky, Chebyshev,...). After abolition of serfdom in 1861, Russia started slowly transform herself from a mostly agricultural feudal country into an industrial capitalistic society. Developing manufacturing, commerce, and banking required replacement of he traditional Russian accounting device called “schoty” (a sort of abacus) by some more elaborate calculators.

Jakobson’s adding machine



The adding machine was invented by ***Jevno Jakobson***, a mechanic and clock master from town Nesvizh, sometime around 1770. The machine operated with numbers up to 109 and was mainly intended for adding and subtraction. It included a combination of pinion wheels for addition,subtraction and tens carry. It was also possible to do multiplication in the following way:

• add the first multiplicand to itself the number of times equal to the digit in the rightmost position of the second multiplicand and write down the result;
• add the first multiplicand to itself the number of times equal to the digit in the 10’s position of the second multiplicand, multiply it to 10 and write down the result;
• add the first multiplicand to itself the number of times equal to the digit in the 100’s position of the second multiplicand, multiply it to 100 and write down the result;
• and so on;
• add all intermediate results.

Slonimski’s multiplication machine

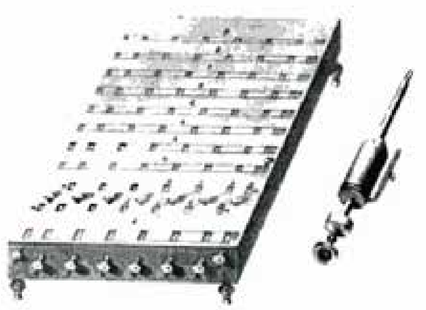
Hayyim Z. Slonimski (1810–1905)

Hayyim Z. Slonimski from Bialystok (then Russia) was a deeply knowledgeable Talmudist and a self-taught mathematician.He designed a machine was based on the theorem discovered by him. The machine allowed to receive products of any number (whose digit capacity did not exceed a digit capacity of the device) on 2, 3, 4..., 9. It was something like the mechanical table of multiplying of any number by 2, 3, 4..., 9. Since the amount of related numbers was not that large, they were put on the cylinders, which – when moved appropriately – were showing the multiplication results in small windows.

In 1845, Slonimski presented the machine to the Russian Academy of Sciences in St. Petersburg, and obtained their recommendation for the Demidov Prize, which was awarded to him (2,500 rubles). He was also granted patent for this machine in Russia for the period of ten years. The Slonimsky theorem is derived from the Farey sequences. Each Farey sequence starts with the value 0, denoted by the fraction 0/1, and ends with the value 1, denoted by the fraction 1/1 (although some authors omit these terms).the Farey sequence of order n is the sequence of completely reduced fractions between 0 and 1 which, when in lowest terms, have denominators less than or equal to n, arranged in order of increasing size.

F2 = {0/1, 1/2, 1/1}
F3 = {0/1, 1/3, 1/2, 2/3, 1/1}
F4 = {0/1, 1/4, 1/3, 1/2, 2/3, 3/4, 1/1}
F5 = {0/1, 1/5, 1/4, 1/3, 2/5, 1/2, 3/5, 2/3, 3/4, 4/5, 1/1}
F6 = {0/1, 1/6, 1/5, 1/4, 1/3, 2/5, 1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 1/1}
F7 = {0/1, 1/7, 1/6, 1/5, 1/4, 2/7, 1/3, 2/5, 3/7, 1/2, 4/7, 3/5, 2/3, 5/7, 3/4, 4/5, 5/6, 6/7, 1/1}
F8 = {0/1, 1/8, 1/7, 1/6, 1/5, 1/4, 2/7, 1/3, 3/8, 2/5, 3/7, 1/2, 4/7, 3/5, 5/8, 2/3, 5/7, 3/4, 4/5, 5/6, 6/7, 7/8, 1/1}

On the basis of the theorem, Slonimsky has made the table consisting of 280 columns – by 9 numbers in eash one. This table is put on the cylinders that are the basic element of the device. The cylinders can move in two directions: along an axis and around it. Two mini-cylinders are also on the axis, where the cylinder. On the surface of one the mini- cylinders the numbers from 0 to 9 are plotted, and on the surface of the other one – charactera a, b, c, d and numbers (from 1 to 7).



On the cover of the device there are 11 lines of windows of reading, in the first (lower) line the set number (multiplicand) is visible. In the second and third lines of windows characters and digits appear at installation of in setting multicand. Their combination is the key for an operator. Due to it he knows, what screw and haw far is necessary to turn. After that in the 4-11-th lines of windows there appear numbers: in the 4-th line – product of multiplicand by 2, in the 5-th - by 3, in the 6-th by 4 and so on. Thus, there is the product of the multiplicand by all bits of the factor at our disposal. Now all that is left to combine these results and to receive the unknown quantity product by the ordinaly way (on a sheet of paper).

Certainly, all that is not so convenient, and the Slonimsky device was hardly used by somebody requearly. However, it served as the prototype of one more simple multiplying device (Yoffe bars), that got mush wider use.

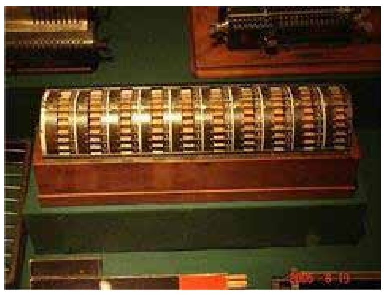
It turns out that Slonimski did not seem to have published the theorem at all. He presented it to the St. Petersburg Academy, where it was recorded in the minutes. Moreover, he never proved it himself. However, it is interesting that a German mathematician August Leopold Crelle, who was familiar with the theorem from Slonimski's personal communication during his visit to Berlin in 1844, and later published Slonimski's paper on his machine [8], took time and proved Slonimski's theorem and published the result in his own journal.

Chebyshev's machine

Pafnuty L. Chebyshev (1821–1894)

In 1876, the famous Russian mathematician ***Pafnuty L. Chebyshev*** made his report "Adding Machine of Continuous Motion" at the French Association of Assistance to Prosperity.It was a ten decimal places adding machine with a continuous tens carry, the first known machine with this type of carry. In a regular calculating with discrete carry, the wheel of higher rank moves on by one point, while the lower rank wheel moves from 9 to 0. During the continuous tens carry, the wheel of higher rank moves from one point to the next gradually and continuously, while the the lower rank wheel turns by one revolution. Chebyshev reached this effect by implementing a planetary transmission. Two years later Chebyshev created a second improved model of his adding device, which was presented in 1878 to the Paris Museum of Arts and Crafts. Later, he made a dividing-multiplying extension unit for the machine, which was also sent to the Paris museum in 1881. So the machine became a real arithmometre (can be used for the all arithmetical operations), which has two separate blocks – one for addition and subtraction, and one for multiplication and division.

The main purpose of the machine was to demonstrate the new principle of continuous tens carry. The dividing-multipying unit also had some innovations, e.g. the automatic shifting of the carriage from decimal place to decimal place. The unit itself served as the carriage part, that is the moving part of the mechanism. It was mounted on the adding machine, thus imposing one single device. To perform multiplication, the operator only needed to turn the handle. The number of turns was equal to the sum of numbers of the multiplication factor, added to the number of its decimal places minus one. After multiplying by a number (digit) of one decimal place, the mechanism automatically stopped multiplication and shifted the carriage to the next decimal place. This was repeated with the next decimal place digit, etc. The number of the handle turns was automatically controlled by means of a special counter, connected to the mechanism for setting the factor.



Since the donation of the machine to the museum was not followed by any publications, this invention didn't become famous. As late as 1890 the French scientist Eduard Lucka displayed a variety of Chebyshev's mechanisms, including the arithmometre, on a special stand at the Paris Museum and gave several lectures about

Chebyshev. Later on the french historian Maurice d'Ocagne contacted Chebyshev for description of the machine and published an article.
In fact, both machines of Chebyshev were made only for demonstration purposes. He never seriously thought of creating a device for practical or commercial use. His personal innovations are continuous tens carry and automatic shifting of the carriage from decimal place to decimal place during multiplication. Both inventions became popular and were widely implemented in 1930s, when electromotive drives came into use in the quickly growing generation of automatic and semi-automatic keyboard calculating machines.

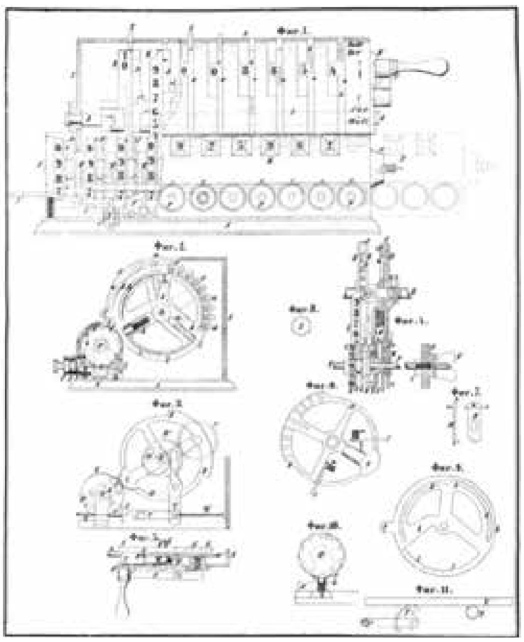
Odhner arithmometer

W. Theophil Odhner (1845–1905)

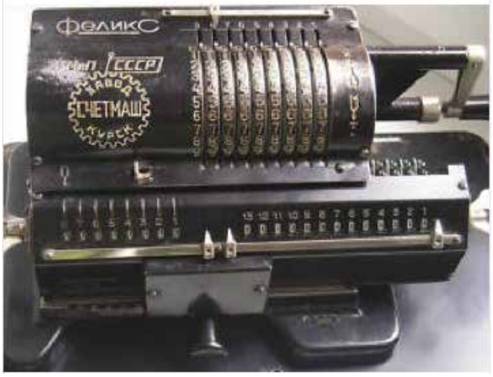
W. Theophil Odhner invented his mechanical calculator in 1873 in Saint Petersburg. He built 14 machines for Ludvig Nobel, his employer at the time, then patented it in several countries and started serial production in 1890. The arithmometer became one of the most successful type of mechanical calculator ever designed with millions sold in 19th and 20th centuries. In 1924, the Soviet government moved the old production facility to Moscow and commercialized their calculator under the Felix Arithmometer name which went on well into the 1970s. Odhner's arithmometer was copied, manufactured and sold by many other companies all over the world. It was recognized that, by the end of the 1940, the Odhner arithmometer was the most popular portable mechanical calculator in the world.
Willgodt Theophil Odhner was born in 1845, in Dalby, Värmland, in central Sweden. Odhner studied mechanics and mechanical technology at the Royal Institute of Technology in Stockholm, but although he completed his third year he never finished his study. Finding employment in Sweden was difficult in those times and in 1868 Odhner moved to St. Petersburg in Russia where he found a job iworking for fellow-countryman Ludvig Nobel – the older brother of the famous Alfred Nobel.
Odhner must have seen (possibly brought in for some repair) or have read about the Thomas de Colmar arithmometer which was designed in 1822. He thought that he could design a better and more efficient calculating machine. His solution was based on a geared pinwheel mechanism and resulted in the well-known barrel-shaped calculating machines bearing his name. It was ready for demonstration in 1875. In 1878 he submitted an application for the patent on his invention to the United States Patent Office which was awarded three months later; this was soon followed by patents in other countries.

The Odhner arithmometer of 1890

Fortunately Nobel saw the merit of the Odhner machine and asked him to produce 14 machines. He also gave Odhner some space in his factory for the manufacture of these machines and he agreed to carry the costs as well as paying Odhner a salary. The two men agreed they would later split the profits of this endeavour. Although the first model carried only 9-digit results, the next version could handle 10-digit answers and this increased to 11 digits by 1889. The machine had three registers: one to manually set the multiplicand, one to register the result and one to count the revolutions of the crank (i.e. the multiplier). For each manual revolution of the crank the multiplicand would be added to the results register, while the revolution register kept track of the number of revolutions. After having done one decimal position the carriage was shifted one position to the left for the next decimal. Clearing of the registers took place through the use of wing-nuts on either side of the carriage on earlier models, clearly visible in above illustration. In later models the wing-nuts were replaced by crank handles.
In 1886 Odhner founded the W.T. Odhner, Maschinenfabrik & Metallgiesserei in St. Petersburg for the manufacture of his calculators. The design Odhner Paten proved quite reliable and the machine was easy to handle.



The patent drawings of Odhner's 1879



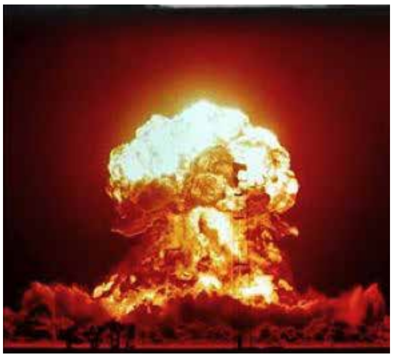
The Soviet Felix arithmometer

Odhner died in 1905, in St. Petersburg and his sons Alexander and Georg took over the reins. Their company produced about 23,000 calculators until 1917. During the Russian Revolution of 1917 the factory was nationalized.

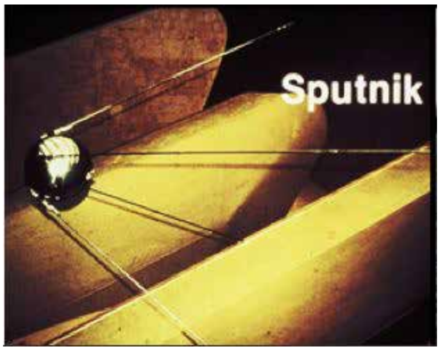
There are many legends about how Odhner became interested in calculating machines at a young age. There are two stories about that told by Odhner himself. First of them is, that as a quite young engineer Odhner had in 1871 an opportunity to repair a Thomas calculating machine and then became convinced that it is possible to solve the problem of mechanical calculation by a simpler and more appropriate way. The other story is that in 1875 Odhner had read an article about Thomas arithmometer and thought it might be possible to construct a simpler calculating machine.

First Computers: Big, Slow, and Amazing

Time Frame



50-s was the first decade of the full-scale Cold War between the Soviet Union and the United States (and their allies). Those were years of intensive economic and technological competition, culminating in the nuclear arms race and the space race. Those races demand solution of complex scientific and engineering problems, which, at the end, required thousands and millions of calculations. Mechanical calculators and analog differentiators could not do it, so ideas of using electronic calculating machines led to the design and construction of the first computers.



Sergey A. Lebedev and ***Isaac S. Bruk*** were the designers of the first Soviet computers. Amazingly, their biographies are very similar: they were born in the same year (1902), graduated from the same college, started their research carriers at the same institution, both came to the development of digital computers via working first on analog computers, and both started their first computer designs at the same year (1948) and finished their projects approximately at same time. They passed away three months apart.

Lebedev and His Computers

Sergey A. Lebedev (1902–1974)

Sergey Lebedev started the design his first computer (the first in the continental Europa) MESM (Mini Electronic Calculating Machine) in 1948 in Kiev, Ukraine, and at the beginning of 1950 he demonstra was organized in Moscow to lead research in computing and Lebedev was invited to head a new project of a larger computer BESM (Big Electronic Calculating Machine), which started the first series of Soviet mainframe computers BESM and M-20 built in 1950-1960s.

The first BESM used more than 5000 vacuum tubes, had 1024 words of the ferrite core memory, 4 magnetic tapes of 30,000 words capacity each, and a fast magnetic drum with a capacity of 5120 words and an access rate of 800 words/second. The computer was capable of performing 10,000 operations per second and was the fastest computer in Europe at the time.

The series was continued with ***BESM-2*** and ***M-20*** (also used vacuum tubes) and ***BESM-3, BESM-4, M-220,*** and ***M0222*** (built using transistors). ***M-20's*** performance was 20,000 operation per second due to fast arithmetic and pipelining of operation. These machines were designed jointly with industry and were better suited for serial production and maintenance.

The culmination of the Lebedev's design became ***BESM-6,*** a computer with a simple yet advance architectural solutions that became the apogee of the Soviet high performance computing in 60-s.

Lebedev's monument in Kiev, Ukraine

Russian envelope, issued in 1977, commemorating Lebedev's 75th birthday

To build BESM, Lebedev needed more than 50,000 vacuum tubes. That was a significant portion of the yearly production of the tubes in the USSR. Besides, the production and distribution of goods were prescribed by the State Planning Committe a year ahead. Lebedev directly approached the plants producing the tubes trying to be the tubes for BESM, but had no success, as they there were no surplus to sell him. During this trips he noticed huge stands with thousands of vacuum tubes, which were tested for 20 days for failures. He proposed the plant to use his BESM as a testbed for the tubes. The management agreed and each 20 days the computer was shut down, all tubes that survived test has been returned to the plant and new tubes replaced them.

Bruk's Computers

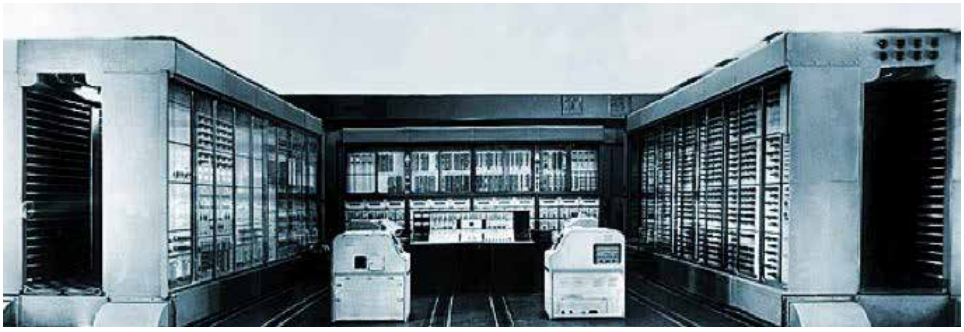
Isaak S. Bruk (1902–1974)

While Sergey Lebedev designed the first general-purpose mainframe computers, ***Isaak S. Bruk*** was the father of the future mini and control computers. Prior to starting work on digital computers, Bruk designed mechanical differential analyzers (with up to thousand rack-wheels). He and ***Bashir I. Rameev*** were awarded the first Russian patent on a "digital computing machine" in 1948, which however was never built. With a small team of enthusiasts and students, Bruk built his first computer ***M-1*** in 1951 and immediately started the second computer ***M-2***, then ***M-3***. These machines were not commercial, they were used mostly for solving some unique problems, such as durability of large hydro power dams built at that time.

He founded the Institute of Electronic Control Machines, which became the head organization that designed computers for real-time control of power stations, power grids, and technological processes.

The First Serial Computer Strela

Strela (Arrow) was the first computer serially produced in 1953–1956 in Russia, in Moscow, though the series was of only 20 machines. The computer had 6200 vacuum tubes, two tapes with capacity 1.5 mln words, used 150 kwt power, occupied an area of more than 3000 square feet, and performed 3000 operations per second. The Strela programmers were pioneers in developing software technology in Russia.



Computer Families: Industry was Born

Time Frame

The first man in space
Yury A. Gagarin

During the 60s, the USSR substantially expanded its influence at the international arena, specifically in the “third world”. The Soviet Union became the second superpower in the military aspects and continued successfully compete in the space. The industrial progress in the USSR was also substantial. However, growth rates slowed noticeably during the final years. The government tried to solve economical problems without reforming the system but rather strengthening the planning aspects of the management. And the road to the better planning was through developing ***automated management systems*** (***ASU***, the Russian abbreviation) for all management levels – from every enterprise to the State Planning Committee. ASUs for such a large economy required collecting, storing, and processing huge amounts of data. Thus, the government started to encourage the design and production of computers not only for research and defense, but also for running ASU applications.

The country’s top man
Leonid I. Brezhnev

The pioneering designs of 50s, which were mostly done in research institutions, were transferred to industry and complementary (and competing) computer families emerged at newly built computer R&D facilities in Kazan, Penza, Minsk, and other cities. They designed computers of proprietary architectures, which were well suited to the domestic engineering traditions and technological conditions.

The BESM and M-20 Family

BESM-2 was a serial (since 1958) version of Lebedev’s first BESM. It contained 5,000 diodes and 4,000 vacuum tubes and was quite reliable for that time. Hundreds of thousands of programs from mathematics, physics, and engineering was executed on this computer. In particular, the trajectory of the rocket, which delivered the USSR pennants on the moon in 1959, had been calculated on BESM-2.

M-20 had 20 thousand instructions per second, the ferrite core memory capacity of 4096 of 45-bit words, floating-point representation, the external storage included magnetic drums and tapes. It used automatic address modification, overlapping of the instruction execution with fetching data from memory, a buffer memory for overlapping printing with calculations, mechanisms for rapid start and stop of the tape.

One of the first Russian operating systems, IP-2, was developed for M-20 at the Institute of Applied Mathematics in Moscow.

BESM-3, M-220, and ***M-222*** were transistor-based computers with architecture derived from M-20. The volume of the ferromagnetic memory was increased up to 16K words for M-220 and up to 32K words for M-222. The M-220 instruction set was also enhanced: e.g. a square root instruction and several commands of switching from one memory unit to another were added. BESM-4 and M-222 had interrupt system, memory protection, and could communicate with other computers. All computers of this group received upgraded external storage and IO devices.

The vacuum tube M-20

The transistorized M-220 to replace M-20

BESM-6 was designed at the Institute of Precision Mechanics and Computer Engineering in Moscow. This was the main computer in research centers and in large data centers, the most influential among the domestic computer designs, very popular among Russian programmers. The production started in 1968 in Moscow. The basic configuration included 192 Kbyte of core memory (a virtual memory system allowed to expand this up to 768K bytes), magnetic drums, proprietary magnetic tape drives, teletypes, typewriters, alphanumeric printers, and punchcard/punchtape IOs. About 350 machines have been produced until early 80's.
The computer speed was one mln instructions per second, the memory cycle was 2 msec with 0.8 msec access time, the parallel interface for the six channels of external memory and 32 communication channels. Other important features:

BESM-6

- Deep overlapping execution of instructions based on an asynchronous pipeline architecture.
- High-speed associative buffer memory.
- The first virtual memory in the Russian computers.
- Operating system with a multiprogram mode.

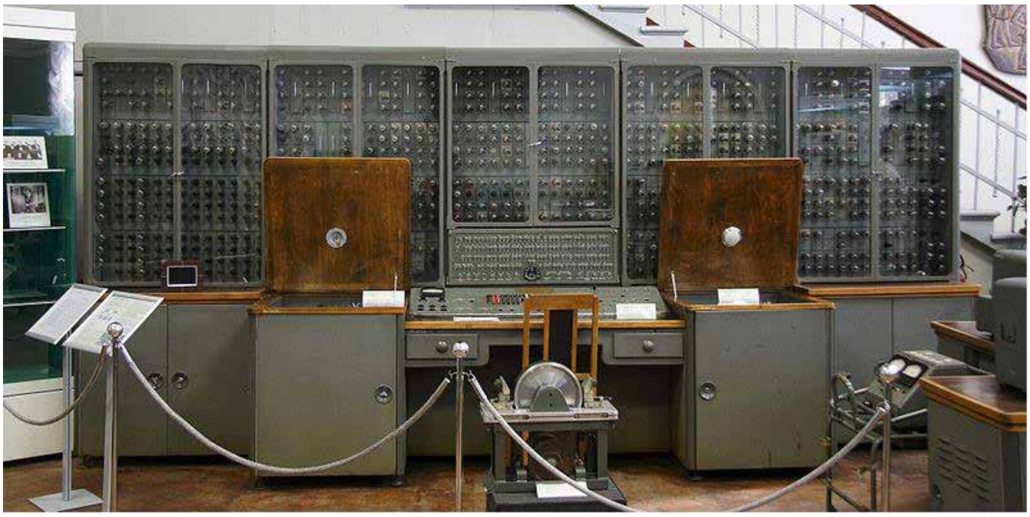
High performance was achieved with relatively small number of semiconductors (approximately 60,000 transistors and 180,000 diodes).
BESM-6 was a "number cruncher", so it had no any specific instructions for symbolic processing. The memory could be addressed only a word by word. BESM-6 had one of the largest and most active user community in the Soviet computing. There were compilers for the most popular programming languages: ***Algol-60, Fortran, Pascal, APL, Lisp, Refal, Forth, C*** , and others. However, inadequate operating system and small programming space forced to use mostly low-level programming languages. This hampered the development of unsophisticated software and applications in the Soviet Union.
An extension of BESM-6 (named AS-6), which was better suited for symbolic processing, has been designed, but only several (4 or 5) systems have been actually built.

The Ural Family

Bashir I. Rameev (1918–1994)

Ural was a family of general-purpose computers focused on engineering and economical applications. They were designed by ***Bashir I. Rameev*** who earlier worked with Isaak Bruk and then was involved in the development of Strela. The first four models (Ural-1, Ural-2, Ural-3. and Ural-4) used vacuum tubes; Ural-P, Ural-14, and Ural-16 were transistor-based computers.

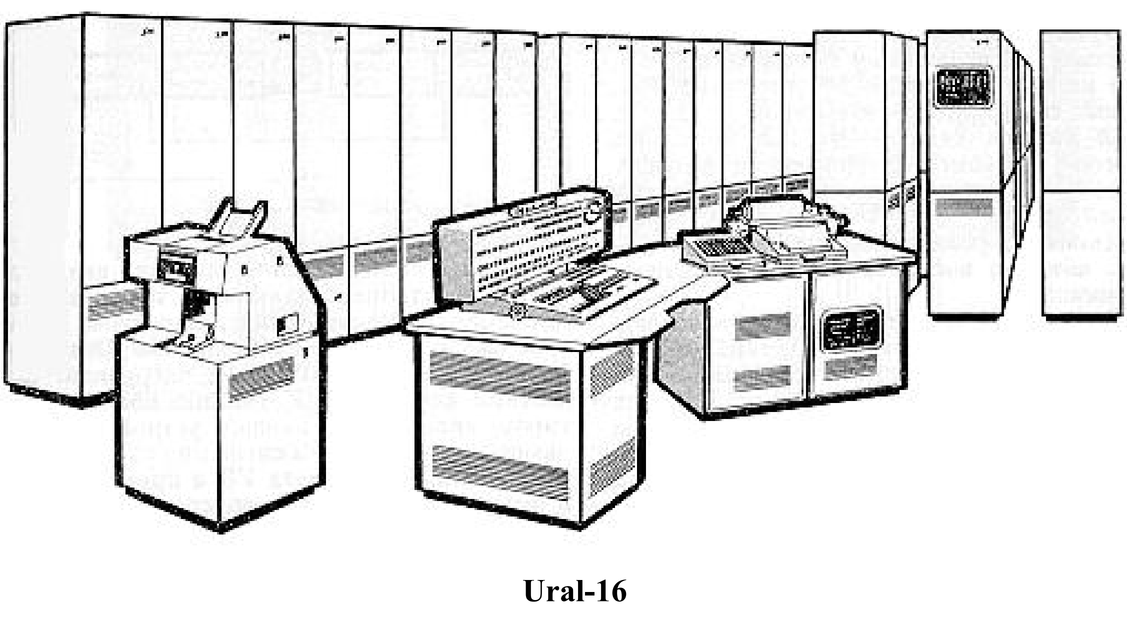
Built in 1957 in Penza, a city south of Moscow, Ural-1 was a small and relatively cheap computer for engineering applications. The machine had small yet developed instruction set with manual control to monitor program performance and interfere in the course of its execution to make corrections during debugging. The main technical characteristics: 36-bit fixed-point number representation, a single-address instruction set, the speed was 100 instructions per second. A magnetic drum, storing up to1024 words served as the core memory. It was supplemented by an external magnetic tape (40 thousand words) and punched tape (10 thousand words). The keyboard printer and the punched tape were the only I/O devices.



Ural-1

In subsequent models, Ural-2, Ural-3, and Ural-4, the ferrite core memory replaced the drum, the capacity of the drum and tape external storages was extended, as well as the spectrum of I / O devices. Those Urals formed a software and hardware compatible series of computers of different performance.

The next Urals (Ural-11, Ural-14, and Ural-16) produced between 1964 and 1971 formed a series of transistor-based computer systems, which were bottom-up hardware and software compatible, had unified interfaces and could be aggregated into various multi-machine configurations covering a wide range of applications. The Urals embodied many of the ideas that were then widely used in the computers of the third generation (extended interrupt system, effective memory protection, advanced system software, etc.).



Ural-16

The Minsk Family

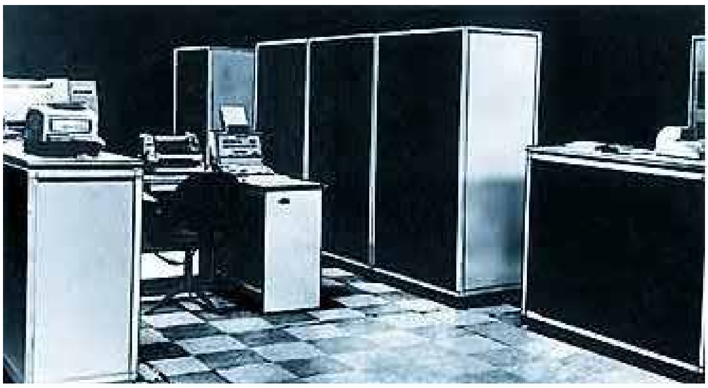
Minsk-1

The first series of the family, ***Minsk-1***, was started in Minsk, Bielorussia, at the end 50-s and was one of the first Russian serial mini-computers on vacuum tubes. Average performance of Minsk-1 was 2,000-3,000 instruction per second. It was used mostly for scientific and engineering applications.

The next series ***Minsk-2*** (Minsk-22 and Minsk-23) was one of the first mass-produced transistor mini-computers in the Soviet Union. It was able to input, process, and output of complex textual information and was widely used in ASU. An aggregate structure and the ability to easily vary the system configuration made these computers popular in data centers, in research institutes, design bureaus, and industrial enterprises.

Minsk-2

Minsk-32 was the most popular Russian computer of the second generation. It has absorbed all the best that had been achieved in the Minsk-22 and Minsk-23 both in architecture and software. The computer was extensively used in the business applications. Most commercial data centers were equipped with these machines. At the meeting of the Comecon in Budapest in 1972, Minsk-32 was recognized as the base computer for developing ASU in the Comecon countries.



Minsk-32

Let 100 Flowers Bloom: Special and Unusual

Time Frame

A Soviet missile early warning station

After the first wave of general-purpose computers had proved their ability to solve complex mathematical problems, computer designers started to look how to expand their spectrum of applications and use them to monitor the airspace, to control technological processes, to process textual information, etc..So, a variety projects of new computers of different power, style, and specialization has been started in Moscow, Minsk, Kazan, Kiev, Yerevan, Vilnius, Severodonetsk, and other places.

To solve those special problems with minimal cost, specialized computers were designed.

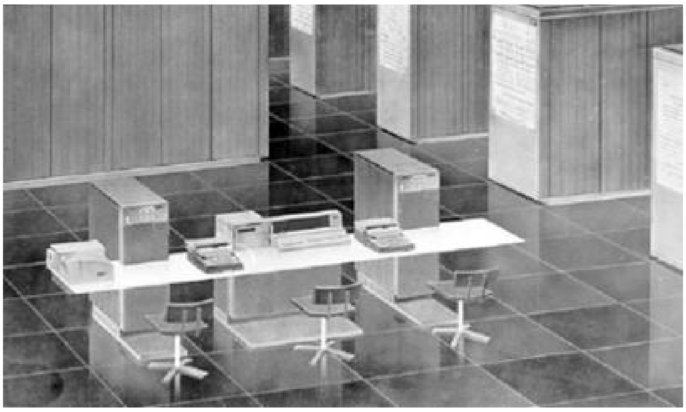
Also, the first computers amazed and attracted attention of many Russian mathematicians. Mathematics (like chess) was the favorite Russian science for years, as it did not required substantial material and financial resources, just good brains that were in abundance. And here were coming “mathematical machines” of an incredible power and sophistication. Naturally many talented mathematicians wanted to be involved in the design of those machines. And they tried to invent new ways to speed up computers, to increase their reliability, and to reduce complexity and cost by using non-trivial computer arithmetic.

Computers Watch the Sky

Mikhail A. Kartsev (1923–1983)

In 1957, the Russian defense industry started to plan using computers in the radar systems for the ballistic missile early warning system and space surveillance. It was a very difficult task at that time due the huge amount of data to be processed in real time, required memory capacity and reliability of the hardware. By that time, the Russian electronics industry just released the first commercial domestic transistors. Therefore, decision was made to design a transistor-based computer M-4 and to appoint ***Mikhail A. Kartsev***, who earlier actively participated in the development of Bruk’s computers M-1 and M-2, as the Chief Architect. The designers of M-4 were actively involved at all stages of M-4 production and configuration. This experience allowed the team to ensure the highest possible at that time level of reliability and maintainability. Dozens of the computers M4 and their modifications M4-2M-3M, spread over thousands of miles of the vast Soviet Union territory, were merged into a single computer network of the anti-missile defense.

M-4 for early warning systems



The multiprocessor system M-10

The next step was multiprocessor computers M-9, M-10. The creators of the M-10 succeeded in solving a rather complicated task: to built a computer with performance was more than 5 million operations per second using relatively slow chips of a low integration. While on the (largely formal) parameters M-10 trailed Cray-1, it far exceeded its architectural capabilities: the average number of machine cycles per operation in the M-10 ranged from 0,9 to 5,3,and from 0,7 to 27,6 in Cray-1. It can be argued that until the early 80s, M-10 was the most powerful computer in the world.

The last creation of Mikhail Kartsev, the vector-pipeline multiprocessor M-13, was transfered into production only after his death. It is discussed in the “Supercomputers: Testing Limits”.

Ukrainian Computers

Viktor M. Glushkov (1923–1982)

Viktor M. Glushkov, the founder of the ***Institute of Cybernetics*** in Kiev (in 1957) and its director until his death, contributed enormously to the Russian computer science and was the chief ideolog of all computers that were designed in the institute.

Kiev was the first computer designed and built in Kiev in 1956. It was the first European computer with a high-level assembly programming language (pointer-based language), as well as the first system for digital image processing and modeling primitive intellectual processes. It has two peripheral devices that allow the computer to simulate the simplest learning algorithms of pattern recognition and goal-directed behavior: a scanner and image display.

The vacuum tube computer Kiev from Kiev in 1956

Dnepr, designed in 1961, was a multi-purpose transistor-based control computer for continuous monitoring and control of technological processes and complex physical experiments.

The series ***Mir*** (Mir-1, -2,-3) were mini-computers for calculations in engineering, research, and businesses. It may be considered as a prototype of the personal computer, though it was not a desktop, it was a desk with the computer inside.

The computer Mir-1 for engineers

Unusual Computers

Ternary computer

Beginning in the 1950s, Soviet scientists ***Sergei L. Sobolev*** and ***Nikolay P. Brusentsov*** conducted research on ternary computers that operated on a base three numbering system of -1, 0, and 1 (ternary arithmetic) rather than the conventional binary system upon which most computers are based. They designed the ***Setun***, a functional ternary computer, at Moscow State University. With a minimal instruction set (only 24 single-address instructions), Setun provided the fixed and floating-point arithmetics, an optimized computation of polynomials , the operation of bitwise multiplication, and three conditional transfer instructions. A simple and efficient architecture allowed a small group of programmers to equip the computer with advanced system programs and a rich set of applications. The computer was put into a limited production, but was supplanted by the more common binary architecture. In 1970 Brusentsov built an enhanced version of the computer, ***Setun-70.***

Setun-70The ternary computer Setun-70

With the advent of mass-produced binary components for computers, ternary computers have diminished to a small footnote in the history of computing. However, ternary logic's elegance and efficiency is predicted by Donald Knuth to bring them back into development in the future. Possible ways on how this can happen is by the combination of an optical computer with the ternary logic system.

RNS-Based Computer

A ***residue number system (RNS)*** represents a large integer using a set of smaller integers, so that computation may be performed more efficiently. A RNS is defined by a set of N integer constants, $\{m_1, m_2, m_3, \ldots, m_N\}$, referred to as the moduli. Let M be the least common multiple of all the m_i. Any arbitrary integer X smaller than M can be represented in the defined residue number system as a set of N smaller integers $\{x_1, x_2, x_3, \ldots, x_N\}$ with $x_i = X \textit{ modulo } m_i$ representing the residue class of X to that modulus.

Israel Akushsky got the idea to build a RNS-based computer in 1954. By decomposing large integers into a set of smaller integers, a large calculation can be performed as a series of smaller calculations that can be done independently and in parallel. Because of this, it can be particularly suitable for hardware implementations. The use of RNS should increase the speed of certain operations and reduce the logic element count of the arithmetic units. The RNS arithmetic would have the following speeds contrasted to a comparable conventional fixed-point computer of reasonable range:

- Addition and subtraction - twice as fast
- Multiplication - ten times as fast
- Division - one-third as fast
- Sign determination - five to ten times slower

It took some time to persuade other people that the idea had merits. Finally, the project was approved and RNS computers (T-340A and K-340A) were built and successfully used in the national air defense system. For the first time in the USSR and in the world, K-340A has achieved performance of more than 1 million instructions per second and reliability of the thousands of hours (a typical computer performance for those days was in the tens of thousands) . More than 50 K-340As were built. Using RNS, Akushsky developed numerical methods for super-large ranges of numbers, which consisted of hundreds of thousands of digits.

Crucial Dilemma: To Copy or To Invent

Time Frame

The IBM S/360

By mid-60s computers started their rapid expansion from their birthplaces - science, high-education, and defense institutions - to banking, commerce, and industrial design and manufacturing. Large-scale production, maintenance, and use of computers required also to move from a variety of non-compatible machine and devices to system families designed to cover the complete range of applications, from small to large, both commercial and scientific. One could expect that in the Soviet Union, with its state economy, the variety of computer models was small and some unification was already in progress by that time. That was not the case. Dozens of organizations were developing their proprietary architectures without any serious attempts to unify interfaces, software, and applications. When IBM created an entire series of computers ***System/360 (S/360)*** of the "third generation" from small configurations to large ones, all using the same instruction set, customers were able to buy cheaper models and then upgrade them to larger systems as their needs increased without the time and expense of rewriting software.

Dilemma: to copy or not to copy

In 1966 the Soviet government requested that new computers for the use in the growing national economy should be built on a unified architecture and microelectronic technology and their system software should be compatible. However, there was no consensus how to reach this goal quickly. Some proposed to start new proprietary compatible computer family from scratch or developing some elements of hardware compatibility that had been demonstrated by some domestic families, for example "Ural" (Ural-11, Ural-14, Ural-16) . Others argued that was better to copy some well-tested and widely popular western families. The acquisition of licenses from ***Siemens*** (Germany) and ***ICL*** (UK) that produced their own compatible computer families was considered. However, the required amount of hard currencies was not available. And it was not possible to get a license from the American government to reproduce the IBM S/360 system.What was possible was to create the Soviet computers programmably compatible with the IBM S/360 system.

Arguments against copying

Copying IBM S/360 will put the Soviet Union several years behind the USA and other countries (the IBM S/360 was launched in 1964).

Switching to copying would destroy the creativity and innovation in the domestic computer community and kill just recently emerged domestic computer R&D institutions.

Copying the American system will make the Russian computers vulnerable to the "cyber attacks" of that time by the American military or CIA.

Arguments for copying

It was impossible to say with certainty how long it would take to build the domestic third-generation computers.

The IBM software was the most rich, well-documented, and advanced by that time. Creating IBM-compatible machines promised quick computerization of the USSR economy.

After a long and heated debate, the Soviet government followed the Solomon judgment: the defense industry would mainly rely on the development of proprietary domestic computer architectures (with a support from the research institutions) and the national economy would embrace the computer families patterned on the most popular American architectures. The first thread was represented by the Elbrus and specialized military computers. The second one was represented by the Unified System and the System of Small Computers.

The Unified System

On March 18, 1968, the USSR Ministry of Radio Industry, which was responsible for production of the computers, issued a directive to start the development of the ***ES (Edinaya Systema, or Unified System)*** computer family, called also ***Ryad (Series)***. The head coordinator of the program became the newly organized the ***R&D Center of Electronic Computer Technology (NICEVT)*** in Moscow (according to The Guinness Book of Records, the NICEVT has the longest building in the world):

The NICEVT, as the ES head organization, coordinated the activities of many other R&D centers both in the Soviet Union and in the Council for Mutual Economic Assistance (Comecon) countries (see the Comecon exhibit). Most of the centers that had been developing the popular Soviet computers families (see Computer Families) in 1960s, such as Ural in Penza, Minsk in Minsk, Nairi in Yerevan, and others were redirected to develop specific members (or components) of the ES family. The proprietary domestic computer dynasties have been exterminated, except for those organizations that worked for the defense and some research projects in the USSR Academy of Sciences.

The Unified System I

The first computers of the Unified System were introduced in 1971–73. The ***ES-1020*** (20,000 instructions per second and the memory capacity of 64-256 Kbyte) was created in Minsk. It was delivered with the DOS operating system, the Cobol, PL-1, and Fortran-4 translators and allowed to perform simultaneously three tasks.
The ***ES-1030*** (70,000 instructions per second and the memory capacity of 128-512 Kbyte) was released in Yerevan. The ***ES-1040*** was launched in Karl-Marx-Stadt (now Chemnitz) in the East Germany and the ***ES-1050*** in the NICEVT.

The ES-1020

The Unified System II

In the summer of 1972, the first meeting of the chief designers of the ES computers raised the question about the second series of the Unified System that should be fully software compatible with the computers of the ***IBM S/370*** series with a larger RAM, virtual memory organization, as well as increased performance and accuracy.
In 1977-1978, the computers of the second series Unified System were created. The ***EC-1035, EC-1045***, and ***EC-1060*** were made in the USSR, Hungary produced the ***EU-1025***, and East Germany introduced the ***EC-1055***.
The ***EC-1060*** has stood out of its brethren. Its speed was 1.05 million operations per second, the RAM memory volume was up to 1.8 MB, the total bandwidth was 9 MB / sec. The operating system ***OS 6.1*** had the regime of virtual memory, means of diagnostics and recovery, a run-time debugging monitor, an optimizing compiler from the language of ***PL-1*** and the software packages that came with it.
Later on, the ES-1060 was upgraded to the ***ES-1061***. This computer had doubled performance, better reliability, smaller size, cost, and power consumption.

The ES-1060

The Unified Systems III and IV

The first computers of the Unified System III appeared in 1984. They were the Soviet ***ES-1036***, ***ES-1046***, and ***ES-1066***, the Czechoslovak ***ES-1026***, and ***Hungarian ES-1016***. The performance of the most powerful EC-1066 was 5.5 million operations per second. As the operating system, was used the OS-7, which consisted of the base operating system and the system of virtual machines.

In the second half of the 1980's, the Unified System IV was initiated with computers ***ES-1130***, ***ES-1170*** and ***ES-1181***. However, in the course of the perestroika the economic situation in the Soviet Union in the second half of 1980's deteriorated sharply. The funding for the Unified System was drying out. To this, the personal computers revolution reached also Russia and the mainframe computers started quickly to be replaced by mini- and micro-computers.

The SM Family of Mini-Computers

The ***Institute of Electronic Control Machines*** (***INEUM*** is the Russian abbreviation) founded by ***Isaak S. Bruk*** has been successfully developing small computers for real-time control of technological processes and small enterprises in 1960's and early 1970's. When the Unified System program was initiated, the similar program was proposed for small computers and the INEUM was designated to be the head organization for the program that was named ***System of Small Computers***, or ***SM***, ***Systema Malykh*** (Machines) in Russian. As in the case of the Unified System, the Eastern European countries of the Soviet block were included into the SM program.

Unlike the Unified System, the SM was not one series of compatible computers differing in performance, but several families of mini- and micro-computer architectures. They were associated with specific applications and different levels of complexity of controlling technological processes. The goal was to ensure that each level of the complexity would have computer systems with relevant capabilities.

The SM-1 mini-computer

The SM-4 mini-computer

The ***SM-1*** and ***SM-2*** families were 16-bit computers with the instruction set of the ***Hewlett-Packard HP-2000***. Other SM computers were mostly built in accordance with the de facto internationally standard architectures developed by ***Digital Equipment Corporation*** (DEC). The models ***SM-3*** and ***SM-4*** were patterned on the ***PDP-11*** architecture, in which all communications between the processor, RAM, and the I/Os were based on a single interface: the common bus. The common bus was also implemented in 32-bit microprocessor-based mini-computer ***SM-1700***, which was software compatible with the ***VAX-11*** and appeared in the late 1980's. The SM computers were widely used in the USSR, specifically in the energy industry.

Supercomputers: Testing Limits

Time Frame

The Cray-1 supercomputer

Each computer generation had its high-performance leaders. But the 1970s witnessed appearance of supercomputers, one-of-the-kind custom designed computers with a top-tier performance. To some extend, they were similar to the racing cars in the automotive industry. ***Seymour Cray*** pioneered the supercomputer design and was followed by other ambitious computer architects. Though by that time the Soviet Union lagged in the hardware technology and in the computer production capacity with relation to the USA and Japan, the hope was that Russian designers could outsmart the competition by developing novel architectural solutions and smart algorithms for solving complex calculation-intensive mathematical problems that were typical supercomputer applications.All supercomputers exploit computational parallelism in its various forms and contain multiple (often many) processors.

M-13

The M-13 supercomputer

The main architectural principles developed by ***Mikhail Kartsev*** in the ***M-10*** multiprocessor computer were implemented and extended in his last project, the VLSI-based supercomputer ***M-13***. Its production started in 1984, one year after his death, and around 20 computers have been made. M-13 was intended for using in complex control computer systems and for processing large amount of information in real time.
Each M-13 processor performed operations on one, two or four pairs of, respectively, 32 -, 16 - or 8-bit operands. Depending on the version, M-13 could contain 8,5, 17 or 34 MB of RAM and 4, 8 or 16 processors, respectively, achieving performance of 12, 24 or 48 million op /sec. The maximum speed was equivalent to 2.4 billion instructions per second.

Elbrus

The Elbrus-2 supercomputer

The original ***Elbrus*** computer family was developed at the ***Institute of Precision Mechanics and Computer Engineering*** in Moscow in the 1970s. It was patterned after the ***Burroughs B6700 and B770 stack architecture***, but it was not a clone of those computers: the instruction set and data structures were significantly different and included more advanced mechanisms for data description, protection, and allocation.
The family included ***Elbrus-1***, the first Soviet integrated circuit computer of the fourth generation, with the speed from 1.5 MIPS (mln instruction per second) to 10 MIPS and a higher-performance ***Elbrus-2*** with the maximal speed of over 100 MIPS. Both Elbrus-1 and Elbrus-2 were built on the same structural principles, their components were functionally identical, and their processors had the same instruction sets and their operating systems were functionally equivalent.
The Elbrus computers were used in the Soviet space program, nuclear weapons research, and defense systems.
The main components of Elbrus were:

- from 1 to 10 central processors
- from 4 to 32 memory modules
- from 1 to 4 input-output processors
- from 1 to 16 communication processors
- control modules drums and discs, forming the storage management system

Each processor can access any memory module via a switch, which also blocks corrupted modules and provides backup modules. The reliability was guaranteed by advanced hardware monitoring and controlling processors and by sharing of information at all levels of the system. The central processor’s instruction set was based on

the hardware implemented stack memory access. The machine-level language was based on the ***Reverse Polish Notation*** (which needs no parenthesis), and represented sequences of operands (or pointers on operands) placed on the stack with operations performed on the operands at the top of the stack. The Elbrus system software was written in proprietary high-level language ***El-76***, which was developed in parallel with the design of the hardware. The Elbrus designers strongly relied on El-76 for all needs to write system level software. It was similar to ***Algol-68***, whose block structure easily executes on a stack-based architecture. El-76 had better-developed condition-handling constructs, but, unlike Algol-68, provided parallelism only at the procedure level. The Elbrus operating system had functionality similar to that of the Burroughs Master Control Program.
Among other available high-level programming languages were: ***Fortran***, ***COBOL***, ***PL/1***, ***Pascal***, ***Refal***, ***Lisp***, ***Forth***, ***Simula-67***, and ***SNOBOL4***.

Elbrus Related

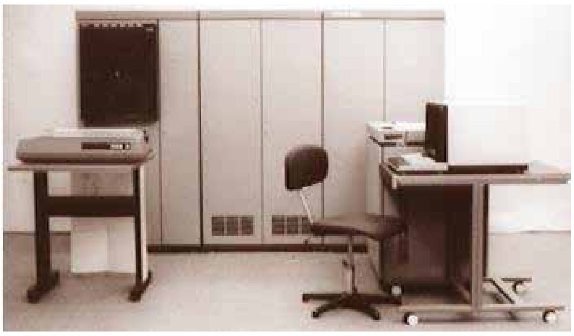
Elbrus 1-K2, or ***SVS***. The Elbrus program was actively supported and financed by the Soviet military-industrial complex. However, delays in the design and production, as well as concerns about to radical switch from previous computing environments to new proprietary architecture and software, force to think about softening the transition from popular BESM-6 to Elbrus by developing ***Elbrus 1-K2***, better known as ***SVS***, a specialized Elbrus processor compatible with the BESM-6 software and Elbrus hardware. SVS significantly expanded main memory and external storage capabilities for old programs of the BESM-6 users.
Elbrus 3-1. The core of Elbrus 3-1 was a powerful modular pipelined processor capable of handling two independent threads: vectors and scalars. Scalars are injected into a vector pipeline and processed between two adjacent components of the vector. The memory switch provided up to 8 concurrent memory accesses per a clock cycle. As a result, the processor speed reached 500 MFLOPS on on vector operations. It was assumed that SVS, which had a decent amount of memory and rich BESM-6 software, will act as a host machine, using Elbrus 3-1 as a powerful vector-scalar co-processor.
Elbrus 3. Elbrus 3 developed in 1986 was a 16-processor computer. Its VLIW (Very Long Instruction Word) architecture was completely different from the architecture of both Elbrus 1 and Elbrus 2. Its serial production has never been launched.

Elektronika SS BIS

Vladimir A. Melnikov, one of the designers BESM-6, left the ***Institute of Precision Mechanics and Computer Engineering*** to start a new project, independent of the Elbrus design. The project was sponsored by the semiconductor industry to test how the LSI (Large Scale Integration) chips could by used to build high-performance mainframes. After analysis of the current advances in supercomputing, the decision was made to follow the ***Seymour Cray*** way and to design a vector pipeline computer, called ***Elektronika SS BIS*** (BIS is the Russian abbreviation for LSI).
Elektronika was not a clone of the Cray's computers and its architecture incorporated some interesting new solutions. For example, the operation of division was done in one cycle instead of three cycles as in ***Cray 1***. There were separate functional units for the floating-point scalar and vector operations that parallelized processing of scalars and vectors. There was also a semiconductor mass memory, which was an intermediate broker between the main (RAM, random access memory) memory and the external storage. It was designed to store actively used files and to eliminated the imbalance between the low-speed transmission of data from disks and fast processing of the data in the processor. A specialized processor chose data in an arbitrary order by calculating their addresses on-fly during the communication between the main and mass memories. An important achievement was the creation of an efficient freon cooling system. Completely original was the software for Elektronika SS BIS aimed at achieving high-efficiency in using the hardware and at optimizing the application execution.
In 1985, a prototype was successfully tested. In a single-processor version, it delivered up to 250 MFLOPS, that for the mid-80's was quite consistent with the supercomputer level. However, the final version of the computer appeared only in 1989, when its component base was already outdated, and performance lagged far behind the global standards for the high-performance systems. Nevertheless, by 1991 four copies of "Electronics SS BIS were delivered.

PS-x000

Some specialized applications, such as geophysics, fluid dynamics, real-time process control, and similar needed relatively cheap high-speed computers. A joint effort of the ***Institute of Control Problems*** and the ***Institute of Electronic Control Machines*** produced in 1970s the ***PS-2000*** and in 1980s PS-3000 multiprocessors for that applications.The computers had some features in common, yet had significantly different architectures.



The SIMD multiprocessor PS-2000

PS-2000 consisted of a parallel SIMD (Single-Instruction Multiple-Data) processor with between 8 and 64 processing units together with a monitoring host subsystem and an external storage. The processing units are linked together, each element with two its neighbors plus a serial bus linking all of them, and can be also segmented into clusters. The processing units worked under a single control units that broadcasts instructions and operands for simultaneous execution on all (or a part of) the units. The maximal speed was around 200 mln instruction per second. . The main disadvantage was the 24-bit word length. Effective use of the PS-2000 parallelism was difficult. The majority of software developed for PS-2000 has been written in an assembly language. There were around 150 PS-2000 systems installed by the mid 1980s.

The PS-3000 multiprocessor system

PS-3000 was a 32-bit multiprocessor system used primary for real-time process control. It was a MIMD (Multiple-Instruction Multiple-Data) system consisting of four SIMD multiprocessors. The developers claimed the maximal speed of 3 bln operations per second. However, the system did not went into serial production and not widely used.

Experimental Developments of the 1980s

As in the USA and other western countries, new ideas and solutions in computing were born in academia. The first Soviet computers has been designed in the USSR Academy of Sciences (or in a close cooperation with it). New architectural ideas for supercomputers were also emerging in the Academy . However, the Academy had no enough funds to do ambitious projects and had no access to the development and production facilities. Some most entrepreneurish researchers were able to sell their ideas to the government and industrial institutions in the late 1970s and early 1980s and initiated joint experimental projects in the supercomputer architectures. However, the perestroika in the 1980s and collapse of the Soviet Union canceled any possible follows up for those projects.

ES-1766. The theoretical foundations for the ES-1766 were developed by ***Viktor M. Glushkov*** in 1970s and a prototype was built in 1984. The ES-1766 was a “macro-pipeline” MIMD multiprocessor, in which different processors repeatedly execute different large fragments of a program and send the output to their neighbors (it was a sort of non-von Neumann data-flow architecture). With a complete set of 256 processors, the computer should achieve 0.6 bln operations per second. To be efficiently executed on the macro-pipeline multiprocessor, a program should be parallelized into fragments with balanced execution and communication time slots. So, the ES-1766 had a software development environment that hides all hardware details from the user. The operating system managed the assignment of program fragments to processors.

MARS-M. MARS stands for the Modular Asynchronous Reconfigurable System and grew from the late 1970s idea of an open hierarchical architecture with functional partitioning of subsystems at each level. The partitioning was implemented on the set of asynchronously communicating functionally specialized modules (processing, or memory, or control, or communication processors). Idealistically, such an architecture can be viewed as a fractal structure. In practice, it intended to make a shift from widely-used general-purpose architectures to more flexible multi-purpose architectures easily customized for specific application areas. The idea of the MARS architecture originated at the Siberian Branch of the USSR Academy of Sciences in Novosibirsk. MARS-M was also designed in the Novosibirsk scientific centre Akademgorodok with the support from the Elbrus project. The only prototype of MARS-M was built using the Elbrus-2 hardware technology. With the clock frequency 10MHz, the minimal configuration reached the peak performance of 20 MFLOPS due to the VLIW instruction set and functional concurrency.

MVS

MVS is the Russian abbreviation for Microprocessor Computing Systems, multiprocessor systems built of a (large) number of COTS (commercial off-the -shelf) microprocessors. The MVS chief architect, ***Vladimir K. Levin***, was among the leading designers of Soviet computers since the 1950s mostly focusing on high-performance computers for special applications. He started to work on the MVS in the 1980s and completed them in the 1990s, in the post-Soviet Russia, probably beating the record of professional longevity among the Russian computer architects.

MVS-100 was based on microprocessors with speed of about 100 MIPS, the interprocessor communication was provided by transputers. The MVS-100s with the speed up to 50 billion operations per second were successfully used in several data centers of the Russian Academy of Sciences and in industrial data centers. They were successfully used for solving complex application problems of aerodynamics for aircraft and a jet engine, nuclear physics, dynamic systems control, pattern recognition for navigation of moving objects, seismology, meteorology, bioengineering, and others. The possibility of an effective parallel computing and processing data.

MVS-1000 was built on microprocessors Alpha with the speed up to 1.2 billion operations per second. The total performance of the system installed at the Joint Supercomputer Center of the Academy of Science and Ministry of Education reached 200 billion operations per second.