Pioneers of Soviet Computing

By Boris Nikolaevich Malinovsky

Anne Fitzpatrick, editor

Emmanuel Aronie, translator

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Introduction to the English language version of *Pioneers of Soviet Computing*

In recent history, no other phenomenon has impacted our society and culture as much as information technology. Entirely based on computing - the action of using or operating a computer - information technology's origins may be traced back for centuries to primitive counting tools and calculating methods. Large-scale contemporary number crunching for business or scientific purposes, however, took hold only in the mid-twentieth century and grew exponentially.

While the history of computing in the industrialized nations of America, Western Europe, and Japan has received a good deal of attention, thorough historical understanding of computer technology developments in the Soviet Union has remained elusive even after this nation's breakup in the early 1990s.

Professor Boris Malinovsky was the first Soviet-era computer practitioner to publish a full-length Russian language book on the history of Soviet computing in 1995, Istoriya vuichislitelnoi tekhniki v litsakh, or The History of Computing in Personalities. The title deliberately emphasized its focus on the people who led the Soviet Union's early computing industry and fought for its survival in the face of political intrigue and as the Soviet economy collapsed in the Brezhnev years. This English language version is a slight abridgement of Malinovsky's original book, but is a close translation, intended to retain the substance implied by his Russian language title.

The end of the Cold War allowed this history to reach the West. Malinovsky himself was forbidden to write on many of the technical topics found in this book prior to the early 1990s because they were secret, military-supported projects. Although not all of the Soviet computing industry was military-oriented, it became increasingly so as computer technology matured, mostly because the Soviet political machine never understood the ever-increasing value of computing for its society. Thus, computing as an independent scientific field never achieved the high-profile public status like the Soviet space and nuclear-military complexes. Nevertheless, it provided a technological base that made most of these other glorified scientific achievements possible.

Based on all available evidence, Russian and Western historians of technology have concluded that Lebedev's and many of his other colleagues' early computer designs were original. The editor confirmed this herself while living and working in Moscow and Kiev. Soviet computing, as Malinovsky keenly elucidates in this book, has its own story independent from that of the West or Japan. This story combines intrigue, scientific and technological enthusiasm, politics, war, often corrupt and yet sometimes sympathetic bureaucracy, and numerous engaging personalities. No scientific or technological effort is entirely separate from the culture in which it is undertaken: while Soviet scientists often had similar research and development goals as their counterparts in the West and Japan, their history has a distinctive Russian flavor, as readers will understand from Malinovsky's account.

Many specialized fields of research science flourished in the Soviet Union, particularly in physics and mathematics. Likewise, innovations in technology and engineering were numerous in the Soviet countries, especially early on during the Cold War when, for example, Yuri Gagarin became the first human to orbit earth in 1961, carried by a crude but effective Vostok space capsule. Russian scientists and engineers often describe Soviet technological and military innovations with a famous Russian proverb – "Better is the Enemy of Good." This was true of Soviet computing as well. They did not necessarily build the most cutting-edge, slickest looking machines, but instead designed their computers as workhorses that would last a long time. When a computing laboratory could not obtain certain technologies, such as advanced vacuum tubes and other components, workers fabricated their own devices or made up for the lack of the most advanced components by designing unique architectural features or pushing algorithmic development: indigenous Soviet computers of the 1950s and 1960s were often more efficient at number-crunching than their Western counterparts.

The computing industry in the Soviet Union always lagged behind those of the United States and Europe. The reasons for this were varied, but stemmed from having almost no industrial base at the time of the 1917 Bolshevik revolution, no large-scale punched card industry, and no commercial computing industry analogous to IBM that would have helped foster competition. Also, the Soviet government did not aggressively promote computer construction before the Second World War or immediately after.

Soviet computer designers worked diligently to close this gap, given the poor economic conditions they faced in the post-war period. The heroes in Malinovsky's account – Sergei Lebedev, Viktor Glushkov and several others, deeply believed in the Soviet government's emphases on education and socialized progress, and devoted their lives and careers to improving the state of the art of computer technology in the communist bloc countries. According to Malinovsky, when their government decided to copy the IBM 360 system in the 1960s instead of relying on their own enormous community of scientific and engineering talent, Lebedev, Glushkov, and several of the Soviet Union's established computer scientists fought this directive vigilantly while trying to retain faith in their political leaders. This decision remains a topic of dispute among former Soviet computer scientists. Those Soviet scientists who pursued the IBM 360-based series of computers – the well-known ES (Unified System) machines - undoubtedly had their own good reasons for following this path. Their story deserves to be told as well.

The opinions expressed in this book belong solely to the author, and are not those of the editor, editorial consultant, or translator. Malinovsky's narrative addresses only part of the history of Soviet computing, focusing mainly on certain developments in hardware and the people responsible for them. A separate manuscript that analyzes programming, algorithmic, and software innovation in the former Soviet Union awaits another scholar. Sadly, though, while there are some efforts in the Commonwealth of Independent States (CIS) to preserve Soviet era hardware and computing-related documentation, much primary source material about the history of Soviet-era computing has been destroyed or lost.

The Soviet legacy for science and engineering is two-sided. On the one hand, Soviet bureaucratic mismanagement and lack of a safety culture is partially responsible for the Chernobyl accident and numerous other less-known aviation, naval, and environmental disasters. On the other hand many of the CIS countries still boast a highly literate population and one of the world's largest cadres of talented scientists and engineers, Nobel Prize-winning physicists, and top-notch computer programmers.

Lebedev, Glushkov, Alexei Lyapunov, George Lopato, and several other eastern bloc scientists all received the prestigious Computer Pioneer Award of the American Institute for Electrical and Electronics Engineers (IEEE) Computer Society after the fall of the iron curtain. This bronze medal is awarded annually for significant contributions to concepts and developments in the electronic computer field that have advanced the state of the art in computing. For the first time in English, these Soviet computer pioneers are portrayed as people in this book, along with some extremely detailed descriptions of many of their technical achievements and advances made in the computing field.

This book demonstrates clearly that scientists in this once totalitarian group of nations strived to keep on par with Western science and technology, and that Soviet computing in many respects did not lag staggeringly far behind its equivalents in the West and Japan. From the materials presented in this book, readers will better understand not only the history of technology in a formerly closed community of nations, but also how the undermining of democratic principles, free thought and open research can devastate a nation's scientific community and ultimately its society.

Today, from a Western point-of-view, many of the nations within the CIS are struggling to gain a foothold in the global economy while still shedding the Soviet-era political and economic infrastructure. We can only hope that in time, these nations will make more significant, visible strides in science and in technological research and development, and both seek and welcome increased peaceful cooperation with the West and other world regions, leading to economic betterment and more equal participation in today's globalizing world.

Anne Fitzpatrick
Washington, DC, 2006

Instead of a Preface

The history of science, technology and culture chronicled in scientific annals would not be as bright, interesting or complete without the recollections of many outstanding individuals who helped define the events of their era.

Unfortunately, very few of these people have been able to write about their experiences. Some lack the time, others are far too modest, while the rest believe that the results of their work will speak for themselves. Far too often, a lot of time has had to pass before they could speak out about their participation in secret work.

In the former Soviet Union, not one of the founders of computer science and technology has ever published memoirs. The recollections of their contemporaries are scanty and inaccessible for the majority of readers; their labs, once popular one room museums, have been steadily loosing public interest. Only one such exhibit, dedicated to the creators of the first electronic computers, remains at the State Polytechnic Museum in Moscow.

It is still possible to recover and preserve for future generations the many images of the distinguished founders of digital computer technology in the Soviet Union and to learn about the renowned achievements of the scientific teams they directed. This is not just a possibility, but a duty and a necessity. "Wretched are the people without a past," Pushkin once noted.

The heroic era of the formation of digital computer technology in the difficult post-war years belongs to all of the countries of the former Soviet Union. Those years witnessed the appearance of a truly unique collection of scientists of different nationalities who successfully mastered and developed space travel, atomic energy, missile technology, and digital electronic computers. It is important to emphasize that the fulfillment of the Soviet nuclear weapons and space programs would not have been possible without the timely development of electronic computers.

Such accomplishments in the difficult post-war years are heroic examples of service to science and our nation. It is an inalienable part of the post-war renaissance that unfortunately has not been reflected in historical literature. This book *Pioneers of Soviet Computing* (original title in Russian - 'The History of Computer Technology in Personalities') fills part of this void. The author, Boris Nikolayevich Malinovsky, is famous in the field of computer technology; he was a witness and a participant in the first steps of its formation and development. He was also fortunate to meet and personally speak with the distinguished scientists about whom he writes.

This is an anthology of the establishment and development of digital electronic computers, embracing the period from the 1940s through the 1960s and, as far as I know, is the first thorough and serious effort to detail the lives and creative work of the former USSR's computer pioneers.

The first electronic computer in continental Europe was created in Kiev at the National Academy of Sciences of Ukraine under the supervision of Academician Sergei Alexeevich Lebedev. Even at that time, Lebedev suggested that his students prepare and publish materials about the formation and development of computer technology in the Soviet Union. "In the West, they consider us to be worse than we really are. We have to change their opinion of us", he said. Unfortunately, his idea was not properly implemented at that time and only now has been embodied in this book.

It is a pleasure to note that this book has been prepared within the walls of the National Academy of Sciences of Ukraine and with the scientists who were present at the birth of the digital electronic computer technology.

B.E. Paton
President, Ukraine Academy of Sciences

From the Author

In 1835, the English scientist Charles Babbage began work on the construction of a computing machine that he described as "analytical." In a letter to the President of the Royal Academy of Science in Brussels, he wrote: "I am astonished at the power of the machine I am creating." And he was only referring to its ability to perform calculations! He could not foresee other applications for his brainchild for a simple reason: although Babbage's machine was based on the same construction principles and featured an arrangement similar to the first computers that appeared half a century later, his device remained a mechanical one. It was a huge assembly of gear wheels, levers, and other components that could be set in motion only by a steam engine. Yet Babbage was ahead of his time.

The second half of our century has presented mankind with a dazzling array of remarkable achievements in the field of computing. Our global society is indebted to the millions of workers – scientists, engineers, and technicians who created the modern electronic computer, computer software, and huge information networks. However, the number of those who laid the foundation for computer science and technology was far more limited. They had a difficult task – to create something completely new. There scientists, engineers, and mathematicians lived and worked in many different countries. One of the consequences of the Second World War and the Cold War that followed was the loss of collaboration among them; their work was shrouded in secrecy, while the first computers they designed were mostly for the military. As a result, the creators of computer technology were known only to the specialists in their own nations.

Nowhere was this truer than in the Soviet Union. In the difficult post-war years, the efforts of the Soviet computer scientists and the teams they supervised made the USSR one of the world's leaders in computer manufacturing. It is a great pity this leadership role was relinquished during the Period of Stagnation. [1] It was not the fault of computer science students who succeeded their renowned teachers.

The extremely rapid development of the computer during the difficult post-war years was an extraordinary feat, as were the great achievements in the fields of satellite technology, rocketry, and nuclear fission; much has been written about the latter three areas. And although the computer played an enormous role in carrying out these developments, this fact has not received great mention.

It also must be noted that the establishment and development of computer technology in the USSR advanced in the post-war years virtually without any contact with the Western scientists. The development of computers abroad was conducted secretly because at first, digital electronic computers were designated for military purposes. At the same time, the computer technology in the USSR evolved independently as well, led by top Soviet scientists.

This book reveals for the first time the comprehensive history of Soviet scientists' remarkable achievements in computing technology, including the creation of computers which served as a critical base for our national defense complex and allowed for parity between the Soviet Union and the United States - a major factor in preventing a nuclear war. Leading these efforts, S.A. Lebedev, V.M. Glushkov, I.S. Brook, M.A. Kartsev and many others, stand out as the pioneers. Beyond the scope of this book is the whole range of Soviet software developed during the Cold

[1] *Translator's note:* The Brezhnev years.

War and the distinguished scientists behind it, this including A.A. Lyapunov, M.R. Shura-Bura, A.P. Ershov, V.M. Kurochkin, E.L. Yuschenko, and others.

This book is dedicated to the lives and creativity of the founders of digital electronic computing and computer research in the USSR. The author was able to obtain a lot of the original material on computer history, as well as archival documents and large illustrative prints. Unfortunately, many pioneers of computer technology are no longer with us. Therefore, it was necessary to use the recollections of their students, colleagues, and close relatives, as well as the author's own memories. For this, the author expresses much gratitude to: T.A. Mavrina, N.S. Lebedeva, E.S. Osechinskaya, A.A. Dorodnitsyn, V.A. Melnikov, V.S. Burtsev, G.G. Ryabov, P.P. Golovistikov, V.I. Riszov, B.I. Rameev, M.K. Sulim, T.M. Alexandridi, N.P. Brusentsov, Y.V. Rogachov, I.Y. Akushsky, V.M. Glushkova, and M.A. Kartsev.

The main objective of this book is to illustrate the short history of the formation and initial development of the digital electronic computers in the Soviet Union through the eyes of its ingenious creators. In addition, some of the material presented here will also clarify the obvious reasons the Soviet Union lost its leading position in the computer technology arena long before the destructive force of "Perestroika." First, the government refused to cooperate with Western European firms who were interested in developing fourth-generation computers jointly with the Soviet Union. Second, the Soviet government decided to copy and "sovietize" the American IBM-360, a strategy many leading Soviet computer scientists vehemently opposed. Third, in the 1970's, the Soviet government made an irrational decision to split the computer industry into three separate sections that began developing a whole range of computers independently of each other. One tragic result was more duplication of already existing software and hardware designs, primarily American IBM and Digital, making the Soviet computer industry lag even further behind the rest of the industrialized world. Fourth, the Soviet mind-set underestimated the value of the connection between academic science and the computer industry. This profoundly hindered scientific advancement for many years to come.

For over more than half a century, computer technology has made great progress, but still has not matured. Certainly, in the twenty-first century our present-day computers will be regarded as obsolete, just as the first computers are now viewed. And although the world history of computer science and engineering will no doubt become more and more interesting and exciting, these pages remain dedicated to the establishment and original development of digital electronic computers, and the lives and creativity of their first inventors in the Soviet Union. I sincerely hope that the materials presented in this book will appeal to all readers and researchers for generations to come.

B.N. Malinovsky

Chapter 1: The Way to Immortality

The ability to show the way is a sign of genius. – F. Nietzsche

Pioneers among Pioneers: The Founders of Soviet Computer Technology

Between 1940 and 1970 Soviet computer technology developed rapidly. During this time the most famous Soviet computer science schools were founded by Sergei Alexeevich Lebedev, Victor Mikhailevich Glushkov, Isador Semenovich Brook, and Bashir Iskandarovich Rameev. But Lebedev was truly a unique individual. He possessed an extraordinary brilliance that reigned over the field of computer science from the time when the very first vacuum tube computers--performing mere thousands of operations per second--were conceived, to the time of super high-speed computers based on semiconductors, followed by the time when computers based on integrated circuits were used every day. Fifteen high-production computers, the most complex machines of their time, were completed under his guidance. Each of them was a new step in computer technology, more reliable, and more user friendly.

From 1948–1951, at the Academy of Sciences of Ukraine (ASU), Lebedev directed the design and development of the first stored program computer in continental Europe. Although Lebedev named this machine the Small Electronic Computer [in Russian: *Malaya Elektronnaya Schetnaya Mashina,* or MESM], it incorporated six thousand tubes and could hardly fit into the left wing of a two-story building of a former Orthodox monastery near Kiev, where it was assembled. There, in the Kiev suburb of Feofania, a branch of the Kiev psychiatric hospital used to operate before the Second World War. When the Nazis reached Feofania in 1941, they murdered all the patients and established a military hospital. The building was badly damaged during the liberation of Kiev. In 1948, it was given in this condition to the Academy of Sciences Institute of Electrical Engineering to be used as a laboratory. It was not easy to get to Feofania by bus, because the roads during the spring and autumn were practically impassable. In the summer, however, Feofania, enclosed by a grove of oak-trees, became a beautiful spot teeming with songbirds, rabbits, and an abundance of mushrooms and berries.

I met Sergei Alexeevich for the first time in autumn of 1950 at one of the conferences of the Electrical Engineering Institute council. There was nothing striking or unusual in his appearance or manner. He was short, thin and wore black-framed glasses that made his face look harsher than it actually was. His voice was loud, a bit hoarse, but even. He conducted the conference in a quiet and business-like manner, listening attentively to the speakers. His remarks were usually brief. If someone told a good joke, he laughed loudly and infectiously.

> When a smile came over Sergei Alexeevich's typically serious face, it was like a burst of sunlight appearing in a dark room. His face would become kind, childlike, sweet and unguarded. Since Sergei Alexeevich rarely smiled, those who had never seen his smile had no idea about how much gentleness and humanity he possessed.[2]

Sergei Alexeevich Lebedev was born November 2, 1902 in Nizhniy Novgorod, Russia, to a family of a teacher. His parents believed that a teacher must serve as a role model for his pupils

[2] Lev N. Dashevsky, and Ekaterina A. Shkabara, *Kak eto nachinalos'* (Moskva: Znanie, 1981), passim.

as well as for the children of his own family. The main principles of Sergei Alexeevich's upbringing were honesty, integrity, impeccable work ethic, and intolerance for pettiness and subservient attitude. These early influences shaped the personalities of Sergei Alexeevich and the other Lebedev children.

In 1923, Lebedev entered the Baumann Technical Institute in Moscow. There, he immediately became absorbed in science. He majored in the field of high voltage technology and wrote his senior thesis on "The Stability of Parallel Work of Electric Power Stations." This was an important paper of great scientific and practical importance.

Having received his Diploma with a degree in Electrical Engineering in April, 1928, Lebedev simultaneously became a teacher at the Baumann Institute and a junior research worker at the V. I. Lenin State Electrical Engineering Institute (VEI). He quickly became a head of a research group at VEI and later ran the Laboratory of Electrical Power Networks. In 1933, together with A.S. Zhdanov, he published a monograph titled *The Stability of Parallel Work of Electrical Systems,* which in 1934 was revised and republished. A year later the State Higher Diploma Commission [in Russian: *Vuishaya Attestatsionaya Kommissiya,* or VAK] honored the young scientist with a professor's post. In 1939, Lebedev, not even a Candidate of Science yet, successfully defended his doctoral thesis.[3] The premise for his study was his own theory of artificial stability of power systems.

Sergei Alexeevich worked in Moscow for almost twenty years, during the last ten of which he supervised VEI's automation department. Before the Great Patriotic War [Second World War], VEI had been one of the most famous scientific research institutions and many distinguished scientists had worked there. The automation department was working on power systems control, automatic control theory, new means of automation, and telemechanics. The institute was connected to a powerful industrial base that incorporated research results directly into practice.

Almost every project in the field of power engineering developed by the institute's scientists required elaborate computing facilities, either to make calculations for the work itself or to include them in the range of computing devices. Thus, calculations on the 9600 Megawatt, one thousand-kilometer-long electric power line – the Kiubyshev-Moscow hydroelectric project – demanded a highly automated set of powerful inductors and capacitors to simulate the mathematical model of the line. The simulations were done in one of the buildings on Nogin Square in Moscow. The second version of the model was made in Sverdlovsk. A specialized analog computing device used for these models permitted scientists to make the calculations very quickly and then set project assignments for specific electrical power lines.

During the Great Patriotic War, Lebedev developed a stabilization system for tank guns that was immediately adopted on the battlefield. Nobody knows how many tank crews were saved by this

[3] *Editor's and Translator's note:* VAK was the highest scientific certifying body in the Soviet Union. After defending either a Candidate of Science thesis or a Doctor of Science thesis at a special scientific council attached to an educational institution, one then had to send the thesis to VAK in Moscow. Only after VAK approval could one then receive a scientific certification such as the title of Professor. In the Soviet Union, there were three levels of scientific accomplishment. The first, Specialist, required one to graduate after 5–6 years at a university and defend one's diploma work. The second, Candidate of Science, required 2 or 3 years study as a post-graduate, followed by successful defense of one's Candidate's Thesis before a special scientific council, and finally, an obligatory approval by VAK. This is often considered equivalent to a Ph.D. or Doctoral level in the west. The third level was the Doctoral Degree. To become a Doctor of Science, one usually had to firmly establish a new scientific direction or school. This required at least three years and a successful Doctoral thesis defense, followed by VAK approval.

system, which allowed a tank gun to aim and fire while in motion. This feature made the Russian tank less vulnerable, and Lebedev was awarded the Order of Red Labor and a medal "For Valiant Labor During the Great Patriotic War, 1941-1945."

During the war it was necessary to develop analog computing elements to carry out basic arithmetic operations as well as differentiation and integration calculations for the tank gun stabilization system and the automatic guided missile system. In 1945, Lebedev created a simple analog computer to solve ordinary sets of differential equations found in power engineering problems. Lebedev also recognized the value of the binary system in computing. Lebedev's wife, Alisa Grigorievna, remembered the first months of the war, when during the dark Moscow evenings her husband sat in the bathroom and worked by the light of an oil lamp, scribbling the 1's and 0's of binary operations. Vsevolod Vianorovich Bardizh, Lebedev's deputy in the laboratory where the BESM (in Russian, *Bistrodeistvuyshaya Electronnaya Shetnaya Mashina,* or Big Electronic Calculating Machine) was created, is convinced that if not for the war, Lebedev would have developed a computer employing binary arithmetic much earlier; Sergei Alexeevich agreed with this assessment as well.

Professor Anatoly Vladimirovich Netushil, of the Moscow Power Engineering Institute, confirms Lebedev's pre-war interest in digital computing:

> The culmination of my research was my doctoral dissertation on "Analysis of Flip-Flop Elements of High-Speed Pulse Counters." It is well known that later, electronic flip-flop triggers became the basic elements in computer technology. From the very beginning of this thesis work in 1939, Lebedev had expressed a great interest and approval in my research. He agreed to act as an opponent of the dissertation, which I defended in 1945. At that time, nobody even suspected that Lebedev had been formulating ideas for the creation of digital computers, which made his name immortal.

The design documentation and materials concerning the MESM are still kept at the National Academy of Sciences of Ukraine in Kiev. Many of the documents were written by Lebedev himself. Someone's caring hand marked them with – "To Keep Forever" – over forty years ago. Some of the excerpts are included here. In a short message sent to the Coordinating Council of the Academy of Science of the Soviet Union in early 1957, Lebedev wrote:

> I began experimenting with high-speed electronic computers at the end of 1948. Between 1948 and 1949, I developed the basic principles of building similar computers. Considering the computer's great significance in our economic growth and the absence of experience in computer construction and operation in the Soviet Union, I decided to quickly create a small electronic computer, which would help investigate the basic principles of computer building, examine strategies for solving of associated problems, and gain experience in computer operation. We initially planned to create a working model of the machine and then develop it into a small electronic computer. To prevent delays, it was necessary to make a memory bank on flip-flop cells, which limited memory capacity. The development of the basic elements was completed in 1948. The general components of the machine and principal circuit diagrams for its units were finished at the end of 1949. By the end of

1950, the final adjustments on the working model were done and it was successfully presented before a commission.

Two months after the demonstration of the model, Lebedev made a report at a closed session of the Scientific Council at the Institute of Electrical and Heat Power Engineering. The minutes of the session were preserved in the archive of the Academy of Sciences of Ukraine. Considering the great importance of this document in the history of computer technology, it is included here unabridged:

Top Secret

Minutes of Session No. 1 of the closed Scientific Council of the ASU Institute of Electronic Technology and Heat-Power Engineering on January 8th, 1951.

Present:
Members of the Science Council: active members of the ASU I.T. Shvetz, S.A. Lebedev, member-correspondent Teitelbaum, Doctors of Technical Science A.D. Nesterenko, V.I. Tolubinsky, Candidates of Technical Science, E.V. Kruschova, A.N. Miliakh, A.I. Petrov.

Invited:
Chairman OTN Bureau, acting member of ASU, N.N. Dobrokhotov.

Institute of Mathematics: Institute Director, active member of the ASU, A.U. Ishlinsky, Chief of Departments, I.B. Pogrebisky, Doctor of Technical Science, S.G. Krain.

Institute of Electro-Technology: co-workers of the Simulation and Modifications Laboratory (Laboratory Chief S.A. Lebedev), Candidates of Science L.N. Dashevsky and E. A. Shkabara, Junior Assistant Scientific Co-worker Z. L. Rabinovich, Engineer S. B. Pogrebinsky, Co-worker of the Automation Laboratory, Candidate of Science, G.K. Nechaev.

Agenda:

1. The Calculation-Solving Electronic Machine (Report of Director of the ASU Institute of Electro-Technology, ASU Acting Member, S.A. Lebedev).

Heard:
Report of ASU Acting Member S.A. Lebedev "The Calculation-Solving Electronic Machine."

Principles of Operation of a high-performance machine are principles of arithmetic. The basic goal for this machine is the acceleration and automation of calculations. The laboratory was given the task of creating a working prototype of an electronic, high-performance computing machine. In the development of the prototype, we accepted certain limitations. The speed of computing was equal to 100 operations per second. The number of bits was limited to five in the decimal system (16 bits in the binary system).

The machine can add, subtract, multiply, divide and execute other operations, such as compare, shift, and stop, allowing for the possibility of adding other functions.

The basic element of the electronic counting machine is the one that allows for summation.

Electronic relays are used (trigger cells), in which the current is switched from one electronic tube to another by means of a pulse-feed on a grid. This permits summing, from which all other operations are formed. Instead of a decimal system, a binary system is used, which is defined by the characteristics of the trigger cells (S.A. Lebedev uses a flow-chart to clarify how the machine works). In addition to the computing elements, the machine must have other elements that govern the calculation process, such as enabling devices and memory elements.

In 1951 the laboratory was given the task to turn the prototype into a working machine. Up until now, the obstacle has been the absence of automatic devices of data input and automatic output of received results. The automation of these operations will be realized with the help of magnetic tape, which has been developed by the Institute of Physics (in the laboratory of ASU member correspondent A.A. Kharkevich).

Questions presented:

N.N. Dobrokhotov: What other computing machines will be developed in the USSR, and if they are being developed, on what principle?

A.I. Petrov: What is the field of application of the machine?

A.U. Ishlinsky: 1) What is the operating life of machine elements? 2) What is the reliability of the machine, in case of element failure? 3) How did you manage to use foreign technical materials? 4) What are the qualifications of the operators?

G.K. Nechaev: What is the correlation between calculation time and output (input) of the task in the automatic work of the machine?

I.T. Shvetz: 1) What is the state of development of electronic counting machines at other institutes? 2) What about the situation abroad and what are their parameters compared to ours? 3) Who developed the trigger cells, how long ago, and where else are they being used? 4) How do the ASU Institute of Mathematics, ASU Institute of Physics and the ASUSSR [Academy of Sciences of the Union of Soviet Socialist Republics] Institute of Precision Mechanics and Computer Technology participate in this complex?

L.I. Tsukernik: What original solutions have been incorporated in the machine by the ASU Institute of Electro-Technology?

S.G. Krain: What tasks will the developed and automated machine be able to perform?

S.A. Lebedev: I am going to group similar questions together. I have data on 18 machines developed by the Americans. This data has the character of an advertisement, without any kind of information on how the machines are built. As to the question of constructing computing machines, we must catch up with the developments abroad and must do so quickly.

In the available foreign literature, the project design and construction of a machine takes five to ten years, but we want to complete construction in two years. Parameters of the American machines are as follows: multiplication time on the ENIAC is 5.5 milliseconds, on the EDVAC- 4 milliseconds, and on our machine 8-9 milliseconds.

Beside the Academy of Sciences Institute of Electro-Technology, work on developing such machines is going on at: a) the SKB-245 Ministry of Machine and Instrument Construction; where they started developing a machine using mechanical relays, but have now switched to using electronics; b) the ASU Energy Institute, where they use trigger cells; c) the AS-USSR Institute of Precision Mechanics and Computer Technology, in conjunction with our work.[4] This machine is quite like the MESM, but has been intended for high-performance, more so than the existing American machines. The operation time on this machine will be equal to 0.2 milliseconds.[5]

The principal addition to our machine is the new summing element, plus the resolution of the issues of integrating separate machine elements. The machine's basic construction principle was using only proven, well-known elements, and this is also true of the trigger circuitry.

There are numerous applications for the machine. In theory, all problems that can be simplified into a numerical format can be solved with this machine. It can also solve differential equations and produce calculation tables. Another benefit of these machines is the ability to perform the same calculations with varying input data (e.g. calculation of guided missile trajectories). The appearance of electronic calculating machines also allows applying new mathematical methods to solve statistical physics problems.

Taking advantage of experience from abroad is difficult, since published material is so scarce.

We need three types of employees to work on the machine: mathematicians (for program coding); operators (for trouble-shooting the machine); and those able to do both jobs.

The real-time data input and results/output time of the machine are equal to the operation cycle time.

The Academy of Sciences Institute of Mathematics participates in the joint development of programming problems, while the ASU Institute of Physics participates in the development of magnetic recording.

The increase in machine reliability will be realized with preliminary tube testing.

Failure of any of the machine elements can be easily detected.

Presenters:

A.U. Ishlinsky: Creation of a prototype is one of the most impressive achievements of the Department of Technological Science and of S.A. Lebedev's. There is no need to discuss the significance of the machine. The presence of the electronic machine removes much of the difficulty and will help bypass application of those calculation methods currently being employed. It's clear that such machines will be widely used in defense industry as well as in science.

The design of such a machine is a great achievement in science. In the future, the machine will not have to be loaded with the same type of calculations meant for applied purposes. On

[4] *Translator's note:* In Russian, *Institut Tochnoi Mekhaniki i Vyichislite'lnoi Tekhniki*, or ITMVT.
[5] *Author's Note:* This was Lebedev's reference to the BESM, his future computer.

the contrary, with its help, scientific research work will be carried out.

N.N. Dobrokhotov: The importance of conducting research on the calculation machine is quite evident. The task of the ASU is to design a machine better than those existing abroad. In order to ensure that, it is necessary to organize an exchange of opinions, as well as discussions about the crucial points of the machine design. It is imperative to discuss the work on a nation-wide scale.

S.E. Teitelbaum: It is necessary to considerably extend the staff and the material base to speed up of such important work.

S.G. Krain: The utilization of an electronic machine will allow us to apply a number of new technological methods. To facilitate this, we must intensify and maximize our research efforts.

I.T. Shvetz: Lebedev's report, now presented, brings about a feeling of satisfaction and pride in our Academy of Science. The work on electronic computing machines is related to some of the most important work of the ASU. It is necessary to assist the development of such work and to accelerate the machine's performance to the highest degree. These are the shortcomings: 1) S.A. Lebedev does not advocate making this work priority for the ASU. 2) There is not enough interaction between different institutes and we need to ensure closer cooperation between the ASU Institutes of Mathematics and Physics. 3) We should not use the term "logic operation" with respect to the machine because the machine cannot make logic operations. We'd better substitute this term for another. Of course I believe that the scope of work should be increased, but this is not the most important work at the ASU. One also needs to keep in mind that the financial allotment to the ASU in 1951 will decrease. We should consider in detail what we need to ask for from the Presidium of the ASU for the quickest fulfillment of the work.

S.A. Lebedev: I must stress the high importance of work on computing machines. Let's take the following example: the only effective method to intercept a long-range rocket is to send an anti-missile rocket. To accomplish this, we need to determine the possible point of interception. The application of a calculation machine will allow us to compute the rocket trajectory and ensure a precise hit. In accordance with the governmental order, the design for the machine project will be finished in the first quarter of 1951. This schematic project will be submitted to a panel of experts for a comprehensive evaluation. I agree that we should encourage closer cooperation with the ASU Institute of Mathematics and Physics. We have connections with the Institute of Precision Mechanics and Computer Technology not only in the financial area (though that is important because it provides for the possibility of creating a prototype) but also in the scientific field. With respect to the use of this computer, MESM, for calculations, it will be difficult to refuse those who need it; we are compelled to do this because MESM is the only working computer in the USSR at this time.

Resolved:

1) To note that the work of the ASU Institute of Technology—under supervision of ASU member S.A. Lebedev—on an electronic computing machine are quite up-to-date and are of great scientific and practical importance to the USSR's defense, as well as scientific research

work in many disciplines.

2) To recommend to S.A. Lebedev that he apply to the ASU Presidium, requesting funding for further development of Soviet computing machines, to considerably accelerate the work and extend the experimental base in Feofania, to prepare necessary staff, and to assure the necessary participation of other ASU Institutes in this work.

3) Considering the complex character of the work carried out by the ASU Institute of Electro-Technology jointly with the Institute of Precision Mechanics and Computer Technology, and ASU Institutes of Mathematics and Physics, it would be expedient to lay out a plan for the most efficient collaborative research and design work based on the complex participation of the Ukrainian and Soviet scientific institutions, along with the Ministry of Device Manufacturing and Machine Building of the USSR.

Chairman of the Scientific Council, Active-Member of ASU I.T. Shvetz
Scientific Secretary—E. V. Krushchova

There is another very important document, written by Lebedev in his daily notes, which will enable us to present the chronology and stages of the design of the first Soviet computer—the MESM.

Secret Draft
The Stages of Development of the First Electronic (Small) Calculating Machine

1. October-December 1948	Development of the general construction principles for an electronic calculating machine.
2. January–March 1949	The general guidelines are set for the development of separate elements. Seminars on computing machines with the representatives of the ASU Institutes of Mathematics and Physics.
3. March–April 1949	Development of triggers on the 6N9M and 6N15 vacuum tubes. Development of logic units. Development of pulse generators. Development of counters on 6N15 vacuum tubes.

4. May–June 1949	Development of arithmetic units in 6N15 tubes (1st version). Transfer to the new location and set up of the laboratory.
5. July–September 1949	Development of arithmetic units for 6N9 tubes (2nd version). Development of static memory elements. Development of the electronic switchboard.
6. October–December 1949	Creation of the main blueprints for the machine prototype. Development of general machine design. Construction and preparation of the machine's frame.
7. January–March 1950	Development and preparation of separate units and their debugging. Development and preparation of the machine's control panel.
8. April–July 1950	Development of technical requirements for magnetic memory. Installation of the machine units in its frame and assembly of inter-unit connections. Assembly of connections between frame and control panel. Repairing the interface between frame units and group units. Work on magnetic memory in ASU Institute of Physics. Establishing a branch of the Institute of Precision Mechanics and Computer Technology in Kiev.
9. August–November 1950	Debugging the computer from the control panel. First start-up test of the machine prototype (Nov 6, 1950).

10. November–December 1950	Increase the quantity of memory blocks to enlarge the memory unit capacity. Refining operations: addition and subtraction. Refining operations: multiplication and comparison.
11. January–February 1951	Demonstration (January 4, 1951) of the operating prototype to the State Commission. Drafting of the act for the completion of work on the prototype. During the demonstration of the prototype, resolved a problem of computing the sums of a series of odd-numbered factorials raised to a degree. Begin the conversion of the prototype to a working computer (MESM).
12. March–May 1951	Development of a system of constants and commands. Introduction of the photographic recording of results. Development of magnetic memory control systems. Launching the system of constants and commands. Presentation of the operating computer to the government commission and the commission of experts.
13. June–August 1951	Adaptation of the device for separating punched cards for initial data input. Integration of new units for implementation of summing operation commands, input of sub-programs, and connections with the magnetic recording of code. Assembly and debugging of magnetic memory control systems. Issuing of the government resolution (No. 2759–1321 from July 1, 1951), mandating the Electronic (MESM) computer to come on line by the fourth quarter of 1951.
14. August–November 1951	Refinement of division and other operations. Alteration of memory units to increase reliability.

Completing alteration on the small machine prototype and general testing before start-up.

15. December 1951

Start-up of the Small Electronic Machine (MESM) (December 25, 1951).

Solution of a real problem on the machine: computing a probability distribution function.

$$\rho = \frac{1}{C_{2n}^{n}} \sum_{k=[\frac{n}{\alpha}}^{\frac{n}{\alpha}} (-1)^k C_{2n}^{n-k\alpha}$$

585 values of “p” were calculated to five places, for which nearly 250,000 operations were made. Calculations were conducted in 2.5 hours and used to establish a computation table. Based on that table, values for defining and increasing the accuracy of artillery weapons were determined.

16. January 1952

Report by acting ASU member, S.A. Lebedev (January 4, 1952) at the AS-USSR Presidium on ratifying the motion to place the Small Electronic Counting Machine (MESM) into service.

Report by acting ASU member S.A. Lebedev (January 11, 1952) at the ASU Presidium on placing MESM into service.

January 12, 1952

Fulfillment of orders for calculations on MESM. Computation of the function:

$$\mathrm{x}(\theta) = \varphi + \int_{\varphi}^{\theta} \alpha \frac{\cos\varphi - \cos\theta}{\beta - \cos\varphi} \alpha\varphi$$

2100 values for x were found, which required more than a million operations.

January 25, 1952

Calculation of the function: $x = \tan\frac{x}{h}$

850 values for x were calculated and one million operations

	were required.
	Debugging and placing into operation the magnetic memory system.
	Completion of calculations on the stability of the Kiubyshev-Moscow High-Power Electro-Transmission System.
17. June–September 1952	Increase the number of computer digits from 16 to 20 to improve the precision of calculations to 6 decimal places.
18. October–November 1952	Solved the harmonization problem of the synchronous power generators at the Kuibyshev Hydroelectric Station per by the Main Volga Hydroelectric Plant request.
	Similar calculations were programmed at the request of other state organizations for important projects of communism.

Principal Constructor of the Electronic Calculating Machine
Acting ASU member, S.A. Lebedev.

Kiev – the Birthplace of the MESM

The MESM was initially planned by Lebedev to serve as a model for the BESM. At first, MESM was even considered *the* model electronic computing machine. But, in the process of its creation, it became obvious that in comparison it was already a small computer. Because of it, input-output units were added, along with increased memory capacity on a magnetic drum, and the word “model” was changed to “small.”

Given Kiev’s war-torn condition, the Academy of Sciences of Ukraine was faced with the challenge of where to allow the construction of the machine.

But the most difficult part of the whole project was the actual construction of MESM. I believe that it was simply Sergei Alexeevich’s comprehensive experience from previous research that allowed him to cope so brilliantly with the technical aspects of computer building principles. Yet, one crucial miscalculation was made. The MESM had been placed on the ground floor of the two-story building where the Academy of Sciences allowed Lebedev to locate the laboratory. When the unit was assembled and the power turned on, its six thousand vacuum tubes turned the premises into a sauna. Workers had to remove parts of the ceiling in order to deflect some of the heat from the room.

Led by Lebedev and his main assistants, Candidates of Science Lev Naumovich Dashevsky and Ekaterina Alexeevna Shkabara, together with a team of twenty five engineers, technicians and assembly workers, all took an active part in designing, assembling, adjusting and operating the MESM.

Dashevsky and Shkabara later recalled how Lebedev interacted with the team at every stage of the project. When the machine found an error in the computations of two very distinguished mathematicians, he personally offered to check their hand calculations to 9 places, locking himself away for an entire day of painstaking work. He reappeared the following day, with his glasses askew (a sign of success) and a rare smile on his face, saying: "Don't torment the machine. It's correct. It's the people who are wrong." He had found a mistake, duplicated in the hand calculations.

At the end of 1951, an impressive group of scientists from the USSR Academy of Sciences came to Feofania from Moscow to commission the MESM for operation.[6] The group was headed by Academician Mstislav V. Keldysh. In the group were the academicians Sergei L. Sobolev, Mikhail A. Lavrentiev, and Professors K.A. Semendayev and A.G. Kurosh.

When the word got out that there was an operating computer in the Ukraine, a steady parade of scientists from Kiev and Moscow headed to Feofania with scientific and defense-related problems that could not be solved without the aid of a computer. MESM began to work around the clock to help solve the most important problems of that period.

On January 4, 1952, Lebedev presented his report on MESM to the Presidium of the USSR Academy of Sciences. Later that year, after Lebedev had moved to Moscow, the Institute of Electrical Engineering of the Academy of Science of Ukraine nominated the MESM project for the Soviet Union's State Prize. Lebedev, Dashevsky and Shkabara were listed as the leaders of the MESM team, and they undoubtedly deserved the prize: a large portion of the computing principles developed by Lebedev are still employed in modern computer technology. In 1950, when the model of MESM had been tested, the only other similar working machines were Frederick Williams and Tom Kilburn's Baby and Maurice Wilkes' EDSAC in England.

However, each British computer employed a sequential operational arithmetic unit, while MESM worked on parallel arithmetic units.

The Committee on State Prizes had to recognize that in 1952 MESM was practically the only computer in the country that was solving the most important scientific and technological problems from the fields of thermonuclear weapons processes (such as Yakov B. Zeldovich's work), space flights and rocket technology, long-distance electric transmission lines, mechanics, statistical quality control, and others. The following document is one of many that testifies to the importance and originality of the MESM:

TOP SECRET
The Academy of Sciences
of the Union of Soviet Socialist Republics
Department of Applied Mathematics

[6] *Author's Note:* Feofania was the site of the famous St. Panteleimon "The Healer" Monastery.

The V.A. Steklov Mathematics Institute

November 26, 1953, N 438

To the Director of the USSR Academy of Sciences, Institute of Electric Power Engineering, Member-correspondent of the Academy of Sciences of the Ukraine S.S.R., A.D. Nesterenko:

The Board of Directors of the Department of Applied Mathematics of the USSR Academy of Sciences, V.A. Steklov Mathematics Institute expresses many thanks to the Ukraine SSR Academy of Sciences, Institute of Electric Power Engineering for its participation in the great and important computer-calculation work carried out from November 1952 through July 1953 on a small electronic computer (MESM) designed by academician S.A. Lebedev. During this period the scientific group of the USSR Academy of Sciences Mathematics Institute under the direction of academician A.A. Dorodnitsyn and Doctor of Physics and Mathematics, A.A. Lyapunov, in collaboration with the scientific team of Laboratory No. 1 of the USSR Academy of Sciences, Institute of Electric Power Engineering (supervised by academician S.A. Lebedev) performed time consuming and painstaking calculations for three complex programs, carrying out nearly 50 million operations on the computer. We would also like to highlight the meticulous and conscientious work of the following scientists: Deputy of Laboratory Director, L.N. Dashevsky, Chief Engineer, R.Y. Cherniak; Engineers A.L. Gladish, E.E. Dedeshko, I.P. Okulova, T.I. Petsukh and S.B. Pogrebinsky and Technicians U.S. Mozipa, S.B. Rosenzweig and A.G. Semenovsky. These co-workers selflessly dedicated countless hours and expanded monumental effort to guarantee a high-quality trouble-free operation of the machine.

Director of the Department of Applied Mathematics of the USSR Academy of Sciences
Mathematics Institute, Academician M.V. Keldysh.

But Lebedev and his team failed to receive the State Prize. This was the first, but not the last time when the importance of the Lebedev's contribution in the formation and development of computer technology was not properly appreciated.

Unfortunately, the Board of Directors of the Ukraine Academy of Sciences, which at the time was headed by a biologist, did not understand or perhaps did not even attempt to understand the significance of Lebedev's work. The Secretary of the Central Committee of the Ukrainian Communist Party, Ivan Dmitrievich Nazarenko, who visited Lebedev's laboratory in the end of 1950, failed to properly endorse Lebedev's work either. After familiarizing himself with the capabilities of the MESM and the prospects for the advancement and application of computer technology, he expressed his surprise and delight in one word: "Sorcery!" Leaving the laboratory, Nazarenko told Lebedev that he would expect proposals for further development of the project.

Having heard over the course of a week about Lebedev's project, the Presidium of the Ukrainian Academy of Sciences sent a letter to the Central Committee of the Ukrainian Communist Party asking for only modest support to continue computer research. This lack of action, along with the Ukrainian Academy of Sciences and the Ukrainian government's failure to comprehend and properly evaluate the significance of computer technology, continued for the next ten years, until the appearance of Victor Glushkov. A quote taken from a letter sent to the Central Committee of Ukrainian Communist Party in 1956 by Lebedev's former laboratory co-workers confirmed this state of affairs: "The position that our Republic has taken regarding computer technology is equivalent to a crime against the State." The author of this book was among those who signed this letter. Ukraine's chance to assume a leading role in the most important field of science and technology of the twentieth century was lost.

Mikhail Alexeevich Lavrentiev, a vice-president of the Ukrainian Academy of Science and Director of the Mathematics Institute at the time, understood the significance of Lebedev's work and his own complicated position. He wrote to Stalin about the need to accelerate research in the field of computer technology and the great prospects for computer usage, including national security purposes. The result was quite unexpected for the mathematician Lavrentiev: in 1951 he was appointed as the director of the Institute of Precision Mechanics and Computer Technology in Moscow, which by the summer of 1948 had already been selected by the government to develop modern computing technology.

Lavrentiev decided to capitalize on Lebedev's experience. Lebedev had already demonstrated his creative possibilities, conceiving and drafting provisional schemata and diagrams for the BESM. In March of 1951, Lavrentiev established Laboratory No. 1 at the Institute for Precision Mechanics and asked Lebedev to head it. Thus BESM, although initially planned as a prototype in Kiev, was constructed in Moscow.

Lebedev dedicated a short article, "At the Cradle of the First Computer," to Lavrentiev on his 70th birthday, praising him for his role in the creation of both the MESM and BESM.

Lebedev wrote:

> During the early postwar years I worked in Kiev. I had recently been selected as an academician of the Academy of Science of Ukraine, when the laboratory was created in the Kiev suburb of Feofania where the first Soviet computer would be born. That was a difficult time. The country had to rebuild a war-devastated economy. Every small issue became a big problem. The first Soviet computer may not have appeared in Feofania if not for the kind patronage of M.A. Lavrentiev, who at the time was Vice-President of the Ukrainian Academy of Science. Even now, I never cease to be amazed and delighted by that inexhaustible energy with which Lavrentiev defended and promoted his ideas. In my opinion, it would be difficult to find a person who, after meeting Lavrentiev, would not have been infected by his enthusiasm. Mikhail Alexeevich was appointed to be the Director of the ASUSSR Institute of Precision Mechanics and Computer Technology. I was also transferred to Moscow and we began our collaboration to create the big digital electronic computers. When the machine –BESM – was ready, it was in no way inferior to the latest American models and appeared to be a genuine triumph of the ideas of its creators.

After MESM was completed, Zinovy Lvovich Rabinovich began leading the design work for a specialized computer, the Specialized Electronic Calculating Machine [in Russian: *Spetsialnaya Elektronnaya Shetnaya Mashina,* or SESM], for solving sets of algebraic equations. Lebedev's ideas were the basic principles for the construction of this machine. The SESM was Lebedev's last project in Ukraine, but both it and MESM paved the way for many task-specific specialized computers. After Lebedev transferred to Moscow, his students Dashevsky, Shkabara, Pogrebinsky, and others who stayed behind in Ukraine, began developing a new computer, the Kiev. Even though the Kiev's operational features were inferior to Lebedev's new M-20 computer, it was still state-of-the-art at that time.

In 1958 Viktor Glushkov became head of Lebedev's former laboratory and the Kiev was completed under his supervision. Later, the machine was employed for a long time at the Academy of Sciences Computing Center, where a computer laboratory had been established. The Computing Center was eventually reorganized as the Cybernetics Institute; it is now renamed after its founder, Glushkov.

Speaking at the Academy of Sciences Scientific Council of the Cybernetics Institute on the twenty-fifth anniversary of MESM's creation, Glushkov acknowledged the significance of the MESM in the development of computer technology in Ukraine and throughout the Soviet Union:

> Independent of foreign scientists, S.A. Lebedev developed the principles for building a stored memory program computer.[7] Under his supervision the first computer in Europe was created. It was capable of solving the most important scientific and technical problems, which led to the foundation of the Soviet programming school.

Lebedev's service to Ukrainian science has been well commemorated. A street in Kiev has been named after him, and the Academy of Sciences has set up a contest in his honor. The first winners of the Lebedev Prize in Computer Science were Mikhail A. Lavrentiev, Vladimir Andreevich Melnikov, Zinovy Rabinovich, and the author of this book. In Kiev, at the entrance of the Electrical Power Engineering Institute building where Lebedev was a director, a memorial plaque has been placed in his honor. Speaking at the dedication of the memorial, President of the Ukrainian Academy of Sciences, academician Boris E. Paton remarked:

> We will always be proud of the fact that it was at Ukrainian Academy of Sciences, in our dear Kiev, where Lebedev—a distinguished scientist in the fields of computer technology, mathematics and large automated systems, first thrived. He pioneered the creation of the outstanding school of Computer Science in Kiev; his torch was later taken up by V.M. Glushkov. Today, we have the Glushkov Cybernetics Institute, one of the foremost and largest computer institutes in the world.
>
> Lebedev lived and worked during a period of the vigorous development of such branches of science as electronics, computer technology, missiles, and the mastery of outer space and atomic energy. Patriotically, Sergei Alexeevich took a part in the largest projects with I.V. Kurchatov, S.P. Korolev and mathematician M.V. Keldysh, guaranteeing the creation of a shield for the Motherland.[8] The role of the electronic computers created by Sergei

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[7] *Author's Note:* The American scientist John von Neumann's 1946 publications on computer building principles did not appear in the open press of the Soviet Union until the 1950s.

[8] *Editor's Note:* Igor Vasilievich Kurchatov was scientific director of the Soviet atomic bomb project, while his contemporary Sergei P. Korolev was scientific head of the Soviet Space Program. In the Cold War, "The shield of the Motherland" was a commonly used expression for the anti-rocket and anti-aircraft defense systems that protected the Soviet Union.

> Alexeevich in carrying out these projects was, without exaggeration, of enormous importance. His name stands tall in the ranks of the great scientists of the world.

Creative Rivalry

The first blocks in the scientific foundation of digital electronic technology were laid in Moscow, but things changed by the end of the 1940s. Because of Lebedev, the center of the new science shifted to Kiev. When academician Nikolai G. Bruevich was appointed as acting director of the Institute for Precision Mechanics and Computer Technology in Moscow on July 16, 1948, he did not know that secret work on the MESM was going on full speed in Kiev. In 1949, the first news about modern digital computers arrived at the Institute for Precision Mechanics from abroad. Foreign journals reported that in 1946, the first computer in the world, ENIAC [the Electronic Numeric Integrator and Calculator], had been created in America. It employed 18,000 vacuum tubes and performed about one thousand operations per second. Later, news of faster computers with fewer vacuum tubes appeared in the Soviet Union. Because the reports were very sketchy, the principles of building a machine remained unclear.

A year after the Institute for Precision Mechanics was established, a commission from the Soviet Academy of Sciences Presidium headed by Keldysh assessed the institute's work. Quite possibly, Lavrentiev's letter to Stalin prompted this investigation. Keldysh's commission came to a disturbing conclusion: digital electronic computer technology was developing rapidly in the West, whereas in the Soviet Union, it received very little attention. Spurred on by the commission's conclusion, Bruevich approved a decision to organize a department of high-speed computers in the institute through the bureau of Soviet Academy of Sciences Department of Technical Sciences. In September 1949, he charged a group of six scientists from his department to develop the necessary components for the creation of a digital computer.

A participant in the project, Petr Petrovich Golovistikov recalled:

> Many visitors came to watch when we began to assemble the basic parts of the computer such as flip-flop triggers, a computer serial adder, rectifiers, and a decoder. At the time, I did not understand why Bruevich had invited them. It seemed to me that we had very little to show. Among the visitors were people such as the Minister of Machine Building and Instrument Engineering of the USSR Parshin, ministry board member Loskutov, and academician Blagonravov. This excited and compelled me to work every day from the wee hours in the morning until late at night. At last, I got used to these visits. I especially remembered one visit that took place in January of 1950. Bruevich brought in two men. One was tall, stately, and well-mannered; he listened attentively to the explanations. The other was short, wore glasses, and left a strong impression on me. He spoke directly to me and asked many questions. He wanted me to show him the computer's signals at various points and to demonstrate signal delay times in different circuits. He asked to change the generator frequency in order to define the range of scheme operation. He criticized many things and advised us to do some things in differently. To top it off, he asked me to make a prototype of a long circuit of controlled rectifiers.

> He wanted each tube to carry an additional load corresponding to similar tubes, so that the signal in the circuit would not dampen and so that the circuit would have minimal delay. Thus, I made the acquaintance of Lavrentiev and Lebedev. By this time, I knew that developments in the field of computers had begun at the ASUSSR Power Institute under I.S. Brook's supervision and at the Ministry of Machine Building and Instrument Engineering where SKB-245 [in Russian, *Spetsial'noe konstruktorskoe byuro*] was created. But completely unexpected for me was the fact that the first computer in the Soviet Union was developing rapidly under Sergei Alexeevich's supervision in Kiev.[9]

Bruevich worked with the Soviet Ministry of Machine Building to establish by 1949 three organizations that composed a powerful scientific production collective: the Scientific Research Institute for Calculating Machine Construction [in Russian, *Nauchno-Issledovat'elskii Institut Schetnovo Mashinostroyeniya* – NII Shetomash], SKB-245, and the Calculating Machine Factory [in Russian, *Zavod Schetno-Analiticheskhik Mashin,* or SAM]. The director of the both the Schetmash and the SKB-245 was Mikhail Avksentievich Lesechko.

Despite the fact that these three organizations were ordered by the government to build differential analyzers similar to the ones the Americans had built in the 1930s and 1940s, Lesechko, relying on his engineering intuition, agreed with Bruevich's proposal to design and build vacuum tube based electronic computers.[10] Yet a visit to the Institute for Precision Mechanics changed his mind. Lev Israelevich Gutenmakher, director of one of the Institute's laboratories, was attempting to build an electronic computer based not on vacuum tubes, but on electromagnetic non-contact relays [magnetic amplifiers]. His work appealed to of the Minister of Machine Building and Instrument Engineering, Petr Ivanovich Parshin, who took a keen interest in it.

When a change in leadership occurred at the Institute for Precision Mechanics in mid-March of 1950, the newly appointed director, Mikhail A. Lavrentiev, found himself under pressure on many fronts. First, there were very few specialists in the field of digital computer technology at the Institute. Second, the few relevant scientific departments that did exist were scattered throughout Moscow. Third, it appeared that the government was about to adopt a resolution mandating that the Institute develop a new digital electronic computer – a gigantic construction project consisting of thousands of vacuum tubes and significantly more complex than what Lavrentiev had seen in Kiev at Lebedev's laboratory. Thus, in an order dated March 20, 1950, Lavrentiev appointed Lebedev as Director of Laboratory No.1 of the Institute: Lebedev was now employed in both Kiev and Moscow. Also by this time, the Ministry of Machine Building and Instrument Engineering was commissioned to design and develop the other digital electronic computer based on Gutenmakher's ideas.

Before approving the governmental decree to develop and build two computers, Stalin required that several individuals be assigned to oversee each machine. Lavrentiev and chief designer of the BESM, Lebedev, were appointed from the Soviet Academy of Sciences. From the Ministry of Machine Building and Instrument Engineering, Lesechko and Yuri Yakovlevich Bazilevsky,

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[9] *Author's Note:* SKB was the general Russian abbreviation for Special Construction Bureau, whose task was the design and preparation of any product for mass production.

[10] *Editor's Note:* In the United States, Vannevar Bush led the effort to build the first differential analyzer at MIT beginning in the 1930s.

chief designer of the Strela (Arrow) computer were appointed. Thus, Lebedev's powerful rival collective of the SKB-245, the SAM, and the SRI Schetmash was born. Clearly, the center of activity of the Soviet Union's digital electronic computing had shifted from Kiev to Moscow. For anyone else but Lebedev, the situation at the Academic Institute for Precision Mechanics would have seemed hopelessly complicated. Instead, he brought from Kiev his already sketched out plans for the BESM.

According to Golovistikov:

> There is a legend that the BESM's full schemata was drafted on separate sheets of paper and kept by Lebedev on Kazbek cigarette boxes. This is simply not true. He had many thick notebooks that contained scrupulously drawn diagrams and designs, with all of the structural schemata of the machine, provisional diagrams of the units' operations, and detailed descriptions of all methods of individual operations. Having arrived from Kiev, he immediately began transferring this enormous volume of information to us…
>
> Initially, I wasn't confident about the work I was performing. Lebedev assigned me to design the arithmetic unit, but also wanted me to understand the principles of other operational units. Kiril S. Neslukhovsky was commissioned to develop the control unit and needed to know how the machine as a whole would operate. Neslukhovsky became Sergei Alexeevich's technical operations manager. Later, this post was filled by Bardizh.
>
> To find appropriate personnel for the Institute, Lavrentiev and Lebedev went to colleges to hand pick students with practical experience. They were placed on staff and immediately received specific design assignments, while the development of all main computer units for the preliminary prototype was overseen by specialists. Students also took part in preparing project outlines relating to their own area of specialization. With only small modifications, according to the requirements of their colleges, these materials satisfied their graduation requirements.

By the end of 1950 the prep work on the prototypes of BESM's individual components was in full swing. In spring 1951, the staff of Laboratory No. 1 had grown to about fifty people – many were the most highly skilled specialists lured away from the Moscow Power Institute. Candidate of Technical Sciences O.K. Guschin (an assembly worker at that time) recalled the formation of the young team at the Institute under Lebedev's supervision:

> It seems to me that everyone was proud of their participation in this great and important affair – the creation of Soviet computer technology, a gigantic device in its infancy, the so-called "electronic miracle" with hundreds of thousands of components. It should not be forgotten that the most complex radio-electronic device of that day was the KVN-49, the first Soviet television set.
>
> Our work went on day and night, and nobody expected to have any time off. We built the prototype elements and components of the BESM. We made chasses and stands; we drilled and riveted, assembled and adjusted different versions of flip-flop triggers, counters and computing units, and then checked

> their reliability in operation. At every stage of the work, Sergei Alexeevich demonstrated an exemplary selflessness. After an intense workday, he often sat up until 3:00 or 4:00 a.m., by the control desk or oscillograph, actively taking part in the fine adjustments of the machine.

Lebedev's competitor, Gutenmakher, encouraged by the support of the Ministry of Machine Building, was also working very hard. In 1950, he came up with an additional schematic for an electronic computing device for the SKB-245 based on ferrite-diode elements. At this time the situation in the Ministry changed drastically: Bashir Rameev appeared at SKB-245 project, having been collaborating with Isaak Brook until 1948 on programming controls for electronic computers.

Rameev immediately got to work and prepared an advanced electronic computer project based on vacuum tubes. Subsequent events unfolded very strangely. In Rameev's absence, the technical council of SKB-245 considered Gutenmakher's project. Then, in Gutenmakher's absence, they listened to Rameev. In the end, the decision was made to support the machine based on vacuum tubes, instead of Gutenmakher's design. Thus the BESM had a serious competitor—the Strela. The SKB-245's managers appointed Rameev as the deputy director for Yuli Bazilevsky, the chief designer of the project. Rameev was only 32 years old at the time, but he already carried heavy personal burdens. Being the son of the "enemy of the people," he was expelled from the institute during his second year and ended up serving in the army; he was also a highly driven person and had an insatiable desire to work.

Thus Lebedev now faced a competitive-triumvirate: Lesechko, Bazilevsky and Rameev; while the Institute for Precision Mechanics faced a powerful competitor – SKB-245 together with the SAM and the Schetmash. The center of gravity of digital computing technology work had been relocated from Kiev to Moscow.

Having lost the support of SKB-245, Gutenmakher continued to work on his project by himself. In his laboratory at the Institute for Precision Mechanics, a machine based on ferrite-diode elements had already been designed and was being built at the same time as the BESM. I became acquainted with it sometime in 1954, when it was already operating. Its productivity was very poor. Due to the low quality of the elements it was also unreliable; the impulse power source was cumbersome and uneconomical. Under the pretext of secrecy, entrance to the laboratory was prohibited, and early in the 1960s it was completely closed. The strict secrecy in which Gutenmakher conducted his research ensured that very little was known about his machine. Nevertheless, it was a defining milestone in the history of computer technology.

On April 21, 1951, a State Commission assembled to review the two projects, BESM and Strela. The commission included such people as Keldysh, the Chairman, Minister of Machine Building and Instrument Engineering Parshin, academician Anatoly Arkadyevich Blagonravov, and others. Earlier, members of the commission visited Kiev where Lebedev demonstrated the MESM. A detailed analysis of the BESM and Strela projects had already been made in Moscow by the time the commission began evaluating these projects. Commission member Anatoly Alexeevich Dorodnitsyn remembered a curious argument that occurred during one of the sessions:

> Strela's chief designer, Bazilevsky, declared that his machine, performing at 2,000 operations per second, could solve all the mathematical problems in the Soviet Union within four months. Therefore, the BESM with its higher

> performance of 8,000 -10,000 operations per second was unnecessary! Sergei Alexeevich parried the argument saying that due to its low capacity, Strela would not be able to work out a problem during the time between two errors and would display incorrect results, whereas BESM would succeed.

Both Bazilevsky and Lebedev successfully defended their proposals. The management of the Institute for Precision Mechanics decided to support the creation of an experimental model of the BESM. Sergei Alexeevich, in light of his experience creating and operating the MESM, recommend a modular design for the BESM – a bold move because many machines at that time were made with non-modular units. Luckily, the number of different modular blocks needed turned out to be small.

Lebedev and his team began the design and fabrication of racks, circuit boards, and machine units, but could not finish the project as planned. If this project had been completed successfully – all that it needed was a supply of industrial cathode ray tubes for the memory – then BESM would have far superseded its competition not only in the Soviet Union, but all over the world. Its projected performance of 10,000 operations per second would have been five times faster than Strela's. At that time, no machine had ever achieved such speed.

The Soviet Ministry of Machine Building and Instrument Engineering held a monopoly on storage tubes, and ignored the interests of not only Lebedev's institute but of science in the Soviet Union in general: the Ministry supplied only the Strela workers with storage tubes. Even Lavrentiev could not help Lebedev, and the BESM team found itself in a difficult and humiliating position. One could imagine Lebedev's shock in coming so close to meeting an advanced technical goal and then receiving such a blow. He had always been cooperative and offered his help, even to SKB-245. A few years earlier, when Lebedev and Bazilevsky visited Kiev, Sergei Alexeevich had explained MESM's operation in great detail to the scientists on the project, and also helped them reach an agreement with the Institute of Physics for the development of a magnetic-tape storage system. Moreover, the BESM was not a secret project as much as it was a rival. Unfortunately, the competitors did not respond in kind. Former SKB-245 project co-worker, F.N. Zikov, remembered that when Lebedev visited SKB-245 to learn about the Strela, the staff showed him the machine "…packed in boxes, ready to be shipped out."

Without access to cathode ray tubes for BESM's memory, Lebedev was forced to use acoustic mercury-delay line storage tubes, reducing BESM's performance to Strela's level and causing many problems. The amount of mercury needed for rapid access storage at full volume needed to be several hundred kilograms. The memory included 70 mercury tubes, each nearly one meter long: 64 were for storage, one tube was made for clock rate, and 5 served as spares. The mercury tubes had been developed in 1949 on Lebedev's order at the Institute of Automation. All of the tubes were placed inside a giant thermostat, which in turn was installed in a special room equipped with an exhaust hood, where work with mercury could be carried out.

The electronic parts of each channel were assembled in one large standard unit. The control panels and power supply units were substantial, while the external dimensions of the memory panels occupied an entire room. It was located at the end of a corridor on the first floor, a sizeable distance from the arithmetic unit, which was connected by cables carefully soldered onto foil. A large console for each of the mercury memory units included a dot-matrix indicator, a very elaborate console that simplified the life of the shift engineer by allowing him to examine each of the 64 channels. The layout of the memory unit was further complicated by the analog and electronic schema that worked in a closed ring circuit. Yet Lebedev worked tirelessly to adjust the rapid access memory. For two months, he practically lived in the room where the rapid access memory was located. According to Elena Petrovna Landera, "When Sergei Alexeevich made construction decisions, he rarely stopped halfway, and often went to great lengths to make any additional mechanical and assembly adjustments himself."

By the summer of 1952, the machine was basically completed and the adjustment phase had begun. All designers of the machine took part in the work, which continued around the clock. The main defects were in the acoustic-mercury tubes. Many of them burned out during the first hours of operation. But if a tube had already worked several hundred hours, then it was much less likely to fail.

By April 1953 the BESM was commissioned by the State Committee to go into operation and the design engineers stepped aside for the mathematicians. Even though in the beginning the machine performed at below capacity, it was able to solve several national economic problems. Strela had been completed at the same time and had been approved for serial production. Its creators had been awarded I, II, and III degree State prizes. Chief designer Bazilevsky was awarded the title of Hero of Socialist Labor.[11]

On the recommendation of academician Lavrentiev, who had become a vice-president of the Soviet Academy of Sciences, Sergei Alexeevich was appointed as the director of the Institute for Precision Mechanics and he was also elected to be a member of the Academy. At the election banquet, the son of Otto Yulievich Schmidt, Sigurd Ottovich, proposed a toast: "Today we have elected as academicians two distinguished scientists—S.A. Lebedev and A.D. Sakharov!"[12] In 1956, when the BESM had been commissioned by the State Committee again (this time it was made with vacuum storage tubes), S.A. Lebedev was awarded the title of Hero of Socialist Labor. The other main designers also received State prizes.

The First Computing Center

In February 1955 the Soviet Union's Council of Ministers passed a resolution to create the first Computing Center of the Academy of Sciences; academician Dorodnitsyn was appointed as the new director. Located at the V.A. Steklov Mathematics Institute, the center was given two computers: a BESM, and a Strela. Although both Strela and BESM worked around the clock, they could not keep up with the endless stream of problems assigned to them. Because of the urgency of the requested calculations, the Chairman of Ministries of the Soviet Union, N.A. Bulganin, had to prepare the computers' weekly usage schedule himself. According to Dorodnitsyn, the number of people on the calculation teams frequently exceeded the sixty-nine permanent staff members at the computing center. But, people came to the computing center not only to solve problems, but also to study programming. Because of this, an Ural-1 and an Ural-2 – machines from another computer line – were installed at the center and used mainly for training and instruction.

The Academy Presidium created a commission to compare the operational performance of the

[11] *Author's Note:* This was the highest state award presented for the most valuable work completed in a specific field.

[12] *Author's Note:* Otto Schmidt was a renowned polar explorer. Andrei Dmitrievich Sakharov was the chief designer of the Soviet H-Bomb and later in his life a human rights advocate.

BESM and Strela. The commission unanimously concluded that BESM had better prospects for development. Only after this resolution was passed did the Institute for Precision Mechanics receive the vacuum storage tubes that would enhance BESM's capacity. By this time it was already the end of 1954, beginning of 1955. As soon as the memory unit had a full set of vacuum storage tubes, the BESM began to operate at full power. Even two years later, the BESM remained on par with the best American computers and was the fastest in Europe. On average, BESM was performing 8,000 three-address operations per second; its maximum speed was 10,000 operations per second.

Later versions of the BESM turned out to be among the best operating computers in Europe.

In 1958, BESM went into serial production. By contrast, no more Strela models were ever produced after the original seven. The Strela that had been at the Academy of Sciences Computing Center was given to the Mosfilm Studio Complex in Moscow to use on movie sets.

"It Will Be a Good Little Machine!"

The Soviet government's rigid management was not the only cause for the long delays in BESM's mass production. The new M-20 computer – conceived by Lebedev soon after his initial defeat in the competition with Bazilevsky – was also to blame. The "20" referred to an anticipated performance of 20,000 operations per second. Lebedev himself recommended the M-20, not the BESM, for mass production. All the prerequisites for the M-20's success were in place: workers had finished the development of the new high-performance elements, the most up-to-date ferrite memory was installed, and the scientific team gained more members and experience. In addition and perhaps most importantly, Sergei Alexeevich had also secured a governmental resolution ordering Bazilevsky's SKB-245 project to cooperate with Lebedev and the Institute for Precision Mechanics. The Institute was directed to develop the machine philosophy, structure, design, and fundamental elements. Technical documentation and the experimental model would be constructed by SKB-245. Lebedev was appointed chief designer and constructor of the project and Mikhail Kirillovich Sulim (of SKB-245) his deputy.

Three men led the M-20 project: Lebedev, Mikhail Romanovich Shura-Bura, and Golovistikov. Lebedev developed the machine philosophy and structure, Shura-Bura formulated a system of commands and studied mathematical problems, and Golovistikov organized their results into specific layouts based on dynamic elements (mini vacuum tubes) that he had developed himself; he also designed systems for the arithmetic and control units. The structure of the machine, system of commands, and layout of the main units were completed quickly. Many new logic operations were employed and address modification introduced, which considerably simplified the programming. For increasing the speed and performance of the arithmetic unit, they developed a rigid command system that amplified signal speed. As a result, the execution time for simple adding operations decreased significantly, allowing for an increase in speed and performance. Moreover, it became possible to make shifts immediately on 1, 2, and 4 bit-positions, which accelerated the order alignment and normalization of the results from addition and subtraction operations. These and many other innovations had little effect on the number of vacuum tubes used. Actually, the number of diodes used increased, but over time the vacuum tubes were replaced by small but reliable germanium semiconductors.

At the same time, the team worked on the creation of ferrite memory, disk file memory, and peripheral devices. Near the end of 1955, construction of a prototype commenced at the institute. In 1956, adjustments on the machine were performed not only by the coworkers in Laboratory No. 1, but by scientists from other organizations as well. Many enterprises were interested in the rapid completion of the work because the Soviet Union was in desperate need of this class of computers.

Golovistikov remembered how Sergei Alexeevich exclaimed once, “It will be a good little machine!” At the beginning of 1957, the experimental model of the M-20 at SKB-245 was completed. Everyone had to regroup quickly and begin fine-tuning it. Lebedev assumed the most active role, just as he had done with the BESM’s adjustment, while Sulim settled the organizational problems. But at first things did not go smoothly. Although all of the dynamic elements were repeatedly checked on the small models, their reliability once installed in the actual machine body was uncertain. Workers noted the problem during the adjustments phase, while the machine was still at the institute, but failed to diagnose them due to the brisk pace of the difficult development schedule of the experimental model. At SKB-245, some technical workers spread rumors about the inadequacy of the dynamic elements and the flaws in the elemental base. They proposed to do everything the old way, by employing a large number of tubes. Sergei Alexeevich and his team were understandably disappointed, because everything had been going so smoothly up until this time, and suddenly an obstacle appeared. As a result, Sulim got in trouble with the SKB-245 managers, who demanded that the work be completed in an unreasonably short amount of time.

Considering the M-20 situation, Sergei Alexeevich resolved to put the BESM into mass-production. There were several favorable conditions that substantially reduced the amount of work and allowed him to make that decision. First, the team had the ready-made components of M-20, which were suitable for use in the BESM. Second, they had already fabricated reliable mini-tubes that possessed the same features as larger tubes used earlier in the BESM, and high-voltage germanium diodes, which permitted replacement of the tube diodes used in the BESM without any modifications to the construction plans. Third, the ferrite memory of the M-20 was available and could be installed in the BESM instead of storage tubes.

The leading engineers Kiril Sergeevich Neslukhovsky, A.N. Zimariov, Vladimir Andreevich Melnikov, A.V. Avaev and others, spearheaded BESM’s mass-production preparations. Since they had not been involved in the M-20 project or with any other specialized machine, they were able to complete all of the preparatory work for mass-producing BESM in less than nine months, using only the available technical documentation. BESM-2, which outwardly resembled the M-20, went into production at the beginning of 1958. Simultaneously, Golovistikov, Valery Nasarovich Lout and Andrei Andreevich Sokolov, refined the M-20 and improved its reliability.

Later that year the State Committee reviewed the M-20 and named it “the fastest computer in the world.” After that, the M-20 and the BESM-2 both went into mass-production. The need for high-speed computers was so great that M-20 was initially delivered only to the institutions working on the most critical projects in the Soviet Union. Additional production of the BESM-2 slowly reduced the Soviet Union’s high demand for computers designed for scientific calculations.

The scientific teams at both the Institute for Precision Mechanics and SKB-245 were nominated for Lenin Prizes for the M-20, but Lebedev suffered the same fate this time as he had with the MESM: the nomination was rejected. It still remains uncertain why this happened. I only know that one member of the State Awards committee, former director of the Institute for Precision Mechanics Bruevich, expressed his personal opinion about the technical level of the M-20, stating that at that time, the America's Naval Ordnance Research Calculator (NORC) was also performing 20,000 operations per second. This was not true. Bruevich failed to mention that NORC used in excess of 8000 vacuum tubes, whereas the M-20 only required 1600. Although he approved M-20's launch into mass production, his remarks also influenced the committee's decision to not award the Lenin Prize to Lebedev's team.

Despite his rivals, Lebedev was fortunate because he truly loved his work. While preparing this manuscript I visited one of the few still-living M-20 designers, Golovistikov, who spoke warmly about Lebedev, his ability to inspire his colleagues to be creative, and about his immense personal charm. Golovistikov remembered the period when BESM and M-20 were developed, specifically about how Sergei Alexeevich lived at that time, in a cramped sub-basement room, but the joy he extracted from his work allowed him to ignore all discomfort. At the end of our conversation I asked Petr Petrovich if he had any critical observations about his teacher. "There is one!" he replied, "After the BESM and M-20 were finished, I was appointed as the director of the laboratory for designing new computer components. My scientific work suffered because I had to deal with managerial issues, and I feel that I gave less to science than I could have." Like Sergei Alexeevich, Petr Petrovich was interested in neither high positions nor rewards, but in the *work* itself—to invent and create a more advanced computer. I will discuss the BESM series of machines in more detail in Chapter Four.

There are no Prophets in My Country!

In the 1960s, Soviet scientists proposed building third-generation integrated circuit computers. The majority believed that it was necessary to develop a family of software and hardware-compatible computers. But that was the only point that they agreed upon. Lebedev, having demonstrated the soundness of his ideas and his ability to predict future prospects for development of computer technology, proposed to create a family of small and mid-size general use computers. In addition, he proposed developing a separate supercomputer because its technology would be enormously different (structurally and architecturally) than that of the smaller general use machines.

By the late 1960s, Lebedev, Glushkov, and their followers believed that Soviet scientists had accumulated a significant amount of experience in computer technology and had a considerable production potential. They wanted to collaborate with large Western European computer manufacturers in developing a fourth-generation machine before the Americans did. Lebedev's political adversaries proposed a different option – to duplicate the American third-generation IBM-360 system, created several years earlier. Although no scientists of Lebedev's caliber were among them, they were the political figures who had decision-making power. The Soviet government passed a resolution to develop a Unified System of Computers [in Russian: *Yedinaya Systema Elektronnoi Vuichislit'elnoi Mashini,* or ES EVM], reverse-engineered from the configurations of the IBM-360[13]. The Institute for Precision Mechanics was not mentioned in the resolution. When writing the resolution, its authors tried to persuade Sergei Alexeevich to

[13] *Editor's Note:* Those computer scientists who supported the decision to go with the IMB-360 argue that their ES-EVM series turned out to be very reliable and productive.

take part in the development of the ES EVM. After consulting with the leading specialists, Lebedev refused, saying: "But we are going to make something extraordinary!" This meant that he would continue his work on supercomputers no matter what.

The decision to copy the IBM-360 may not have had any real consequences for the Institute for Precision Mechanics or any other computer technology outfit if not for a rival organization, the Radio Industry Ministry's Scientific Research Institute of Electronic Computer Technology – or NISEVT [in Russian: *Nauchno-Isledovat'elskii Tsenter Elektronno Vuichislit'elnoi Tekhniki*], which aspired to be the leader. Sulim, then 40 years old, was appointed Deputy Minister of the Radio Industry. He understood the importance of computer technology for the national economy, and in 1967 initiated a government resolution to construct computer-manufacturing factories throughout the Soviet Union. The resolution also included the creation of the mammoth NISEVT.

According to Sulim's plan, the core computer development organizations, such as SKB-245, the Schetmash, and the Institute for Precision Mechanics, were all to be housed within the NISEVT. But this part of the proposal failed. NISEVT was set up at the SKB-245 – the old rival of the Institute for Precision Mechanics. By now, the latter had established its own unique working culture. Its highly qualified staff could easily estimate the advantages and disadvantages of computers developed abroad and improve their own machines accordingly. In contrast, scientific teams at the huge NISEVT were formed in a hurry and lacked cohesiveness. Even the first-class specialists recruited by NISEVT (only a handful including Rameev and Vladimir Konstantinovich Levin), failed to fit in or to make any positive changes in the organization. NISEVT continued to clone obsolete foreign computers, while the Soviet government appointed it as the leading group for the development of the ES EVM.

Aware of the government's final decision to copy the IBM-360 system, Sergei Alexeevich – a chain smoker – ignored a life-threatening pulmonary illness to seek a meeting with Minister Alexei Nikolayevich Kosygin, to warn him that cloning the IBM-360 would lead to the demise of the Soviet computer industry. He was refused and sent to the Minister's deputy. The visit did not yield any results. After that, Lebedev's illness intensified. Occasionally, there was hope that he would recover, but not for long. Lebedev's strong constitution, undermined by years of stress and endless work, was failing. He was awarded the Order of Lenin on his 70th birthday, and it was presented to him at home. By now, Lebedev was very ill and rarely got out of bed. The prize brought him little pleasure because the cause, to which he had dedicated the most productive years of his life, had suffered.

On July 3, 1974, Golovistikov returned to Moscow from Kiev and visited Sergei Alexeevich at the hospital. Golovistikov told him he had recently visited Feofania, where the MESM had been created. Lebedev listened carefully but did not look at him, staring off into the distance. Petr Petrovich remembered that look for the rest of his life. Then all of the sudden, the gravely ill Lebedev became excited. Perhaps he recalled those hard but happy years spent in Kiev, where he was able to realize his ideas. That was the last day in the life of a great worker, a scientific genius, and a very good man – Sergei Alexeevich Lebedev.

People such as Lebedev stood in the way of the expanding Soviet bureaucracy and its thoughtless decisions. Unfortunately for the Soviet Union, Lebedev's predictions came true. In the United Stated and other nations, computer development continued growing in the directions that he originally proposed. By then, foreign countries were developing high-performance supercomputers and personal computers plus a series of smaller, less powerful computers for specialized applications.

The Soviet government spent enormous sums of money on the ES EVM computer family. Copying the IBM-360 caused many problems, extended project deadlines and strained design team efforts. Of course, there was some value in copying this obsolete system in terms of mastering the new technology, developing a vast complex of peripheral units and acquiring new skills in “Sovietizing” computer systems from abroad. Overall, very little progress was made, particularly because IBM-360 documentation was difficult to procure. If one stops to think about the damage caused to the Soviet computer science, to our nation, and to European interests by attempting to make the IBM-360 work for us instead of using our own formidable brainpower and technical skills, it becomes clear that an enormous expenditure of labor, time, and money resulted in marginal benefits at best. The new political reformers – Viktor Yushchenko, Vladimir Putin, and others, must remember the role of science and the impact the truly outstanding scientific minds have on the technological progress and the society as a whole. We must not forget the immortal, heroic deeds of Lebedev, the founder of Soviet computer technology, nor the glorious years during the creation of the MESM and the work at the Lebedev’s institute, which greatly advanced the construction of electronic computers by relying on its talented people.

Chapter 2: Legacy of the Scientist: his last Triumph

To live and perish is so hollow, but if you fill your life with deeds of greatness and sacrifice, eternal memory will follow. – Boris Pasternak, Death of a Sapper

Academician Viktor Mikhailovich Glushkov is known for his accomplishments in cybernetics, computing and mathematics. Despite the variety of scientific problems that interested Glushkov, they all boiled down to one – the global problem of computerization and information-sharing. All of his colleagues agreed that he was an extraordinarily talented man, and one of the most outstanding scientists of the modern age. Anyone could see that as soon as they read one of his reports, or listened to one of his lectures, or simply spoke with him.

Glushkov first published in the field of abstract algebra at the age of twenty-seven. Out of the eight hundred books and articles on cybernetics, more than five hundred were his alone, the rest were co-authored with his colleagues and associates. The majority of his publications addressed trends in cybernetics and nearly one hundred of them involved computer design and engineering theory.

Glushkov was born August 23, 1923 into the family of a mining engineer. By the time he graduated from high school, he already had a good grasp of higher mathematics and quantum mechanics. He dreamed of becoming a theoretical physicist, but ended up not pursuing it. After finishing a one-year mathematics course at Novocherkassk University, he developed a great passion for the most abstract and difficult field of mathematics – topological algebra. After spending three years working on a solution for Hilbert's generalized fifth problem, he became the world's first mathematician to solve it, which immediately placed him among the top-ranking mathematicians in the Soviet Union. After such meteoric success, he abruptly switched from the most abstract to the most practical empirical science – cybernetics, a field that occupied him for the rest of his life.

In an incredibly short span of five years, he managed to establish the Academy of Sciences of Ukraine Institute of Cybernetics and attract an enthusiastic staff, consisting of young scientists and engineers. In the 1960s and 1970s the Institute became famous in the Soviet Union and abroad.

Glushkov defined cybernetics as a science of complex control systems concerning the general rules, principles and methods of information processing, where computers served as a technical means of practicing this science. This definition appeared in the first worldwide editions of The Encyclopedia of Cybernetics, prepared at Glushkov's initiative, published in Ukrainian and Russian. Its 1974 publication coincided with the expansion of the popularity of cybernetics throughout the world. Among the top one hundred Soviet scientists who took part in the preparation of the encyclopedia (Glushkov was the executive editor), more than fifty were from the Institute of Cybernetics. In 1978, the editors and authors of various chapters of the encyclopedia were awarded the Ukraine State Prize.

Just as the American scientist Norbert Weiner was the leading specialist during the early years of cybernetics' development, the Ukrainian Glushkov took the leading role in this field throughout the 1960s and 1970s. His manuscripts, The Theory of Digital Computers (Kiev: Naukova Dumka, 1967), The Theory of Self-Advancing Systems (Kiev: KVIRTU, 1962), Basic Foundations of Cybernetics (Kiev: AN-USSR, 1964), and others were critical in fostering the new science during its early years. Glushkov's activities spread far beyond Ukraine: he lectured on cybernetics and computer equipment issues in the majority of large industrial cities in the former Soviet Union. His exceptional oratorical skills helped in his active campaign for cybernetics. The professional journals, Cybernetics and Control Systems and Machines, where he worked as the chief editor, were critical in creating, developing and maintaining media coverage of cybernetics.

Being fluent in English and German helped him do presentations at international scientific forums and publish abroad, which in turn brought him worldwide recognition. His international reputation was responsible for him becoming a chairman and a member of numerous program committees for international congresses and conferences on information processing. He gave lectures in almost every major country in the world. In addition, Glushkov was a computing consultant to the governments of the German Democratic Republic and Bulgaria. He was an honored member of the Polish Academy of Sciences, Academy of Sciences of Bulgaria, Academy of Sciences of the German Democratic Republic, and the Leopoldina German Academy of Naturalists. The publishers of updated editions of the Encyclopedia Britannica, the American Encyclopedia and The Big Soviet Encyclopedia invited Glushkov to help them prepare sections on “Cybernetics.”

Glushkov anticipated the large-scale informatization of our society in the early 1960s, when computing technology in the Soviet Union and abroad was still in its infancy and few people could envision its future role in the economy. But Glushkov was able to clearly imagine the great prospects for the development and applications of computer technology and cybernetics and their benefits for humanity.

Glushkov proposed to the Soviet government the first step in implementing this complex large scale project: to create a Comprehensive Computer-Aided Economy Management System (in Russian: Obschya-Gosudarstvennaya Avtomatizirovanaya Sistema, or OGAS).

He hoped that the Soviet government would support this initiative, because the existing paper means and methods of Soviet economic management had been obsolete since the 1940s and could not effectively support the growth of the national economy, which was already complex and top-heavy.

Glushkov was aware that developing OGAS would necessitate accelerating broad development of computing technology and scientific methods of economic management, and creating a powerful network of about two hundred regional and ten thousand local computer centers throughout the nation. It would also require complete computerization of the work places for specialists in science, technology, and administration at industrial enterprises, branches of government and other institutions – this was Glushkov’s ultimate goal.

Soviet Prime Minister Alexei Nikolaevich Kosygin approved this idea and Glushkov, with his characteristic enthusiasm, began work on the OGAS project. Today, one may say that his plan was premature because computer technology was not very sophisticated and the society was not ready for it back then. According to his calculations, the implementation of OGAS would take fifteen to twenty years and require about 20 billion rubles, which was an enormous sum at the time. He was very upfront with Kosygin – the implementation of OGAS would be more complicated and difficult than the space and nuclear weapons programs put together. Besides, it would deeply alter political and social aspects of Soviet life. Glushkov calculated that if properly organized, OGAS would start paying for itself in five years, and after its realization, the national economy and well-being of the population would at least double. Glushkov also insisted on the necessity of organizing an authoritative state supervisory board to manage the OGAS program—similar to the committees overseeing the space and nuclear programs. According to his estimates OGAS would be finalized in the 1990s.

If OGAS had received sufficient support and had been completed, it would have been especially useful after the breakup of the Soviet Union. OGAS could have alleviated the countless problems in the current transition from central planning to a market economy. Its solid hardware basis, program software, data banks, and experienced personnel would have been very valuable to the national economies of the Commonwealth of Independent States as they weathered the 1990's disastrous financial crises.

Undoubtedly, Glushkov was aware that OGAS might not receive active support from the Communist Party and the ruling elite, because true scientific control of the economy would strip away their power and change the nation's destiny. Moreover, OGAS would not receive support from the Soviet bureaucratic system, which was based on administrative tyranny, especially when it came to making the most important national decisions. It was also a challenge to the West –they understood that OGAS would shield the Soviet Union from economic collapse or worse, the Soviet Union might create a modern and efficient system of planned economic management. This idea caused the Soviet press and Western mass media to attack Glushkov in the 1970s, attempting to discredit him in the eyes of the Soviet government and block the realization of his plan, which aimed to radically transform our society.

But Glushkov was determined to succeed at any cost. From his early school years on, he had always managed to achieve his seemingly unattainable goals. This time was no different. He fulfilled his dreams through enormous dedication to his work and principals, surprising his colleagues and opponents, and setting scientific records. It was no surprise that Glushkov became a legend.

The research at the Cybernetics Institute followed Glushkov's lead. It included computer science and equipment development, theory and technical means for computer-aided design and automated systems, artificial intelligence, and methods of optimization. The Cybernetics Institute's first significant products were new types of hardware. Supervised by Glushkov, the Ukrainian scientific school of digital computing provided the majority of original ideas and principles that became the basis of computer design in the 1960s and 1970s. During those years Soviet-made computer equipment was on par with the rest of the world.

In the history of computer science, Glushkov's name is foremost connected with the theory of computer design. During the late 1950s and 1960s, Glushkov personally supervised a very important part of the work on the theory of highly intelligent control computers. These computers were necessary for two reasons: first, for the automation of technological processes; and second, for automation of engineering calculations. These machines were prototypes of today's personal computers (PCs), used by specialists processing information right at their desktops.

Later, the Institute of Cybernetics turned to the design of modules and architecture for all-purpose highly intelligent computers. In this area, the Institute of Cybernetics was the leading organization in the Soviet Union from the 1950s to the 1970s, performing research at world-class standards. By the end of the 1970s and early 1980s, the last stage of this research involved outlining the principles of super-speed multiprocessor macro-pipeline computers with non-von Neumann architecture. Along with this, Institute workers also developed software for multi-processor systems. A mere ten years later, such systems were at the forefront of world-wide computer design. Glushkov's idea of macro-pipelining at the end of the 1970s was a breakthrough into the future of computer technology.

As noted above, the majority of theoretical work carried out at the Cybernetics Institute was realized as hardware. In the 1960s and 1970s, Soviet industry mass-produced more than fifteen types of computers designed at the Institute. Incorporating theory into the hardware was one of Glushkov's main principles – traditions he learned from Lebedev. Many years later, Austrian scientist Heinz Zemanek, eulogizing about Glushkov's contributions to the field of computer design, noted: "Glushkov's scientific work, along with his scientific and practical research results, will influence the development of computer science in the whole world for many years to come."[14]

Glushkov was also renowned for increasing the intellectual capacity of robots and image recognition theory; he regarded artificial intelligence as the most promising direction in cybernetics. Early in his career he pondered the possibility of designing logical mathematical models of human intelligence that would be capable of thinking outside the body and what effect they would have on the immortal spiritual genius of human beings. Besides concentrating on artificial intelligence problems, Glushkov also worked out the fundamentals of discrete self-organized systems theory.

Viktor Mikhailovich played a tremendous role in creating a Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) system, with a wide range of applications. In this area, as well as in the field of computer technology, scientists at the Institute faced the task of obtaining not only fundamental but also practical results. They needed to design real control systems for technological processes plus control systems for complex scientific and industrial experiments, enterprise management systems, and industrial systems. Via these efforts, Glushkov completed monographs on the design principles of CAD and OGAS, such as Introduction to CAD (1972), The Fundamentals of Paperless Information Technology (1982), Macroeconomics Models and Principles of OGAS Design (1975) and several other scientific articles published in various periodicals.

Glushkov was involved in many activities that extended beyond the limits of the academia. He worked for several organizations of the Soviet Ministries as a scientific adviser and a chairman of various committees, and, of course, he was frequently regarded as a "trouble maker" among the Soviet government bureaucracy.

Glushkov's monumental efforts constantly ran into a wall of indifference, misunderstanding, and at times, animosity in the top echelons of the command-administrative system. Glushkov's wife, Valentina Mikhailovna, noticed her husband's disappointment after many of his trips to Moscow. In the Soviet Union, cybernetics was met with resentment from the very beginning, even within the scientific community. It is well known that cybernetics, together with the theory of complex systems, claimed to have a scientific validation of the control processes not only in life forms and machines, but in society as well. Unfortunately, not on the basis of Marxism-Leninism, but on the basis of exact sciences such as mathematics, automatic control, and statistics. Thus, it contradicted long-cherished Soviet management "methods."

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[14] Zemanek, Heinz, "Euloge: Viktor Mikhailovich Glushkov, 1923–1982," *Annals of the History of Computing*, Vol. 4, No 2, 1982, pp. 100–101.

The Communist Party Central Committee Secretary, Andrei Kirilenko, openly ridiculed OGAS in front of Glushkov: "Why do we need it? I come to a plant, make a speech in front of the workers, and the plant increases its efficiency by five percent! It's much better than your two percent!" Glushkov's former colleague Anatoly Ivanovich Kitov recalled another Communist Party official discussing computer technology's applications in defense work: "Optimization methods and computer-aided control systems are unnecessary because the Party has its own methods. For this purpose, it asks the advice of the Soviet people." The Soviet leaders who supported Glushkov – Kosygin, and Defense Minister Dmitrii Fyodorevich Ustinov, were the only individuals who did not mock or criticize him.

Glushkov did not give up. Beginning in 1962 and for the next twenty years, he persistently promoted the idea of national computerization and pressed the Soviet Council of Ministers in Moscow to approve a basis for OGAS. Only one barrier remained – the Politburo,[2] and it had to give the final consent for the organization of a state committee for the supervision of the OGAS project. They refused Glushkov.

When this issue was discussed at the Politburo session, Glushkov made the following prophecy: "The problems in our economy are such, that by the end of the 1970s we will have to go back to the OGAS project. Otherwise, our economy will collapse!" When he returned to Kiev, he was summoned by the First Secretary of the Central Committee of the Ukrainian Communist Party, Petr Efimovich Shelest, who warned him to stop promoting OGAS among the top officials and get down to "basics," meaning the creation of computer-aided systems for factories. But even before this order, Glushkov had already assembled his staff from the Institute of Cybernetics to design two systems. First, the Lvov System was a CAD/CAM system, designed and installed at the Lvov Television Factory; and second, the Kuntsev System, was installed at a radio plant in Kuntsevo near Moscow. According to Glushkov, these two systems would set the national standard.

At that time Ustinov supported Glushkov, and offered to introduce the OGAS project, at least partially, to the defense industries. The highly organized defense sector supported the fast creation of a series of effective computer-aided systems for enterprise control, but Glushkov's opponents insisted that computer-aided control systems were unreliable and unprofitable. The subsequent policy that emerged prevented the rapid computerization of Soviet society. As in the case with cybernetics, the opponents of CAD/CAM managed to briefly gain the upper hand.

Glushkov could not participate in this foul game forever. In the early 1980s aggressive astrocytoma became his new, merciless enemy, making his political opponents irrelevant. Nevertheless, Glushkov's memory remains in the hearts of those who worked with him, and I hope that the readers of this book will understand why. If one becomes acquainted with Viktor Mikhailovich's work, it is clear that modern information networks are a legacy of his ideas. That system was created without any "high ruling body," and mostly for reasons of economic expedience. The appearance of personal computers in the offices of engineers, designers and managers is a testimonial to Glushkov. And now a huge information network – the Internet – is stretching across the Commonwealth of Newly Independent States and around the world, fulfilling Viktor Mikhailovich's dreams and predictions of forty years ago.

During a chance meeting with Vladimir Petrovich Krasnikov, a prominent journalist from Kiev, I told him of my intent to write a memoir about the invention and development of computer technology in the Soviet Union. He informed me that he possessed cassette tapes of Glushkov's firsthand stories about his childhood, youth, and first years in science. It turned out that Krasnikov met Glushkov many times in the early 1970s and had intended to write his biography, but suddenly fell ill. When he recovered, he realized that he had lost his impressions of Glushkov. His notes were left unused, so he gave them to me.

Viktor Mikhailovich's wife, Valentina, shared with me the family relics and her husband's memoirs, dictated to their daughter Olga during the last nine days of his life, which I have maintained in my personal archive in Kiev. In a way, it is an insight into his creative genius. I share some of the most telling and powerful stories and memories below. They are supplemented by the recollections from his closest students and colleagues at the Institute of Cybernetics, by fragments from friends' letters, by his wife's reminiscences, and by my own personal comments.

Nine Days in 1982

Personal Reminiscences of Viktor Glushkov. January 3rd 1982

During the preparation and defense of my doctoral dissertation at Moscow State University, I lived with several graduate students from Ukraine who introduced me to the academician Boris Vladimirovich Gnedenko, from the Ukrainian Academy of Sciences. At that time, Gnedenko was working as the director of the Institute of Mathematics and the academic secretary of the Department of Mathematics and Mechanics. In March 1956, he invited me to come to Kiev; it was my first trip there. After a brief tour of Kiev University, Gnedenko showed me personnel files of young specialists who were about to graduate and had been selected for work at the Institute of Mathematics in Lebedev's former laboratory. This laboratory had been moved from the Institute of Electrical Engineering. In autumn of 1956, during my second trip, my transfer to Kiev was finalized. I became the director of the laboratory of computing equipment at the Institute of Mathematics. The laboratory was supposed to be reorganized as a computing center for the Ukrainian Academy of Sciences, according to a 1955 decree to create computing centers in the academies of the Soviet Republics.

Rabinovich remembered:

> It took Glushkov half a year to make a difficult decision—instead of topological algebra, where he had already obtained brilliant results, he shifted to cybernetics, which back then was frequently criticized by the authorities. The original laboratory staff had been selected by Lebedev and by now was a seasoned, cohesive group of scientists. It could have been the main reason why they were slow to welcome the mathematical theoretician Glushkov, although personally, he was liked by everybody from the very beginning. Glushkov's unquestionable talent, brilliant intellect, charm, his infectious enthusiasm about the new science, and personal diligence were instrumental in gaining the support of the laboratory staff and his progress in cybernetics. It's worth mentioning some of the major research work carried out in the laboratory employed the MESM. Specifically, the research into the theory of programming, led to Vladimir Korolyuk and Ekaterina Yushenko's creation of address mode language, followed by the creation of statistical and optimization problem solving methods by Gnedenko, Vladimir Semyenovich Mikhalevich, and others. Dashevsky was the head of this group, assisted by Solomon B.

Pogrebinsky, Alla Leonidovna Gladish, and others. The same staff took part in other design work and the testing of new logic elements, in particular ferrite-diodes and semiconductors.

At the same time, the computing machine SESM had already been tested and was operating at the laboratory. This was the first computer in the Soviet Union that worked on the basis of matrix-vector processor with pipeline organization of calculations and combined input of data and output of calculation results. The architecture of the SESM represented Lebedev's ideas. But Glushkov did not dismiss it. On the contrary, he took an active interest in the project. Overcoming the designers' unwillingness to summarize a paper on the SESM's design philosophy (the computer was already completed) Glushkov insisted on writing a book about it. This was reasonable as the SESM had a number of structural novelties that could be used as independent units, such as dynamic registers on magnetic drums, a system of internal diagnostics, etc. The book was even published in the United States, apparently one of the first Soviet books published abroad.

An exceptionally important project at the laboratory was the Kiev computer. The project was established and supervised by Gnedenko; Dashevsky was responsible for the design. The machine was intended for use in the new Computing Center established at Lebedev's former laboratory and was supposed to represent a new breed of technology. It was also supposed to have these additional components: asynchronous control (the first in the Soviet Union), ferrite Random Access Memory (RAM), external memory on magnetic drums, a decimal input/output system (as in the SESM), passive memory with a set of constants and subprograms of elementary functions, and an enhanced operational system, including group operations with address modification, enabling operations to be done on complex data structures. The same group of scientists that created the MESM initiated the Kiev's design. Scientists from Institute of Mathematics – Korolyuk, Pogrebinsky, and Yushenko – worked on selecting operations. Glushkov joined this effort at the final stage of technical design, assembly, and computer adjustment, and shared leadership of the project with Dashevsky and Yushenko.

Another major project that began before Glushkov's arrival at the laboratory was the design of a double computer system for radar air target tracking and directing jet fighters to intercept them. Malinovsky and Rabinovich headed two small groups for this project. Malinovsky was in charge of the radar information processing and Rabinovich led the computer targeting design. With Glushkov's arrival, the work took on a new shape. He put everything on a strict scientific basis and formulated a mathematical theory for the targeting process. The results of his work were approved and used to create the Soviet Union's standard anti-aircraft defense system.

How did Glushkov captivate and motivate the laboratory staff so quickly? First and foremost, it was his innate ability to see the big picture. It was as if he could see the entire world in all directions at the same time. He was able to assess the full complexity of developing computer technology, to clearly

> formulate basic ideas for its design, and to outline present and future goals in the field. His personal unshakable conviction in our scientists and their ability to accomplish anything they set their minds to, was infectious.

Personal Reminiscences of Viktor Glushkov, cont'd. January 3rd 1982

The computing machine designs of that time were based on engineering intuition, so I had to learn the principles of computer design on my own. As a result, I became intimately familiar with the inner workings of a computer. Since then, the theory of computing machines has become one of my specialties leading me to transform the art of computer design into science. Naturally, the Americans were working on the same issues, but they achieved similar results later. The theory of automatic machines as the basis for computer design was not sufficiently developed back then. Apparently, the first people to express the idea of the possible applications mathematical logic in the design of technical devices were Claude Shannon in the United States, and V.I. Shestakov and Mikhail Alexandrovich Gavrilov in the USSR. They applied the simplest formal mathematical logic to a design of telephone switching circuits. It appeared to also be useful for simple electronic circuits. Therefore, in the post-war years when digital computing technology started developing, attempts were made to apply formal mathematical logic for solving tasks in computer circuitry. I began to work on this problem and organized a seminar on the theory of automatic machines. The essence of one my first projects was the discovery of a much more elegant, algebraically simple and logically clear concept for Kleene's automatic machine and I obtained all of Kleene's results. But more importantly, even beyond Kleene's results, I was developing a theory aimed at real tasks of machine design. At the seminar, we discussed issues in Kiev's design and were able to see which parts of my theory would work and which parts would not.

Alexander A. Letichevsky, another of Glushkov's contemporaries, recalled:

> Julia Kapitonova became the "soul of the seminar." She was Glushkov's favorite student. Viktor Bondarchuk and I were also faithful participants in the seminar. It was a romantic period: a new science was being born right before our eyes and we were expanding its frontiers with our own hands. We were proud when we managed to solve the tasks our teacher gave us. The theory of automatic machines was not chosen accidentally by Glushkov. It was a well-planned technical move. As an algebraist, Glushkov saw that the concept of automatic machines, coming from Stephen Kleene and other authors in the well-known *Automata Studies* [published in 1956, Princeton, N.J. under the editorship of Shannon and McCarty; translated into Russian the same year under the editorship of Alexei A. Lyapunov] presented a powerful mathematical model for a discrete information processor. This model could be studied by application of a rich array of contemporary mathematics. At the same time, the expansion of applied theory on the basis of rational mathematics could attract the attention of engineers who lacked sufficient knowledge of mathematical theory to design devices containing memory elements. In addition, the theory of automated machines could become the basis for the design of cybernetic system models with various applications.

Personal Reminiscences of Viktor Glushkov, cont'd. January 3rd 1982

I was directing a large team for the first time, so I had to define some organizational principles. I didn't write them down, but I followed them consistently, and it always led to success. In particular, I used the principle of unity between theory and practice with a new twist: when undertaking a large design project, consider both the present and future goals. In a new science like cybernetics, one must always break down a long-term project into smaller, more manageable pieces. Each stage would then become a step toward the ultimate goal with its own timeline. At the same time, its completion would yield an independent result with distinct benefits.

I have a habit that developed in my early childhood: when I am interested in a new field of study, I like to do preliminary research before beginning to work in it.. Prior to my arrival in Kiev, I was involved with topological groups. I had a clear idea of what can be expected from any scientist dealing with this problem. That is, I easily felt the rhythm in problem solving, and I knew I had to stay a step ahead. The feeling of excellence was necessary for me to consider myself a specialist. For three years, I'd been racking my brain trying to solve the basic theorem on Hilbert's generalized fifth problem. My subconscious worked even when I was sleeping. Sometimes at night, it seemed like I had solved it, but then in the morning I would get up, sit down at my desk and alas, somewhere, somehow there was a logical mistake. A continuous three-year onslaught ended in 1955. My wife and I went on a hiking tour of the Caucasus. While climbing an ice field on Mt. Kazbek, I was struck by an idea that enabled me to solve Hilbert's problem. However, I had gotten so used to the fact that there was always an error in my reasoning that at first didn't believe I had finally solved it. I looked for errors, but couldn't find any. On the way back, riding on the train, I quickly wrote down the solution and spent the next six months polishing it. It came to sixty pages and proved only one of the theorems. Up until that time, no one in the world was able to come up with a shorter proof. This work brought me recognition among mathematicians and a tremendous creative satisfaction, so to speak.

I believe that I was able to coordinate the work at the laboratory not because of good organizational skills, but because I can see things in the larger context, and I can direct research, set goals, motivate people and guide them through the process. That is my saving grace. Somehow, I learned something; I even formulated several organizational principles along the way, but it is not my strong suit. I like to spend my free time proving theorems. That's what I truly love and feel most comfortable doing. Organizational work, on the other hand, is a burden to me. Sometimes it becomes interesting, and I get absorbed in it, but only because I enjoy seeing things through to the end.

Personal Reminiscences of Viktor Glushkov. January 4th 1982

In December 1957, the government and the Presidium of the Academy of Sciences of Ukraine made an official decision to establish the Academy's Computing Center. By that time, our staff consisted of more than 100 people. The Ukrainian Academy of Sciences allotted financial support for the construction of the Center on Lysogorskaya Street, and a block of apartments for the staff. In the beginning, the Computer Center was to be supplied with three computers: the Kiev, the MESM, and an Ural-1. The latter machine was the latest one manufactured. The building was designed to house 400 workstations and had three large halls in which to install the computers. In 1959 our staff moved from Feofania to Kiev, but the building was not finished in time. That was an interesting period in the history of the Computer Center. According to the *technical requirements, the premises where the computer equipment was to be installed had to be clean and air-conditioned. Yet, we had to do the final checks and launch the Kiev computer before the building had a roof. What really helped in this difficult process was the enthusiasm of our young staff. Of course, the building was finished shortly thereafter.*

The Kiev computer played a significant role in our work, though it was never put into serial production. The second Kiev computer was bought by the International Institute of Atomic Research in Dubna, near Moscow. During 1956–1957, nuclear research was booming. Therefore, collaboration with this Institute helped and taught us a great deal. On one hand we were on the forefront of science; on the other, we were learning how to cooperate with industrial enterprises. During this time my main task was to establish the fundamentals of computer theory, which I completed in 1961. The research was extremely intense and time consuming. I spent whole days at the Institute; during the nights, I poured over books and articles, and often wrote until five in the morning. Working so hard and for such long periods of time without rest, took a toll on my health. At the beginning of 1963, I suffered a brain seizure and was briefly hospitalized. After that, I was forced to change my working habits and take care of my health.

Glushkov's wife had tried to step in and make her husband pay more attention to his health. But she did not manage to convince him:

> He worked eighteen to twenty hours a day. He would get so busy at work that he forgot to eat. When he came home, he rushed to his desk and worked until the wee hours of the morning, sometimes until dawn. Viktor did not listen to warnings about the dangers of overexerting himself, but his reasons were understandable. In a short period of time, he was supposed to learn all of the latest trends in his scientific field. In addition, he was responsible for a large staff of scientists this time, not just for himself. A lot of organizational difficulties came up and everything new required a great deal of effort to break through. After his treatment was over and he returned to work, he changed his schedule a little bit, but he still did not rest enough. He had this note at home; it was always under the piece of glass covering his desk: "Today is the first day of the rest of your life. Don't waste it."

Personal Reminiscences of Viktor Glushkov cont'd. January 4th 1982

My book, The Design of Digital Automatic Machines, was published in 1961 and became the basis of a new scientific trend in our Institute and probably played a positive role in the nation as well. In 1964, my book received the honorable Lenin Prize. I wrote several other books during that time. The monograph Introduction to Cybernetics was finished while I was still in the hospital; it was published in 1964. Both of those books were also published in the United States and in many other countries. At the same time, I also wrote a theoretical article, which established the basis for many works on the theory of automaton with applications for algebraic theory of automatic machines. This article, 'Abstract Theory of Automatic Machines,' was published in the magazine Successes of the Mathematical Sciences, and therefore available to a wide circle of mathematicians. It was republished as a brochure in the German Democratic Republic and other countries. Influenced by this article, many of our algebraists became involved in the theory of automaton. I have to point out the special feature of our school: we strived to be more practical rather than theoretical.

Simultaneously with theoretical research, we pursued the creation and application of computer technology in Ukraine. At that time, enterprises used simple analog computing devices for computer-aided manufacturing control. For each technological process, they created its own separate device, especially for the ones that could be described by simple differential equations. In 1958, at the Computing Conference in Kiev, my proposal to build a multi-purpose digital control computer with a transistor was met with hostility. Moscow scientists, led by the academic Vadim Alexendrovich Trapeznikov and many other Soviet computer science specialists, had the same negative attitude towards it: they still believed that computers should be based on electronic vacuum tubes. These devices required huge amounts of space and proper air-conditioning, which conflicted with the realities of manufacturing and on-site control of technological processes.

At that time, Boris Malinovsky was one of the first to do research work on semiconductors, which was very helpful to us in developing a Universal Control Computer. We outlined the basic ideas, which later became the governing philosophy: the computer had to be built with semiconductors, needed to be portable, have reliable protection, and a word length of 26 bits – long enough for technological control of the majority of the processes. But the main idea was a special interface unit (a set of computer controlled analog-to-digital and digital-to-analog converters) that could connect the computer to the technological processes.

Malinovsky was the chief designer of this machine and I acted as the scientific advisor. From the time this idea was presented at the June 1958 conference, it took only three years to begin serial production of the computer (in July of 1961) and to install it at some facilities later that year. As far as I know, this is still the shortest time frame for the design and installation of new technology.

The Universal Control Computer, later named the Dnepr, was a collaborative effort with several Ukrainian enterprises to incorporate the control of complex technological processes. Jointly with the Dzerzhinsky Metallurgy Plant – in the city of Dneprodzerzhinsk – we analyzed issues in controlling the process of steel casting in Bessemer converters. We solved similar problems of column carbonization with the workers at a soda factory in the city of Slavyansk. I also initiated an experiment – the first of its kind in Europe – to control those processes remotely for several days in a row. In addition, we conducted research on Dnepr's applications to computer-aided welding processes at a plant in the city of Nikolayev. Malinovsky, Vladimir Illich Skurikhin, Gleb Alexandrovich Spinu, and others were deeply involved in these projects.

We learned later on that American scientists started developing a universal semiconductor control computer – analogous to Dnepr – earlier than us, but began producing it at the same time, in June 1961. This was a point when we managed to catch up with the Americans in one very important scientific area. It should also be noted that our computer was the first Soviet semiconductor device [with the exception of computers for military purposes]. Dnepr turned out to be a very sturdy machine, able to withstand extreme weather conditions, vibration tests, etc. It also set a longevity record – Dnepr was manufactured for ten years, from 1961 to 1971, while typical computer equipment required serious modernization after five to six years in production. After much debate during the joint Soviet-American Soyuz-Apollo space flight, this computer was chosen to control the display screen at the Flight Control Center. Dnepr was also exported and employed in many Socialist countries.

It should be noted, that the seven-year-plan (1958–1965) for Soviet industrial development in Ukraine did not include the manufacturing of computers. The first Dnepr computers were made at the Radiopribor factory in Kiev. At the time of Dnepr's design, we initiated the construction of a Control Computer production plant (in Russian: Zavod Vuichislitel'nikh i Upravlaushikh Mashin, or VUM, now called the Electronmash) that was supported by the government. Thus, the heroic period of our development came to an end. I call this time heroic because we worked in difficult conditions and were always expected to perform above and beyond the scope of our jobs.

I frequently wrote and spoke about this. Unfortunately, my organizational efficiency coefficient (as I once calculated) did not exceed four percent. What does that mean? It means that in order for a problem to even be considered by the government, I had to speak with twenty-five officials. However, after the success of Dnepr, I was generally well received and with much less skepticism than before.

Research on control computers did not stop with Dnepr. Let's skip forward to note the following basic design projects: in 1967, in cooperation with the Institute of Cybernetics, the VUM plant started manufacturing a new model, Dnepr-2. This computer contained complex multilevel interrupt system and an effective real time operational system. Unfortunately, its productions soon stopped. In 1976, a terminal processor control computer, BARS [in Russian: Bazovaya Aparatura Razrabotchika Sistem, basic system creation apparatus. The noun 'Bars' also means 'Snow Leopard' in Russian], was designed by Vladimir Skurikhin, Anatoly Morozov, and others. Its design received the Golden Prize at the International Exhibition in Dresden, and it was used at several industrial plants. In 1977, the M-180 computer control complex was created and put into production, along with a system of technical interfaces designed by Malinovsky, Pavel Sivachenko, Alexander Palagin, Yuri Yakovlev, and Vladimir Reutov.

Personal Reminiscences of Viktor Glushkov. January 5th 1982

In 1962, our Computer Center was reorganized and renamed the Ukrainian Academy of Sciences Institute of Cybernetics. The Institute grew quickly and we were involved in many areas: probabilistic automatons, functional reliability of automatons, economic and energy saving, and interference resistant coding. The research started shifting from finite-state to infinite-state automatons. We discovered the connection between the theory of automatons and the theory of formal grammar. We implemented new methods of analysis and automaton design; besides me, Letichevsky and Kapitonova were actively involved in this research. Their work gained wide recognition.

In 1959, I began designing a computer that would perform engineering calculations. This project started with the design of a digital calculating automaton. In 1963, we launched serial manufacture of the Promin computer. By that time we understood that we needed a design bureau, which was established in 1963, but its prototype appeared much earlier at the Institute of Cybernetics. The staff that created the Promin later joined the design bureau.

Promin's manufacture began at the Severodonetsk computer plant because the Kiev plant was still under construction. Technically, the Promin had a number of innovations, in particular, memory on cards coated with metal. But most importantly, it was the first widely used computer with step-by-step micro program controls. Unfortunately, we were not able to obtain an international patent for the new scheme of control. Back then, the Soviet Union was not a *member of the International Patent Union and we could not obtain the copyrights. Later, the step-by-step program control was used in the computer Mir-1 for engineering calculations. In 1967, at an international computer show in London, the Mir-1 computer was purchased by the IBM – the biggest computer company in the United States and the exporter of eighty percent of the computer equipment in the western world. It was the first – and unfortunately the last – purchase of a Soviet electronic computer by an American company. As it became apparent later, IBM did not buy the computer for calculation purposes, but to prove to their American competitors who had patented the principle of step-by-step microprogramming in 1963, that the Soviets had known about this principle long ago and had used it in serial production of their own computers. In fact, we put it to use even earlier, in the Promin.*

A new and upgraded computer, Mir-2, went into production in 1969, followed by Mir-3. These computers were unmatched in their analysis conversion speed. For example, Mir-2 successfully competed with larger, standard structure all-purpose computers, which exceeded Mir-2 in nominal rate of speed and had a hundred times the memory capacity. The Mir was the first Soviet computer to implement a dialog mode, using a display with a light pen. Each of these machines also represented a large step toward designing computers with artificial intelligence. It was a strategic breakthrough in the development of computers.

What was the difference between Mir and other computers? We considerably upgraded the machine language. However, back then the popular point of view was that machine language must be as simple as possible and the rest would be done by software. We were even mocked for our efforts to develop different computers. The majority of computer scientists in the world believed that it was necessary to develop computer-aided programming, that is, to create software that would help produce other programs. Our colleagues Korolyuk, Yushenko, and other scientists were engaged in this field and were the first in our nation to suggest an effective address language for the Kiev computer, creating the so called 'programming programs' (translators) for other computers. But I did not take part in the work.

In designing the Mir machines, we had tackled a daring problem – to match the machine language as close as possible to the human language, and here I mean mathematical nonverbal language, though later we made attempts with normal human language. So, we created 'Analytic,' a special mathematical language, supported by an internal interpretation system.

Mir computers were used in all regions of the Soviet Union. Their creation became an intermediate stage in research aimed at the development of artificial intelligence, since the intelligence realized in them was still fairly primitive. It also looked very impressive when a machine quickly solved independent and dependent integrals, while not many professors of mathematics were able to solve them. In addition, the machine found substitutions, not just the easy ones from tables, but the difficult ones as well.

In 1966, Glushkov and Rabinovich published the first article in the world on improving computer efficiency by simplifying the human-machine interactions: "On a Few Problems of Algorithmic Structures in Computer Systems," (*Cybernetics in Service to Communism*, Moscow: 1966). At that time, those were "revolutionary views" acknowledging that the direction of computer development was shifting. The first battle for this new ideology had already occurred (in 1962) at an international conference on computer development in Kiev. Participants came from Bulgaria, Hungary, Poland, and Czechoslovakia. Glushkov was scheduled to talk, but suddenly fell ill. Despite his high fever, he decided to make his briefing because he believed that the conference was very important. Unfortunately, his illness prevented him from speaking with his characteristic zeal, which would have electrified the audience. After the presentation, he was bombarded with hundreds of challenging questions. The renowned Moscow specialist, Mikhail Romanovich Shura-Bura, sarcastically remarked that if one were to realize all of Glushkov's suggestions, the proposed computer would be larger than the building in which the conference was being held. At the end, things settled down, but his opponents clung to their opinions.

The importance of integrating artificial intelligence into computers was recognized in 1963 at a rather modest symposium, organized by the Cybernetics Institute and Uzhgorod University in which Lebedev, Glushkov, Mikhail Sulim – chief administrator of computer technology in the Ministry of Radio Production – and several others took part. In general, the atmosphere in which we discussed our proposals for computer architecture was friendly, and our critics remained quite benevolent. Another camp of mathematicians was present, and I remember that even though our discussion was emotional, everyone remained quite businesslike. Lebedev liked our proposals and noted that several of them overlapped with the ones used in BESM-6's development. As the result of the conference in Uzhgorod, our proposals were discussed and approved, and all of the participants expressed their recommendations regarding the direction of computer development. The "high-level side" – Lebedev and Glushkov – finally agreed that the Institute of Precision Mechanics and Computing Technology would work on creating supercomputers, while the Ukraine Institute of Cybernetics would take on the development of smaller and more specialized computers.

Returning to Kiev, Glushkov began designing Mir-1 with renewed energy. Within two weeks he had drawn up the preliminary plans, identifying the main architectural and structural contours of the machine. It contained a series of original solutions, which would serve as the basis for an invention patent. A close working relationship between scientific colleagues at the Institute of Cybernetics and the scientists and engineers of SKB-245 led to brilliant results – the Mir computer family was quickly developed and put into serial production, receiving high marks from its users. Its creation was a giant step in the development of artificial intelligence in small computers.

Unfortunately, the potential of the Mir computer line was never fully realized. During my 1979 presentation in Novosibirsk on the integration of artificial intelligence into computers, I heard the academician Andrei Ershov criticize the Institute of Cybernetics by saying: "If you had not stopped upgrading the Mir family, the USSR would have had the best personal computers in the world."

Personal Reminiscences of Viktor Glushkov, cont'd. - January 5th 1982

Computer architecture is following a special path because new ideas still come from people. In our work on computer architecture, I took consecutive departures from the well-known Von Neumann principles. For example, the sequential structure of language: the fulfillment of one command after another; a command-address principle; a command containing address operands; commands which are saved as operands in memory; the simplest system of commands; and the simplicity of machine language. There are other principles, but these are the main ones. The appearance of such principles was not surprising. In the era of vacuum tube computers, when each arithmetic bit in the structure required a minimum of one triode, a simple machine with simple commands was necessary.

Even back then, I anticipated the development of microelectronics to the point where all hardware components would be made at the same plant in a streamlined process and become very cheap. To prepare for this, I proposed for our physicists to construct a physical medium for the creation of a computer. In this situation, Von Neumann's principles were not applicable. I suggested a complex machine language as one of the new principles, because compilation systems were becoming more intricate. It was necessary to simplify the programming process from both ends – for languages and for compilers – in order for the machine language to simulate the input language. After partially integrating this idea into the Mir computer series, we continued to develop it in accordance with the principles of progressively complex machine languages, to get closer to human language. My goal was to be able to speak directly with the computer and issue commands in our language.

In order to have a conversation with a computer in a spoken language, the logical reasoning components must be automated first. That is the easiest step since some of the formalisms needed are already known. But further analysis showed that the classical mathematical logic does not account for all of the necessary steps. Therefore, the task of constructing a practical mathematical logic was put forward and was successfully resolved. It was a pivotal point to realize that a mathematical proof can be designed like a program, based on language. When we are able to accomplish this, we can then introduce such a language into the architecture of the machine. Computer-aided proof of mathematical theorems is my ultimate dream. It is the basis of my ideas for new computer architecture; for the kind of computers that are capable of complex creative processes and deductive reasoning. In other words, computers, that build other computers. That is where the new ideas for computer design will come from. However, only the people who work with both computers and artificial intelligence will be able to build them. That is our strength.

At the end of the 1960s, Glushkov began supervising the development of the Ukraine computer and appointed Rabinovich as the chief designer. His chief assistants were Alexander Stogny and Ivan N. Molchanov. It was the next step in the departure from von Neumann's principles towards integrating artificial intelligence into computers. This time it was tied in with the development of high-performance, universal computers and a schematic realization of high-level language.

The development of the Ukraine computer was an important landmark in the growth of Glushkov's scientific school. The ideas embodied in the Ukraine machine surpassed many of the ones used in the American computers in the 1970s. Besides making the machine language more complex, we tried to switch from von Neumann's principles of sequential command execution to a multi-command mode. We encountered many obstacles until someone came up with the idea of a macro-conveyer and we were finally able to make a multi-command computer with many command streams and data channels.

Glushkov proposed a macro-conveyer principle based on the idea that each processor was given a separate task during every step of the computing process, which allowed it to work independently for a long time without the interference from other processors.

In 1959, at the Soviet All-Union Conference on Computer Technology in Kiev, Glushkov spoke about the idea of a brain-like computer structure that could be realized when the designers were able to integrate not thousands, but billions of elements with practically limitless connections between them, into a single system. There would also be a confluence of memory and data processing, a system in which data would be processed throughout the memory with a highest possible degree of parallelism in all operations.

At the 1974 International Federation of Information Processing (IFIP) Congress, Glushkov presented a paper on the recursive computer, based on new principles of computer system organization. He argued that only the development of new non-Von Neumann computer architecture, based on a current level of computer technology, would solve the problem of creating a supercomputer with unlimited growth in productivity and progressively more sophisticated hardware. Unfortunately, further research showed that a comprehensive realization of the construction principles of recursive computers and brain-like structures was beyond the level of electronic technology at that time.

"It is imperative to find a reasonable solution in order to transition from the Von Newman principles of computer design to the brain-like computer structures of the future," Glushkov said in his report at the Novosibirsk Conference in 1979. Glushkov promoted this idea as the basis of the original structure for a high-performance macro-conveyer computer, and worked on this even during his tenure as Vice-President of the Presidium of the Ukraine Academy of Sciences.

In 1981, a well-known nuclear weapons designer, academician Yuli Borisevich Khariton, visited the Institute of Cybernetics at the Ukrainian Academy of Science. He had become very interested in the unusual macro-pipeline computer because of its computing speed, which was significantly faster than any other machine and it greatly reduced valuable processing time for many important projects.[15]

Glushkov understood the importance of Khariton's visit for the future of macro-pipelined computers and the institute as a whole. By this time, Glushkov was already terminally ill with a rare brain cancer – medulla astrocytoma – that made talking very difficult, plus his speech was constantly interrupted by a nasty cough. Nevertheless, he received Khariton himself. Glushkov was brimming over with enthusiasm for the idea of a powerful Soviet supercomputer. He truly believed that its completion would greatly help our physicists. Glushkov did not live to see the realization of his ideas in the Unified System (ES)-2701 and ES-1766 macro-pipeline scientific computers.

According to a Soviet government commission that evaluated the project, these computers were unique in the world. With its full complex of 256 processors, the ES-1766 was estimated to perform at a half billion operations per second. The ES-2701 and ES-1766 design plans were transmitted to the Calculating-Electronic Machines Factory in Penza, Russia, for serial production in 1984 and 1987, respectively. These machines rivaled the best American computers, were extremely powerful and sought after for scientific applications. Unfortunately, very few of them were ever produced.

Up until this time, the Soviet Union put many computers into serial production via the Institute of Cybernetics at the Ukrainian Academy of Science and the SKB. These included series of mini-computers, specialized computers, and keyed-program computers: SOU-1, Neva, Iskra-125, Mria, Chaika, Moscow, Scorpion, Romb, Orion, Express, Pirs, and others. The Institute of Cybernetics, in conjunction with the S. P. Korolev Scientific-Manufacturing Company, created a whole complex of microprocessor computers: the Neuron series and the debugging systems SO-01 and SO-04, developed by Malinovsky, Palagin, and Valery Iosifovich Sigalov. They also took

[15] Khariton was the scientific director of Arzamas-16 (now Sarov), the Soviet secret nuclear weapons design laboratory, for over 40 years.

part in the design of the first Soviet microcomputer Elektronika-S5, manufactured at the Svetlana Electronics Plant in Leningrad.

Modern computers were impossible to build without a system of computer-aided design. The Institute's extensive research enabled it to create a series of unique systems: the Proekt family—Proekt-1, Proekt-ES, Proekt-MIM, and Proekt-MVK—for computer-aided hardware and software design. The Kiev computers were initially employed for this process, and later the M-20, M-220, and BESM-6. The Proekt-1 was a specialized, programmable device with its own operating system. Glushkov, Letichevsky, and Kapitonova pioneered the optimized automation of algorithm design for it. The Proekt series was experimental: they laid down the groundwork for software and hardware design, and were subsequently utilized by dozens of organizations and computer scientists.

The Proekt-1 system was used in the automated project design of BIS (in Russian: *Bolshiye Integralniye Skhemii*, or Large Integrated Circuits), with the help of special electro-ionic technology. In Vitaly Pavlovich Derkatch's department at the Cybernetics Institute, the Kiev-67 and Kiev-70 computer installations employed these technologies. The Proekt's computer-aided design system had a communication interface with Kiev-67 and Kiev-70 that controlled an electron beam during the chip base processing in real time. In 1977, Glushkov, Derkatch and Kapitonova received the Soviet Union State Prize for their work on this project.

Computer-aided programming was one of Glushkov's main interests, and he viewed the development of algebra for algorithmic languages as the path to perfecting this technology. In studying this problem, he considered not only the general mathematical principles, but also philosophical concepts. Comparing numerical and analytical methods of task solution in applied mathematics, Glushkov asserted that the development of general algorithmic languages and structures for such languages would allow them to be widely used, just like the analytical expressions have become in today's computer programs. Today, the differences between analytic and general algorithmic methods are disappearing, and computer models are becoming the basic platform for the development of new mathematics.

Personal Reminiscences of Viktor Glushkov. January 6th 1982

Simulation of sight and hearing are important research components in the field of artificial intelligence. The most important element, of course, is sight; it provides the greatest amount of information.

From the very beginning, I wanted to automate robotic motor functions. I began with the task of creating an automatic arm on a handcart, which could move along a control panel and change the position of the tumblers, pull-switches, turn knobs and so forth. It would be equipped with primitive sight, capable of perceiving only the position of device indicators or units on a scale. Unfortunately, I could not find a person who loved working with his hands. I was working on this task in 1959, when no one had even mentioning robots. If we had had good workshops and mechanics, then by 1963 we could have been the first in the world to develop a mechanical arm. Regrettably, we did not succeed.

At the same time, we began working on phrase recognition in Russian, or what is now called semantic networks. Alexander Stogny and Letichevsky were both involved in this project and we achieved good results. I developed the algorithms, and Stogny wrote the programs. The algorithm built a semantic network based on the sentence flow, identifying which of the words *corresponded with which. For example, although the sentence "The chair stands on the ceiling," is grammatically correct, semantically it is not.*

When Stogny changed the direction of his work, I also had to stop. We simply had to let the project go. Even though we needed to link the algorithm with an advanced computer, there weren't enough people to complete the work, and I could not spend all of my time and energy on semantic algorithms. Nevertheless, when I wrote a paper on this subject for the 1961 IFIP Congress in Munich, it became a sensation – the Americans had nothing like it at the time. After that I was selected to be on the committee for the International Federation of Information Processing.

G.L. Gimmelfarb, a retired employee of the Cybernetics Institute, recalled:

> The Kiev computer became the first machine in Europe with a system of digital imaging that was capable of modeling intelligent processes. Two innovative peripheral units were attached to the Kiev and enabled it to simulate the simplest algorithms for learning image recognition and single-purpose behavior: an input unit for images on paper carrier or photo film, and an output unit for images from the computer. Both units were designed by V. I. Ribak. During those first years, the computer image output units – the prototypes of today's monitors – were found only in the United States.
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> The Kiev computer, under the direction of Glushkov in the late 1950s and early 1960s, fulfilled several research tasks for artificial intelligence: studies on recognition of simple geometric figures, on prototypes of automated readers for handwriting and text recognition, on tracking movement, on simulating the behavior of a group of automatic devices in the process of evolution, on the automatic synthesis of functional computer schemata, and others. That is how Glushkov got involved in both the theory and practice of simulating intelligence during the infancy of computer technology, when many people perceived computers simply as "big counting machines."
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> Later Kiev's input-output image units were modernized and carried over to the BESM-6. With these units many types of work were carried out, including the digital analysis of photographs of real objects, particularly for the discovery and compression of trace physical particles in bubble chambers; also the tracking, recognition and compression of movement of different means of transport, the recognition of text messages, and others.
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> The experience gained in creation and use of input-output image units gave rise to the development of the first Soviet simulator in the 1970s for the modeling of intelligent hand-eye type robots. At the core of the simulator was the BESM-6, a television system for image input and an electro-mechanical manipulator with six degrees of mobility, connected to the computer through an M-6000 mini-control computer. Glushkov was greatly interested in this work because he considered robotics to be one of the most important practical directions for using the methods and means of artificial intelligence.

The Future of Experimental Science

Personal Reminiscences of Viktor Glushkov. January 7th 1982

The automation of scientific research began with the computerization of measurements and data processing. In the early 1960s we processed data from the Atlantic Ocean by remote control, from the research vessel Academic Vernadsky. The availability of the Dnepr control computer with an object communication unit permitted us to automate experiments at the Ukraine Academy of Science before the Americans did. The Americans used the CAMAC system, created in 1967 with improved technical capabilities, while Dnepr's object communication unit was designed in 1961. In 1972, the council on automation of research work was established at the Presidium of the Academy, with Malinovsky as Chairman. As Vice-President of the Academy, I supervised this work, as well as the activity of two other councils: the Computer Technology council headed by Stogny, and the Computer Aided Manufacturing Council headed by Vladimir Sergeevich Mikhailevich.

Computerization of physical science research was closely connected with the automation of testing of complex industrial machinery, which was done for the Navy and for aviation research. When the President of the USSR Academy of Science, Anatoly Petrovich Alexandrov saw our results, he didn't believe them, and we had to show him a system installed on one of our naval vessels. It had 1200 channels of information input.

As the next step, I envision deductive construction algorithm design, where a computer would not only be able to process results, but check hypotheses and build theories based on all available data. This is the future for computerized scientific research.

Generally our research fostered new trends in computer networks and databases. We believe we were the first in the world to propose the idea of networks, as well as transmitting information for computer processing over long distances. Regardless, if we were not the first to discover networks, we were indeed the first to establish distant terminals, when Kiev processed information received from a scientific research vessel in the Atlantic Ocean.

We were the first to complete a draft project of a computer network, the United Government Computer Centers Network. N. Fedorenko and I created this draft between 1962 and 1964, by personal order of Soviet Prime Minister Kosygin. Creating this network allowed us to collect and effectively use economic, scientific-technical and any other information, plus be able to exchange this data, which is critical when transitioning to an information technology-based society.

Personal Reminiscences of Viktor Glushkov. January 8th 1982

The next research direction emerged slowly, even though it had been conceived long before: this was the theory for an economic control system of many branches of industry, and automated systems for the technical facilities control. Work began in 1962 with the creation of a project plan for the general governmental computer centers, and for computer-assisted, industrial control systems, which commenced in 1963-1964. Then in 1965, we began formulating the Lvov System, for the large-scale serial production of televisions at the Lvov Television Factory. Skurikhin and Morozov had taken up this project, supervising this large-scale initiative at the Institute of Cybernetics and in our SKB of Mathematical Machines and Systems. In 1970, after *this system had been successfully implemented, its creators received the Ukrainian Government Prize.*

In the summer of 1965, Glushkov went to Lvov to speak at a conference sponsored by the Lvov Sovnarkhoz (government regional supervisory group). In his inspiring lecture, he emphasized the need to begin employing computer-aided enterprise control systems. Director of the Lvov television factory, Stephan Ostapovich Petrovsky, was present at the lecture and proposed that Glushkov create an industrial control system at his factory, promising maximum support. Glushkov lit up after hearing about this opportunity – at that time no such system existed anywhere. Glushkov sent Skurikhin to Lvov with a team of fifteen people. After two years, the system was in place. Skurikhin and his closest assistants lived in Lvov practically the entire time, sometimes working more than 12 hours a day, and rarely taking breaks. Reminiscing about these memorable days, Skurikhin recalled how he spent the New Year's Eve in 1965: "After a very stressful day I did not return to my hotel, but fell asleep at my desk instead. Yes, I slept straight through the New Year's night, into 1966."

Personal Reminiscences of Viktor Glushkov, cont'd. January 8th 1982

The direction we chose after creating the Lvov System involved establishing a general interchangeable system for machine and instrument construction enterprises. At the end of the 1960s and in the early 1970s, we completed work on the Kuntzev System, which helped us accomplish the majority of the tasks in the instrument and machine construction branches of industry. We were able to sign a decree mandating that the development of 600 systems for nine defense ministries was based on the Kuntzev System. However, the policy of standardization was carried out primarily at the Ministry of Machine Building and to a small degree at the Communications Industry Ministry. Other ministries that had their own systems did not want to be standardized. Nevertheless, even one Machine Building Ministry required more than 50 CAD/CAM systems to be installed at important large-scale factories.

In the beginning of the 1960s, Anatoly Kitov served as Glushkov's deputy in Moscow for the Institute's work with the Soviet defense sectors. He was responsible for the creation of computer-aided control systems for defense installations. Kitov also published the first computer science textbook in the Soviet Union, *Digital Computing Machines* (Moscow: Soviet Radio, 1956). Kitov was a veteran of the Great Patriotic War, one of its very few young survivors. In 1950, Kitov graduated from the Dzerzhinsky Military Artillery Academy in Moscow with a gold medal. He was sent to the Academy of Artillery Science, where he was assigned to the machine-building unit SKB-245 to study electronic computer technology and its possible applications for the Ministry of Defense.

In 1952, Kitov acquired a copy of *Cybernetics: Control and Communication in the Animal and Machine* (1948), by Norbert Weiner. After reading and discussing it with Alexei Lyapunov, he came to the conclusion that the official Soviet position on cybernetics as being a bourgeois pseudoscience was incorrect. Kitov prepared an article outlining the theory and significance of the new science. For three years the article was discussed at various conferences and seminars. Finally, after many revisions by Lyapunov and Sobolev, it was published as "The Basics of Cybernetics" in August 1955, along with E. Coleman's "What is Cybernetics?" in *Questions of*

Philosophy.[16] This presented computers in a positive light and led to further development of cybernetics in the Soviet Union.

In 1954, Kitov was appointed as the director of the Soviet Union's Defense Ministry Computer Center. While working on the computer-aided control in the military sector, he pondered the possibility of computerization and streamlining of the Soviet economy. In January 1959, he sent a letter to Nikita Khrushchev in which he stressed the necessity of developing computer technology. After it was forwarded to Brezhnev, it inspired a flurry of activity. An interdepartmental commission, chaired by Axel I. Berg, prepared a resolution for the Central Committee advocating accelerating the design and production of computers and their incorporation into national economy. The proposal was approved.

In fall 1959, Kitov came up with the idea for a unified computer-aided control system for the military and the national economy. It was based on a network of computer centers, created by and serving the Ministry of Defense. Despite being far behind the United States in mass-producing computers, the high concentration of machines in the powerful Soviet computer centers and their reliable support by military personnel would have allowed us to make more efficient use of them. For several months he worked on substantiating this idea and presented a lengthy report to the Central Committee. A Ministry of Defense commission chaired by Konstantin K. Rokosovsky was created to review this document. The report contained sharp criticism of the Defense Ministry's lack of support for computer development, which made the Soviet government officials view it in a negative light. The bureaucrats at the Central Committee and in the higher echelons of administrative power, especially those at the Defense Ministry, felt that the serious restructuring of computer administration would result in their personal loss of power. They could not allow it. As a result of writing and filing his report, Kitov was thrown out of the Communist Party and fired from his position.

Glushkov knew about Kitov's situation and understood the possible fate of his own chosen path. But it was Glushkov's nature to always look ahead, energetically developing and supporting computer-aided design of complex control systems.

Personal Reminiscences of Viktor Glushkov, cont'd. January 8th 1982

It turned out that an independent idea generated during the creation of complex systems became the actual model for one such systems with the help of universal languages, SLENG and NEDIS, which we developed specifically for them. The goal was to combine the methods of system optimization with simulation languages and the descriptions of big systems.

A new stage in the development of computer-aided enterprise control systems (CACS) began in the second half of the 1970s. This complex naturally united the goals of computer-aided project design, computer-technology control, automated tests of finished production, and management controls. A CACS complex is now under development at the Ulyanovsk Aviation Factory. Skurikhin supervised this project.

Skurikhin was a worthy partner for Glushkov and his contribution was critical to the creation of computer aided control systems, design systems, and automated production experiments. From 1959 to 1963, Skurikhin actively participated in the creation of the Avangard system at the Sixty-

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[16] A.A. Lyapunov and S.L. Sobolev, "The Basics of Cybernetics," 48-53, and E. Coleman's "What is Cybernetics?" 113-118, both in *Questions of Philosophy* (No 8, 1955).

One Communards Shipbuilding Plant in Nikolaev. This was the first computer-aided shipbuilding system in the Ukraine and in the Soviet Union. This system did the so-called *plazovy* (deck) work – the cutting of the ship's hull from a sheet of steel. Planned initially as a debugging system for program-controlled gas-cutting robots, it evolved into an early prototype of an integrated system for the entire complex of *plazovy* work in ship hull design, and in the preparation of the blueprints for their serial manufacture.

The Avangard idea was further implemented in the computer aided design system for submarines from 1968 to 1978: the Chertezh system, – a large-scale manufacturing system that shortened the project design time by a factor of twenty to twenty-five. A larger-scale engineering version of this was established at one of the secret naval design institutes in Leningrad where a powerful, multi-level technical program complex was created.

Personal Reminiscences of Viktor Glushkov. January 9th 1982

I required all co-workers who went on business trips to Ukraine to visit colleges and either give lectures or do consulting work so they would become familiar with the students and attract the more capable ones to work at our institute. We did this type of work even with school children. The institute would sponsor the schools where programming was taught in the higher grades. They arranged competitions and academic Olympics at our institute; the staff also helped organize the Academy for Gifted Children in the Crimea, where young students could go in the summer to listen to the lectures given by the best computer specialists from Kiev, Moscow, and Novosibirsk.

Scientists at the institute – in the beginning I was alone, then others began to help – lectured at the House of Scientific Technological Propaganda that requalified engineers and technicians from Kiev. We developed curricula for colleges, and naturally, post-graduate programs, since the computer science field was so new. We also trained technical computer operators, even though many other places didn't. This sub-specialty was introduced at one of the technical schools in Kiev. As a result, a solid base was being created in Ukraine to prepare the necessary staff for the development of computer and cybernetic systems.

For higher education – Doctors and Candidates of Science – the emphasis remained on educating and promoting Doctors of Science because the institute needed to have enough trained staff to direct and advise postgraduate students and to make up the nucleus for the future scientific counsel who would handle the defense of dissertations. Ten years after the Institute was founded, it had sixty Doctors of Science and nearly five hundred Candidates of Science on its staff. Many of Doctors of Science had been trained to work for other colleges and new organizations.

The highly qualified teams of specialists in informatics, computer technology and cybernetics who had been trained at higher institutions and specialized academies, worked in many scientific research organizations and enterprises throughout Ukraine. This was part of Glushkov's legacy – working for Ukraine's future.

Glushkov was very close to his students and colleagues and treated them as dear friends. "Whenever we got together with friends or co-workers, he always became the soul of the group," remembered Glushkov's wife Valentina:

> A brilliant sense of humor made him particularly attractive. He loved to sing, especially the Ukrainian folk songs "I Wonder at the Sky," "Two Colors,"

"The Wide Dnepr is Roaring and Groaning," and others. He could recite poetry verses by heart for hours. The only thing that he never learned how to do was dance. For some reason, he was very shy about it.

His favorite and singular pastime was fishing on the Dnepr. At the resort, the very next day, he would find a pad and a pen, and go to work. Cadres of men, students, and young scientists – those who believed and went with him into a new field of computer technology, were always tramping off to go fishing on the Dnepr with him. Wives rarely came to visit. They always exchanged tons of jokes, fishing tales, anecdotes, and funny stories there. The songs carried far along the Dnepr.

He was never happy to be alone. If he was reading and found out something interesting, he would have to immediately share it with someone. He read classical literature constantly, regardless of how busy he was. He believed that without it, he could never have achieved what he had been able to achieve in science, especially in mathematics. He felt that reading classical literature taught a person to dream, to develop the kind of imagination that was necessary to be a good mathematician. He tried to spend time with our children – with our daughters Olga and Vera, especially when they began to grow and develop personalities. It's too bad that he wasn't more hands-on with their upbringing, but he often gave good advice. At times, it seemed to me that he was too harsh with the children. He constantly said that we should not spoil them; instead they must learn to overcome difficulties starting from childhood. We can support them during that time, but within reason. He always said that a person must always have a goal, a dream, an objective toward which they must strive and conquer obstacles along the way; only after realizing it, would a person experience real joy and satisfaction.

Personal Reminiscences of Viktor Glushkov. January 10th and 11th 1982

First Deputy Prime Minister Kosygin instructed me to begin work on a computerized control system for the economy in November 1962, because I had already expressed these ideas to the President of the Soviet Academy of Science, Mstislav Keldysh, who brought me to see him. I briefly outlined for Kosygin what we wanted to do; he approved; the Council of Ministers of the USSR issued an order for the creation of a special commission (with me as its chairman) to prepare materials for a government resolution. On this commission were economists, notably Academician N.N. Federenko, chief of the Central Statistical Department Vadim Nikitovich Starovsky, First Deputy Minister of Communications A.I. Sergeichuk, and people from other administrative bodies.

The commission was granted many privileges. This allowed me to visit any cabinet, minister, or even the Chairman of Gosplan [in Russian: Gosudarstvennii planovii komitet, the state economic planning agency], and ask questions or simply sit in a corner and watch him make decisions and procedures. Naturally, I received permission to familiarize myself, as needed, with any production site, enterprise, organization, etc.

By that time we already had a concept for a unified system of computing centers for economic information processing for the entire country. The famous economist Vasily Sergeevich

Nemchinov and his students proposed using computers already operating in computer centers, but not in a remote access mode. Neither the economists, nor the computer technology specialists were aware of it at the time. They basically copied the 1955 proposal by the USSR Academy of Science to create a system of academic computing centers for scientific calculations, which led to the creation of the Computer Center at the Ukraine's Academy of Science. They proposed to do exactly the same thing for the economy: to create large government computing centers in Moscow, Kiev, Novosibirsk, Riga, Kharkov, and other cities. Workers from various economic institutions would bring their problems to these centers, make their computations, receive their results, and leave. Of course, this was not acceptable to me, because by that time we were already manipulating data remotely and were able to send, receive and process the data from the Atlantic Ocean at Kiev's computing center.

All of the governmental organizations in our nations were poorly prepared to process economic data. The blame could be placed on both the economists, who never computed anything, as well as on the computer designers. As a result, the statistics and planning agencies were still equipped with 1939-vintage mechanical calculating machines at the time when America had completely switched over to the electronic digital computers.

By 1965, the Americans were working on two lines: scientific high-capacity binary floating-point machines and business-oriented sequential binary-decimal devices with advanced memory. The IBM Corporation was the first company to produce these two lines of machines simultaneously. At this time, we only had scientific computers, and no one was developing machines for economic purposes. Therefore, the first thing I tried to do was stimulate interest in developing machines for economic applications, which were sorely needed. I turned to the best computer designers, mainly Bashir I. Rameev, the designer of the Ural-1 and Ural-2 computers, and Victor V. Przhyakovsky, the designer of the Minsk series, and urged them to start working on this problem.

I formed a working group at the Institute and single-handedly came up with a program to outline the task assigned by Kosygin. I spent a week at the Central Statistical Department studying every detail of their work; I examined all the links between them and the regional stations. I spent a lot of time at Gosplan, whose office staff was very helpful, especially Vasily Mikhailovich Ryabikov, Gosplan's First Deputy Minister. Both of them had extensive experience in the military economics and of course, intimately knew Gosplan. With their help, I was able to study all the tasks and planning steps, and anticipate the difficulties that might emerge.

In 1963, I visited at least one hundred various sites, from factories and mines to state collective farms. Over the next ten years, the number of sites had increased to almost a thousand. Therefore, I knew more than anyone else about every detail of the national economy and understood the peculiarities of the existing management system, which allowed me to predict the difficulties that might arise and what calculations would be necessary.

I quickly understood technological needs as well. Long before I was fully aware of the scope of the project, I had envisioned not individual government centers, but an entire network of computing centers with remote access capability. In other words, I expanded the concept of shared data processing to include contemporary technological methods. The first draft of the project for the Unified State Network of Computing Centers included nearly one hundred centers in large industrial cities, connected via wide-band communication channels. These centers, spread throughout the country, would be united with smaller regional centers to process *economic information. We estimated there would be twenty thousand of these, composed of large enterprises, ministries, and key centers that served the small enterprises. An important characteristic of the system was its data bank and the ability to access it remotely from anywhere in the network after an automatic identity check. We worked out a number of information protection issues as well. In addition, in this two-level system the main computing centers exchanged information with each other not by channel, but through messages, which is now standard. I suggested combining these one to two hundred centers with wide-band channels to bypass channel-forming apparatus, so it would be possible to copy the information from a magnetic tape in Vladivostok directly onto a tape in Moscow without a reduction in speed. All of the procedures would be greatly simplified and the network would gain additional capabilities. Nothing like this existed back then and until 1977 our project was a secret.*

In addition to the network's structure, I developed a system of mathematical models to manage the economy, in order to receive a regular flow of information. Consequently, I presented our plan to Keldysh, who approved it except for the electronic currency system. The model would still work without it. According to Keldysh, such a system would only stir up controversy and should be treated as a separate issue from the economic plan. I agreed with him and we did not introduce this factor into the project. I did write a separate letter about it to the Central Committee; it came up for discussion several times but eventually disappeared, and no resolution concerning the creation of electronic currency system was made. Once we finished the final draft of the project, we submitted it for review by the commission.

Personal Reminiscences of Viktor Glushkov. cont'd, January 10th and 11th, 1982

Unfortunately, after the commission reviewed the project proposal, they dismissed most of it. The entire economic portion was removed, and only plans for the network itself remained. The removed portion of the economic proposal was burned because it was top secret and dangerous to the Soviet bureaucracy. We were not even allowed to keep a copy of it at the Institute, and unfortunately, we are unable to recreate it. The head of the Central Statistical Department, Starovsky, was one of the staunch opponents of the project. His criticisms were purely demagogical. We proposed a new system of accounting, which would allow access to any piece of information from any point. Starovsky argued that the Central Statistical Department had been organized on Lenin's initiative, and so far was managing its assigned tasks quite well. He was somehow able to convince Kosygin that the information from the Central Statistical Department was sufficient for state control, and there was no need for a new system.

In June 1964 we presented our project to the government for approval, and in November, I made a presentation about it at a session of the Presidium of the Council of Ministers. Naturally, I mentioned the Central Statistical Department's objections. That's when a decision was made to give the project to the Central Statistical Department for reworking, with the assistance of the Radio Industry Ministry. For two years, we worked from the bottom up; not from the ideas of what was best for future of the country, but from what already existed. The regional offices of the Central Statistical Department in the Archangelsk region and the city of Nukus in the Karakalpaksky Autonomous Republic (two of the most distant points from Moscow) were assigned to study the information flow. They were supposed to determine how many documents, statistical reports, and letters were received in these regional offices from enterprises, organizations, etc.

According to the Central Statistical Department, when arithmometers were used to process information, each input digit or letter required 50 sorting or arithmetic operations. Feeling smug, the authors of this project reported that if they were to use electronic digital computers, the number of operations would increase tenfold. God only knows why they wrote this. Furthermore, they took the number of statistical reports being processed, multiplied it by 500 and came up with the required operating speed. The number was ridiculous: if the computers were installed in Archangelsk and Nukus, they would have to perform at 2000 operations per second! This was the conclusion that they presented to the government.

Another commission was created to accept this project. They wanted me to chair it, but I refused on ethical grounds. After the commission members reviewed the project, they declared that although they did not agree with all of my ideas, at least my proposal had a planning phase, whereas the Central Statistical Department had only statistics. Except for me, the commission unanimously rejected the project. Considering the vital importance of this project for our country, I suggested to mark the project as unsatisfactory, but move onto the technical development phase to be carried out by the Ministry of Radio Production, the Academy of Science of the Soviet Union, and Gosplan. My proposal was rejected again, but my recommendation was recorded as a special opinion and Gosplan was ordered to start over.

Gosplan required two years to do this, and it was already 1966. They dragged their feet until 1968, and accomplished absolutely nothing. Moreover, instead of preparing the project outline, they wrote a decree for the USSR Council of Ministers, restoring the old system of branch control. As the result, they were absolved of any responsibility for the project. If every ministry created its own branch system, they would merge at the end and function as one comprehensive governmental system. Everyone breathed a sigh of relief, nothing more needed to be done and so it was ordered. The resulting OGAS became a sbornaya solyanka – a hodge-podge soup of mismatched bits.

Valentina Glushkova recalled that more than once after returning from Moscow, her husband would say, "It's terribly depressing that nothing ever needs to change." Glushkov used to keep a note under the glass top of his desk during those years:

> 100 times I've sworn this oath:
> 100 years I'd rather languish in a dungeon,
> 100 mountains I'd rather grind to dust,
> If only I don't have to make a fool to see the truth.
>
> – Bakhvalan Machmud

But the problem was not with the "fools," it was a deliberate denigration of Glushkov's ideas.

Personal Reminiscences of Viktor Glushkov, cont'd. January 10th and 11th 1982

Starting in 1964, when my project was first announced, many people began to openly oppose me, among them the economists Lieberman, Belkin, Birman, and others; many of them later left for the United States and Israel. Kosygin, who had always been a very practical man, became interested in the projected cost of our project. In the preliminary budget, it was estimated at 20 billion rubles. The main part could be done in three five-year periods, but only if it were organized and funded like the nuclear and space programs. I did not hide from Kosygin that this program was far more complicated than the space and nuclear programs combined. Plus, it would be much more difficult to coordinate, because it involved industry, commerce, planning *agencies, administration, and control. The working model anticipated that after the first investment of 5 billion rubles during the first five-year period, the return would be in excess five billion rubles, because we planed for the program to pay for itself. And after three such five-year periods, the program would bring no less than 100 billion rubles in revenue – and this was a conservative figure.*

But the "ivory tower" economists convinced Kosygin that the economic reform would cost nothing, except for the price of paper to print the Council of Ministers' decree, therefore bringing more revenue in the end. Our ideas were shoved aside once more and moreover, we was treated with suspicion; Kosygin was not happy.

In many of his scientific articles and monographs, Glushkov proposed and worked out ideas for enhancing the government's administrative system. These included regulating production and social processes, technology for establishing standards, a technical basis for coordinating production programs on a country-wide scale, implementing a more equitable distribution system, creating a system which would prevent graft and money-laundering, and the introduction of an electronic currency system. Many of these ideas, which in Glushkov's day seemed too revolutionary, have been realized today.

Personal Reminiscences of Viktor Glushkov cont'd. January 10th and 11th 1982

By the end of the 1960s, both the Central Committee and the Council of Ministers of the Soviet Union had received information that the Americans had completed a plan to build several information networks – two years later than us. The difference was that the American government did not argue over this and carried it out, and planned to make ARPANET and several others operational in 1969, connecting computers in different American cities. That is when our government began to worry. I sent a note to Kirilenko about the necessity of returning to my project ideas. 'Tell me what you think we need to do and we'll create a commission,' he replied. I answered along these lines: 'I implore you not to create a commission because it always gets in the way of progress and ruins every project.' But a commission was created anyway; Vladimir Alexeevich Kirillin was appointed as the chairman and I was his deputy.

This commission consisted of higher level officials than before, including a minister of finance, minister of instrument building, and others. It had to prepare a resolution for the creation of OGAS to be reviewed by the Politburo, which would then decide if it was a go or not. So, the work began again. This time, I focused not so much on the essence of the project, since that was already done, but on the actual steps for the realization of OGAS.

The reality was that people like Korolev and Kurchatov had their own representative, who was a member of the Politburo, and they could go to him to immediately resolve any problems. Unfortunately, we had no such person to turn to. Issues related to computerization were the most complex and controversial ones, able to greatly affected politics, and any mistake would have had dire consequences. We badly needed a benefactor in the Politburo because our problem was political first and scientific-technological second. We planed to create a state committee on modernization of government administration (in Russian: Gosudarstvennii Komitet po Sovershenstvovaniu Upravleniya, or Goskomupr). Its scientific center would contain ten to fifteen institutes, which already existed; therefore, we only needed to create one leading institute for control and dealing with the Politburo. The rest would be selected from various Academies of Science.

Everything went smoothly and everyone agreed. By this time, a draft directive of the 26th Communist Party Congress was published, which included all of our formulations. Our proposal was reviewed by the Politburo twice. At one of the sessions they reviewed the overall project and agreed that OGAS had to be implemented. But how? By creating Goskomupr, or was it necessary to create something else? This is where the arguments began. I succeeded in "convincing" all the members of the commission, except the Minister of Finance Garbuzov, and then we presented them again to the Politburo.

But when we came to the session – incidentally, it took place in Stalin's former office – Kirillin whispered to me, 'Something's happened, but I don't know exactly what.' The question was reviewed at the session with neither the General Secretary nor the Prime Minister: Brezhnev had left for Baku to commemorate the 50th anniversary of Soviet leadership in Azerbaijan, and Kosygin was in Egypt at Abdul Nasser's funeral. Mikhail Suslov conducted the session. Kirillin spoke first, then me. There were many questions and I answered all of them. When Garbuzov came up to the podium and responded, his speech sounded like a joke. He addressed Mazurov, Kosygin's First Deputy Minister, 'Kyrill Trofimovich, I went to Minsk to observed poultry farms, as ordered. And there, on this one particular poultry farm, the poultry maids were using a computer.'

I laughed out loud. He shook his finger at me and warned: 'Don't laugh Glushkov, we are discussing serious matters here.' But Suslov interrupted him, 'Comrade Garbuzov, you are not the chairman yet, and it's not your business to bring a session of the Politburo to order.' Then, Garbuzov – the self-assured and conceited person that he was – continued as if nothing had happened, 'The computer executes three programs: it turns the music on when the hen lays an egg, it turns a light on and off and on and so forth. This program has significantly improved the egg production on this farm.' At this point he declared that now all poultry farms in the Soviet Union need to be automated and only then could we begin to think about such stupid things as the general governmental system. I laughed again and thought: 'All right, whatever.'

A counterproposal was issued, which simplified everything: Goskomupr was reduced to a department within the existing State Committee on Science and Technology and the whole system became more technical, that is, the focus was changed from the control of industrial and management processes to a government network of computing centers. Anything related to economic or mathematical models for OGAS was scrapped. It became a hardware solution without any appropriate software support.

Just before the end of the session, Suslov stood up and said, 'Comrades, perhaps we are making a mistake by not accepting this project as a whole, but because it calls for such a revolutionary transformation, it will be difficult to realize at this time. So let's go ahead with the counterproposal for now, and then we will see what's what.' He then turned not to Kirillin, but to me, and asked, 'What do you think?' I replied, 'Mikhail Andreevich, I will only say one thing: if we do not do this correctly right now, then during the second half of the 1970s the Soviet economy will encounter such problems that we will be forced to return to this question.' But in the end, my opinion did not matter, and they accepted the counterproposal.

Sometime in November, Kirilenko asked me to come to his office at the Old Square. When I entered his reception area at 9:58 am, I saw our 'Rocket Minister,' Sergei Alexandrovich Afanasiev, who had a scheduled appointment with Kirilenko at 10:10 am. He asked me, 'Is yours supposed to be a short meeting?' I responded that I had no idea why I was there.

I went in first. Andrei Pavlovich stood up, greeted me, and said, 'You have been appointed Kirillin's First Deputy. I have already confirmed this with Leonid Ilyich (Brezhnev), who asked me if he needed to have a little chat with you, but I told him no, I will take care of everything myself.'

I replied, 'Andrei Pavlovich, why didn't you discuss this with me first? What if I won't agree? You know that I was against the accepted proposal because it will only disfigure OGAS and yield no positive results. If I were to agree with your proposal now, then both of us would look guilty: I brought you a proposal, you supported it, they appointed me and put everything in my hands, but nothing gets done. You are a smart man, you understand that from this position, it's impossible to make even a simple rocket, never mind a new economic system of government administration.'

We sat down, and he started to pressure me, 'You've put me in an uncomfortable position with Leonid Ilyich. I've already told him that everything was arranged.' But I would not budge. He began using some ugly word to force me to agree, but to no avail. His tone alternated between nasty and polite for an hour. Then, just like that, he let me go. In the end, we had not agreed on anything. He didn't even say good-bye to me, and I didn't speak to him again until we met at the 24th Party Congress. Later, our relationship improved. He ended up recommending his friend, Dmitri Zhimerin, as Kirillin's deputy, and I agreed to be the scientific supervisor of the head institute.

Meanwhile, the Western press was in an uproar. At first, no one knew about our proposals because they were secret. The first mention of OGAS appeared in the proceedings of the 24th Communist Party Congress.

The first ones to get upset were the Americans. Of course, they would not have started a war with us – it was only a ruse. They were using the arms race to crush our economy, which was already weak. Any news about even a possibility of strengthening our economy frightened them, so they immediately opened fire on me with every weapon at their disposal. Two pieces appeared: one was in The Washington Post, entitled 'Punch Cards Control the Kremlin,' by Viktor Zorza, who wrote that, 'The Tsar of Soviet Cybernetics, Academic V.M. Glushkov Proposes to Change the Kremlin Leadership with Computers.' It was a nasty article.

The second article, in Britain's The Guardian, was aimed at the Soviet intelligencia. It stated that Academic Glushkov proposed to create a network of computing centers with data banks; while it sounded very modern and was more advanced than anything currently available in the West, its real purpose was not economic, but actually a part of a KGB plot, intended to gather Soviet citizens' thoughts in order to keep track of them. This second article was republished many times all over the Soviet Union and Eastern bloc countries.

At the same time, all of my opponents in the Soviet Union, particularly the economists, began sneering at me. In 1972 Izvestia published an article by Boris Milner, Deputy Director for the Institute of the United States and Canada, titled, 'The USA: Lessons of the Electronic Boom.'[17] In it, he attempted to prove that the demand for computers in the United States had dropped. Several economists, who had taken business trips to the United States, sent reports to the Central Committee comparing computer technology to a passing fad, sort of like abstract painting. It was rumored that the capitalists bought the new machines because it was trendy and they did not

[17] *Izvestia*, March 18, 1972, 4.

want to appear old-fashioned.

This completely disoriented our leaders. It also negatively impacted the decision about our proposal. Garbuzov actually told Kosygin that the Central Committee would use Goskomupr to monitor the economic decisions made by him (Kosygin) and the Council of Ministers. This turned Kosygin against us and assured that the Goskomupr proposal would not be accepted. But I didn't learn about that until two years later.

In 1972, Kirilenko supervised a national conference on computerization, with an emphasis on the control of industrial processes. He intended to slow down the work on the Automatic Control Management Systems and speed up the work on Automatic Control of Technological Processes.

In my opinion, the Central Committee was somehow influenced by the CIA and their clever disinformation campaign, intended to hinder attempts to improve our economy. Perhaps they figured that such a diversion was the simplest and cheapest way of winning the economic competition. I was able to do some things to counteract this. I asked our science advisor attaché in Washington to prepare a report on the actual usage of computers in the United States, which former ambassador Anatoly Dobrynin sent to the Central Committee. Because this report originated directly from our ambassador in the United States, every member of the Politburo received it and read it. This maneuver seemed to work, and it softened the blow a bit.

During the preparations for the 25th Congress of the Communist Party, attempts were made to completely eliminate the word 'OGAS' from the project resolution. After the draft of the 'Basic Directions' had been published, I wrote a note to the Central Committee, proposing to create several branch systems of computerized administration and later unite them under OGAS. It was accepted.

The same thing happened five years later, during the preparations for the 26th Congress. But this time, we were better prepared: we sent materials to the commission that wrote Brezhnev's speech. I spoke with almost all of its members and swayed them in our favor; they promised to push our proposals through. Initially, we wanted the proposal to be included in Brezhnev's speech at the 1980 October Plenum of the Central Committee. But it was too long and much of the information was withheld. We were able to include a large portion of the proposal in the review report on computer technology.

I was advised to publicize the OGAS program in Pravda. The editor of the paper, a former administrator, backed me. They named my article 'For the Whole Country,' which was hardly accidental, because Pravda was the media wing of the Central Committee of the Communist Party of the Soviet Union, and no article could have appeared there without approval.[18]

Glushkov's daughter, Olga, recorded the OGAS story on January 10 and 11, 1982. After *Pravda* published Glushkov's article, he hoped that OGAS would finally be realized for the whole country. Perhaps this inspired the ailing Glushkov to be able to dictate his last words. On that very day, Defense Minister Ustinov's assistant visited Glushkov in the hospital's intensive care unit and asked, "Can the minister be of any help?" Glushkov, who had just finished dictating his story of trials and tribulations could not help but remember the wall of impenetrable bureaucracy and misunderstanding that he encountered with OGAS.

[18] December 13, 1981 by V. Glushkov and Y. Kanigin.

"Ask him for a tank!!" Glushkov answered angrily, surrounded by life support equipment, which was barely keeping him alive. His mind was as clear as ever, but his ability to endure the soul-wrenching, physical pain was coming to an end.

History confirmed Glushkov's prediction, and by the end of the 1970s the Soviet economy was facing enormous problems. Until the end of his life Glushkov remained true to the creation of OGAS, which might have saved the ailing economy. Perhaps he was a hopeless dreamer? Or a romantic scientist? History will have the last word.

Glushkov's story about the struggle to create OGAS is an indictment of the Soviet government for not fully utilizing its own powerful scientific talent. The same was true not just for Glushkov but for many other scientists. There is no doubt that this is one of the most important reasons why the Soviet Union – a great nation – stumbled on its way to the 21st century, depriving millions of people of confidence in tomorrow's world, in the future dignity of their children, and the belief that their lives were not in vain.

Glushkov was undoubtedly right, setting forward a plan for computerizing Soviet Union. But under such conditions, he could do nothing without a high-level resolution from the government and the Central Committee of the Communist Party, which had become a barrier on his path. Glushkov was ahead of his time. The government and society were not prepared to comprehend OGAS. They completely misunderstood his intentions, which for him were so noble and obvious, and it became his tragedy.

On the morning of January 30, 1982, Glushkov passed away.

According to a resolution of the Ukrainian government**,** the Institute of Cybernetics was renamed after its creator.

Chapter 3: The Glorious Triad

For leaders no one marks the way, for them there is no precedent in history to follow…
Eduard Asadov

A Pioneer of Computer Technology

In 1939, Isaak Semyonovich Brook, a 37-year old Doctor of Technical Sciences, presented a paper at a session of the Presidium of the Academy of Sciences of the Soviet Union, in which he described a mechanical integrator capable of solving differential equations up to the sixth order. The integrator was built under Brook's supervision at the Electric Systems Laboratory of the Academy of Sciences Power Engineering Institute. Brook's report aroused great interest because there were no other such machines in the Soviet Union at that time. Only the US and Great Britain had one model each.

Brook achieved a remarkable feat – the integrator contained more than one thousand gear wheels. The integrator's racks, with its numerous bars and holes for gear wheel axles, took up an entire room of 60 square meters. Using it to solve a problem meant having to set gear wheels in specific positions – a task requiring anywhere from several days to several weeks. By modern standards, Brook's mechanical integrator was in fact an analog computer.

During the same year, Brook was elected a Corresponding Member of the Soviet Academy of Sciences, most likely due to his earlier report at the Presidium. Brook's main research focus at that time was electric power engineering. Because of his interest in that field, Brook, like Lebedev, understood the need for creating computational means capable of supporting research that required complex calculations.

Brook's and Lebedev's life stories were surprisingly similar. Both were born in the same year, educated at the same institute, and became scientists in the same scientific organization. Both started out in the field of power engineering and from it migrated to the computing technology. Both became directors of leading scientific schools in the area of digital computers. And both were pioneers in this field.

In August 1948, Brook and Bashir Rameev became the first scientists in the Soviet Union to design an electronic computer with micro program control. At that time, the only other machine of this kind was the American ENIAC, completed in 1946. Brook and Rameev also received the first Soviet Union patent for a digital computer with a common bus in December 1948. Unfortunately, these projects and inventions were not implemented in a timely or practical manner because Rameev was drafted into the Army.

Brook was also the first Soviet scientist to propose and implement the idea of using small computers in scientific laboratories. Under Brook's supervision in 1950–51, the first Russian small electronic digital stored program computer, M-1, was built. This machine contained 730 electronic vacuum tubes (instead of the 6000 in the MESM computer). After test operations in 1952, it became the only fully operational computer in the Russian Soviet Republic.

In the M-1, for the first time, Brook and his team utilized copper-oxide semiconductor rectifiers instead of electronic vacuum tubes with diodes, a teletype roll of paper for printing long numbers instead of the narrow teletype tape with only one number printed on each line, and a two-address computer instruction system.

Brook's desire to be ahead of everyone else and his constant need for the latest innovations often prevented him from completing his projects. Only one-third of the computers developed under his management went into industrial mass production. Brook's research on these computers originated more from his desire to show off his abilities in an emerging branch of science and technology than from his actual research interests. According to one of Brook's former colleagues, Alexander Borisovich Zalkind, "The work on the M-1 computer at the Power Engineering Institute was conducted in a semi-legal manner. Today they would say that it was just a hobby of the director." During this period, Brook also continued his research in power engineering. He pushed for computer implementation in electric power stations and was keenly interested in economic management issues.

Brook's passion for computer development was carried throughout the work of his most promising students – Nikolai Yakovlevich Matyuhin and Mikhail Alexandrovich Kartsev. At the scientific schools led by Brook and his students, many significant contributions in computer manufacturing were made. There was even an unofficial creative rivalry between the two leading computing schools – Lebedev's and Brook's – that continually motivated their respective staff to innovate. It is impossible to compare the results of these two teams and determine a "winner." Only one thing is clear: the victory of the scientific-technical progress.

Brook was born in Minsk, Belarus on November 8, 1902 into the impoverished Jewish family of a tobacco factory worker. He finished secondary school in 1920 and in 1925 graduated, as did Lebedev, from the Baumann Institute in Moscow. While still a student, he took a great interest in science, and completed a diploma project on new methods of asynchronous electric motor regulation. After completing the Baumann Institute, Brook was sent to the Lenin State Electrical Engineering Institute, where he gained a great deal of practical experience, participating in the development of a new range of asynchronous electric motors and making trips to the Donbas region for related work at several electric power stations.

"He inherited the abilities and interest in technology from his father," remembered Brook's sister, Mira Brook, herself a Doctor of Science in Art Education. While attending a secondary school in Minsk, he was fond of mathematics, physics, and technology. Sometimes, his school laboratory instructors gave him old mechanical devices to play with. He often visited the Minsk *Energiya* power plant and spoke to the technicians who worked there. Recognizing his extraordinary interest in technology, the foremen took the time to explain to him the working principles of the machinery and even gave him some old spare parts.

His sister recalled, "My brother read a lot and liked books by Jules Verne, Jack London, and James Fennimore Cooper. He was fascinated by astronomy and gave me Camille Flammarion's *Stella* to read. He enjoyed drawing and collected art reproductions. From my repertory – I studied at music school – he loved listening to compositions by Beethoven, Tchaikovsky and Grieg."

In 1930 Brook moved to Kharkov, Ukraine, to work at a factory designing and building several innovative electric machines, including an explosion-proof asynchronous electric motor. In 1935, he moved back to Moscow and began work at the Power Engineering Institute of the Soviet Academy of Sciences [in Russian it is called today: *Krzhizhanovsky Energeticheskii Nauchno-Isledovat'elskii Institute*, or ENIN]. His dossier there contained a letter of recommendation to the Institute's Director, academician Gleb Maksimilianovich Krzhizhanovsky, from academician

Klavdii Ippolitovich Shenfer, the Soviet Union's most renowned specialist in electric machinery. Knowing Brook from the Lenin Electrical Engineering Institute, Shenfer referred to him as a "bright and talented scientific researcher and engineer." In his application for a job at the Power Engineering Institute, Brook wrote that he would like to work on problems of compensation of reactive power in long-distance transmission lines. At the Lenin Institute laboratory he initiated the research to compute the modes of high power engineering systems. In order to simulate the complex electric networks in the laboratory conditions, he designed a calculating stand using alternating current. In fact, it was a crude computing device.

Brook was awarded the Candidate of Technical Science degree in May 1936, without submitting a dissertation. In October of that same year he presented and successfully defended a doctoral thesis on the subject of "Longitudinal Compensation of Electric Transmission Lines."

During the pre-war years, Brook became focused on developing a mechanical integrator, which led him to become a corresponding member of the Soviet Academy of Sciences, as I mentioned earlier. During the Second World War, Brook worked on the fire control systems for anti-aircraft defense. He invented an aircraft gun synchronizer that allowed shots to be fired through the rotating propellers of an aircraft. In 1947, he was elected to be a member of the Artillery Academy of Science of the Soviet Union. Soon after the war he managed the research on the statistical stability of power systems, developing equipment for the frequency regulation for the biggest electric power stations in the Soviet Union. At the same time, he continued the work on analog computing devices and oversaw construction of the Electronic Differential Analyzer [in Russian: *Elektronii Differenstialnii Analizator*, or EDA] led by senior designer Nikolai N. Lenov; this machine was intended for integration of 20th order differential equations.[19]

In the late 1940s, Brook became interested in the digital electronic computers, largely due to the availability of foreign publications on the topic, and became an active participant in a scientific seminar on the problems of automating calculation. The seminar took place in 1947, under the Presidium of the Academy of Sciences, and was organized by the Academy's scientific secretary, Nikolai Bruevich. At the seminar, participants considered a proposal for the establishment of a special institute for computing technology. In July 1948, with strong support from the Academy's president at the time, Sergei I. Vavilov, the Institute for Precision Mechanics was created. Bruevich became the Executive Director of the Institute. It seemed logical that Brook, and his innovative laboratory of computer technology, would have joined the new institute's staff. But by then, he was already in charge of the digital computer project with Rameev. They had even come up with "A Project Proposal for the Establishment of an Electronic Digital Computer Laboratory at the Institute of Precision Mechanics and Computer Technology."

It is still not clear why this proposal was not accepted. There were several possible reasons. First, the institute had neither the buildings nor the equipment at that time. Second, Bruevich, the Institute's director, was not a supporter of electronic digital computers; having been a mechanic, he could better envision the development of mechanical computing devices. Third, Brook grossly underestimated the complexity of creating a digital computer. Considering the project already developed by him and Rameev as a significant step toward this objective, Brook probably hoped to build the computer with his laboratory staff exclusively. Unfortunately, he had gravely

[19] Editor's note: Readers will note that the USSR was still actively producing differential analyzers at this time, whereas the Americans were already rapidly moving towards developing electronic digital computers.

miscalculated.

In 1949, Rameev was called to military service and Brook lost his only collaborator. His plans for this digital electronic computer stayed on the drawing board forever. But Brook did not abandon his ambitions and was no doubt excited by news of Lebedev's work on a computer at the Institute for Precision Mechanics. After succeeding Bruevich as director of the Institute, Lavrentiev created Laboratory No. 1 and invited Lebedev to manage it. Simultaneously, computer construction was going on at the SKB-245, where Rameev suddenly reappeared after only a few months of military service.

In January 1950, Brook asked the personnel department at the Moscow Energy Institute to find some capable young specialists graduating from its Radio-Electronics Department that could work for him. Highly qualified specialists with clean personnel records were in great demand during that period because most of them were sent to work in top secret organizations, which were filling classified government orders. Brook did not have, nor did he want any such specialists, because they could tie his hands and hinder fulfillment of his research agenda. Instead, Brook needed talented but blacklisted specialists, who were not eligible to work on classified projects because of the "spots" in their personnel files.[20]

Brook ended up with some talented specialists. In early March 1950, the Moscow Energy Institute sent Nikolai Matyuhin – the "son of an enemy of the people." He had received a diploma with excellence for brilliant academic work and participation in scientific research while still a student. However, Matyuhin could not pass a staff commission examination required to enter graduate school because of the blemishes in his personnel file.

Matyuhin's appearance was extremely fortunate for the laboratory. In April, only two months later, Brook submitted a resolution for the Presidium of the Soviet Academy of Sciences about the development of a digital electronic computer, later called the M-1.

Initially, Matyuhin, a young specialist in radio-technology, did not grasp the concept of an electronic computer. Nor did he understand his first assignment to design a decoder – an important unit in a computer – especially one without any vacuum tubes. Brook personally selected the relevant literature for Matyuhin to read and explained in great detail the working principles of a computer, the binary notation system, and numerical calculation methods. It was Brook who suggested for Matyuhin to use copper-oxide rectifiers, which had been acquired as war reparations from Germany, along with Soviet-made electronic vacuum tubes, to construct the computer's logical elements.

Today, since both Brook and his favorite pupil, Matyuhin, have passed away, it is uncertain who was ultimately responsible for the final design structure and architecture of the M-1 computer. One can only conclude, from the recollections of the remaining participants in the project, that Matyuhin was in fact M-1's chief engineer, whereas Brook acted more as the scientific director of the project.

[20] *Editor's note:* "Spots" referred to suspicions about a person whose parents were repressed by Stalin's regime.

The M-1, M-2, and M-3 Computers and Their Creators

Having rapidly grasped the workings of a computer, Matyuhin began developing a detailed design for the arithmetical-logical unit and a magnetic drum unit for external control of memory. His first assistants arrived shortly.

Tamara Minovna Alexandridi was sent to Brook's laboratory for her diploma project in September 1950. She was also "hand-delivered" there by the Moscow Energy Institute's personnel department, knowing that Brook preferred to hire young specialists not thorough questionnaires, but after evaluating their capabilities. The young Alexandridi had no spots in her personnel file other than her unusual surname, which raised suspicion among some people.[21] But the Energy Institute's staff officers decided to avoid any risks by retaining her, even though they knew everything about her history since the Great Patriotic War. I will discuss Alexandridi and her career in more detail later in this chapter.

Brook immediately included Alexandridi in the computer design effort, offering her to work on either electronic or magnetic storage devices. Alexandridi chose the electronic option. Then, Brook proposed that she investigate the possibility of creating memory storage devices on cathode ray tubes that had been used in oscilloscopes. While a graduate student she was supported by the laboratory engineer Vyacheslav Vasilievich Karibsky. Naturally, Brook did not expect the diploma project of a female student (he was mistrustful of women) to become a part of the scientific report on the M-1 computer.

In autumn 1950, Mikhail Alexandrovich Kartsev, a student of the Energy Institute's radio faculty, came to the lab to work part-time. Brook put him to design the M-1's control unit, which was the most complex part of the computer. At the same time, Kartsev prepared his diploma project by solving problems of Hamming code usage. This code, which improved the reliability of information transmission, was implemented in the development of the M-1's central control unit.

The young specialists were assisted by the technicians Lev Mikhailevich Zhurkin, who designed the external storage on magnetic drums, Yuri Vasilievich Rogachov, who worked on electric mounting and fitting, and Rene Shidlovsky, assigned to electrical mounting and fitting.

In 1951 they were joined by Alexander Zalkind, who had graduated from the Energy Institute in February 1950, and Igor Alexandrovich Kokolevsky, a construction engineer who designed the M-1's frame. Zalkind had participated in the adjustment of the arithmetic logical unit and the design of the input-output unit.

For this small group of young inexperienced specialists, building a computer was a difficult challenge; fortunately for them, they did not immediately realize it. These types of projects were only just beginning to unfold in the Soviet Union and other parts of the world. Moreover, because of Brook's personality, the group worked in complete isolation from other enterprises.

The laboratory's facilities were not appropriate for such large-scale work as building a computer with hundreds of electronic vacuum tubes. The project experienced frequent delays due to a

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[21] *Translator's Note:* Alexandridi is a common name among thousands of Greeks living in the Black Sea region of the Soviet Union. However, for inhabitants of Central Russia the name sounded strange, and thus aroused suspicion at the domestic security service in Moscow.

constant shortage of parts and supplies, but Brook's energy and resourcefulness kept them going. He proposed using appropriated German electronic parts for the computer – copper-oxide rectifiers and reliable pentodes (the Soviet analogues were the 6Zh4 electronic vacuum tubes). Cheap and available oscilloscope cathode ray tubes were used as storage devices, and wide rolls of German army teletype paper were used for data input-output. In the end it all came together and the M-1 became the first Soviet small-size computer, using semiconductor elements and memory storage on ordinary oscilloscope cathode ray tubes.

The laboratory's young collective was full of enthusiasm. They worked from morning till late in the evening, inspired by the idea of building the first digital computer that would open the new age of scientific technical progress.

Matyuhin was living with his mother at the outskirts of Moscow, in a tiny 5 square meter room, which could barely accommodate a table and two beds. Matyuhin was so absorbed in his work, that he usually finished around midnight, by which time he neither had the energy nor strength to go home. He would often end up spending the night in the laboratory. This cycle went on for months on end. Kartsev's personal situation was similarly uncomfortable. To make matters worse, while studying at the Energy Institute, he came down with tuberculosis but quickly recovered.

Certainly, this group would not have been as productive if not for their involvement in team sports. Every Sunday was devoted to exercise and the team often went hiking at Istra water storage pond. They also constructed a volleyball court near the laboratory building and enthusiastically played during their infrequent breaks.[22]

The M-1 computer went into operation less than a year and a half after its inception. Out of the nine members of the team, only Brook had an advanced scientific degree. Considering the conditions they worked in, the M-1 was quite a remarkable accomplishment for the young scientists. Brook, Alexandridi, Zalkind, Kartsev, Matyuhin, and the other members of the team kept the final project report, "The Automatic M-1 Computer," approved by Director of the Power Engineering Institute Academician Krzhizhanovsky on December 15, 1951. Kartsev later commented on this period:

> In 1950, the Electric Systems Laboratory of the Power Engineering Institute, managed by Corresponding Member of the Academy of Sciences Isaak Brook, assembled the original team of young scientists who would advance Soviet computer technology. Nikolai Matyuhin, currently a Corresponding Member of the Soviet Academy of Sciences, was the first one of us to receive his diploma. Back in the 1950, he was a young specialist, assisted by several graduate students from the Moscow Energy Engineering Institute. I, a fifth-year undergraduate engineer, was admitted on a part-time basis. Yuri Rogachov came to us after his release from the Army. Now he has the State Prize of the Soviet Union, a Candidate of Technical Sciences, and is a Senior Engineer at the Institute. Rene Shidlovsky was a young specialist, a recent graduate from a technical college that was sent to work in out lab. He is now

[22] *Translator's Note:* Sunday was the only official day off in the Soviet seven-day calendar week from 1936–1965. Before 1935, the official Soviet week was equal to six days that had no names such as Monday, Tuesday etc. Every sixth day was a day off. After Stalin's Constitution of 1936, a seven-day week was declared, with ordinary day names. Until 1965, Sunday was the only day off and Saturday was an ordinary working day.

> Deputy Senior Constructor, manager of one of the leading departments of the Institute, and Laureate of the State Prize of the Soviet Union. Altogether, we were a group of about ten people. Before coming to the laboratory, not only were we *not* computer specialists, but we didn't even know about the existence of computers or their possibility. Nevertheless, we began making one of the first Soviet computers—the M-1. We may have been overconfident, but never careless and always professional in out work.
>
> In the beginning of 1950, a strange part was discovered amongst the items delivered from a war reparations warehouse. I cannot say exactly who found it; maybe Brook, maybe Matyuhin or Rameev, who had worked for us earlier. For a long time none of us could guess its origin or purpose, until later we figured out that it was a miniature copper-oxide rectifier. Once the value of this part was fully understood, the M-1 became the world's first computer whose logic circuits were based on semiconductors.
>
> In the summer of 1951, roughly at the same time, both the MESM and the M-1 computers began operating.[23] The first tasks to be solved on the M-1 were set by the academician Sobolev, who at the time was academician Igor Kurchatov's deputy for science exploration. The M-1 had an operating speed of only 15-20 (not thousands or millions) instructions per second with 23-digits numbers, and a storage capacity of 256 words. Many famous scientists and official state visitors came to the laboratory to see our technical marvel.

Such interest in Brook's new device was quite natural. There were no other functioning computers in Moscow. At this time the BESM was still being assembled at the Institute for Precision Mechanics, and SKB-245's Strela was in the same condition.

Yuri Rogachov remembered:

> In May of 1950 I was discharged from the army, where I had been a radio operator, and began looking for a job. I had no specialized education and – as was the rule – I was expected to become a student before any job prospects would be open to me. I didn't like that plan. One day, as I was walking along the Lenin Prospect [in Moscow] – at that time it was still called the Great Kaluga Street – when I noticed a small sign on the wall of building No. 18. It read "Electro Systems Laboratory." I decided to inquire within. I was ushered into the office of the Laboratory Director, where a number of people were congregating. During our conversation, a short, heavy-set man walked into the room. He stopped near me, blurted out, "Are you looking for a job?" and immediately started asking about my experience in the army. He said that I would have to work on devices and working principles for a new direction in technology. He spoke as if I was already a member of the laboratory staff. That was my first encounter with Brook.

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[23] *Author's Note:* Kartsev meant that the M-1 had started to do arithmetic operations in semi-automatic mode. The total outfitting of the M-1 was completed at the end of the year. As the M-1 designers have noted, the real operation of the M-1 started in January, 1952. In Brook's book *The High Performance M-2 Computer* (1957), he claimed that M-1 began to operate in spring of 1952.

I began working at the lab in June of 1950. On my very first day on the job, Brook told me about the automatic digital computer project, and the new group that was being formed under Matyuhin's leadership. He pointed to a tall, slender young man in his office, and that was how I met Matyuhin. Nikolai Yakovlevich briefly told me about the lab and showed me around. The Electro Systems Laboratory was divided into two halves: one part was located within the main building belonging to ENIN – No. 19 Lenin Prospect. The other part was on the first floor and in the basement of the right wing of the building No. 18. Most of the time, engineers and energy specialists had the ENIN building at their disposal. A mechanical integrator was located there, which they used to solve various problems. Building No. 18 had a calculating stand with alternating current, intended for modeling complex electrical circuits.

Matyuhin taught me about the digital electronic computer, about how with the assistance of an electronic circuit one could execute arithmetic operations. He explained that the most suitable basis for those calculations was the binary system, which consists of only two digits – 0 and 1. He showed me how these digits could be represented in electronic trigger circuits. He also explained in great detail how to work with the arithmetic unit. In the end, I modeled an electronic trigger scheme based on Matyuhin's design.

Despite the fact that Matyuhin had just graduated from the Energy Institute, he handled the role of chief designer of the M-1 brilliantly. Moreover, together with Brook he invented the concept of a "small" computer, which they managed to build despite the scarcity of the materials available to the laboratory. The entire project was financed by the Soviet Academy of Sciences.

To prepare the space for assembly and installation of the computer, they constructed a 1.5 by 1.5 meter base in a room of only 15 square meters. At the center of the base, they installed a square vertical ventilation column, with holes for cooling. There were three frames for mounting electronic circuit panels positioned on the sides of the column: a frame for the arithmetic unit, a frame for the main program unit, and a frame for a storage device. Under the base, a ventilator that supplied the frames with a cool airflow was installed. As the completed panels were received from the assemblers they were installed according to their positions in the frames. The off-line adjustment of the unit as a whole was a step-by-step process that didn't rely on having the complete set of panels. The mounting and separate circuits were checked at the same time.

Using this kind of assembly method considerably shortened the timetable for starting the complex fine-tuning of the computer. After the mounting of the panels was completed in December 1950, the off-line adjustments of the arithmetic unit only took a month and a half, and were completed in January 1951. At the same time the preparation and the off-line adjustment of the main program control unit continued. During the adjustment phase of the equipment on the frames, Matyuhin and Kartsev worked 16–18 hours per day. By spring of 1951, the magnetic drum with a cylinder coated with ferromagnetic material had been produced as well. The adjustments of the magnetic memory –

> alignment of the magnetic heads and electronic circuits for reading and recording – began after that. This was done by Zhurkin under Matyuhin's supervision. When Zalkind came to the laboratory, he also became involved in the fine-tuning of the arithmetic unit and later designed the input-output unit.
>
> The first half of 1951 was devoted to the adjustment of units in the off-line mode, the fitting of their electrical and functional interfaces and then, the complex adjustment of the computer as a whole. By the summer holidays, the computer had reached the point where it could perform all arithmetic operations in manual (non-automatic) mode. The overall success of the project established a family-like atmosphere among the team members, which was nurtured by Brook's fatherly attitude toward his staff. We worked very hard; motivated in part by Brook's overwhelming ambition and in part because we were young and just beginning our careers. The project never seemed tedious either, mostly because we were delighted to be at the forefront of this emerging technology. In fact, it was actually quite enjoyable. The newness of the work, our enthusiasm and desire to obtain new results as soon as possible – each step forward yielded exciting results – made us loose track of time. We gladly worked overtime without extra compensation, starting in the early morning and finishing late in the evening.
>
> At the end of August we began the final calibrations: running the arithmetic and logic operations in automatic mode. And with the operation of the input-output device, programming began. The first programs were designed for simple tasks. One of them was a calculation table for the function $y = x^2$. This task had one feature: the values of the "y" function for positive and negative values of "x" were identical. Thus, we could check the computer's calculations by comparing the results. It was a lucky break because at the time we had no idea about special test programs for checking the accuracy of a computer. One could say that the parabolic equation $y = x^2$ was the first test program for the M-1. The second one was a program for the equation $y = 1/x$. With the solution of these equations, the M-1's complex adjustment was complete.
>
> At the beginning of 1952, the M-1 went into trial operation. Various tasks were solved on it, with the aim of checking the technical solutions and refining the programming technology. It became clear, for example, that we needed a control panel and a "Stop" operation, which the design engineers had not foreseen.
>
> During that period, everybody took an active role in operating the computer and identifying the strong and the weak features in its circuitry.

Zalkind remembered an interesting episode concerning the M-1's operation and usage by the military:

> Machine time on the M-1 became extremely important for 'The Beard' group, a clandestine governmental department.[24] The Beard's right-hand man

[24] *Translator's note:* In Russian *boroda*, or beard, was the affectionate nickname given by his employees to Igor Kurchatov, scientific head of the Soviet nuclear weapons program. Kurchatov fashioned wearing a long beard.

responsible for mathematics – because the term "software" did not yet exist – was the well-known Sergei Lvovich Sobolev. He often visited the M-1's room and was very supportive of our work. His group needed to calculate the reverse matrix of large dimensions, which was done on the M-1 in the beginning of 1952.

At this time we began receiving the first domestic 6Zh4 electronic vacuum tubes, but our attempts to change out the German variants for domestic ones were a complete fiasco because of the wide deviation of the cut-off voltage in domestic pentodes. All work on the M-1, even the testing, completely stopped. It was very frustrating for Sobolev, but for our team it was a complete disaster.

I was sent to the Svetlana Vacuum Tube Manufacturing Plant in Leningrad [today St. Petersburg] to obtain several hundred 6Zh4 vacuum tubes that had passed the quality control inspection. To fill this order, we had built a simple stand with a wall outlet plug and a single tube socket, a power supply for the pentode and a current tester. We had also prepared a basic business letter: "As part of your technical assistance to us, we kindly ask you to allow our representative, Mr. Zalkind, to select from your 6Zh4 tubes. We guarantee payment."

Just before leaving for Leningrad, Sobolev visited us. He told me: "Should any problems come up, you must make a telephone call… and at the start of the conversation don't forget the password…" Sobolev then mentioned the name of a well-known flower.

After such an unusual briefing, I remember feeling fearful and insecure as I walked up to the office of Svetlana's Senior Engineer, Mr. Gavrilov. I nervously waited near the door, while Gavrilov, without getting up from his armchair, suddenly barked: "Looking for tubes?" "Yes," I answered. He retorted: "Get out of here!"

Feeling miserable, I returned to the hotel, but then remembered Sobolev's parting words. I made the call. After someone answered, I named the flower. The voice on the other end of the receiver gave me the address of an apartment building on Nevsky Prospekt [the main boulevard in St. Petersburg] opposite a knitwear shop. I went there; it looked like a typical apartment. They let me in, listened attentively and said: "We act only on the level of the Third Secretary of the Regional Communist Party Committee. You need to wait two days and then call us back in the same manner."

Two days later they answered my call: "Everything is in order with Gavrilov. You may visit him again."

At the Svetlana plant, Gavrilov smiled, shook my hand and issued an order to provide me with everything I needed. I brought 300 6Zh4 vacuum tubes to Moscow.

Those were the type of strategies used by the "Gordorstroi" [the common Soviet abbreviation at the time for the MGB, the Security Ministry responsible

> for supplying the Soviet Union's nuclear weapons project]. With the M-1 working around-the-clock, Sobolev was pleased.

Returning to Rogachov's reminiscences:

> Encouraged by the M-1's success, in April of 1952 Brook asked a group of engineers and technicians under Kartsev's management to create a new and improved computer with more advanced features that ever before. Again, the young team pulled off this seemingly impossible task, and by the end of 1952, just six months later, a new, more powerful computer was being installed and prepared for adjustment.

Kartsev talked about how he started out in science and the M-2 computer project at the 15th Anniversary meeting in 1967, before a group that he established himself at the Institute of Computer Complexes of the Ministry of Radio Production of the Soviet Union:

> In the spring of 1952, immediately after I had received my diploma, Brook assigned me to a group of seven people to design and build the M-2 computer. Today, it's difficult for me to understand how we managed to do it. We developed the technical documentation first, then watched as parts were manufactured at a number of sites – an experimental factory of the Institute of Combustible Mineral Resources of the Soviet Academy of Sciences, an experimental construction branch of the MEI, the Sokol medical equipment plant, and about ten other places. Then we gathered all of the parts and began assembling the computer. We started in the spring of 1952 and by October 10th the first two frames – the control and arithmetic units – were operating, just in time for the opening of the 19th Congress of the Communist Party of the Soviet Union. By November 7, 1952, we had finished the power supply frame and the magnetic drum. And on December 5th – the Constitution Day – the electronic memory was installed and tested. By January 1953, the computer began operating using a magnetic drum, and in summer 1953 it was fully operational.
>
> Generally speaking, the M-2 machine remained the only one of its kind. The Chinese tried to copy it, but we have no definite confirmation that it actually worked.[25] It was a serious computer, used for large-scale and very important calculations were. Strictly speaking, over the course of several years, there were only two operating computers in the Soviet Union: our M-2, and the BESM of the Institute of Precision Mechanics.
>
> Sobolev conducted large-scale calculations for Kurchatov. By a special government order, we were commissioned to make calculations on the stability of the dams for the Kuibyshev and Volzhskaya hydroelectric power stations. These calculations were managed by the Institute of Precision Mechanics. We also conducted calculations on our computer for M.A. Mikheyev from the Alikhanov Institute of Theoretical and Experimental Physics (at that time

[25] *Author's Note*: Tsai Chuan Yuan wrote for *Druzhba* magazine (no.11, 1958) "2000 Instructions Per Second," claiming that the Chinese M-2 began operating in October 1958.; *Translator's Note*: *Druzhba* [Friendship] was a popular, mass-circulation illustrated magazine, dedicated to Soviet-Chinese relations.

> called the Academy of Sciences Heat Engineering Laboratory) and many, many others.

All calculations done on the M-2 computer were approved and coordinated exclusively by Brook. However, the first actual shakedown calculation on the M-2 violated this "iron" rule, but Brook didn't find out about it until 15 years later. Here is what happened. At the end of 1953, when the adjustment of the M-2 was completed, Brook went on vacation to Kislovodsk, a famous resort town in the Soviet Union. At the same time, a group of scientists at the Combustion Physics Laboratory in the Power Engineering Institute, directed by Tatiana Bazhenova, were completing tables of thermodynamic and gas-dynamic air parameters necessary to build fire-proof protective shells for rocket hulls. The group had begun calculations in the summer 1953 and promised to finish them by December.

Bazhenova recalled:

> Despite the fact that the calculations accounted for only two components of the air – oxygen and nitrogen – the task was extremely time consuming. It required solving dissociation equations for oxygen and nitrogen, then adding ionization equations for their atoms to form nitric oxide, then adding equations of collision processes, and finally, applying the law of conservation of energy and wave interference laws of gas dynamics. As a result, a system of thirteen differential equations had to be solved by a method of sequential approximation.
>
> At first, the problem was given to two laboratory technicians, but no matter how hard they tried to complete the work on time, the calculations proved too cumbersome for them. So it was turned over to the First Moscow Factory of Mechanical Calculations, where an entire staff of young women with hand computers attempted to solve the problem. The work went faster, but the completion deadline loomed even closer. At that time, BESM was the only electronic computer that worked on serious, urgent orders and it was booked ahead for a long time. And then some unexpected help materialized.
>
> We knew that in the neighboring laboratory directed by Brook, there was work was going on with some kind of a new secret machine. On my birthday, friends from that laboratory with whom I used to go on ski trips, came over and presented me with some ski grease, which back then was scarce. The cans of grease were stacked one on top of another and wrapped with paper tape covered with straight lines of numbers. Despite the fact that I knew almost nothing about computers, I noticed that the paper tape resembled computation printouts. "Is this your tape?" I asked the guys. "Yes, it's ours," they replied. After this it was easy to guess what kind of secret machine was being created in the laboratory next door. Through Prziemsky, our laboratory Communist Party organizer, we turned to our friends, Misha Kartsev, Yuri Lavrienyuk and Tamara Alexandridi. They understood our difficulties, plus the computer had not yet come on line and had no orders. Consequently, the "Brookians" decided to test the M-2 using our problem. At the same time, our missile specialists were camped out around the clock near the building No. 18 on Lenin Prospect. As the portions of the tables were completed, they took turns

> taking them back to our lab to perform additional calculations for the coating of the hulls of our first intercontinental ballistic missiles. In retrospect, the rush was justified: possession of such missiles gave our country weapons parity with the United States.[26]

The M-2 was never mass-produced, despite its excellent construction and time proven superb performance. During the fifteen years it was operational at the Power Engineering Institute in Moscow; it was responsible for solving a wide range of problems in many different branches of science and technology.

During the M-2's construction, Kartsev talent really shined through. Unlike the small M-1 computer, the M-2 was appropriately classified as a large machine. During its first period of operation it had the same speed of 2000 instructions per second as the Strela and the BESM. The M-2 represented Kartsev's first step towards founding his own scientific school, where the main focus would become the creation of specialized supercomputers.

In Brook's laboratory, almost simultaneously with the M-2, design work began on a smaller electronic computing machine – the M-3; Brook appointed Matyuhin to manage this project.

The decision to begin design work on two computers at the same time by such a small design team can be attributed to the fact that Brook's two leading scientists, Matyuhin and Kartsev, had been striving for independent work and begun to display leadership skills early on. Such characteristics were quickly noticed by the shrewd scientific director Brook.

The M-3 could have also remained a one-of-a-kind machine (its development was not officially sanctioned by the government), had it not been for the academician Viktor Amazaspovich Ambartsumian. Upon his arrival in Moscow in 1954, he asked his friend Andronick Gevondovich Iosifian, Director of the All-Union Soviet Scientific Research Institute of Electro-mechanics [today the *Vserossiskii nauchno-isledovatel'skii institut elektromekhaniki*, or VNIIEM], to help him obtain a computer for the Armenian Academy of Sciences. Iosifian turned to Brook, and the two of them agreed to manufacture three M-3s at the Institute of Electro-mechanics, which had its own manufacturing facility. One computer was to be built for the Institute of Electro Mechanics, one for the Yerevan Institute of Mathematics of the Armenian Academy of Sciences, and another for Korolev's space program. They formed a joint group of specialists: Matyuhin (from Brook's laboratory), Boris Moiseevich Kagan, George Petrovich Lopato (from Iosifian's Institute), and others. In 1956, the first of the M-3's was fine-tuned and presented to the State Commission, together with technical documentation required for industrial mass- production.

Boris Kagan, the informal leader of the joint group, spoke about the M-3 computer at a ceremonial meeting celebrating Isaak Brook's 90th birthday:

> …Because the M-3 was actually a self-initiated project, independent of any state plans, the State Commission headed by Bruevich and assisted by Shura-Bura showed its true character by not wanting to acknowledge this computer, claiming that it was "born illegitimately." Although they did eventually accept it, two years went by without it's going into mass production. During this time, the Yerevan Institute of Mathematical Machines was founded and began

[26] *Author's note*: In 1968, 15 years later, Bazhenova wrote about this incident in the article "Space in Tubes" in *Science and Life* magazine.

> producing its own computers using our documentation for the M-3.[27] At the same time, the first industrial computer factory in Minsk, Belarus, was built, but had nothing to produce. The factory managers learned that Iosifian had a model of a computer but nobody had given him permission to make it. Only then were the M-3's documents transferred from the Institute of Electro Mechanics to the factory in Minsk and the M-3 computer became the basis for computer manufacturing in Yerevan and Minsk.
>
> I would also like to note that the first computers in Hungary and China were built using our documentation. As for the Institute of Electro-mechanics, this work became the springboard for the development of a foundation for large-scale research and production of control computers and systems.

So in the end, the "Brook Brigade" succeeded in joining the ranks of the designers of industrial mass-produced computers.

New Enthusiasm

At a 1956 session of the Soviet Academy of Sciences, Brook presented a report on automation in which he set forth the major directions of computer usage in the industrial sector. Two years later, he wrote a proposal, "The Development of Theory, Principles of Construction, and Application of Special Computing and Control Machines," and submitted it to the Soviet government.

Essentially, these two documents were the first drafts of a program to automate the Soviet Union's economy with computers. For the first time in domestic practice, the question of computer application in areas other than their traditional use, such as technology, physics and mathematics, was being considered. There was also a need to resolve the serious problem of controlling technical installations and performing economic computations, such as the calculation of balances between various industrial sectors, optimized distribution of transported goods, price determination, etc.[28]

Brook's 1958 report was the first step toward the organization of a number of new scientific-research institutions and construction bureaus at the end of 1950s. In 1956, a former electric systems laboratory at the Power Engineering Institute was reorganized as the Control Machines and Systems Laboratory [in Russian: *Laboratoriya Upravlayuschikh Mashin i Sistem*, or LUMS]. Later in 1958, the Institute of Electronic Control Machines (in Russian: *Institut Elektronnikh Upravlyaushikh Mashin*, or INEUM) was established and Brook became its first Director. At the same time, the Presidium of the Soviet Academy of Sciences confirmed Brook's assigment to the position of scientific manager for the state project "Development of the Theory, Principles of Construction and Application of Control Computers."

At the Institute of Electronic Control Machines, under Brook's management, the following

[27] *Author's Note:* These Armenian machines included the Aragats, and Razdan-1 and Razdan-2 computers.
[28] *Translator's Note:* These sorts of economic problems were to a great extent the result of the Soviet Union's centrally planned economy, controlled by government units. For example, the price calculations of durable goods were not set by their manufacturers, but instead by a central state body, the State Prices Committee.

computers were built:

The M-4 (1957–1960) for the solution of special system tasks at the Radio Technology Institute.

The M-5 (1959–1964) for economics tasks, planning and management of the state economy.

The M-7/200 and M-7/800 (1966–1969) for control of power generation units (the Konakovo Heat Electrical Generating Station, Slavyanskaya Heat Electrical Generating Station) and technological processes.

After retiring in 1964, Brook stayed on at the Institute as a scientific consultant and manager of its scientific-technical council, maintaining an active interest in its work. In the last five years of his life, he received 16 invention certificates. He is credited with more than 100 scientific works, including more than 50 inventions. Brook's contribution to science and technology was highly valued by the Soviet government: he was awarded four Orders of the Red Banner of Labor and a series of several medals.

Veterans' Recollections

A portrait of Brook drawn from the official materials alone cannot provide an accurate picture of this complex and controversial person. Vladimir Danilovich Belkin, a doctor of economics and a professor at the Soviet Academy of Sciences, had worked alongside Brook for many years. Towards the end of his career, Brook became interested in economic problems connected with emerging economic reforms. Belkin recalled:

> Brook was one of the few people who responded to the need for radical economic reform. He wanted to build socialism if not with a human, then with at least a proper economic face. But all of this was horribly sabotaged from 'above.' There was hardly anything left of the old monolith, yet it was expected to continue supporting the entire system. The leaders saw assassination attempts on old the system in every proposal from our economists. Brook clearly predicted that our national economy was headed towards a collapse, claiming that it was due to insufficient communication between our dual systems of government – the Soviet Ministries, GOSPLAN, etc. – and the Communist party. 'Our overall government system, which the party created, could react rapidly to the party, but the party lacked the ability to react to the government,' Brook declared. Only a person with Brook's sagacity could say such things in public.
>
> The big battle occurred in GOSPLAN regarding pricing politics; its director, Pyetr Fedayevich Lomako – the last bureaucrat of the Stalinist era – told Brook, 'You have attacked the authority of GOSPLAN and this mutiny will cost you dearly.' Brook was forced to retire.[29]

[29] *Author's note:* In the late 1950s INEUM was pulled out of the Academy of Sciences and transferred to aid in the creation of the State Economic Committee under GOSPLAN.

Veterans of Brook's laboratory, Alexandridi, Zalkind, Rogachev, and others, helped me describe Brook's character. Alexandridi recalled:

> To me, Isaak Semyonovich seemed to be both distinguished and formidable back then. Judging by today's standards, he was a relatively young scientist, only in his late forties. But at the time, I saw him as an old man with advanced scientific degrees and accolades.
>
> He wanted to do everything faster. He literally flew through the laboratory, running from one worker to another, asking about the progress of various projects, giving advice, listening carefully to requests, and making notes about incomplete work.
>
> Intellectually gifted, highly educated, and quite demanding of himself, Brook drew great admiration from others who wished to imitate him. He treated his colleagues like a stern but caring father. For example, when he discovered that Matyuhin had no coat, he brought him his own leather jacket. He tried to help others in similar ways.
>
> Brook inspired us with his enthusiasm and obsession with work, teaching us that we could overcome any obstacles. We were young and seldom realized what kind of person was working next to us. Now, after considerable experience in my field, I have come to understand that I have never met a person of Brook's caliber, even though I have worked with many other academicians.
>
> His extraordinary talent, energy, ability to attract people to his work, encyclopedic knowledge—he seemed to know everything—outstanding mathematical education, and a never-ending stream of ideas, demonstrated what an exceptional person Brook really was.

Brook's Laboratory technicians N. N. Lenov and N. V. Pautin recalled:

> He was never superficial or hypocritical, which is the reason why he appeared to the outside world – at the scientific councils, meetings, and conferences – as an ill-tempered, quarrelsome opponent, a hair-splitting critic, in brief – an enfant terrible. Only someone like him could say, for example: 'This technology is from the Stone Age!' when describing the 'Strela,' the first mass-produced Soviet computer.

Alexandridi further commented:

> Brook was a very secretive person and made everyone adhere to the strict rule of keeping all of the information about the laboratory stay inside its walls. He avoided participating in government projects, which tended to attract other groups of people. The work on the M-1, M-2, and M-3 computers was carried out as internal projects, ordered by the Presidium of the Academy of Sciences of the Soviet Union. We worked under difficult conditions. There was always a feeling that we were making the computers illegally, and since they were not a part of any State plan and hence, there were no guarantees that would be able to obtain modern equipment or parts for them. Sometimes, we were forced to use tools and components from a German property reparations warehouse.

> Brook was always brimming with new ideas and so preoccupied with innovation that sometimes, in the middle of the development, he abandoned not only the project, but the people involved as well.

Pautin agreed:

> Those character traits could only hinder the advancement of his career. Barely a third of the M-3 computers that were developed in his laboratory went into a modest mass-production, but later experienced a rebirth in the industry. It was not until 1958 that Brook was able to organize the INEUM that he had conceived of long before.

Lenov:

> 'It is impossible to make a scientist,' he would say, insisting that the conventional scientific postgraduate path was ineffective. 'Get involved in the work and everything will pan out!' he would say. He did not hurry even his best students – Matyuhin and Kartsev. Moreover, he contributed to the delay of their thesis defenses, believing that in the beginning they should obtain extensive engineering experience. Maybe that was why he could not keep them on staff. Both of them left the Institute and later became great scientists and founders of their own scientific schools.

I met Brook in March of 1956 during a conference on the "Development of Soviet Machinery and Instrument Building" in Moscow, a meeting that drew specialists in computer technology from all over the Soviet Union. The plenary session in the great hall at Moscow State University was overcrowded. The conference was opened by its organizer, academician Lebedev. Professor D. Y. Panov made the first report, "The History and Development of Electronic Computers," in which he remarked:

> At the present time, everybody knows about the universal electronic computer BESM, built in 1952 under the academician Lebedev's supervision. The performance of this computer surpasses all European models and most American computers.
>
> During the International Conference in Darmstadt in autumn 1955, academician Lebedev gave an overview of this machine, which was highly rated by the foreign scientists and engineers who visited the conference.
>
> At this Conference you will hear the reports of many Soviet scientists and engineers, including academician Lebedev's report "High Speed Universal Computers," about the Soviet digital electronic computer M-2, designed under the management of the Corresponding Member of the AS USSR Brook, and about the Strela, developed by Bazilevsky and others. You will also hear reports by Ushakov, Gutenmacher, Korolkov, and others, about our work on simulation devices.

I have to say that I paid close attention to the reports, and closely scrutinized the faces of the conference participants during the breaks in the hope to become better acquainted with the people I haven't met before. I presented my paper on "Devices Based on the Combination of Crystal and Magnetic Elements," at the section on universal digital computers. Tamara Alexandridi also appeared at this section. Her paper, "The Electrostatic Memory Device of the

M-2," and she personally – young, graceful, and vivacious – attracted my attention. I approached her with some questions, and later managed to visit the Electro-Systems Laboratory where she worked.

Back then, Isaak Brook was 54 years old and at the height of his career. After the conference I saw him a few more times. Brook passed away on October 6, 1974, only three months and three days after Lebedev died.

I had also become better acquainted with Matyuhin and Kartsev. Nevertheless, my knowledge of them at that time, and later, did not extend beyond the information about the machines that were built under their supervision, or the books and articles they had written. When I decided to write this book, they were already gone.

George Lopato (I will talk about him in Chapter 4) and Tamara Alexandridi helped me tremendously in preparing this book. Almost forty years after the 1956 conference, Alexandridi shared with me a great deal of insight and information about the "Brook Brigade," herself, and her husband Matyuhin, whom she married in the 1950s.

As a rule, Brook invited only men to work in his laboratory. Alexandridi was the sole woman to work with the group responsible for the development of M-1. Brook was intrigued by Alexandridi's atypical surname, which she got from her father, a "russified" Greek from Krasnodar.

Alexandridi was born on September 26, 1924. When she was two years old, the family moved to Moscow, where she was raised by her mother. She studied in the Moscow Radio Club and received a special degree as a radio operator. At the beginning of the Second World War she volunteered for the Army, witnessed the siege of Sevastopol, and lived through the great battle at the Volga, all the time working as a radio operator. She returned to Moscow in June 1945 with Second Order Award of the Great Patriotic War, and five medals. Later that year she enrolled at the Moscow Energy Institute and in 1950 was sent to Brook's laboratory. At the time we met again, 40 years later, she had become a professor at the department of automated systems at the Moscow Automobile Roads Institute, where she still teaches.

Nikolai Matyuhin

Having being rigorously trained by Isaak Brook, Matyuhin went on to become a great scientist and the founder of his own scientific school. He was born in Leningrad in 1927. His father, Yakov Vasilievich was born in 1880 into a peasant family, and he had worked as a factory electrician in Petrograd until the 1917 revolution.[30] His wife, Margarita Fedorovna, was a housekeeper.

Yakov Matyuhin participated in the revolutionary movement, was a member of the regional committee of the Socialist Democratic Revolutionary Party (SDRP) between 1909 and 1910, in the Vyborg district of Petrograd. He was well acquainted with Kalinin, Dzhugashvili, Ordzhonikidze and other famous members of the SDRP.[31] They all used Matyuhin's apartment

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[30] *Editor's note:* Tsar Nicholas II changed the name of St. Petersburg to Petrograd in 1914 in order to inspire patriotism during World War I. After the revolution in 1924 the communists changed the city's name again to Leningrad. In 1991 the Russian government change the name again changed back to St. Petersburg.

[31] *Editor's Note:* Dzhugashvili was Stalin's family name. The name Stalin (*steel*) itself was a party alias, like

as a secret meeting place. After the revolution, Matyuhin abandoned political activism and worked again as an electrician. In 1932, Kalinin secured a job transfer to Moscow for him, and the family was given an apartment in a government house on Granovsky Street. At the time, the Matyuhins gave little thought to what might come of this, because they were happy to be living in a nice apartment in the capital.

In 1935 Nikolai Matyuhin started school. He was a fast learner and his parents were happy with his academic success. His mother Margarita was a highly educated person, well read, and a wonderful storyteller; she supported the comprehensive development and education of her son.

This happy childhood was destroyed by Stalin's repression. In 1937 Yakov Matyuhin was arrested and the family never found out what happened to him (in 1957, he was posthumously exonerated). The family was evicted from Moscow. After selling their personal belongings, his mother managed to rent a small room in a wooden house at the outskirts of Moscow, in the village of Solntsevo. At the beginning of the Second World War in August 1941, the Matyuhin family was evacuated to the city of Penza, where they lived with relatives.

After graduating from secondary school in 1944, Nikolai Matyuhin entered the Moscow Energy Institute's radio technology department. He received only excellent marks and during his third year became involved in the invention of a new radio transmission system with improved electric power efficiency. He received two invention certificates for his work on this system. In February 1950, he graduated with honors and in accordance with the recommendations of the State Examination Commission, sent his application for post-graduate work to the Moscow Energy Institute's transmitter's department, a naive move on his part.

The Energy Institute personnel commission rejected his candidacy because his father had been repressed by Stalin. Thus he came to Brook's laboratory, where he took on the role of the project manager for the M-1 and later, the M-3 computer.

I wanted to find some of Matyuhin's personal reminiscences about this period. Searching my archive, I found an old issue of *Power,* the Moscow Energy Institute's newspaper, from October 23, 1976. The entire issue was dedicated to the department of computer technology celebrating its 25th anniversary, and there I found Matyuhin's article, "First Steps." When it was first published, Matyuhin was already a professor with a PhD in Technical Sciences. He wrote:

> During my final semester at the Radio Technology Department of the Moscow Energy Institute, I became seriously interested in the field of meter-wavelength radio transmitters, and never expected that after finishing the Institute it would lead to a sharp change in the direction of my career. Within a month of defending my diploma project, I got to meet the Energy Institute's Assistant Rector, Chursin. He introduced me to a rather short, but very lively and

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Lenin, whose actual last name was Ulyanov. Mikhail Ivanovich Kalinin was one of the Lenin's fellow revolutionaries who took an active part in Great October Socialist Revolution of 1917 and later became a member of the Politburo. He became part of Stalin's inner circle after Lenin's death and between 1930 and 1940 sanctioned massive repressions in the Soviet Union. Kalinin was one of the most faithful Communist Party servants yet his own wife was punished on Stalin's order. Kalinin served as Chairman of the Presidium of the Supreme Soviet beginning in 1938. Grigory Konstantinovich Ordzhonikidze (Sergo) was a fellow Georgian and long-time friend of Stalin's. From 1932 he headed the Soviet heavy engineering industry. He was also a member of the Politburo, an ardent communist, and a popular figure. At the peak of Stalin's repression's in 1938 Ordzhonikidze committed suicide with his own revolver.

energetic man, who immediately started asking detailed questions about my interests and my work. Finally, he invited me to join some 'cutting edge' work at one of the Academy of Science institutes. The man was the academician Isaak Brook, my future chief and mentor.

At that time, the Academy of Sciences seemed like Mount Everest to me, inaccessible to ordinary mortals. Just being there seemed incredible. I should explain that placement of post-graduate specialists from the Radio Technology Department was 'harsher' than that of normal higher education institutions. Most of our post-graduates were not sent to research institutes, but to factories, primarily in faraway Soviet cities.

I accepted Brook's proposal without hesitation, although I could not imagine exactly what 'cutting edge' work meant. From my point of view, any work at the Academy of Sciences would be fascinating! And that is exactly how it turned out – I became a part of a team that created of one of the first Soviet digital computers.

Computer development in Moscow was handled by three very different groups in terms of their organizational structure: academician Lebedev's group at the Institute for Precision Mechanics, Brook's group at the Power Engineering Institute, and Bazilevsky's group at SKB-245.

Our group was the smallest of all, which was the most likely reason why Brook directed our efforts towards small (for that time) computers. He had assembled about ten post-graduates from the Energy Institute, the Moscow Aviation Institute, and Nizhniy-Novgorod University. Naturally, none of the recruits could possibly imagine the complexity of the work, and had no fears about building the computer, while the seasoned specialists, knowing the level of radio-electronic technology back then would have had serious doubts about the feasibility of our task. Luckily, we were not familiar with the reliability theory, and had no idea that vacuum tubes and other electronic parts malfunctioned quite often. Hence, we started the work unencumbered by doubts.

My first job was assembling combination three-entry adders for 6X6 diode vacuum tubes. After an initial search for the correct combinations of zeros and ones, I remembered learning something similar in O.A. Goryianov's course, "Automation and Telemechanics," at the Energy Institute. When I originally took it with my classmates, also radio operators, we considered it secondary to studying radar or impulse technology. In those days, technical literature was in a very short supply, so I always kept scrupulous notes from all of the lectures on technical subjects. I remember searching through them and using some Boolean algebra equations in the progress report for Brook, which highly impressed him.

It was extremely interesting to work with Brook, especially since all of us were very young. He personally managed our group's activities, and that was truly inspiring. However, conversations in his office were rather rare. Usually in the morning, he swept into our room and started talking right there at the

> workbench. It seems to me that the success of our first computer and its rapid development was partly due to Brook's decision to use large-scale semiconductor elements. At that time, these were available only in the form of miniature copper-oxide rectifiers, which were produced for the needs of measurement technology. Brook agreed to develop a specially modified rectifier that was same size as a typical resistor, and we came up with a set of circuit designs. We prepared and assembled the units in the laboratory workshop, and in less than a year the computer had already begun "to breathe" (with its several hundred vacuum tubes and several thousand copper-oxide rectifiers).
>
> During M-1's construction, we were compelled to examine a wide variety of issues – from voltage regulators for powerful direct-current motor generators (that supplied the computer's secondary power) to the instructions system design and programming.
>
> Our choice for the instruction system was not easy. Back then, the generally accepted and widely used method was a three-address instruction system based on von Neumann's work, which required categorical register equipment with a rather large word length and memory. Our limited options drove us to look for more economical solutions.
>
> As it generally happens in hopeless situations, an accident helped us. Brook invited the young mathematician Yuri Schrader to work with us, and during a joint hands-on training session in programming, Schrader noticed that in many approximation formulas the calculated result of one operation was used as an operand for the next operation. From there, it was a short leap to the first two-address instruction system. Our proposals were approved by Brook and after the M-1, they were developed further in the M-3 computer. The next round of events led the M-3 to Minsk, where the building of the Ordzhonikidze factory, the first computer manufacturing plant in Belarus, was just completed. The original small batch of machines was made there, practically by hand, and later the plant began to develop and produce the well known Minsk computer series.
>
> And that is how the genealogical roots of the Minsk series were found in the modest premises of the former electrical systems laboratory at the Power Engineering Institute. Finally, I would like to note that I intentionally limited myself here to the discussion about my teachers and senior managers. Much more could be said about my colleagues during those years, many of whom are well-known specialists in computer technology now, but that really requires a larger framework that goes beyond the mention of one or two names in a small article such as this.

In 1957, Nikolai Matyuhin transferred to the Scientific Research Institute of Electronic Computing Technology at the Radio Industry Ministry.[32] Being the chief engineer at the Institute, he participated in building a computer for the Soviet Union's air defense system, and was the principle designer of mass-produced computers and special control computer complexes.

[32] *Translator's Note:* Despite its name, the Radio Industry Ministry was mainly responsible for design and production of electronic equipment for the Soviet Army Air Force, accounting for more than 80% of its products.

In 1962 Matyuhin successfully defended his Candidate's thesis, and in 1972 received a Doctorate of Technical Sciences degree. In 1979, in recognition for his role in the development of computer technology and as one of the founders of Soviet Union's computer industry, he was elected as a Corresponding Member of the Soviet Academy of Sciences. Later in the year, he was awarded the State Prize of the Soviet Union for his work on control systems. He successfully combined his scientific research with teaching by becoming a professor at the Moscow Institute of Radio Electronics and Automation.

Some of Matyuhin's most important scientific achievements in computer theory and systems were the development of computer architecture principles and installation design for complex, widely separated, computer-aided real time control systems and their data transmission.

Matyuhin was the chief designer of a number of computers and complexes that played an important role in national defense. Under his guidance, families of sophisticated second and third generation computer complexes were designed. They were mass-produced and successfully put into operation. One such complex, for instance, was manufactured and used for more than ten years, thanks to its superior operational, technical, and architectural characteristics, which guaranteed effective system performance in various mobile and stationary air defense services.

For the first time in the Soviet Union, during the period from1968 through 1971, multi-complex computer systems were created under Matyuhin's supervision. They were based on ES-type computers, and showed their effectiveness for the applications in the developing systems. Between 1972 and 1975, further development of these principles enabled Matyuhin to build a center of data exchange for information networks. It was also the first large-scale Soviet effort in the rapidly changing field of science and technology during those years. Matyuhin published over one hundred scientific papers (including seven inventions) and in 1980 was awarded the Order of the Red Banner of Labor. His wife, Alexandridi, recalled, "In his private life, among colleagues, friends and family, Nikolai Matyuhin showed himself to be an extremely kind, modest and attentive person. He was very loyal to his friends, family and children."

She continued:

> As far his character is concerned, he was a very enthusiastic and emotional man, who captivated people with his ideas. This could be said not just about his work, but also about his leisure activities – sports, entertaining friends, or travel.
>
> Nikolai's favorite leisure pursuits were mostly amateur sports. In the summer during holidays, it was kayak boat trips with family and friends through the rivers of central Russia. Sometimes, it was car trips or bicycling. In the winter, he liked alpine skiing. He started skiing rather late, at the age of 40, but really took to it and quickly reached a high amateur standing.

Matyuhin died on March 4, 1984. Like many of his colleagues, Matyuhin had been deeply involved in the development of computers for military purposes, particularly at the Radio Industry Ministry. During the Cold War, most of the projects carried out under the Radio Industry Ministry's auspices were "closed," top-secret endeavors that intended to protect the Soviet Union from air attacks and other possible military conflicts. I will discuss some of these projects in the next chapter.

Chapter 4: Secrets of the Post-War Years

Many of Brook's employees went on to work in computing projects for the military. Alexander Zalkind shared with me some of his intimate knowledge of formerly top-secret projects completed at the Scientific Research Institute of Automatic Equipment. The following is an excerpt from Zalkind's account:

> In 1957 we – O.V. Rosnitsky, A.I. Shurov, our leader Nikolai Matyuhin, and I – decided to move to the Research Institute of the Radio Industry Ministry to develop the Soviet version of SAGE.[33] The Scientific Research Institute of Automated Equipment was founded in 1956. Dr. G.L. Shorin was the director and chief designer of the projected air defense system. In 1958, our group became engaged in developing the 'Earth' System.
>
> The Earth system began with the ordinary telegraph equipment. The information about moving objects was transmitted through a telegraph network. Telegraph operators formatted the messages and delivered them to digital board operators, who coded them into discrete data; this data from the boards was passed on to the data calculation equipment to obtain the coordinates and trajectories of moving objects. The output data was kept on a magnetic drum that acted as a buffer. Then the data was transmitted from the magnetic drum to a secondary processing computer and workstation that used a special cathode ray tube. The letters, figures and logical symbols were drawn on the screen of the tube by electronic beam masking.
>
> All of the equipment was built very fast to meet a deadline. In the second quarter of 1960, the State Commission reviewed our equipment and concluded that the system was not reliable due to the insufficient dimension-mass performance of the units employing electronic vacuum tubes. The Commission decided to prohibit the usage of electronic tubes in all future projects.
>
> One of the reasons we mention the Earth system here is to offer some perspective on our team's subsequent successes. Within fifteen years, our institute had created a fully operational global network that included more than twenty regional switchboard centers. This network provided around-the-clock information exchange with the Air Defense System. During this period, the system was virtually failure-free. Tetiva, the first model of Soviet semiconductor computer, was conceived in 1960 for this specific purpose.[34]
>
> The Tetiva was the first Soviet computer that used a micro program kept in the binary storage memory matrix [in Russian: *Dvoichnoe Zapominaushchee Ustroistvo*, or DZU]. Later, this micro program control system was used in the Armenian Nairi computer developed in 1964, the Mir, and the ES-1020

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[33] *Editor's Note*: SAGE was the acronym for Semi-Automatic Ground Environment, the computerized air defense system designed at Massachusetts Institute of Technology.
[34] *Editor's note:* In Russian, *Tetiva* means bowstring.

> computers. Tetiva's arithmetic unit used only direct operand codes. This kind of arithmetic unit was more expensive than anything previously developed, but it was the fastest and had the best self-controlling processor.
>
> The Minsk Computer Factory manufactured the Tetiva series and by 1962 eight of them were placed at various national defense installations. The initial information input for Tetiva was carried out with the help of a special mechanical switch that took the objects' coordinates from a cathode ray tube screen. The computer program semi-automatically provided information about the location of the missile.
>
> In order to guarantee the function of the air defense system around-the-clock, two Tetivas operated simultaneously to create a 'failure-free computer complex.' If a problem appeared in one computer, the system automatically switched to the other machine. This computer complex faithfully served the Soviet Air Defense for over thirty years and in 1987 caught Mathias Rust's flight into Soviet air space. The development of a Tetiva based system was still in progress when the work began on the first series of mobile variations of the computer, 5E63 and 5E63.1. In 1967, after successful tests, the computers went into mass-production. Since then, hundreds of them have been manufactured.
>
> Also in 1967, we began to work on the first ES-compatible computer using the execution module of the 5E76. The first 5E76 was used as part of a six-computer complex.
>
> In 1969, we started working on the 'Global-Scale' air defense control system, intended to serve the area from the Baltic Sea to the Pacific. Its main feature was a guaranteed connection through the regional message switchboard centers and constant twenty-four hour, three-hundred and sixty-five day reliability in automatic operation mode. Physical workspaces for manual operation were built into the system allowing for a "man-machine" connection if necessary, but they were intended only for auxiliary control.
>
> Due to space limitations and reliability requirements of the switchboard center computers, we developed a dual-computer system made up of two 5E76-B computers – modernized 5E76s. This new system was called 65s180, and between 1972 and 1992, thirty-two of these had been manufactured.

All of these machines were developed under Matyuhin's management and designed by him and his colleagues solely for the Soviet air defense systems. This topic itself awaits exploration by other scholars and researchers.

The Second Birth of the M-3

The M-3 was one of the first small computers to be mass-produced. It was so simple to operate that a number of organizations could independently assemble and employ it using only the documentation provided by the Institute of Electro-mechanics. In 1958, M-3's blueprints were delivered to the Minsk computer factory for a small production run, and the first model was completed in September 1959. Its operational storage was on a magnetic drum (2048 31-bit length words), which limited its productivity to 30 operations per second, despite the fact that the arithmetic unit had parallel operation.

This computer earned a good reputation and the government decided to modernize it. Ferrite cores were added to the storage device on the magnetic drum memory, which increased the computer's productivity to 1500 operations per second. Earlier-manufactured M-3s were also given this ferrite core supplement.

One year later, the SKB was given an order to design a new computer that would be inexpensive, simple to install and operate, and easily adaptable to customer's requirements. George Lopato supervised this project, producing the Minsk-1, a two-address machine with a performance speed of 3000 operation per second. Its structure was made up of autonomous functionally completed modules. When its simple logical schemes and modular construction were combined with the great enthusiasm of its developers and factory workers, the first Minsk-1 was completed in only 14 months.

This machine's modular unit construction significantly reduced the debugging time and considerably simplified the safety measures needed for its users. Beginning in 1961, Minsk machines went through a period of rapid development, with a series of modifications based on end-user needs: Minsk-11, for work with communication channels; Minsk-12, with extended storage; Minsk-14 for communication channel work with expanded memory; and Minsk-16 for processing telemetric information from space satellites.

These models were the most popular first-generation small computers in the Soviet Union. They were used in higher education institutes, colleges, research institutes, and construction bureaus. Some of them were employed in factories for solving engineering problems.

The second generation of Minsk computers was divided into two groups. The first group included the basic computer Minsk-2 and its derivative models Minsk-22 and Minsk-22M. The second group included the Minsk-23 and Minsk-32. Two additional variants, Minsk-26 and Minsk-27 were also created in order to broaden the applications of the Minsk system capabilities. The Minsk-26 was used for processing meteorological information gathered from the Meteor earth satellites. Minsk-27 was used for processing telemetric information from the high altitude balloon probes in the atmosphere. Both of these models were the first in the Soviet Union to combine magnetic tape transport mechanisms and telemetric data processing.

The Origins of Computing in Belarus

Corresponding member of the Russian Academy of Sciences – George Pavlovich Lopato – made the greatest contribution in the field of computer development in Minsk. Lopato was born on August 23, 1924 in Ozershina village in the Gomel region of Belarus. His father, the son of a peasant, graduated in 1916 from the Goretska Agricultural Academy and served in the Russian Civil War as a soldier in the First Red Army Cavalry. After the war he worked as a land surveyor. In 1924, he was admitted to the Leningrad Polytechnic Institute, graduating in 1929. He worked as a Chief Engineer at a Moscow factory and later became a lecturer at the Moscow Institute of Agricultural Mechanization and Electrification.

George Lopato started elementary school in 1931. In the summer of 1941, after graduating from high school, he helped build defense fortifications near Moscow to protect against the invading Germans. In October of that year he was drafted into the Red Army and became a Private in the 314th Squad Battalion of Moscow's Air Defense District. In 1946, he was demobilized and entered the Electro-Physics Department of the Moscow Energy Institute. He graduated in 1952 with a degree in Electro-mechanics. Subsequently, Lopato began working at the Gosplan's Electro-mechanic Scientific Research Institute [in Russian: *Nauchno-Isledovat'elskii Institut Electropromishlenosti Gosplana*] in Moscow, where he designed electro-mechanical devices. In 1954, he was sent to work at the Control Machines and Systems Laboratory for several months. There, under Matyuhin's management, Lopato became involved with the development of the M-3 computer.

Lopato participated in the calibration of the M-3 after it was assembled at the Institute of Electro-mechanics. At the end of 1957, the Soviet government sent the M-3's technical specs to both the Hungarian and Chinese Academies of Science. Using those specs, the Chinese assembled a model of the M-3 computer in a telephone factory in Peking, and Lopato was sent to China to help put the machine into operation. It was a difficult job, but Lopato handled it successfully. After returning to the Soviet Union, he was invited to become a Senior Engineer at the Special Construction Bureau at the Minsk computer factory, and started working there in April of 1959. Five years later he was appointed as the manager of the Special Construction Bureau and in 1969, as the manager of the Minsk branch of NISEVT. In 1972, when the branch was modernized and renamed the Scientific Research Institute for Computing, Lopato became its director.

Under Lopato's twenty-eight years of management, the Institute created fifteen models of first and second-generation Minsk computers; eleven models were mass-produced and four models were special orders. Lopato's Institute also produced five ES series models, several personal computers, six special computing complexes, a series of operating and software systems, and more than fifty types of peripheral devices.

Lopato was the chief designer of the Minsk-1, the multi-computer system of homogeneous machines including Minsk-222, and the Naroch dual-use system, which combined 12 ES computers and was employed at the Schetmash to design hardware and software systems. Lopato was the Deputy Senior Designer of the 70K1 system, and later the Senior Designer of several transportable computers for the military.

Lopato was one of the founders of the Minsk school of computer design. It emphasized practicality, placing special importance on cost reduction, reliability, and compatibility of computer technology resources. The work at the Minsk school was time tested; their computers were rapidly placed into mass-production. For example: the Minsk-32 and IBM clone ES-1020 were rolling off the assembly line only two months after the completion of their designs.

Over the course of his engineering career, Lopato emphasized personnel education and training programs. He founded the Computers and Systems Department at the Minsk Radio-Technology Institute and managed it for ten years. He defended his Ph.D. thesis in 1969 and became a Doctor of Technical Sciences in 1975. In 1979 he was elected Corresponding Member of the Soviet Academy of Sciences. He published more than one hundred and twenty scientific works and received forty-five invention certificates. George Lopato received the Order of the October Revolution in 1972, the Red Banner of Labor in 1976, the Soviet Union State Prize and the Order of Lenin in 1983, the Sign of Honor, nine other medals, and four Certificates of Honor from the Belarusian Parliament. He died in 2003.

Mikhail Alexandrovich Kartsev

Mikhail Kartsev belongs to the category of scientists whose discoveries and contributions, for some incomprehensible reason, were fully acknowledged only after their death. The academic elite never presented Kartsev with any special awards or recognition for his work. Not until ten years after his death was the Moscow Scientific Research Institute of Computer Complexes [in Russian: *Nauchno-Isledovatel'skii Institut Vuichislitel'nikh Kompleksov*, or NIIVK], the institute that he himself had founded, renamed in his honor. Computer science and technology was his calling in life, bringing him both happiness and sorrow. He dedicated all of his time to it - at work, at home, and even on vacation.

His son Vladimir remembers:

> Every time I think about my father, I remember him being completely immersed in his work. He had no hobbies to speak of, and if he had spare time, he preferred to read. Occasionally, we went to the movies. He never played sports, and was an active opponent of both dachas and cars. However, as he got older and began to experience leg pain, he purchased a Volga and fell in love with it. Learning how to drive at his age was difficult, but he knew Moscow's streets like the back of his hand and got around the city very well. My father never complained or discussed his problems. It was nearly impossible to get him to talk about the war. He lived in the future, not the past.

Mikhail Kartsev was born in Kiev on May 10, 1923. After his father died that same year, the family moved several times. Kartsev lived with his mother in Odessa and Kharkov, eventually moving back to Kiev in 1941, where he finished secondary school. In the summer of 1941, he was sent to Donbas to work on fortifications. In September, he was drafted into the Soviet army where he served until February 1947. During the Second World War, tank operator Kartsev fought in the south and southwestern areas of the Soviet Union, in the Northern Caucasus and on two Ukrainian fronts. He participated in the liberation of Romania, Hungary, Czechoslovakia, and Austria. The Soviet government awarded him a medal for bravery, the Red Star Order, and medals "For the Conquest of Budapest," and "For Victory over Germany." In November 1944, while still at the military front, he was accepted as a candidate for membership in the Communist Party of Soviet Union, and in May 1945 he became an active member.

After demobilization, Kartsev studied at the Moscow Energy Institute in the Radio-technology department. At the end of his third year he passed all examinations without ever attending any of the lectures. In 1950 – by then a 5th year student – he began working part-time at the Laboratory of Electrical Systems at the Academy of Sciences Power Engineering Institute, where he worked side-by-side with Brook developing the M-1. In 1952, he was appointed to the permanent position of junior scientific assistant. During the design phase of the M-2 computer, he demonstrated exceptional talent – his small team finished the machine in just one and half years (by comparison, the BESM took twice as long and was developed by a larger and much more experienced team). Although the M-2 was not as powerful as BESM, Kartsev called it as a "solid machine."

In 1957, the director of the Radio-Technology Institute, academician Alexander L'vovich Mints, asked Brook to design an electronic control computer for a new experimental radar-tracking complex. To be more exact, Brook accidentally initiated this process himself by bumping into Mints while on vacation at the Kislovodsk resort. While discussing the projects he was working on at his laboratory, Brook mentioned the possibility of using control computers for radar tracking. Together, they came up with a proposal and in 1957 the technical order for the M-4 computer was approved. Kartsev was appointed as the project manager, marking the beginning of his service in designing computer systems tailored for the use in early warning missile defense systems and space observation. At that time, these were the hardest problems to solve because they needed a large quantity of data to be processed. Plus, they demanded the highest calculation speeds, enormous memory, and highly reliable equipment.

In 1957 the first Soviet transistors were beginning to be mass-produced. Thus, Kartsev decided to base the M-4 design on semi-conductors.

For this project, Special Laboratory No. 2 was set-up under Kartsev's management at the newly founded Academy of Sciences Electronic Control Computer Institute. In March 1958, the government approved the draft for the M-4, and in April, the Soviet Cabinet of Ministers issued a special order for manufacturing the machine and assigned a factory already experienced in computer production to Kartsev's laboratory. In April 1958, Kartsev gave the completed construction blueprints to the factory and it began preparing for production; the M-4 designers were present during all stages of manufacturing and adjustment. In 1959, the factory finished the production phase of the two M-4 units and began their fine-tuning. By the end of 1960, the first complex was put into operation and was turned over to the Radio-Technology Institute.

In November 1962, the government issued an order to begin the mass-production of the M-4. However, Kartsev, backed by his team, proposed another new computer for mass manufacturing. He wanted to eliminate the 'bugs' still present in the current model, hoping to make it more technically efficient during production and adjustment. At this time Kartsev's group had just developed a new system of logical elements using high frequency transistors that could make the units operate with greater speed. With the appearance of powerful transistors in the Soviet Union, vacuum tubes were no longer needed.

Kartsev and his team members completed the construction blueprints for the new M-4M very quickly. In March 1963, they delivered design plans for the computer's arithmetic unit to the factory and in August of the same year they finished the rest of the plans for the overall machine design. Exactly one year later, the factory completed the first two models of the computer. The M-4M's adjustment and interface matching required only two months. In October 1964, both models passed technical tests and were accepted by their purchasers. Instead of just meeting the original requirement of one hundred thousand operations per second, the M-4M performed at two hundred twenty thousand operations per second. The computer was technically advanced and required practically no calibrating. The M-4M continued to be manufactured up to 1985; several hundred of them were built.

The M-4M series was eventually produced in three models, designated 5E71, 5E72, 5E73. All differed in operational storage volume. To enhance their capabilities, remote systems AS-1, AS-2, AS-3, etc and an external calculator 5E79, were developed. With the M-4Ms functioning as the base, multi-computer complexes were built and connected in a powerful computer network that operated in real time.

Kartsev recalled this period with excitement and pride:

> Twenty-five years ago, in 1957, one of the first Soviet transistor computers that worked in real time, the M-4, began its development.
>
> In November 1962, the government issued an order to mass-produce the M-4. However, we clearly understood that this type of computer would not be easy to mass-manufacture because its design was based on transistors and it would be difficult to calibrate. We were fortunate though, that during the period from 1957 to 1962, semiconductor technology took a gigantic leap forward, allowing us to build a machine that would be much better than the M-4 plus more powerful than any computer produced in the Soviet Union up to that point. During the winter of 1962–1963 we argued continuously with the Electronic Control Computer Institute because they were firmly against the development of a new machine. They claimed that we would never finish it in the allotted time, it was a huge gamble, and the project would surely fail.
>
> The Military-Industrial Commission of the Presidium of the Soviet Cabinet Ministers resolved the argument in our favor in March 1963. That same month we gave the prepared design plans for the computer's arithmetic unit to a factory managed by V.A. Kurochkin. In August 1963 we finished all of the design plans and one year later the factory completed the first two working models of the computer, ready for adjustment. In October 1964 the first two models were delivered to their customers, and in December 1964 the factory completed five more M-4Ms. These computers were manufactured for over 15 years and are still operating.

Kartsev completed a doctoral dissertation based on his M-4M work, and in 1967 was awarded the State Prize of the Soviet Union.

Ahead of his Time

It would have seemed appropriate for Kartsev to take it easy, or to at least take a short break after working so hard, but it just didn't happen that way. Back in 1966, Kartsev proposed a plan for a multi-computer complex consisting of machines that were especially designed to work together. Preliminary research showed that such a complex could achieve an operational speed of one billion operations per second. At the time, no machine in the world was capable of reaching that speed. That goal inspired Kartsev and his subordinates, and by 1967 they had completed a draft for the design of the M-9 Computing Complex. The Defense Ministry quickly approved the project.

The M-9 Complex consisted of a control processor and four types of computers: a functional-operator, a numerical computer, as associative computer, and a peripheral calculator. The M-9 was supposed to work not just with single numbers, but with groups of numbers that were the approximate representations of functions, or multi-dimensional vectors. In other words, Kartsev designed the M-9 to analyze more in-depth relationships between the data than the contemporary machines were able to do at that time.

The main distinction between this machine (Kartsev named it the functional operator) and the typical computer was in the structure of the arithmetic units' interface, which were timed by the same clocked circuit. At the end of every operation - each computer performed its command during one or two clock cycles - and beginning of the next, the exchange of information between the output from an arithmetic unit and the input into a memory unit (writing down previous commands), and between input into an arithmetic unit and the output from a memory unit (reading the next set of data), occurred without a significant loss of time.

The numerical vector machine, which was part of the M-9 complex, carried out operations on partial functions and multidimensional vectors. The high performance associative machine carried out most of the routine work of sorting and organizing information arrays. The numerical computer worked with an independent program and also with the programs that were synchronized with other computers in the M-9 complex. It coordinated the work of multiple computers and allowed the complex to maintain high productivity while processing heterogeneous information and creating a universal digital means for solving a wide class of problems that demanded very high performance computers.

Unfortunately, the M-9 complex was not mass-manufactured, although its design and the successful demonstration of the prototype were important achievements for Kartsev's team. 1967 was an excellent year for the M-9's designers because NIIVK was founded. Kartsev was appointed as its director and his department became the backbone; it was an official endorsement of Kartsev's scientific school.

In 1969, the Soviet government ordered the construction of the M-10 electronic computer, which was to be based on the already proven M-9 vector computer. Doctor of Technical Sciences Leonid Vasilievich Ivanov recalled, "The event was preceded by a compelling meeting to consider the future of two projects already in the making: the Elbrus, managed by Lebedev, and the M-10, managed by Kartsev. Lebedev vigorously argued against a multi-processor version of the Elbrus, insisting on a single processor version for maximum productivity. Academician Glushkov supported both directions, and they were approved."[35]

Early in 1970, the production factory began setting up to assemble its first M-10 model. Later that same year the construction blueprints were finalized and by August 1971 the prototype of M-10 had been manufactured and ready for adjustment. At the same time, the construction plans for the industrial model of the computer were undergoing revision in preparation for their mass-manufacture. 1971 turned out to be a very hard year for Kartsev and the strenuous work took its toll: a heart attack left him bedridden for several months. Fortunately, he recovered.

By June 1973, every system component of first M-10 model was assembled and tested according to the technical specifications, and the machine finally came together as a complete unit. In September, the first industrial model of the M-10 successfully passed all technical tests and was placed into trial operation for additional software debugging.

By December, the factory had finished testing the second model and begun its mass-manufacture; the M-10 was produced for more than 15 years. Dozens of these computers were made and many of them are still in service today. Several powerful computer complexes had been built using the M-10 computer as the base. In 1976, an M-10 model from one such computer complex, and its software, successfully passed the rigorous state testing.

[35] Ivanov's article appeared in the Russian-language journal *Questions of Radioelectronics* [*Voprosii Radioelektronniki*], Vol. 2, 1993.

A group of NIIVK specialists and the factory were awarded the Soviet Union's State Prize for the M-10 in 1977. Among those from the NIIVK receiving the prize were Deputy Senior constructor Leonid Ivanov, Alexander Alexandrovich Krupsky, Leonid Yakovlevich Miller, Yuri Rogachev, Rene Shidlovsky, and software designer Alexander Karasik, along with Senior Engineer Anatoly Shishilov and Deputy Senior Constructor Valeri Alexandrovich Mushnikov from the factory. As chief of the project, Kartsev was awarded the Order of Lenin. Over a hundred of NIIVK specialists and factory workers were awarded other special Soviet orders and medals.

The M-10 computer was actually a synchronized multi-processor system and was part of the third generation of Soviet computers: its basic logic elements consisted of the 217-series Posol microprocessors. The computer was intended to support complex automated control systems in real time and to solve a variety of scientific problems. Having inferior microelectronics for its technological construction base, it did not perform as fast as the CRAY-1, which appeared at about the same time. Yet the M-10 possessed some architectural potential advantages in terms of the average number of processor cycles per single executed operation. The lower the number, the better the computer's architecture: the M-10's average number of processor cycles per single operation ranged from 0.9 to 5.3. The Cray-1's ranged from 0.7 to 27.6. The minimum values for both computers were close, but the M-10's maximum value was significantly less than that of the Cray-1.[36]

The M-10's value becomes even more apparent when considering why it was originally built: Kartsev and his colleagues designed the M-10 in absolute secrecy for the Soviet Missile Attack Warning System [in Russian, the *Sistema preduprezhdeniya o raketnom napadenii*, or SPRN] and for general outer space surveillance.[37] The system provided the Soviet Union's military leaders with comprehensive information regarding a possible threat of missile attacks and continuous observation of the cosmos. In space, via satellite, the SPRN detected missiles launches. On the ground, the system was composed of nine powerful radar-tracking stations located along the Soviet Union's borders near Riga, Murmansk, Pechera, Irkutsk, Balkhash, Mingechaur, Sevastopol, and Mukachevo, which were supported by a network of M-10–based computing complexes.

Up until the early 1980s, the M-10 reigned as the highest-performing computer in the Soviet Union in speed (it ran at about 20-30 millions operations per second), internal memory capacity, and data transmission in a multiplex system. For the first time in the world, its design allowed for seven computers to be connected and have a direct information interchange (without multiplex channels) between individual computer programs. Also, the system featured automatic reconfiguration of a field of processors, a second level internal 4-megabyte random access memory, and external access to both levels of internal memory.

These innovative technical features received eighteen invention certificates and five industrial

[36] *Author's note:* For more on this, see B.A. Golovkin, "The Evolution of Parallel Architectures and the M Series Computers," in *Questions of Radioelctronics*, No. 2, 1993.

[37] Editor's note: The first public information about this was disclosed only on April 1, 1990 in *Pravda*, with the publication of A. Gorokhova's "Stoyanie pri Pestryalove," or "The Problem at Pestryalov." Pestraylov was a top secret Soviet military site.

model certificates. Beginning in 1980, Kartsev and his team gave the system new storage devices and renamed it the M-10M. The M-10 and M-10M computers had fully compatible software and hardware. In his presentation at the NIIVK's 15th anniversary, Kartsev discussed these memorable years:

> In 1967, we made an audacious proposal – to build the M-9 computing complex. Because it was the 50th anniversary of the October Revolution, I nicknamed the complex "The October." The Ministry of Devices building, where we were set up, was too small for us, but the officials told us: 'Since you already work for Kalmykov, go see him.'
>
> The M-9 project was never realized. But in 1969, we started the M-10 project, and it was up and running by 1973. For many years, it was the most powerful computer in the Soviet Union. This complex is also responsible for some unique scientific discoveries, particularly in the field of physics. Yet, the project was not greeted with open arms, and frankly speaking, the authorities told us that we were crazy, that we could never make a computer out of a heap of metal, and that the whole thing would never work. Only now we've got them convinced, and subconsciously they understand that a big computer needs a huge amount of equipment. But back then, nobody could picture it. The work was extremely difficult; our team had to work at a number of sites around Moscow: at the Sokol-1 enterprise and on Great Pochtovaya Street, plus in a number of sub-basements: on Great Vasilevsky Lane, on Burdenko Street, Plyushchikha, and on Shchukina Street.
>
> After the establishment of the Electronic Control Computer Institute, the team acquired 590 square-meter premises of a former cabinet-maker's shop at Sokol square. In order to accommodate the whole team, we still had to lease other premises – mainly sub-basements – all around Moscow. The Institute constructed a separate building for us in 1975, and then added the laboratory wing as a special project, but not until 1985 through 1986. Nevertheless, the Ministry's managers were always friendly and supportive, as were our customers. They helped us get down to business and we came of age.

It was not difficult to understand the skeptics' position, especially considering some numbers: the BESM-6 computer operated with 60 million transistors, 180 thousand semiconductor diodes and 12 million ferrite rings. The M-10 computer used 2 million microchips, 1.2 million transistors, and 120 million ferrite rings. It was not a "heap of metal" as Kartsev called it, but an unimaginable number of electronic elements that was supposed to be seamlessly integrated with complex circuitry. When all of the bugs were finally worked out and the machine became operational, its total annual loss of productivity amounted to only 10 minutes!

The Last Battle

In 1978, Kartsev began developing a multi-processor vector computer, calling it the M-13. By 1981, his team delivered the blueprints for its separate units to the manufacturers. The M-13, whose main purpose was real time large data processing, marked the fourth generation of Soviet computers and used large integrated circuits as its elemental base. Architecturally, it contained four general units: a central processor, hardware equipment for operational system support, remote equipment interfaces, and a special processor.

The M-13's special processor was used for working with large arrays of relatively short digit-length, such as Fourier transformations, correlation function calculations, threshold comparisons, etc. The operational speed of the M-13's special processor at its maximum performance capacity could reach up to 2.4 billion operations per second.

Kartsev finished his May 1982 speech at the Institute's 15th anniversary ceremony with the following words:

> …It seems to me that we have never completed a project as successfully as we have now,[38] nor have we ever had a project as difficult as this one, where we encountered so many problems. But I just wanted to remind you, that we have fallen in love with every project that we have ever attempted, and the problems were always staggering. Again and again I wake up in a cold sweat because our 'brain child' is going through production problems. Of course, it is probably just insomnia of an old man. On the other hand, only two years and eight months have passed since we received the order from the government to build the computer. It is simply not possible for our group, which consists not only of the seasoned gray-haired veterans, but the highly energetic educated youth, to fail our 'brain child.'
>
> Someday, when we think of this moment, we won't believe that it really happened to us, but for now, all we need is this victory, just this one single victory, and we would gladly give up anything to achieve it.[39]

Kartsev's words became a living testament among specialists at the Institute that he had founded. He died on April 23, 1983. Rogachev succeeded Kartsev as the director of the Institute and completed the M-13 project; in 1984 it went into mass production.

One of the Few

Some specialized M-series computers designed under Kartsev's direction were employed for weaponry-related calculations by the Soviet Army. The M-4M computers known under the army codes 5E71, 5E72, and 5E73 were ten times more powerful than their contemporary civilian models, M-220, BESM-4 and others, and operated at military facilities from 1967 to 1981. The M-10 computer, known by its army code 5E66, significantly exceeded other contemporary domestic models such BESM-6 and the ES-1060. Using computer models 5E71 through 5E73 and 5E66, the Soviet Union's largest multi-computer complex was formed. Operating around the clock, its 76 computers functioned on a common algorithm and were connected by data transmission channels spanning tens of thousands of kilometers.

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[38] *Author's Note:* Kartsev was referring to the M-13.

[39] *Translator's and Editor's note:* This last sentence Kartsev quoted from Bulat Okudzhava's song, known by heart by most Soviet citizens and first heard in the 1970 film *The Belorussian Railway Station* [in Russian: *Belorusskii Vokzal*], directed by Andrei Smirnov and produced at the Mosfilm studios. It is an epic tale of victory at the end of the Second World War and wartime camaraderie. Kartsev, who had served as a tanker on the front lines in the Great Patriotic War, had been awarded a medal for bravery and the Red Star Order at age twenty for his heroism.

Kartsev understood that computers designed at NIIVK were not only capable of serving the military air defense warning system, but could produce significant results in scientific research that required complicated calculations, which were not solvable on any other Soviet computers of that period due to their slow operating speed and small internal memory. Despite the military leadership's resistance, Kartsev got permission to publish the technical documents on the M-10 computer and actively pursued establishing connections with the scientific research organizations that were in need of high-performance computers. Because of his initiative, a variety of extremely complex scientific calculations were completed, including plasma collapse simulations that could not be done on the American CDC-7600 computer.[40]

Kartsev wrote five books and fifty-five articles on the theory of computer technology and held 16 invention certificates. His *Arithmetic Units of Electronic Digital Computer*s, published in the Soviet Union in 1958 and later abroad, and *Digital Computer Arithmetic* (1969) provided the theoretical base for arithmetic units and its conclusions have been widely used in textbooks. His last works, *Digital Computer Architecture* and *Computing Systems and Synchronous Arithmetic* (1978) were the first attempt to establish a scientific base for computer architecture and parallel calculation design.

Kartsev was one of the few who initiated computerized optical-electronics research in the Soviet Union, and his Institute built a fiber-optic system for a multi-computer complex of six M-10 computers. For his achievements, Kartsev was awarded the "Medal of Honor" Order in 1966, a medal "For Valiant Labor" and the State Prize of the USSR in 1967, the Order of Lenin in 1978, and the Order of the Red Banner of Labor in 1971. In 1993, his institute was renamed the Kartsev Institute of Computer Complexes. The author finishes this section on Mikhail Kartsev with an excerpt from a letter he received from Kartsev's son, Vladimir:

> The few pages that I am sending you are, of course, much less than what my father deserved.
>
> The more I think about him, the harder it is for me understand what kind of person my father really was. Without a doubt, his work was his life. Nevertheless, he would have enjoyed success in any other field, had destiny led him away from computer design.
>
> My father valued talent and skill above all other individual qualities, regardless of whether it was the ability to solve theoretical problems or to drive a car. Unfortunately and quite frequently, he was forced to place the fate of his work in the hands of the people who lacked such qualities, which generally resulted in him having to do most of the work. He once said, 'Every project manager must be ready to do the whole project with his own hands. It's not that easy, but it's worth it!'
>
> Father disliked incompetence, regardless of the reason. I remember his indignation when he tried to put together a children's radio-set kit, in which none of the parts matched the diagram. On the other hand, he was extremely

[40] *Author's note:* Some of these results were published in the Soviet Academy of Sciences reports in volume 245, 1979, No. 2, pages 309-312; and in the *Proceedings of the XV International Conference for Ionized Gas Phenomena* held in Minsk, July 1981.

patient in overcoming problems that he considered worthy of his attention. When he was doing what he loved, he was extraordinarily calm.

In addition to his regular work during the day, my father gave evening lectures at the university. He even became a professor, almost as an afterthought. When his students took his exams, it was always open book, and they were allowed to bring any books they wanted. Of course, and I firmly believe that, he did not require them to know as much as he did. Nevertheless, his exams were considered difficult. He never asked them to memorize the information, but instead wanted them to understand the subject. How many people can say that?

Father's intellect remained in his books and in the work of his followers. But the essence of his being, his personality, his style and his elegance, remained only in the memory of those who knew him. My father's intellectual demeanor made him vulnerable when he needed to assert himself or to gain support from the authorities, but without it, like without a sense of humor, the person we all remembered would not have existed.

My father's favorite books were *The Twelve Chairs* and *The Little Golden Calf* by Ilf and Petrov. Together, we also read their *One-Storied America*, and *The Two Captains* by Kaverin.[41] Father could recite Pushkin's *Eugene Onegin* by heart. Books, and not just scientific books but literature in general, were his great passion. He easily read in English also, but mostly scientific works, and once was lucky enough to practice his conversational English with two Arabs, who happened to be sitting next to us in café.[42] When I was learning German in school and was cramming for a test, my father, who memorized the passage by listening to me read it over and over, suddenly began speaking to me in German. Formally, he only studied English, but long ago, when German was a popular foreign language to study, he read every textbook his school had and apparently retained most of it.

One of father's favorite movies was the Soviet film *The Taming of Fire*.[43] It seemed that father was not a stranger to romanticism, and I would even go as far as to say that in general, intellectuals are often prone to be romantics. He must have seen something familiar and close to his heart in the movie. It must have been for the same reason he loved Viktor Nekrasov's *In the Trenches of Stalingrad*, although he usually did not read books about the war, considering them to have little in common with his personal war-time experience.

He never worried about his health. He probably would have lived longer if he exercised and took regular vacations. But then, he would not have been true to his nature. He wanted to live and die on his own terms; to be a real director of

[41] *Editor's note:* Ilya Ilf and Eugene Petrov were Soviet witty satirical writers well known by all Russians. Veniamin Kaverin was a socialist-realist Soviet writer who published this novel in 1947.
[42] *Translator's Note:* Today it is difficult for westerners to understand how problematic it was for Russians to meet foreigners who spoke English. Living in the closed society, particularly for a scientist employed by the military, provided little chance for free and informal communication with foreigners. That was why Kartsev had limited practice in his foreign language skills.
[43] *Editor's note:* This film was produced by director Danil Khrabrovitskii in 1972. It celebrates those who developed the Soviet rocket and space program.

> the Institute he had established and to continue to lead computer technology in the direction that he pioneered.

He was dear to everyone he came in contact with; not just as an authority figure, or a leader, or a great worker, but as a kind man who cared about people, was very honest and unassuming. If he had any shortcomings, there was only one—he was too trusting and considered others to be just as fair, honest, and compassionate as he was. Mikhail Kartsev was and remains one of the world's greatest figures in the history of computer science and technology.

The Post-War Renaissance

Only a handful of people know that in November 1953, half a year after Lebedev and his team completed BESM, the first sequential computer, TsEM-1 [in Russian: *Tsifrovaya Elektronnaya Mashina-1*], went on-line at the Institute of Atomic Energy in Moscow and operated until 1960. The decision to develop this machine was almost accidental. At that time, Sergey Sobolev was Kurchatov's assistant director at the Institute of Atomic Energy, and in 1950 he happened to come across the description of the ENIAC in an American magazine. Being aware of the Strela and BESM projects, Sobolev handed the American magazine to the supervisor of the institute's measurements laboratory, N.A. Yavlinsky. The magazine then turned up in the hands of a young specialist, Gennady Alexandrovich Mikhailov, who had graduated from the Ivanovsk Power Institute just three years prior. Among the scarcely available foreign publications, he was able to find only a couple more articles in British journals about the EDSAC computer, which was constructed at the Cambridge University. Unfortunately, these journals presented only the flowchart and operational features of the machine. The binary system, as well as programming, was not widely known at that time, and there were no textbooks on solving problems using numerical methods. There was yet another difficulty: the team that designed and assembled the TsEM-1 consisted of only four people – two engineers and two technicians – Mikhailov included.

Just like the MESM and BESM's designs are attributed exclusively to Lebedev, the TsEM-1's scheme belongs entirely to Mikhailov's.

The TsEM-1 contained an operating memory of 128 binary 31-bit digits on 32 mercury delay lines; each one had 16 digits with a sequential retrieval rate of 512 kilobytes per second. The memory capacity was later extended to 496 digits – 4096 digits on a magnetic drum. Data input and output were performed using as ST-35 telegraph apparatus. Digital printouts on telegraph tape were copied onto 5-track perforated tape, and data input from the same perforated tape was sent through a photographic reader at high speed. The machine's operational modes were observable on an oscilloscope – a precursor of our modern digital displays. The average addition and subtraction speed of the TsEM-1 was 495 operations per second, 232 operations per second for multiplication and division. It contained 1900 electronic vacuum tubes, consuming roughly 14 kilowatts of power per hour. The machine was housed in six metal racks measuring 80 x 180 x 40 centimeters each. The main physical limitations of the TsEM-1 were found in its mercury delay lines: because of its 1000 millimeter long, 18 millimeter diameter quartz acoustic radiator, it was necessary to constantly check for sharply focused ultrasonic rays and for the reflection levels from the receiving quartz. Luckily, weekly preventive maintenance guaranteed consistently reliable operation of the TsEM-1.

Like MESM and BESM, TsEM-1 was an original project, based on ingenuity and imagination of its creators, and it was substantially different from EDSAC. For example, multiplication was carried out by rounding off; division was done without recovery of a remainder; and a two-address instruction system replaced the previous one-address unit. Lebedev proposed these improvements during the TsEM-1's construction. In addition, the command modification system by means of "control characters" was unique. It facilitated program compression, which in view of the computer's limited immediate access memory was very important.

Even within the Atomic Energy Institute TsEM-1 was not acknowledged in its early years. The supervisor of one the institute's branches, physicist Lev Andreevich Artsimovich, was initially quite skeptical about this kind of technology. After some time, he changed his mind and found the computer to be useful and powerful when he saw what it could produce: at the end of 1954 Mikhailov had programmed and solved an equation on the TsEM-1 that described the process of plasma filament compression in experiments on controlled nuclear fusion. S.M. Osovtsev, who was a member of the theoretical physics team headed by Mikhail Alexandrovich Leontovich, had set up the equation. At first, Artsimovich rejected the result of the accelerated plasma filament compression with oscillations overlaid on it. However, after three or four days of theoretical analysis, he obtained the same results. A great number of calculations on nuclear reactors functions and dosimeters were made on the TsEM-1; Lebedev, M.D. Millionshchikov and others became quite familiar with the machine. Mikhailov adds some new touches to the portrait of Lebedev:

> In the 1950s, working as a staff engineer at the Kurchatov Atomic Energy Institute, I was fortunate to meet many of our distinguished scientists. Some of them I only saw from afar at lectures and seminars, people like Kurchatov, Kikoin, Tamm, Ioffe, Timofeev-Resovskii, and Sakharov. Others, such as Sobolev, Artsimovich and Leontovich, I developed closer, more personal relationships with.[44]
>
> When I defended my Master's thesis, the test administrators for computer technology were academicians Artsimovich and Lebedev. It still gives me a great pleasure to think about being in the company of those two brilliant scientists, plus remembering many other talented scientists of the 1950s and 1960s. My only worry is that if Sergei Alexeevich were to be judged solely by his appearance, he would have looked ordinary compared to his colleagues; he had neither a remarkable statue nor a determined face. But it was his humility along with his immeasurable talent that made Sergei Alexeevich stand out above the rest.
>
> I heard of him for the first time from my lab colleagues, who referred to him as an exceptionally talented scientist. Our team, headed by N.A. Yavlinsky, moved to the Nuclear Power Institute where Lebedev was working. Yavlinsky and Lebedev were friends and their families spend a lot of time together until 1962, when Yavlinskii perished in an airplane crash along with his wife and son. Thanks to that friendship, I had the pleasure of seeing Sergei Alexeevich

[44] *Editor's note:* Mikhailov is referring to the famous Soviet physicists Igor Tamm, Isaak Kikoyin and Abram Ioffe, and biologist Nikolai Timofeev-Risovskii.

> at family parties as well. Even then, he remained unobtrusive and plain, without a hint of self-flattery or false modesty.

In 1959, Mikhailov moved to Kiev and became a department head at the Ukraine Academy of Sciences Computer Center. He continues:

> Summer of 1961 was the last time Sergei Alexeevich visited Kiev, which had always been dear to him. He visited our computer center that had already moved from Feofania to Lisogorsk. We organized a trip to Feofania so Sergei Alexeevich could once more see the place where he started his work. By that time, he had achieved almost everything: he had become an Academician, a Lenin prize-winner, a Hero of Socialist Labor… it seemed to be the time for honors. But Sergei Alexeevich was rather modest and would never allow grand meetings, banquets, or celebrations to be held for his arrival. There was no secret about his coming, but only a few of us knew about it.
>
> Once, at his anniversary celebration at the Institute for Precision Mechanics' conference hall, he looked very embarrassed and uncomfortable dressed in an Uzbek robe and *tyubeteika* [an embroidered Central Asian skullcap], while great fuss was made over the entire procedure.
>
> I never heard a bad word about him. But, at the same time, it would not be true to call him an infinitely kind soul. On the aforesaid Masters' examinations, Sergei Alexeevich quietly gave a deserved "two" (equivalent to an "F") to his own graduate assistant. I remember when we discussed defending the theses, he made an ironic remark: 'In our institute we have a division of labor: some people make machines, others defend dissertations.'
>
> Having visited our laboratory and scrupulously tested TsEM-1, Sergei Alexeevich surprised us with this question: 'Don't you bang it with a hammer?' It turned out that a rubber mallet was a common laboratory tool used on the BESM, and banging it on the machine's solid-state metal frame was typical machine maintenance! No less surprising would be an order not to work on a problem longer then fifteen minutes, unless it required recalculation, so as not to waste the machine's time.

Everything mentioned above relates to the first generation of computers with vacuum tubes. Second-generation machines were developed without them, and Lebedev's first semiconductor machines were the BESM-3 and BESM-4. These machines emerged as a result of youthful enthusiasm: these developments came about at SKB and at the Institute for Precision Mechanics outside of the state "plan" – at the initiative of the young engineers and technicians.

Lebedev's team member, A.A. Gryzlov, recalled that a relatively small group of young coworkers – engineers, technicians and self-taught inventors – was commissioned to master the first semiconductor components in 1964 in order to prepare the SKB staff for the upcoming BESM-6 project. First, they were given the task of developing prototypes for the computer's main units to gain some design experience. The final prototype was named BESM-3M. Inspired by their success, the young coworkers proposed a daring idea: to develop a new machine based on the available prototype which would repeat the block-logic diagram of the M-20 computer, only using new components. SKB's head at that time, O.P Vasiliev, supported the young workers' ideas, and Lebedev raised no objections to the "unproven" youth and thus, BESM-4 was born in the creative and friendly atmosphere that pervaded Lebedev's institute.

The State Committee headed by Dorodnitsyn noted the high performance and innovative features of the first Soviet multi-purpose semiconductor computer. The machine was characterized by its reliability, small size, and low price; it quickly became popular among users. When a BESM-4 was installed in the Soviet Academy of Sciences Computing Center and people inquired about it, the always answer was: "Your machine demoralizes young engineers. They don't have to do routine maintenance checks because the machine is error-free. It is too reliable." Nothing else needed to be said.

The Scientist's Triumph

After the work on the vacuum tube-based computers BESM-2 and M-20 was finished, the design of the second-generation supercomputer BESM-6 – the semiconductor based masterpiece – commenced at the Institute for Precision Mechanics. Two of his former students – Vladimir Andreevich Melnikov and Lev Korolev – assisted Lebedev with this project. Melnikov and Korolev both became Lebedev's operations managers and famous young scientists in their own right. They studied and analyzed everything they could get their hands on that was published about designing high-speed computers. Lebedev led the mathematical modeling of the machine. As a result, they developed a machine with an original system of commands that made programming user-friendly, had a simple internal structure, reliable system of elements, and a design that simplified maintenance.

The BESM-6 became the first Soviet computer that was approved by the State Committee with a complete software package, and many leading Soviet technical specialists were involved in its development. However, Lebedev was the first one to realize the effect of the joint efforts by the mathematicians and engineers on the creation of computer systems. The development of computer technology evolved from a purely engineering to a mathematical problem, which could only be solved by the pooling of resources.

Finally, and this is also important, Lebedev formulated all diagrams of BESM-6 with Boolean algebra, which opened vast horizons for the automation of design, and preparation of assembly and operational documentation. Later, the design was further streamlined by Gennady Grigorievich Ryabov, creator of the Pulse System for which he was awarded the Soviet State Prize.[45]

BESM-6 featured: 1) a pipeline control system, or as Lebedev called it in 1964, "plumbing," according to which the flow of commands and operands were simultaneously processed (up to 8 machine commands at each stage); 2) the use of associative memory on super-speed registers that reduced the number of retrieval calls to the ferrite memory, thus optimizing calculations; 3) a stratification of operating memory into autonomous modules, which enabled simultaneous, multi-directional calls to memory units; 4) a multi-program operational mode for real-time work on several problems with specified priorities; 5) a hardware mechanism for transformation of mathematical addresses to physical ones, which made it possible for dynamic distribution of the operating memory in the computational process; 6) a page system of memory that in turn

[45] *Editor's note:* Ryabov became Director of the Institute for Precision Mechanics in 1984.

developed protection mechanisms for numbers and commands; and 7) an up-to-date interrupt system that facilitated the automatic transfer from one computational task to another, accessing external units and controlling their operation.

BESM-6 contained 60,000 transistors and 180,000 semiconductor-diodes. Its element base was brand new at the time and became the foundation of circuit engineering for third and fourth-generation computers. The principle of dividing complex machine logic built on diode blocks using single transistor amplification guaranteed a simplified manufacturing process and reliable operation. BESM-6 achieved average speeds of up to one million operations per second.

The BESM-6 prototype was tested in 1965; in 1967, the first manufactured model had its trial run. Three additional models were made at the same time; because of joint collaboration with the manufacturer, there was virtually no lag time to prepare the computer for mass production.

The State Committee headed by Keldysh, who was still the President of the Academy of Sciences in the 1960s, understood BESM-6's importance. With this technology, the Soviet Union established computing centers that facilitated real-time control systems and coordination of data tele-processing systems. BESM-6's were used for simulating complex physical processes and control processes, and also for development of new computer software in computer aided design systems. The basic technical design that Lebedev and his colleagues had employed during BESM-6's development gave the computer an enviable service life: BESM-6 was manufactured for over seventeen years. Their users loved these machines, and by the 1970s BESM-6 set the standard for high-speed computers in the Soviet Union.

The 1975 Apollo-Soyuz space mission was controlled from a new computer complex that included a BESM-6 and other domestic high-speed computers developed by Lebedev's students. Prior to this, the space mission telemetry data processing would have taken approximately thirty minutes. Using the new computer complex, the work was performed in one minute. Soviet scientists completed all of the Apollo-Soyuz mission's data processing one half hour earlier than their American colleagues. This marked Lebedev's real triumph: his school and his students developed a first-class computer that was capable of competing with the best machines in the world. For their work on BESM-6, Lebedev and his team won the State Prize.

While writing this manuscript, I came across the work of the German philosopher Frederick Nietzsche. One of his statements caught my attention: "The ability to show the way is a sign of genius." Immediately, I thought of Lebedev.

"To Avoid a War"

From the very beginning, Soviet computer technology was employed for military purposes. Lebedev's role as a chief computer designer for the Soviet Union's anti-missile defense system was considered top secret, and his work was shrouded in secrecy. In 1990, sixteen years after his death, Lebedev's participation in the development of the Soviet Union's first anti-missile defense systems was finally revealed in *Sovietskaya Rossia* [Soviet Russia] newspaper article, August 5 issue, "Money for Defense" by Grigorii Vasilievich Kisunko.

BESM-2, M-20, and BESM-6 enhanced the rapid development of scientific solutions to the most complex anti-missile defense problems in the post-war years. They became the foundation for the huge computing complexes that supported the anti-missile defense systems. Other nations were able to solve the same problems, but many years later. Such military developments were the result of the Cold War, and Sergei Alexeevich could not separate himself from the demands of that time: the backing from the Soviet military greatly improved the economic position of the Institute for Precision Mechanics and accelerated research on universal high-speed computers that would eventually support defense computing centers in the Soviet Union. This was the Institute for Precision Mechanics' main function throughout the Cold War.

Lebedev anticipated all of this. While still in Kiev, he sent a letter to the Ukraine Academy of Sciences Presidium on January 15, 1951:

> The Ukrainian Academy of Sciences is developing a prototype of a high-speed computer. This computer will be capable of solving problems with unmatched speed and accuracy. For example, it would be able to solve problems in such areas as intra-atomic processes, jet technology, radar location, the aircraft industry, structural mechanics and others. Tremendous speed and accuracy would enable us to develop missile control devices for accurate targeting through continuous in-flight corrections of guiding missiles' trajectories.

The Ukrainian Academy's Presidium could not support Lebedev's idea because there was no money available for it: Ukraine's national economy was devastated after the Second World War. Moreover, Ukraine's leaders did not understand the computer's importance. After moving to Moscow and becoming the director of the Institute for Precision Mechanics, Lebedev implemented his long-term plan to integrate computing into national defense when the work on the BESM was almost finished. During this period, Sergei Alexeevich mentored the young specialist Vsevolod Sergeevich Burtsev, who had distinguished himself by calibrating the original BESM. Having lost his parents during the war, Burtsev became very attached to Lebedev. Earlier, he had worked at one of Moscow's scientific-research institutes devoted to developing radar systems and applied that knowledge to his projects at the Institute for Precision Mechanics: Between 1952 and 1955, the Institute developed two special computers, Diana-1 and Diana-2, for automatic data reading and radar air target tracking. Subsequent research led to the design and development of a whole generation of computers for use in the anti-missile defense system.

Lebedev appointed Burtsev as his chief assistant, responsible for integrating computers with the defense sector. Sergei Alexeevich's trust in Burtsev inspired the young specialist, who contributed significantly to the M-40 vacuum tube computer. It began operating in 1958 at 40,000 operations per second, several months ahead of the M-20. Soon after, the Institute produced the M-50, which featured floating-point arithmetic. These machines were supplied with a channel multiplexer that enabled them to receive data asynchronously from six directions. The first Soviet anti-missile defense system incorporated them. The government appointed 35-year old Grigorii Kisunko as lead designer of the first soviet anti-missile defense system.

Even though some of the experts laughed at his idea, claiming that shooting down a flying missile with another missile was pure fantasy, Kisunko was undeterred by their ridicule. He firmly believed in the potential of combining the latest radar technology with the new computer technology – the two developing scientific fields that could became the basis of a new defense system. Kisunko headed a group of enthusiasts who developed and substantiated the principles of the anti-missile defense system. Over the course of a year, the group solved several complex problems: How to detect and effectively track small, fast moving ballistic missiles? How to set up automated connections between distant anti-missile defense installations? How to rapidly process data and make appropriate decisions? How to successfully shoot down a target? To solve these problems, they came up with the idea of developing an experimental system – the "System A."

West of Lake Balkhash in the Kazakhstan Republic, a desert area inhospitable to humans stretches out for hundreds of kilometers. Temperatures rise to forty degrees Celsius during the summers, and the only living creatures are poisonous spiders, snakes, and scorpions. In 1956, first workers arrived there to begin construction of the Polygon, an anti-missile experimental test site. Manufacturers and military researchers followed, and eventually thousands of people were employed there. The desert became "imaginary Moscow," surrounded by the anti-missile defense system in preparation for a missile attack from Kapustin Yar and Plesetsk.[46] Workers were supposed to set up the experimental equipment to detect incoming missiles and then shoot them down over the test range, which was unofficially called Sari-Shagan, after the nearest populated area. Everyone worked under wartime-like conditions: builders lived in dugouts and there was a dire shortage of water. Dust storms were common. Construction on railroad tracks, highways, and electric power lines was carried out simultaneously. A military base was erected along with civilian housing and a research complex, followed by a communication network.

Kisunko, Lebedev, and Burtsev displayed tremendous foresight and courage, even though their task seemed impossible and the vacuum tube computers they depended upon were not always reliable. When Kisunko first viewed the BESM he thought that this "home made" machine would never be mass-produced, so decided to concentrate on the Strela. He signed a contract with SKB-245 to build a special computer for the Polygon based on the Strela, and as a backup made a similar arrangement with Lebedev's Institute. Work continued at the Polygon complex, and a large hall where both machines were supposed to be located was divided into two sections. The general contractor for this project quickly realized that half of the hall allocated to SKB-245 would remain unoccupied, while the M-40 quickly materialized on the other side. Thus the scientists at the Institute for Precision Mechanics were able to demonstrate that they could write scientific papers just as well as solve complex anti-missile defense problems with their M-40 computer, which was based on the BESM.

Within a year, the first successful experimental missile-detection radar system in the Soviet Union was in operation. Two years later anti-missile launch tests commenced, using the fully completed computer-based System A. The system's components were new at that time: high-quality radar, an automatic control system based on the M-40 high-speed computer, fast and maneuverable antimissile devices with precision guidance capabilities and electronic digital coding. Things did not go smoothly at first because some Communist leaders overseeing the project remembered that Kisunko was the son of a repressed kulak.[47] But eventually, the test day arrived, and everyone remembered for the rest of their lives…

…As soon as the dummy missile was launched, it immediately appeared on the radar locators. Then, the anti-missile launch command was given and the operator pressed the launch button. The instant the target mark became visible on the screen, the anti-missile device was launched. Minutes later, an indicator sign lit up: "Target Destroyed." The following day, recorded footage

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[46] *Editor's note:* Kapustin Yar and Plesetsk were top-secret Soviet missile bases.
[47] *Editor's note:* Kulaks were landowning peasants who, in the 1930s were brutally repressed, arrested, and stripped of their land and societal status by Stalin.

of the event proved that the anti-missile defense system was indeed successful - the ballistic missile's warhead was completely destroyed.

This event marked a breakthrough in military might, in science, and even in politics: Nikita Khrushchev casually remarked about it at a press conference, "One may say that our missiles can hit a fly in outer space." At the time, many world leaders were not sure whether Khrushchev was serious or not. Other nations had not considered non-nuclear means for destroying ballistic missiles, and Soviet progress in anti-missile defense systems forced the United States to sign the anti-ballistic missile defense system restriction treaty in 1972.

Once, one of Sergei Alexeevich's daughters asked him: "Why do you make computers for the military?" He replied: "To avoid a war."

Behind these accomplishments stands a colossal body of work by many teams of scientists, including the ones Lebedev supervised. They spent a great deal of time at the Polygon. The creators of the first anti-ballistic missile defense system were awarded the Lenin Prize. Among them were Kisunko, Lebedev, and Burtsev. Their vacuum tube machines employed at the Polygon were eventually converted to semiconductor computers. One of them was a three-processor computer that performed 1.5–2 million operations per second. This was the first Soviet computer based on integrated circuits. Eventually Soviet scientists and engineers oversaw the development of a reliable, miniature multi-purpose computer that took up only 2 1/2 cubic meters. The experience of building the first third-generation computer served as the base design of the Elbrus* supercomputers.[48]

Lebedev's Scientific School

Lebedev's scientific school was the culmination of his life's work. It came as the result of his monumental dedication and the creative contributions that his colleagues made during the development of the most complex classes of computers: universal high-performance and specialized. Leading technological progress in a new direction, plus establishing a new scientific school is an intricate and innovative process, and the creation of Lebedev's scientific school is definitely a classic example of such process. From the beginning, Lebedev adopted and consistently practiced one core principle of computer construction—the process of early computational parallelization. The arithmetical units in both the MESM and BESM were equipped in parallel, as were the M-20 and M-40. The BESM-6 used a kind of pipeline calculation method, and subsequent computers were built on a multiprocessor basis.

Every new computer was the result of a radical reworking of the preceding one, with a critical overview of everything new in the world of computers, both in the Soviet Union and abroad. In the Soviet Union however, the inferior technological and industrial capacity significantly undermined the speed of development. To simply exchange one elemental base for another, only slightly improved one, did not bring creative satisfaction: the semiconductor-based BESM-4 was an advanced machine that clearly went beyond its proposed plan, but it still incorporated the structure and commands of the M-20, and Lebedev did not give it high marks. He unquestionably supported the initiatives of the young scientists who created the first

[48] Elbrus is the highest mountain in the Caucasus and Lebedev was an amateur mountain climber.

semiconductor computer, yet, together with his able assistants Alexander Tomilin and others, he was already building a prototype of the future BESM-6, trying to theoretically substantiate the structure and parameters of a new machine. "Before developing a computer, one has to design it," Lebedev noted immediately after developing the original BESM. He consistently upheld this principle.

Lebedev had the ability to take a well-planned idea and make it a reality, and he cultivated this quality in his students. In order to teach them how, he played all the roles: designer, constructor and assembler, adjustment engineer, technician, operator, and so forth. In other words, he taught through living, setting his own example. Later, when qualified specialists appeared, Lebedev entrusted them with the majority of the work, leaving only the most complex tasks of theoretical substantiation of innovations, computer structure, and parameters for himself.

It is not hard to believe, given Sergei Alexeevich's skill as a scientific supervisor, that his staff was highly motivated and reached phenomenal output during the 1950s and 1960s. What qualities did Lebedev possess that inspired them, gave them strength, and got their creative juices flowing during a period when working conditions were far from ideal? First, like no other person at that time, Lebedev was an expert in this new field of science and technology and was able to set very clear goals for teams of designers; then, with a complete understanding of the work, he actively participated in the projects. Second, Lebedev possessed enormous engineering experience and intuition, which allowed him to convince himself and others that it was possible to coordinate the operation of thousands of vacuum tubes. Third, Lebedev set an example of dedication to science by never avoiding tedious or menial work, for him no job was too small. Lastly, he was always able find common ground with the people he worked with.

Lebedev also had a gift for selecting the best personnel and effectively organizing the work. In Kiev and in Moscow, Lebedev had two or three able assistants who had decent creative and organizational abilities. The rest of the teams he hand picked from the recent graduates of top technical institutes, attracting them with the novelty and grandeur of his ideas.

The thrill of creating digital technology, with its future prospects, was an important factor. Computer technology was developing rapidly, holding the promise of new, more efficient applications for many branches of science that would promote technological progress and the growth of creative research. Lebedev's numerous publications played a great role in fostering these ideas. No less important was the creative rivalry that arose between the various organizations that were working on computer development and their desire to be on the same level with similar institutions abroad.

In Kiev, Lebedev had a laboratory with a large group of specialists. In Moscow, the Institute for Precision Mechanics became a leader in computer science carrying out Lebedev's plan to promote diverse research in the field of computer technology. On Lebedev's initiative, a department of computer technology was set up at the Moscow Institute of Physics and Technology to prepare teams of specialists. Upon completion of their training, these teams were sent to the Institute for Precision Mechanics, which Sergei Alexeevich headed until 1973.

Even though the MESM and BESM never received proper recognition or timely support, they still became basic building blocks in the field of computer technology and contributed to the growing prestige for Lebedev and his students; the Institute for Precision Mechanics became famous worldwide. Gradually, though belatedly, Lebedev began receiving official recognition. Despite his indifference to rewards and interference from his opponents, Lebedev received many awards, such as the Order of Lenin in 1954, 1962, and 1972, the Lenin Prize in 1966, the State Prize of the Soviet Union in 1969, and the Order of the October Revolution in 1971. Many of his colleagues also received prestigious awards.

Many of Lebedev's students turned out to be great scientists as well. In Moscow, Sergei Alexeevich mentored Melnikov, a participant in the BESM-2 project who also helped with the manufacture of the first computers in China. After becoming convinced of Melnikov's remarkable abilities, Sergei Alexeevich appointed him as the operations manager at the start of BESM-6's development. After the work on the BESM-6 was finished, Melnikov, Lebedev, and Sokolov were appointed as chief designers of the AS-6 computing system, compatible with BESM-6's software. The AS-6 computing system was developed in a short time and embodied many ideas that would be the basis of future supercomputers. Along with BESM-6 it was used in the Apollo-Soyuz space program and subsequent space vehicle launches. Melnikov was chosen as a corresponding member and, later, a full member of the Soviet Academy of Sciences. He was awarded the Order of Lenin Prize in 1956, the Order of Red Labor Banner in 1971 and 1976, the State Prize in 1969 and 1980, and laureate of the Ukrainian Academy of Sciences Presidium's S. A. Lebedev Prize. Starting in 1976, he served as the director of the Glushkov Institute of Cybernetics and as chief designer of the Electronika SBIS supercomputer. He died suddenly in 1993.

Burtsev, known as the "Adjustment Ace," turned out to be a scientific whiz. When he presented his Master's thesis for his Candidate of Technology degree (the thesis incorporated his experience in building the Diana-1 and Diana-2 computers), the scientific council unanimously nominated him for a doctoral degree. Burtsev became Lebedev's trustworthy assistant in the development of high-speed control and information complexes for the anti-missile defense system and space flight control centers. After Lebedev's death, Burtsev served as Director of the Institute for Precision Mechanics until 1984. He was elected a corresponding member, and later a full member of the Russian Academy of Sciences.

The Elbrus Soviet supercomputer, using the latest principles of optical data processing in multi-machine and multi-processor complexes, was developed under Burtsev's supervision. The principle of calculation paralleling proposed by Lebedev, found a logical development in Burtsev's work for which he was awarded four special orders: a Lenin Laureate Prize, two State Prizes, and the S.A. Lebedev Prize.

Dozens if not hundreds of specialists trained in Lebedev's school remain true to its principles. Some of them have retired; others are still working, but the majority of them are still connected with the Institute for Precision Mechanics. Unfortunately, it is impossible to describe all of their work in detail within the scope of this book.

The S.A. Lebedev Institute for Precision Mechanics and Computer Technology did not yield its leadership position during the Soviet years: after the supercomputers Elbrus-1 and Elbrus-2 were completed in the 1980s, the subsequent supercomputer Elbrus 3-1 was completed in 1991.

Corresponding member of Russian Academy of Sciences Ryabov and the chief designers of the complex's main machines, Andrey Andreevich Sokolov and Mark Valerianovich Tiapkin, have remained at the Institute for Precision Mechanics since 1986, through the unstable period that followed the collapse of the Soviet Union. Today, according to unanimous opinion, they are the highest ranking specialists – the "gold stock" of the institute.

Sadly, the majority of other Soviet computing organizations have experienced a different and declining fate during the decades after the war. I will discuss this in greater detail in the subsequent chapters.

Chapter 5: A Son of the Soviet Era

I never cared if others judged me, I always had faith in my own people. Happy at the thought that I was needed, I forged ahead and laughed at the blizzards. – Eduard Asadov

Outstanding Talent

During a business trip to Moscow in 1954, I visited the special construction bureau SKB-245 of the Machine and Instrument Building Ministry. In those days, it was one of the most well known organizations that developed computers. Since the purpose of my visit was to learn about the latest projects, I was able to see the big room where the Ural-1 computer was being assembled and got to meet the leader of the project, Bashir Rameev.

I had heard of him before and knew that he was one of the designers of the new Strela computer. He was young and handsome, of medium height and slim build; he wore glasses. He was a quiet person and spoke with very little emotion. As I stood next to him, I realized that even though we were roughly the same age, his life and professional experiences had been much more profound than mine.

That was the beginning of our acquaintance. In later years, when Rameev worked in the city of Penza near the Ural Mountains' region, I saw him occasionally at national computer conferences where specialists gathered from all over the Soviet Union.

From what I remember, Rameev's name was not on the list of esteemed conference speakers. Fortunately, this didn't diminish his prestige because he managed the highly reputable Penza scientific school, which was renowned for its huge creative output in the development and manufacturing of general-purpose computers. In those days, one out of every two computers in the country was made in Penza. While Lebedev and his Moscow group worked on development and manufacturing of supercomputers, provincial Penza developed and mass-produced "ordinary," all-purpose computers.

Over the years, I came to know the extraordinary, very modest and talented Rameev very well.

Rameev avoided contact with journalists and newspaper reporters and in fact, tried to eliminate all publicity about his work; very few articles about him or his work were ever published. That is why only a few specialists knew that Rameev and Brook developed the Soviet digital electronic computer M-1 and received an invention certificate for its common bus, or that Rameev had been Deputy Senior Constructor of the Strela, the first mass-produced computer. He was also the first to develop the principle of hardware and software compatibility, implementing it in the family of computers designed under his management. Like Lebedev, Rameev devoted his life to computer development, and the results of his work are comparable to the best foreign achievements of that time. Because he was a "son of an enemy of the people" he was dismissed from his institute in 1938 and was not able to receive a higher education. Nevertheless, owing to his extraordinary talent, he became Chief Constructor of the Ural series of universal computers, which were named in memory of the place where he grew up.

In one of the newspapers issued at the Penza Institute where Rameev worked, some of his colleagues complained about their manager's introversion, quoting him: "It is easier for me to make a new computer than to stand at a podium and give a speech!"

Indeed, he hardly ever spoke at conferences or large meetings; but the results of his research always showed up in technical reports, operational documentation for manufacturing computers, in computers themselves, and through the accomplishments of organizations that used the Ural computers in the 1960s and 1970s.

Because of his efforts, Penza became the cradle of rigorous scientific training in the field of universal digital machines. At the end of the 1960s, when the third generation computers were in their planning stage, Rameev had every reason to count on the Penza school taking the leading role in the process and spent a great deal of time on the preparations.

Like Lebedev, Rameev was a proponent of developing genuine Soviet computers. At the same time, he and his supporters were counting on a close partnership with European firms, which were looking for an alliance with the Soviet Union in hopes of eliminating the American monopoly in the computer market.

However, the scientifically sound proposals by Lebedev, Rameev, and Glushkov – the most authoritative Soviet computer scientists of the period – were ignored by the Soviet Union's elite political leaders, who resolved to copy the IBM-360. Because he disagreed with this decision, Rameev was removed from the game like a superfluous pawn, despite the fact that his career was blossoming. By the age of 44, he had trained a remarkable team of technicians and designers who in turn had created dozens of universal and specialized computers, plus more than a hundred peripheral devices.

The results of the Soviet government's decision were deplorable and moreover, tragic. Although still in their formal life cycle, by the 1980s most of the 13,000 manufactured ES models no longer operated; the ones still working produced diminished economic returns and didn't recoup their original investment. Such was the sad reality of living under a dictatorial administration and Rameev publicly condemned their resolution.

While writing this book I visited Mikhail M. Botvinnik,[49] an old friend of Rameev's. I wanted to hear his opinion of Rameev as a person and friend.

I was pleasantly surprise by Botvinnik's youthful appearance because he was already in his eighties when we met. He told me of his first meeting with Bashir Rameev during a trip to Penza, noting that a deep friendship developed between them. "Gentle, kind, modest and extremely honest," that is how Botvinnik described Rameev. "At the same time, he was incredibly talented, possessing a unique combination of technical savvy and practicality. Even though the beginning of his life was difficult because of the arrest of his father in 1933, it did not detract from his dignity, love of people, and desire to serve our nation."

Computers evolve; the new generation quickly surpasses the old one. This allowed Rameev to design first, second and third generation computers. At one time, his designs comprised the majority of universal computer stock in the Soviet Union. Today, a few of them remain only in museums. Political administrators halted the development of the Ural computers, because the battle between the opposing parties was unfavorably stacked in favor of the bureaucrats. But it was a Pyrrhic victory that brought no glory to the Soviet government.

[49] *Translators Note:* Mikhail Botvinnik, born in 1911, was a world chess champion from 1948–1963, and a Doctor of Technical Sciences.

Family Roots

Bashir Iskandarovich Rameev was born on May 1, 1918. When passports were established many years later, his father registered his son's birthday incorrectly, listing it as May 15. Rameev's life and work mirror the events of the post-October Revolution era, which began in 1917.

His well-educated grandfather, Zakir Rameev (1859–1921), was a poet of classic Tatar literature. He signed his poems with the pseudonym Dardmend, which means "sad" or "suffering" in Persian. He was a member and chairman of many charitable societies, published a newspaper and did much for the establishment of Tatar national culture. During his lifetime, only one of his published poetry books was translated into Russian: only two thousand copies were released and he remained largely unknown. Unfortunately, most of his poetry was lost after his death. In 1921, when many people were cold and starving, saving poetry was not important.

Only now, when justice and humanitarian principles are being reestablished in the Soviet Union, these events are finally coming to light. The truth is that Zakir Rameev was also a rich businessman, a gold mine owner, a member of the Russian State Duma, and a staunch liberal. He spent a considerable part of his profits on charity, support for orphans and foreign education of talented youth, with the aim of creating a Tatar intelligentsia. But after the October Revolution, such qualities were no longer admirable and instead were considered criminal: his son Iskandar and grandson Bashir would end up paying for them later.

Zakir Rameev sent his son, Iskandar, to study at the Freiberg Mining Academy in Germany. Iskandar returned to Russia the day before the First World War started, and worked in one of his father's gold mines. After the revolution, he became the chief engineer at a copper smelting plant in the town of Baimak. He was arrested for the first time in 1929 and released a year later without any charges. Bashir was only eleven years old and could not imagine the trouble yet to come, but he instinctively prepared for it, finding work as a photographer for a geological expedition and later as a bookbinder. He finished school in 1935 in Ufa, where his family had moved; his father had become the director of the Bashkiria gold trust. Iskandar Rameev was a talented engineer; he developed and implemented automatic milling units that could be operated by just one man, sharply increasing the level of gold extraction.

In April 1938 when Stalin's purges began, Iskandar Rameev was arrested again. His blueprints for the gold extraction unit disappeared into the bowels of the NKVD archives.[50] After two years under investigation he was convicted and sentenced to five years in a prison camp in the Kemerovo region. In 1943, ten days before his scheduled release, he died.

Iskandar Rameev was posthumously exonerated over twenty years later. Unfortunately for his son, Bashir Rameev became the "son of an enemy of the people" in April 1938. By that time, he had successfully graduated from high school and was in his second year at the Moscow Energy Institute. He enjoyed tinkering with gadgets since childhood and once entered an amateur radio contest in Moscow. In 1935, at the age of 17, he became a member of the all-Union society of inventors.

After his father's arrest, he was forced to leave the Institute and return to Ufa. He remained unemployable for a long time because of his blacklisted status. When Rameev was drafted into

[50] *Editor's note*: The NKDV stood for the *Narodnii Komissariat Vnutrennikh Del* (or People's Commissariat for Internal Affairs, the predecessor to the KGB).

the Army in 1939, one of the military physicians detected an inflammation in his lungs and rejected him. He decided to move to the Crimea where nobody knew him, planning to find work at a sanatorium or Young Pioneer camp and improve his health. Penniless, he ended up walking along the entire Crimean coast, but there was no work for him there either. He returned to Moscow, where he finally found a job as a technician at the Central Scientific Research Institute of Communication; it was early 1940, just before the Second World War.

Rameev was lucky: he was allowed to do what he enjoyed and his work had practical applications. During the first weeks of the war, he proposed a method for detecting dark objects from flying planes – by means of infrared radiation passing through cloaked windows. He also invented a relay device that would turn on the warning system during air-raids. He was not allowed to join the Army, but instead enlisted as a volunteer in a battalion of the Soviet Communication Ministry. The battalion served the Senior Command Headquarters of the Soviet Army. At first, Rameev fell in with a group that designed encryption equipment, probably because there was no time for proper assignments. The device that the group designed was accepted by the army and used for a period of time. Rameev took trips to Arzamas and Nizhniy-Novgorod, where Stalin intended to move the Headquarters, to install some of the technical equipment.

During the preparations for the liberation of Kiev, a special group of twenty men was formed. They were equipped with portable radio transmitters in order to provide communication service for the troops. As part of this operation, Rameev ended up at the Ukrainian front in September 1943. After their mission of providing communication for the troops during a forced crossing of the Dnepr and the liberation of Kiev ended, the group was disbanded and Rameev returned to Moscow.

In 1944 he was demobilized in accordance with a government decree that directed specialists to rebuild the economy, and applied for work at the Central Scientific Research Institute No. 108. In the application form, he stated that his father had died, but did not indicate where. Earlier, he sent a letter to Stalin asking for help; he was seeking the leader's official support in his claim that a son is not responsible for his father's actions. Instead of an answer, he received a paper summons for a telephone conversation, where a stern voice warned him: "Live quietly and don't contact us ever again!"

At that moment, Rameev understood that he had to do something unusual, outstanding, and very important for his people and nation in order to give his life meaning.

Academician Axel Berg, a remarkable scientist, was working at the Institute No. 108 at that time. Berg introduced Rameev to computing, applications in radar devices and the field of electronic circuitry. During the same period Rameev became interested in nuclear physics and invented a charged particle acceleration device, for which he received an invention certificate. When physicist and Corresponding Member of the Academy of Sciences, Alexander I. Leipunsky, learned of Rameev's invention, he was intrigued by the young talented scientist and invited him to Obninsk, where they were just beginning to experiment with atomic power engineering. But unfortunately, the political system failed the scientist again, and six months later Rameev was informed that there was no place for him at Obninsk.

The Breakthrough

At the beginning of 1947, Rameev heard a BBC radio broadcast announcing that United States scientists had built an extraordinary electronic computer consisting of eighteen thousand electronic vacuum tubes, all of which were connected by tens of kilometers of cables. When Rameev heard about the ENIAC, he sensed that this was the branch of science and technology which was meant for him. He decided to discuss this with Berg, who was a very approachable person. Berg recommended that Rameev get in touch with Brook, who had been working with computing technology at the Power Engineering Institute. Brook already had a mechanical integrator-analyzer at his lab, a very bulky analog computer which was very difficult to operate. Back then, the air was literally filled with ideas of building digital computers and Brook was happy to receive an enthusiastic assistant. In May 1948 Rameev was admitted to Brook's laboratory as a design engineer worked directly in one of Brook's own offices.

Incredibly, the first result was achieved only three months later, in August 1948: the *Avtomaticheskaya tsifrovaya vuichislitelnaya mashina*, or "Automatic Electronic Digital Computer," ATsVM project – the precursor to the M-1. Corresponding Member of Academy of Sciences, I.S. Brook and engineer B.I. Rameev, filed its project report. The following is an abbreviated copy of the original document preserved in the Moscow State Polytechnic Museum.

The Automatic Digital Computer
(Short description)

Corresponding Member of the AS USSR
I. S. Brook
B. I. Rameev, Engineer
Moscow, August, 1948

CONTENTS

2. Magnetic trigger
3. Magnetic relay, which operates only when simultaneously receiving several control signals
4. Magnetic relay, which responds when one control signal enters any input channel
5. Decoder

V. Appendix. Table of basic parameters of high-performance digital computing machines designed or under development in America.

I. Introduction

Recently, some information has surfaced in the foreign press about plans to design and build high-performance digital computing machines.

The first machine that became operational in America during the war worked on the impulse-counting principle, where impulses were registered on electromechanical counters. This was a general-purpose computer for solving various mathematical tasks by means of counting finite differences.[51]

The computer has a relatively low operating speed and restricted storage capacity (only 60 words).

According to the available information, this machine has been widely used along with differential analyzers to solve problems related to the so-called Manhattan Project. After the first computer, a second and purely electronic one – the ENIAC – was developed and used primarily for solving the ballistics problems at the Aberdeen Army Proving Grounds.

We will not dwell on the design of this machine or its features, which are only known from brief reviews in the current literature. Neither are we familiar with its principal disadvantages or those of its predecessor – the Harvard computer. Currently, several American organizations are busy developing new and improved computers. They are building a new machine at Harvard, two machines for the Bureau of Standards, and several more for universities, institutes, and special Army and Navy research centers. Similar computer projects have begun in England and France.

The current literature also discusses a number of problems that might benefit from the use of such machines. These include the calculation of function tables, astronomy problems, processing statistical data, and preparation of bibliographical reference books. But the main purpose of such computers, which are also very costly to construct, would without a doubt be the solution of scientific and technical problems related to defense and the development of modern forms of military technology.

For example, the American Bureau of Standards – an organization analogous to the Soviet Bureau of Weights and Measures – has a large department to investigate problems of artillery

[51] *Author's Note:* Brook and Rameev are referring to the Harvard Mark-1.

control. As reported in other publications, the same problem is being studied at several research firms, laboratories and special Army and Naval research institutions.

One of these computers is to be used solely for weather forecasting calculations, which is an extremely important task during wartime.

Finally, there is one other area that nobody mentions, but which can definitely benefit from the use of a computer or even a series of computers. It is the field of cryptography, which carries special significance for intelligence work.

It is not possible to list every potential application of computers. Therefore, discussion here will be limited to the general trends in modern scientific research and construction that deal with new military technologies.

The path from the initial idea to the first prototype is incredibly long. Therefore, it is very important to replace expensive and time consuming experiments with computations. Everybody knows how difficult and practically impossible such calculations are, even when the task can be expressed in exact mathematical terms. In addition, the accuracy of the results needs to be extremely high because the absolute error for the size of the values that we are working with (for example, the high speeds and great distances in artillery control), must have a very narrow margin.

Such problems cannot be solved by [hand] calculation bureaus in a reasonable amount of time. All types of mechanical calculators are also inadequate due to their inherent inaccuracy. Implementation of high-performance digital computers to solve such large problems would save a lot of time, materials and labor, plus it would require a relatively small staff of highly qualified specialists, whose only job would be formulating the task and evaluating the results. These factors dictate the necessity of constructing and putting into operation – as soon as possible – one or more high-performance digital computers designed to address the needs of the most important scientific centers.

Besides general-purpose computers, it is critical to develop specialized machines for solving ballistics, weather forecasting problems, and so on. Finally, some very significant problems require machines with many of the elements (counting, programming) used in digital computers. This would improve the problem solving methods and allow us to achieve positive results faster and more frequently than we do today.

The automatic digital computer, which is briefly described below, is based on an original design.

The diagrams of computer elements – adder, multiplier, divider, interpolator, transformers from decimal to binary system and vice versa, plus a series of relay schemes – are presented here for the first time as far as we know. An objective comparison with the computers that are being built abroad (according to our information), shows that our proposed machine has major advantages, as described below. We present here the general design of the machine and its elements; it will require a detailed project plan and a great deal of experimental work on separate units before we can begin building and assembling the computer.

II. General Description of the ATsVM

The ATsVM is a general-purpose computer.

1) Calculations are done automatically. The operator's involvement stops once he has prepared the machine to solve a problem.
2) The calculations are carried out in electrical relay-code circuits. Mechanical moving parts are used in a few of machine elements: the program unit, output printing device and several others.
3) The calculations proceed very rapidly: the machine is capable of performing at up to 2000 operations per second.
4) The computer is "digital." Calculations are carried out as numerical operations. The initial data and results are presented as ten-digit numbers in decimal form. Internal calculations are carried out in binary form.

As the ATsVM project's basis, the high-performance digital computing machine had to satisfy the following requirements:

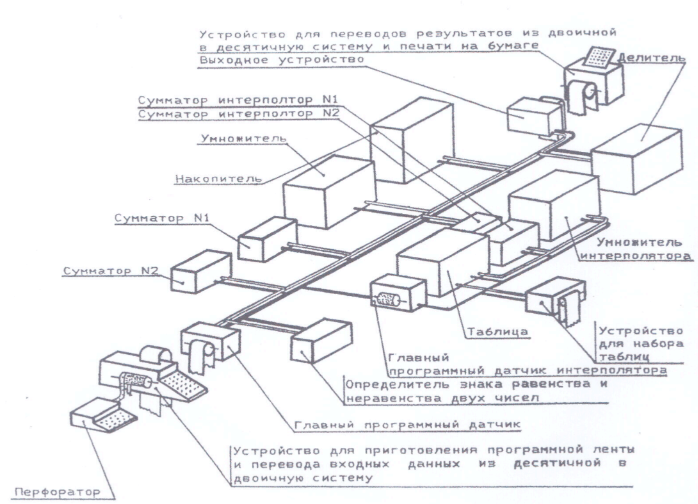
1) The machine must have units for executing the basic numerical operations: addition, subtraction, multiplication and division. Depending on the general scheme of the computer, there could be separate units for each operation or one calculating unit for all operations, since the addition unit could perform the subtraction operation using a supplementary number; multiplication could be done by sequential addition and division could be carried out by sequential subtraction. But using a separate unit for each operation increases the calculation speed and reduces the amount of memory required
2) In order to guarantee high performance in automatic mode, the machine needs a storage device, or memory, for internal data and calculation results. This memory device should receive and send data at the same speed as the numerical operations are performed, which in the electronic computer might be on the order of tens of microseconds.
   The range of problems that the computer can handle depends on adequate memory capacity. For example: storing several hundred thousand numbers when solving algebraic equations with several hundred unknowns would require a substantial memory capacity.
3) The computer needs to have a table for number input. Reading the table may be done by the main computer or by a separate interpolator. The use of a separate interpolator could increase the computer's operating speed, simplify the programming process and reduce the required memory capacity.
4) A high-performance digital computer needs a control unit to manage calculations when solving specific sets of problems. The control speed needs to be the same as the speed of arithmetic operations..
5) The controller will have to choose between two or more sequences of actions (according to predetermined criteria) and execute operations as a result of that decision. There also needs to be a unit that determines the sign of any given number and compares two numbers.

6) The computer should have devices for input of data and output of calculation results. The input and output devices should operate at the same speed as the control unit.
7) Finally, the digital computer must have some means to "transport" the numbers and program signals between the different parts of the machine.

The automatic digital computer consists of the following basic elements:

1) A numerical keyboard device for data input, and a program tape puncher that automatically converts from decimal to the binary system.
2) A main program controller for all of the machine's work. This controller selects the appropriate computer elements that are required for any given operation and controls the sequence and type of calculations.
3) A sign identifier that compares two numbers; it allows the main program controller to simultaneously select between two or more sequential operations and execute them, depending on the result received from the identifier.
4) Two adders.
5) A multiplier.
6) A divider.
7) Storage for "saving" numerical data, intermediate calculations, etc.
8) An interpolator for automatic calculation of intermediate function values, which are presented in an assigned table for small numbers of discrete values of the argument. The interpolator consists of a unit that automatically fills a table.
9) An output device for writing the results to tape (in binary form).
10) A device for converting output results from the binary to the decimal system and for printing them on paper.
11) Digital and command buses for connection between machine elements and transmission of program signals.

The unit-diagram for the ATsVM computer is presented in Figure 1:



Автоматическая цифровая вычислительная машина. Блок-схема

Figure 1. A General View of the ATsVM

The program for a sequence of numerical operations is written on programming tape in this logical format: "from where," "to where," "what to do." This corresponds to the computer's numerical or differential method of problem solving.

In order for the computer to work according to this scheme, all of its elements have a common structure of input and output circuits.

All digits and numerical signs are transmitted simultaneously from one element of the computer to another. The whole computer is served by a single digital bus (33 lines for digits and one line for signs) connected through "logic elements" (gates) to digital inputs and outputs of all computer elements.

Gate units are controlled by the main program controller; their selection is produced by program signal decoders, connected to the program bus throughout the entire computer. Each decoder is assigned a number, the binary form of which is a key for the given decoder. This way, if the "from where" strip of tape has the decoder key for exiting the multiplier, and the "to where" strip has the decoder key for entering adder No. 1, then the number must be transmitted from the multiplier to adder No.1. The "what to do" strip of the program tape describes the operation to be done (for example, receiving, sending, erasing, multiplying, etc.) Besides decoder numbers and command signals, the program tape consists of a start pulse on each line (for each step), which initiates the computer elements that perform calculations at each step and other steps of the program where needed. The "numbers" strip contains written entry data previously converted to binary code.

The input device that prepares the programming tape is the interface between the human operator and the machine and can only work at low speeds. Therefore, it is separated from the high-speed computer. The tape is prepared before running the program. To minimize the difference in speed between the computer and the input device, several input preparation devices may be used simultaneously for several problems. The programming tape is virtually wear free, so it may be used repeatedly when solving similar tasks, but the input data must be copied. For multiple repetition of the same calculation, the programming tape can be glued together and used as a continuous loop.

There is another method for numerical data input into the computer where the numbers are written not on the programming tape but on special "numerical" tape. In this case, the numerical data could be read by a small capacity storage device that is constantly refilled with the "numerical" tape after receiving a signal from the main program controller. This method would also apply for inputting data into a table.

The programming tape, prepared in accordance with the above mentioned logic scheme, is then placed into the main program controller which "reads" it and according to its data selects the elements of the computer that carry out the requested operation. Thus, the tape controls the sequence and type of each operation.

It is necessary to mention that although the computer has fully centralized control, the main program controller selects separate elements of the computer and sends the command to start operations. The operation inside the element is executed automatically and independently under the control of a local autonomous controller. For example: the main program controller selects the multiplier and gives the signal for multiplication. From that moment, the local program controller of the multiplier executes the consecutive addition of partial products as many times as the number in the multiplier, shifting the partial product each time one digit to the left. The independent calculation cycle for separate elements is finished at the beginning of the next step-interval (with the exception of the interpolator). During the same step-interval only one element of the computer can work (with the exception of the interpolator). The computer works in controlled intervals, the duration of which is set by the speed the programming tape. This way, the speed of the computer is easily regulated from the slowest to the fastest, and is defined by the speed with which the arithmetic operations are executed (up to 2000 step-intervals per second).

In cases when it is necessary to change the solution path due to the sign or magnitude of the module of intermediate calculation results, the programming tape must contain two or more ways to solve the task. The "what to do" section of the tape clarifies when a given solution path should not be taken, for example: if the number is "equal to," "less than," or "greater than." The compared number and intermediate calculation result are sent to the sign identifier.

Depending on the result of the identifier's output, the correct solution path will be selected.

A separate element of the computer is used for interpolation and every arithmetic operation except subtraction. This significantly simplifies programming, increases the operating speed of the computer, and reduces the amount of storage required. Two adders are used in the computer, one of which may be used as interim storage for a series of summations.

Numerical data and intermediate results are stored in table form. In order to recall a number from storage, two keys are written on the programming tape. One key identifies the column and the other one the row of the storage table where the number is originally written. Therefore, writing the number and then reading it from storage requires two step-intervals.

As already mentioned above, the required storage capacity depends on the problem being solved. It should be noted that even a relatively large storage capacity might be insufficient for certain solutions, for example: solving algebraic equations with several hundred unknowns.

For such tasks, the storage capacity required would have to be several hundred thousand numbers. If the objective is to calculate at the computer's maximum speed, then such storage capacity would be difficult to realize because of the complexity and high cost of computer construction. Therefore, for solutions requiring a large memory capacity, the computer would have to operate at a lower speeds using large capacity tape storage. It would function as following: the intermediate calculation results are written on tape exactly the same way as the calculation results in the output unit – in the order in which they are received. Then, they are entered into the computer using the above-mentioned second method of numerical data input – into a small capacity storage device, which is constantly refilled with numbers from the tape. The numbers are stored in the same order as they will be used in subsequent calculations.

An important advantage for the digital computer is the potential to input the numerical data in table form, which would require a table reader and, if necessary, an interpolator. In the computer, tables can be constructed in two ways:

a) The function is presented in the form of a series:

$$f(a + h) = C_0 + C_1 h + C_2 h^2 + C_3 h^3 + \dots$$

b) The argument and the corresponding coefficient values are entered into the table

$$C_0, C_1, C_2, C_3 \dots C_n$$

Reading and interpolating the table is executed by a separate interpolator that is in fact a simplified digital computer with fixed programming, which operates in much the same way as the main computer.

For a given interpolation formula, the interpolator's program does not change and is written not on tape, but directly on a magnetic drum that is permanently rotating at high speed.

The overall scheme of the computer is rather complex. However, it consists of several simple schemes: binary counters, gate elements that use an "on-off" principle, triggers, etc. Gate elements are the most common in the scheme. If the gates are constructed using electronic vacuum tubes, then their total quantity will increase significantly, with "gate" tubes amounting to 70% of all tubes.

Taking this into account, we recommend substituting gate tubes with simpler components, such as magnetic and rectifier circuits. Although the time constant of magnetic circuits is greater than electronic ones, magnetic circuits could be used in a number of places. We will not speculate at this time which specific components (magnetic or rectifying) are best to be used as gate devices, and but we are certain that most of the gates can be built with the new schemes. We will also note that replacing electronic tubes in gate devices significantly simplifies the construction, increased reliability, durability and performance of the computer.

The most promising long-range development for gate schemes is the implementation of crystal diodes, or rectifiers. Unfortunately, the Soviet Union is not producing these components yet. However, there is no doubt that we will begin making them very soon, because crystal diodes have many applications in modern radio and radar technology.

Crystal diodes' miniature size and suitability for very high frequencies, combined with the absence of hot cathode ray tubes that have a limited life cycle and expend enormous heat energy, allows for the construction of extremely compact and inexpensive calculating units, which can be used for both stationary and mobile devices. The latter feature is very important for military applications.

* * *

Remember, this document dates back to the mid-1948, and Lebedev had not yet started building the MESM. He would later write, "I began working on high-performance electronic counting machines at the end of 1948."

In the West, ten computers were already being developed in America, one in England, and one in France. Since the computers were developed primarily for military purposes, published materials about them were very brief. Most of these computers were based on electro-mechanical relays rather than on electronic vacuum tubes.

After carefully reading the above report, it becomes obvious that Brook and Rameev came very close to realizing the principle of stored memory programs – originally considered von Neumann's and Lebedev's idea. They achieved it by allowing the programs to be written into memory (on tape), placing the result on the same tape and then inputting it back into the machine for subsequent calculations. In other words, they provided the option to process instructions in the computer's arithmetic unit.

This is what Rameev remembered about these breakthroughs:

> Working in Berg's Institute No. 108 was like attending a fine school. The knowledge I gained in electronics combined with almost twenty years of amateur radio experience and my tendency to invent things may explain why collaborating with Brook was so successful. Together, Brook and I discussed general ideas about the computer. Then I drafted circuit schemes and wrote explanations for his review. He occasionally made notes and corrections to the text (I still have some of the copies with his handwriting). I worked out of his office, in the main building of the Power Engineering Institute.
>
> We also discussed how to implement this project and decided it was necessary to establish a special construction bureau. I worked for two weeks in the Lenin Library, studying the special literature on design of industrial enterprises and factories.[52] As a result, this document was born.
>
> I cannot remember where or what I ate back then, but I remember the room I lived in, where the housekeeper stored potatoes. It had a large wood-burning stove that I heated up with thick volumes of *Legislation of Tsarist Russia* that I found there. From 1944, I leased a room – or sometimes a corner of a room – for two to four months at a time, in many different Moscow districts, changing places ten times. Nobody wanted to register my residence officially and landlords were afraid to rent a room to an unregistered person for an extended period of time. I kept all of my belongings in three paper bags, and I moved with them from one place to another. In 1952, SKB-245 gave me my own room in a communal apartment.

During their year of working together, Brook and Rameev prepared and sent to the State Inventions Committee over 50 invention applications for the various computer units. However, many of the applications were returned without confirmation or with a list of questions. There were no computer technology experts on the Committee yet, and the individual who reviewed the applications was an electric motor specialist. Meanwhile, the Committee gradually accepted

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[52] *Editor's note*: Known today as the Russian State Library, The former Lenin Library [in Russian: *Biblioteka imeni Lenina*] in Moscow contains some 40 million books and periodicals.

the applications. In December of 1948 they submitted the invention application for the "The Automatic Digital Computer" and received notarized Invention Certificate No. 10475 on December 4, 1948 – the first computer invention document in the Soviet Union.

In the beginning of 1949, Brook presented the theory of a digital computer at a closed meeting of the Scientific Council of the Dzerzhinsky Artillery Academy, where he had been a member since 1947. In the presentation, he demonstrated the model of the diode matrix arithmetic unit that Rameev had designed.

In 1949, the Army unexpectedly drafted Rameev as a radio-location specialist and immediately flew him to the Russian Far East. However, the rush was unwarranted, because Rameev had to wait for an assignment for one and half months, before being sent to teach at a submarine school. Brook lobbied non-stop to have Rameev come back to Moscow, and contacted Bruevich and Parshin for help. In the end, Rameev returned to Moscow where he found a letter offering him a new post as the laboratory chief at SKB-245.

In order to accomplish this, Parshin had to sign a special document assuming personal responsibility for the "son of an enemy of the people," due to the secrecy of the project at SKB-245.

Borrowing from some of his and Brook's earlier ideas, Rameev began collaborating with Yuri Bazilevsky, the manager of the digital computer department at SKB-245. That marked the beginning of the Strela project, which was met with enormous enthusiasm. The SKB-245 chief, Mikhail Lesechko, dedicated all of his organizational abilities to the success of this project. His staff, in fierce competition with the BESM project, worked around the clock to achieve what was seemingly impossible. It only took workers a couple of nights to assemble cumbersome equipment for cooling the enormous premises where Strela's assembled units were being installed.

An SKB-245 employee and Strela project participant, Evgenia Tikhonovna Semyenova, recalled the work atmosphere of that time:

> In March 1950 I had asked the personnel department at Moscow Energy Institute for a job at the Scientific Research Institute, or SRI-10. During graduate placement, I agreed to go to work at the prestigious "mail box."[53]
>
> But instead I was sent to the SKB-245, which nobody had heard of. But I didn't complain, I just took the order and went. I got very lucky: first, I found myself in Rameev's lab, where I worked for five years. Everything I learned from him during those years has stayed with me throughout my life. Second, I got to work with the founder and manager of SKB-245, Mikhail Avksentievich Lesechko, who was certainly a very interesting person and a talented manager. I have never met another person like him since. Third, and most important, was the work. We were building one of the first digital electronic computers in our nation. During the first few months there we read American magazines that featured articles about computers; thank God that our managers had a large supply of them. Rameev would generate ideas and then we developed them ourselves. I would have never found such work at the SRI-10!

[53] *Translator's Note:* The phrase "mail box" designated secret Soviet defense enterprises such as weapons research institutes, production plants, and military divisions.

SKB-245 and the Schetmash were established at the SAM site around the end of 1949 or in early 1950. SKB-245 had several departments and since all work was top secret, department titles were replaced by numbers. But sometimes, we called them by their managers' names or even by themes.

The First Department, the Security Department – like the name suggests – protected our work and watched all of our comings and goings. They issued notebooks, which were sewn with thread, numbered, and sealed. Every morning they gave us our briefcases with those notebooks and collected them at the end of the workday.

The Second Department was responsible for analog computers and was managed by Roman Vasilievich Plotnikov. The guys from the Moscow Energy Institute worked in this section: Zhenya Glazov and Misha Yankin. We were close friends, so we always knew what was going on in their department. Vitenberg, Sulim, Gena Petrov and several others also worked there.

The Third Department, headed by Bazilevsky, was ours. We worked exclusively on developing the Strela computer. I will talk about our work later on.

The Fourth Department was managed by Ephraim Arumovich Gluzberg, although he was later replaced by Dmitri Alekseevich Zhuchkov. This department designed standard programs for the Strela and evaluated their operation.

The Fifth Department dealt with finances.

The Sixth Department was developing a differential analyzer and was managed by Alexander Bednyakov.

Later, other departments were added.

Our department had several laboratories. Rameev's lab designed Strela's arithmetic unit and the operational memory component. I designed the multiplier-divider unit, and Boris Zaitsev the addition-subtraction unit.

There was yet another lab managed by George Prokudaev, where Sasha Larionov, Larissa Dmitrieva and Maya Kotlyarevska worked. They were all from the Moscow Energy Institute, but joined us a year after the project began. Prokudaev's lab designed external memory devices using cathode ray tubes, but something was wrong with them. The tubes were extremely unreliable so Rameev and Lazarev started designing external memory on a magnetic drum. The first Strela models were made with external magnetic drum memory.

Trubnikov's lab developed Strela's other external units.

Even thought Rameev often did not get along with his superiors, he was gentle with his subordinates and spoke in a clam, low voice. I remember that Rameev and Bazilevsky had several disagreements during that period. It was pretty normal because there were many debates about the structure of the machine and its component base. For example, should they use vacuum tubes or relays? Rameev insisted that we make the computer with vacuum tubes. I still remember standing in front of the unit frame that contained twenty two hundred of these tubes, holding a P6 electronic tube in my hand. It was not a tiny tube, but a real P6, ten centimeter long. The multiplier's frame was about five meters wide and at least two and half meters high, or perhaps even more.

We worked very hard, often through the evenings and into the nights, especially when high-level officials were about to visit. They came from the Central Committee of the Communist Party of the Soviet Union, and from various other Ministries. We had to prepare ahead of time for such visits and on the days they actually came to the see the facilities, we hid our soldering irons. Rameev would always make a joke, "Here we are, sitting around again with clean necks!"[54]

We could work as late as we wanted, but if somebody was even three minutes late at the start of the day, he was reprimanded by the deputy director-administrator. If they were twenty minutes late, the case was referred to a disciplinary committee. At the entrance of the building was a clock where we were supposed to punch in with our time cards. The overseer was a tough and ruthless woman who refused to give anyone a break if they were ever late.

Now I understand that we designed the computer in an unbelievably short time. Moreover, we designed and built every single component of the machine. We started around March of 1950, and by the end of 1951 the documentation was sent to SAM factory in Moscow. Before the end of 1952, the first models were ready for adjustment.

In 1953 the working model of the Strela was presented to the Stalin Prize Commission. At the same time, Lebedev revealed the BESM computer. The Prize went to SKB-245, because Strela appeared better prepared for industrial production and was cheaper. Our colleagues joked that the reason Strela was cheaper was because we hadn't been paid overtime.

For that time Strela's performance was ordinary, with a 2000 operation per second speed, 2048 words of storage, and 43-digit word length. It was a three-address computer.

By the time the Stalin Prize was awarded, I had already left SKB-245 to teach at the Moscow Energy Institute. But, during my lectures on impulse technology, I always relied on circuit calculation methods developed in the Strela project and I remembered Bashir Iskandarovich.

There was one thing about SKB-245 that bothered me during the entire five years that I worked there: the tight security. A soldier stood at the entrance and there was no going in or out of the building during working hours without a special permission form signed by a manager. Even in case of an emergency at home, the soldier would not let you go. We used to work evenings and weekends, but it still didn't matter!

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[54] *Translator's Note:* This refers to a well-known Soviet joke about getting ready for guests: A mother tells her son, "Your grandparents are coming soon. Please go and wash your dirty neck now." The son replies, "But what if they don't come? Then I would sit around like a fool with a clean neck!"

> And then, the First Department! God forbid if I forgot to return my secret case with all of the notebooks, drafts, or even tiny scraps of paper; a severe reprimand and an immediate inquiry in front of the entire laboratory team. What rubbish! More than once I worked until late in evening while my son and mother waited at home, awake. I would be riding on the Metro and suddenly it would hit me: "The oscilloscope! Did I turn it off? The briefcase? Oh Lord, I don't remember! Oh, yes, I returned it before dinner…"

Rameev acted as the deputy chief designer for the Strela. The SAM in Moscow eventually produced seven models – technically the first industrially produced Soviet electronic digital machines. They were installed at the Academy of Science's computer center, the Institute of Applied Mathematics, and in closed government ministry computer centers that were supporting the space, nuclear weapons, and energy complexes.

Rameev recalled an episode in 1954 when the first Strela had been delivered and installed at the Institute of Applied Mathematics. Keldysh and Lesechko used to frequent the laboratory and during this particular visit Strela performed some very impressive calculations for several nuclear physics problems, which prompted Keldysh to proclaim, "If we could make five to seven such computers, the Soviet Union would be in great shape!"

The Chief Designer of the Ural Computers

After completing the Strela, Rameev redoubled his efforts towards the Ural-1, and eventually it became the work horse for many Soviet computer centers. Rameev's long term goal was to create a family of universal computers with performance capacity ranging from modest to super-powerful.

The Soviet government ordered the Penza factory to manufacture the Ural-1 and in 1955 Rameev – together with a group of talented young specialists who had worked with him at SKB-245 in Moscow – moved there. Under Rameev's leadership, the Ural-1, Ural-2, Ural-11, Ural-14, and Ural-16 were produced over a thirteen-year period. At times they surpassed analogous western achievements.

Rameev wrote to me:

> We organized the Penza design team between 1952 and 1954, when SKB-245 was still in Moscow. In 1953 and 1954 the Ural-1 project commenced. Since the machine was designated for industrial mass-production, I spend most of my time on standardizing the racks, units, and overall design. At that stage, I was personally involved in designing circuitry, followed by manufacturing and adjustment, together with Vasily Ivanovich Mukhin, Andrei Nikolayevich Nevsky, and others. As they gained experience in Penza and their engineering talents grew, I gave them progressively more independent design assignments, beginning with specialized computers. Using standardized vacuum tube elements, they built special computers such as the "Pogoda" system for meteorology, the "Granit" system for calculating probabilities in experimental

observations, and the "Crystal" system for x-ray crystallography. They also developed several special military computers.

Using vacuum tubes, Nevsky, Mukhin, Gennady Sergeevich Smirnov, Alexander Stepanovich Gorshkov, Lev Nikolayevich Bogoslovskii, Oleg Fedorovich Lobov, and several others, designed the universal computers Ural-2 in 1959 and Ural-4 in 1961. During my first ten years in Penza, they produced eleven different computer types and nearly one hundred peripheral units, all of which were delivered to customers and installed at production points.

In 1960, I started working on creating a family of Ural computers that were based on semiconductors. In November 1962, the design work for the Ural-10 complex was completed and the project was slated for automated production. Even though some of its elements had been developed for the Ural-11 and Ural-16 series, they were widely used in many other computing devices and in automation. To satisfy the demand in those areas, several million of such elements were manufactured.

I would like to note here the outstanding contribution made by Vladimir Ivanovich Burkov in the development of the structure, instruction and operating systems, and software of the Ural-11– Ural-16 computer family.

During my time in Moscow and in Penza, I worked for organizations that I could confidently call a synergy between technology and industry. Only one director ran the Scientific Research Institute, a special designers' bureau, and the production plant. That is why there were no problems when we presented the newly designed computers for mass production. In that respect, I was probably in a better position than any other chief designer.

I considered standardization to be one of the most important principles. When I designed the Urals using electronic vacuum tubes, standardization allowed us to create a new series of computers in a short period of time. This issue gained much attention during the development of the Ural-11 – Ural-16 series. Maximum "modularity" of the elements, junctions, units, computers and standard interfaces enabled us to minimize the assortment of assembled circuits, so that the mass-production of component systems and computers became significantly easier and cheaper.

In brief, the main features of the new generation of computers implemented by Rameev in the new Ural series consisted of the following:

The computers should represent a family of machines of varying performance, compatible with each other in construction, circuitry and software. The computers should have a flexible structure and a wide assortment of peripheral devices with standard interfaces to select the most compatible applications for any given task. This would also facilitate customizing the computer during its life cycle in accordance with the end user's needs and integrating newly developed units.

The design and circuitry need to allow several computers (same or different) to be joined together to form information processing systems and guarantee easy modifications of the system's components to increase performance, plus expand the number of solvable tasks and fields of application.

The backup units would guarantee a highly reliable system for real-time information processing. We need to plan for: a system of circuitry to protect information, access to programs regardless of where they are located in the memory, a system of relative addresses, a sophisticated method of starts and stops with a corresponding set of instructions which would allow us to coordinate complex systems of simultaneously working devices and time-sharing of many tasks.

The ability to work with floating and fixed points, in decimal and binary systems, and to select and execute operations with words of both fixed and variable lengths would allow us to effectively solve a wide variety of economical, informational and scientific-technical tasks; a system of hardware control for storage, addressing, transmission, and processing of information.

A large operating memory capacity with direct selection of words with variable length, effective hardware means for the control and protection of programs from each other, partition addressing, a developed system of starts and stops, the ability to access a large external memory on magnetic disks and drums, usage of timers, equipment for interfacing with communication channels, and operator keyboards for communication with the computers. This will allow us to build information processing systems for multiple users that should work in a time-sharing mode.

All elements, blocks, and units are standardized for optimization of mass-production and technological processes, which would guarantee a reliable, high quality product.

These main features of the new generation of computers were presented in a draft document outlining the Ural-11, Ural-14, and Ural-16 family of computers. It appeared a year and a half before a similar publication about the American IBM-360. Thus, Rameev proposed the idea for a computer family with compatible hardware and software independently from the Americans, and it was implemented practically at the same time. It is important to note that unlike the first models of the IBM-360, the Ural family was capable of supporting information processing systems, which were made up of similar and/or different computers with networking capabilities and other upgrades.

Academician Dorodnitsyn signed a State Commission Act that approved the Ural software:

> For the first time in the USSR, a systems approach to software development has been implemented for a series of computers. We designed an original operating system, incorporating all of the main functions that such modern systems are capable of realizing at this time. Our software documentation is of the highest quality; it is comprehensive and has a uniform layout.

Penza also developed a number of systems for the Soviet economy and national defense. In 1962 Rameev was awarded the degree of Doctor of Technical Sciences without having to defend a thesis – an extraordinary case in the Soviet Union.

The Unrealized Hopes

Extensive experience with the Ural projects and leaps in foreign technology allowed Rameev to envision a whole new generation of world-class computing machines. Lebedev, Dorodnitsyn, Glushkov, and others were also thinking along the same lines because of the favorable conditions in the Soviet Union.

The Soviet government allocated significant resources to develop computing machinery. By the 1960s, there were dozens of computer plants and several large scientific-technical institutes in Moscow, Minsk, Kiev, Leningrad, Penza and Yerevan, which already had experience with second generation computers. Also, by the late 1960s Moscow boasted one of the most powerful scientific organizations in the Soviet Union –NISEVT. By now, the official political attacks on cybernetics were a thing of the past, and computerizing the economy, science, and industry were considered high priorities. Thus the Soviet government decided to develop the Unified Computer System series (ES-EVM as noted in Chapter One) using integrated circuits.

In the West, computers were initially developed in the United States, followed by Great Britain and West Germany. In America, IBM developed the first model 360 System in 1963–1964. This series had models with varying performance capabilities that were supported by a large selection of software. For small models, the DOS/360 operating system was proposed and for large models, the OS/360 operating system; the latter was designed because the DOS/360 was not powerful enough for large computers. The experience of developing these complex and extensive operating systems showed that they required even more labor – thousands of man-years – than creating the hardware itself.

Later, the British company ICL developed the third generation System-4 family of computers, which were simpler from a software point of view. Almost simultaneously the Siemens Company produced an analogous computer family.

The first country in Eastern Europe to develop a series of analogous computers was the German Democratic Republic, where the political establishment decided to copy one of the American IBM-360 models.

Behind the Iron Curtain, discussions about the structure and architecture of third generation computers began in the late 1960s. On January 26, 1967 Glushkov chaired a joint meeting of the Soviet Academy of Sciences Commission on Computer Technology, headed by Dorodnitsyn, and the Council of Ministers State Committee of Science and Technology, headed by Glushkov. There was only one item on the agenda: which ES computer system to select for development in the Soviet bloc nations? The decision was made to use the IBM-360 logic structure and command system as a prototype. Glushkov was the only opponent, and his dissenting opinion was that drawing on foreign experience would certainly be beneficial, but not to the extent of simply copying an entire system, which was already several years old.

At this time, Nikita Khrushchev put forth a government order to transfer several Soviet Academy of Sciences Institutes to various industrial ministries. The Institute of Precision Mechanics was transferred to the Radio Industry and belonged to the Academy of Sciences in name only, thus weakening the authority of its specialists in electronics technology, or to put it more bluntly – completely undermining them.[55]

Glushkov and Rameev offered to pioneer a new computing project based on Soviet computer experience, while keeping an eye on foreign achievements. In October 1967, they wrote to the

[55] *Author's note*: The implications of this decision were enormous. Under the aegis of the Academy of Science, scientists had more creative freedom. At an industrial ministry, one worked only under orders, and creative initiatives were not usually supported.

Radio Industry Ministry, which was in charge of the ES project:

> The resolution to build a unified series of computers for applications in national economy and government is appropriate and timely. It requires a strong team of software engineers. Based on a foundation of streamlined technological design, we can sharply increase our production of computers, and integrate compatible computers into a variety of applications.
>
> Success, which we hope to achieve as the result of developing a unified computer system, depends entirely on how we plan to resolve this question. It is impossible not to have serious objections to the decision to copy the IBM-360 model, proposed by the Commission on Computer Technology on October 26, 1967.
>
> It is imperative to bear in mind that the IBM-360 system, built in 1963-1964, is already lagging behind the standards and current demands placed on mathematical machines.
>
> …The proposal to copy the IBM-360 system is equivalent to manufacturing 1970s computers using the technical standards of the early 1960s. Considering the existing trends in science and technology, the architecture of the IBM-360 will be obsolete in the 1970s, and it will not be capable of meeting the current demands.
>
> Copying foreign work excludes the possibility of utilizing our own collective experience of computer research, and in the immediate future, will hinder our ability to employ new principles. This will bring the development of computer technology in our nation to an end.
>
> The design teams of Soviet mathematical machines have sufficient experience to build a family of computers that would satisfy future requirements.
>
> …It would be a better decision to develop the architecture of a unified series of Soviet computers based on our own domestic experience and achievements, while still keeping an eye on foreign innovation.

The Ural designers had solid grounds for this conclusion. They had already produced a family of Ural-11, Ural-14 and Ural-16 – programmable semiconductor computers. A comparison of the architectural decisions and functional possibilities of the Urals with those of the IBM-360 and System-4 showed that the Soviet machines were competitive with their foreign counterparts. At this time, the Penza factory was just completing the development of the multiprocessor computer Ural-25, while Ural-21 – a design based on integral microchips – had been successfully fine-tuned and put into production.

The transformation to an integral microchip element base and further development of the structure and architecture of the Ural family would certainly have resulted in an advanced unified computer system. Although the Urals had a limited software library, this disadvantage would have disappeared once in mass-production and as the number of users gradually increased.

The proposal to develop ES computers received the full support of the Eastern European socialist countries. Moreover, all of them except East Germany opposed copying the IBM-360. After the negotiations in August 1968, the multilateral document "General Technical Principles of the Creation of ES Computers" was signed and approved by Bulgaria, Poland, Hungary, and Czechoslovakia – with the exception of East Germany – in which the following opinion was expressed:

> The structure of the ES computer should be analogous to the structure of modern systems like IBM-360, Siemens-4004, and System-4. During the development process, it should be possible to change the structure in order to take advantage of the latest computer innovations with an accepted degree of compatibility of software and technical features, while employing domestically patented computer technology, and yet maintain the same development schedule for the entire project.

During further multilateral talks, all of the Eastern European socialist nations unanimously adopted an index of non-privileged instructions for the ES computer that matched the instruction lists of the IBM-360, Siemens-4004 and System-4. The issue of privileged instructions was discussed several times, but no decision was made. The East German specialists, who insisted on duplicating the IBM-360, suggested using its list of official instructions, while other delegations disagreed. A special multilateral meeting in November 1968 aimed at the selection of a logic structure for the ES computer did not reach a unanimous decision; therefore the problem was passed on to an Eastern bloc council of chief computer designers.

The development of Soviet computer technology did not exclude extensive international cooperation. On the contrary, its advocates – Lebedev, Rameev, and Sulim – understood the advantage of cooperating with Western European companies and consciously made efforts in that direction. Western European manufacturers of computer technology were eager to compete with IBM, given the Soviet Union's huge scientific and industrial potential. ICL took the first steps towards establishing collaboration with the Soviet Union in computer design and manufacturing, offering to share some of its System-4 technology.

Rameev was an active supporter and participant in these negotiations and he signed a series of bilateral agreements to cooperate with ICL. He figured that System-4 components could be produced by one or two Soviet computing factories, while the SRI and other construction companies could create an improved series of computers based on both domestic accumulated experience and the most recent foreign achievements.

Thus, there was every reason to conclude that the 1970s would bring new great success. But how did these events actually unfold? Why were the leading specialists, Lebedev, Rameev, Glushkov, Dorodnitsyn, and Sulim ignored, while their opponents ended up victorious in the selection of a prototype for an ES?

This problem was not discussed in the Soviet media, and it remains controversial even now. Archival materials and participants' recollections of the discussions of this issue make it possible to reconstruct the chain of events here.

The wishes of Soviet designers to employ foreign technology, mainly software libraries, were certainly clear: it was quite natural to be curious about the IBM-360 and System-4.

Yet to properly integrate the software, it was necessary to:

- Obtain the full software documentation for the prototype system, which would be needed for manufacturing, support and operation.

- Establish contact with the firm that supported the software.
- Obtain sufficient information that would guarantee software/hardware compatibility of the prototype and any newly created system.
- Provide software-equipped prototype computers for software programmers.

The Soviet Union's choice of the IBM-360 as a prototype did not match any of the above conditions, because IBM had no intention of cooperating with the Soviet Union during that period: America had placed an embargo on the sale of computers to our nation. Any documentation that was available in the Soviet Union for the IBM-360 software was incomplete because it did not come directly from IBM, but was obtained through industrial espionage. The purchase of genuine IBM-360 computers was possible only through "intermediaries," which caused enormous problems.

Soviet relations with ICL were much better, due to the efforts of Sulim, Y. D. Gvishiani – Deputy Chairman of the State Committee on Science and Technology in the Soviet Cabinet of Ministers, and other supporters of cooperation with European companies.

In accordance with a memorandum of April 26, 1968, initiated and signed by the head of ICL and Chairman of the State Committee on Science and Technology, negotiations continued in order to promote cooperation in the area of computer software.

ICL agreed to share detailed information about System-4's software with Soviet scientists and was willing to send their specialists for further assistance during development, production, and software support of Soviet-made third generation computers.

During the negotiations, which included Sulim, Rameev, and several others, ICL's representatives agreed to begin cooperative development of the next generation of computer technology. In order to compete with IBM, they prepared to commit significant funds for this joint venture and provide full documentation of System-4's hardware and software by September 1, 1969.

Excited by these promising possibilities, Rameev agreed to move to NISEVT in 1967 as the deputy chief engineer of the upcoming project; to him, the choice of the prototype seemed clear. However, the biased attitude towards both the "manufactured" success of the provincial Penza school and Moscow's monopolizing organizations – in the first place NISEVT – became apparent much later.

In April 1969, the Council of Chief Designers headed by NISEVT's director Sergei Arkadyevich Krutovskikh, decided that the ES required a logic structure and instruction system that precisely matched the IBM-360, despite the objections from Bulgaria, Poland, Hungary, and Czechoslovakia.

Krutovskikh based his decision on the fact that collaborative work had already begun between NISEVT and its main partner – East Germany, which was studying IBM-360's software and was vehemently opposed to taking any other approach. Chief of the Radio Ministry Industry, Valery Kalmykov, and President of the Soviet Academy of Sciences, Keldysh, backed them: the top leaders had fallen under the hypnotic influence of the proposal to avoid domestic software development.

This plan's proponents argued that IBM had the world's richest and most popular software library, which could not be rejected by even fourth generation computers; and if the Soviet

Union copied the 360 series of machines, then we would be saving time and money. In December 1969 a meeting was held at the Radio Industry Ministry, at which Rameev took detailed notes as acting recording secretary.

The meeting was attended by Kalmykov, Keldysh, Gorshkov (a representative of the Military-Industrial Commission) [in Russian: *Voenno-promishlennaya kommissia*, or VPK], Savin, Kochetov (a representative of the Communist Party Central Committee), Rakovsky, (a deputy representative of Gosplan), Sulim, Lebedev, Krutovskikh, Gorshkov, (Deputy Chief of the Radio Industry Ministry*),* Levin, Shura-Bura, Ushakov, Arefeva, Przhialkovsky, Matkin, and Dorodnitsyn. [56]

According to Rameev's notes, the discussion went as follows:

Sulim: Regarding the state of negotiations with the GDR and ICL.

The option of IBM-360: The GDR is familiar with the IBM-360, and they are successfully developing one of the models (R-40). We have reserves and a team able to start the project. Mastering the operating system of the IBM-360 will require 2200 man-years and 700 workers. We have no contacts with the IBM; problems could develop with the acquisition of an analogous machine, which will cost 4-5 million dollars. The GDR has only a portion of the required documentation.

The ICL: We will receive all of the necessary technical documentation and support to master it. We will need to perform some alterations for which ICL is offering to purchase a batch of its recently manufactured machines. We will be able to use our team of software engineers to design additional application programs.

A group of our programmers has already received on-the-job training at this company. There is a strong likelihood of developing fourth-generation EVMs in the near future. This company is being very helpful in all aspects, because it hopes to compete with IBM after strengthening their alliance with other European companies and us. In addition, Italian and French companies have agreed to participate in the creation of fourth-generation computer technology.

Przhialkovsky: With the IBM-360, we have a system of 6 thousand microinstructions and 90% of the diagrams for the technical-electronic memories; 70% of them have flowcharts; 7000 units have design documentation. To collaborate with the ICL we will have to abandon all of these preparations and start over, which will result in one to one and half years delay. It will also require a lot of money (to purchase the ICL computers). On the other hand, collaboration with the GDR, who is successfully working on the IBM-360, is preferable. If we strengthen our teams of mathematicians, the DOS can be operational by 1971. It's time to stop vacillating.

Krutovskikh: Our project is modeled after the IBM-360 systems. If we collaborate with ICL, the composition of the models will need to be different. The technical characteristics will change and require four to five months for a preliminary design. At ICL, there is no clear distinction among their high-end models. They are included in the series of small and medium-sized computers as supercomputers. This is best not done. To change the direction at this time will push back the deadline for preparing technical documentation by one and half to two years, or perhaps more.

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[56] *Editor's Note:* The description of this meeting and its interpretation are the opinions of the author and not of the editor, editorial consultant, or the translator. Without a doubt, the scientific proponents of the IBM-360 had their own good reasons for their arguments.

Having worked with the GDR on the IBM-360, we can receive DOS and OS and begin serial production, without having to develop them ourselves. The Germans have gone too far to able to start over in a new direction with the ICL. The British are only interested in competition and they will likely jerk us around. They will not collaborate with us on larger machines; plus, we cannot buy 150 of their machines right now.

Dorodnitsyn: The issue of mastering the IBM-360 is oversimplified here. In actuality, it is considerably more complex. Mastery of the OS will require no less than four years, and we don't know how useful that will be. We need to collaborate together with ICL to create our own DOS and OS and produce our own computers.

Lebedev: The IBM-360 system series was developed ten years ago. We will have to limit our line of machines to small and medium capacity because the architecture of the IBM-360 is not adaptable to larger models (supercomputers). The British want to compete with the Americans after the transition to fourth generation computers. Machines with higher productivity require more specialized structure. The British are laying the foundation for automated design. The software system for the "System-4" is dynamic, and we will be able to develop it with the Brits. In turn, this will facilitate hands-on training of our personal, which would me more effective if done while developing our own proprietary system (together with the British).

Shura-Bura: From the point of view of the system software, the American version is preferable. The OS will require modifications and we will need to be familiar with all programs to achieve that.

Keldysh: We need to purchase licenses and design our own machines; otherwise we will simply repeat what others have already done. In general, we would have to create larger machines ourselves.

Lebedev: Our mathematicians believe that our programmers would receive better training using British methods.

Rakovsky: We need to consider long-term effects and come up with a unified concept. Everyone has agreed that the IBM has the most up to date software, but its operating system is very cumbersome. It would be virtually impossible to master it in four to five years. Although difficult, a decision needs to be made right now. If we choose to collaborate with the ICL, there will be political fallout with East Germany; plus, over the next five years they will produce two hundred models of the R-40. And still, we should accept ICL's offer.

Krutovskikh: Every developer except Rameev is against working with ICL. Besides, the R-50 will be ready in 1971.

Kalmykov: On the plus side, if we have DOS, we will be able to use the machines as soon as we produce them. We can also obtain many programs from the Germans. But on the minus side, we do not have any of the IBM-360 machines, and we will not have any contact with the IBM. We will loose time if we decide to collaborate with the ICL, but we will have direct contact with them and there is the promise of collaborating on the development of fourth generation computers, which is a greater advantage. They plan to design it without the Americans to compete with IBM.

Keldysh: We should not collaborate with the ICL now, but must team up with them on the design of the fourth generation of computers.

Kalmykov: Collaboration with the ICL is not going to happen. Instead, we need to ask the Germans for more help.

Those active supporters of copying the IBM-360 were General Designer of the ES-EVM Krutovskikh, his first deputy Levin, Shura-Bura, and Przhialkovsky. If at Kalmykov's conference on 18 December, 1969 – where the final design decision was made – the project leader would have taken a stand against copying, the computer technology development in the Soviet Union would have taken a different path.

A few months later, the Radio Ministry approved the final proposal in favor of copying the IBM-360 system.

Sulim immediately resigned from his post as Deputy Minister; a desperate gesture of protest from a man who had done everything possible to establish contacts with ICL and understood the negative consequences of copying the IBM-360 only too well.

Rameev asked to be removed from his position as Deputy General Designer of the ES computer.

As mentioned earlier, Lebedev failed to reverse the decision; the refusal of his subsequent attempts only worsened his condition and accelerating his death.

The scientific basis for the solution to this important problem – what kind of machine the ES computer was supposed to be – was substituted by the administrative order to copy the IBM-360 system: the Radio Industry Ministry, the Soviet Academy of Sciences, and NISEVT's managers did not bother to take into account the opinions of leading computer scientists from the Soviet Union and other Eastern Bloc nations.

This decision resulted in negative and tragic consequences for Soviet computer science. In his 1991 study, Rameev analyzed the enormous labor and material costs. Following are some of Rameev's conclusions:

Up through January 1, 1989 the entire Soviet Union had 13,613 general-purpose computers. This stock consisted of:

24.9% computers of 1965 vintage (ES-1022);
12% various computers issued between 1965 and 1970;
13.6% computers issued in 1971 (ES-1033, ES-1055);
36% computers of the 1973 and 1978 era (ES-1035, ES-1036, ES-1045, ES-1046, ES-1060, EC-1061);
13.5% other computers issued between 1971 and 1980 (23 various models of ES computers, automated work stations based on ES computers, and imported foreign computers).

Model	First production year	Quantity in stock as of January 1, 1989	Portion in overall stock in percentage	Analogous prototype	First production year of analogous prototype
ES-1066, 1086	1984	43	0.3	IBM-3033	1980
ES-1061	1980	400	2.9	IBM-370/158	1973

ES-1060	1977	237	1.7	IBM-370/158	1973
ES-1055	1978	456	3.3	IBM-370/155	1971
ES-1046	1984	375	2.8	IBM-3031	1978
ES-1045	1979	1069	7.9	IBM-3031	1978
ES-1036	1983	933	6.9	IBM-370/148	1977
ES-1035	1977	1872	13.8	IBM-370/138	1976
ES-1033	1975	1405	10.3	IBM-370/145	1971
ES-1022	1974	3396	24.9	IBM-360/50	1965
Various computers built from 1965- 1970		1635	12.0		
Other imported computers	1971-1978	1774	13.2 (less than 1% of each model)		
	Total	13,613	100		

The choice of foreign analogs was derived by nominal productivity without taking into account additional parameters, which would have defined technical standards.

At first glance, the technical level of the computer inventory, expressed in years, appears to mean nothing. However, these figures hide huge differences in technical/economical indicators and effectiveness.

The use of obsolete computers and information systems wasted massive quantities of personnel, financial and materials resources, and overshadowed the technical and economic benefits they managed to achieve. The losses caused by work-stoppages ("down-time"), and trouble-shooting (low reliability) of computers and systems in 1989 cost the Soviet Union about 500 million rubles.[57]

Such were the consequences of the Soviet government's willful decision to copy the IBM-360. The "sovietization" of the IBM-360 system was the first step in surrendering the forefront position won by Soviet computer scientists in the 1950s and 1960s. The second step, which led to an even further retreat, was the mindless copying of subsequent American microprocessors, an initiative led by the newly founded Ministry of Electronic Industry. The culmination of this

[57] *Translator's Note*: The official currency exchange rate in 1989 was about 0.6 rubles to $1.00.

process was the replacement of computer research and development in the Soviet Union with importing large quantities of computers from abroad.

After receiving Rameev's letter of resignation from the position of Senior Designer of the ES computer, Kalmykov did not even bother to analyze the reasons why the country's leading computer designer and founder of the Penza scientific school made such a choice. Just like countless times before, the Communist administration failed to take advantage of this famous scientist's great creative potential, causing irreparable damage to the scientific-technical progress and to the society as a whole.

During the last years of his life, Rameev lived in Moscow. On the bookshelves in his apartment, he kept his reports, projects, and photos. Gradually, these items were donated to the Russian State Polytechnical Museum in Moscow. Rameev passed away on May 16, 1994.

The Creator of the Ternary Computer

On June 21, 1941, Nikolai "Kolya" Petrovich Brusentsov was an eighth-grade schoolboy living in Dnepropetrovsk, Ukraine. The next day, along with millions of other Soviet citizens, he heard Vyacheslav Molotov's radio proclamation that Germany had invaded the Soviet Union: Molotov's famous words, "Victory will be ours!" accompanied by Borodin's *Bogatyrskaya Symphony,*[58] marked the last day of Brusentsov's childhood.

He was born on February 7, 1925 in the village of Kamenskoe, Ukraine. His father died in 1939 at the age of 37. Kolya's mother was left to care for him and his two younger brothers. When the war began they dug holes in the ground near the house and hid there during the bombings. Eventually they were evacuated to the Orenburg region of Russia. The Urals greeted them with -40°C temperatures. At first, the evacuees lived in tents and later on made crude barracks out of straw and mud; most of them were part of the construction crew that built the Orsko-Khalilovsky metal manufacturing plant. Kolya worked as an apprentice for a cabinet-maker. In spring 1942 the Ural River flooded, submerging the straw and mud barracks where the Brusentsov family lived, destroying all of their remaining property.

Nevertheless, Kolya did not leave school. He attended night school in Novotroitsk during the winter of 1941–1942, and in the summer moved to Sverdlovsk (now Ekaterinburg). He had already been accepted at the Kiev Music Conservatory – which had also been evacuated to Sverdlovsk – in the Folk Music Instruments Department.

In February 1943, at the age of 18, Brusentsov was drafted into the Army and sent to radio classes in Sverdlovsk. Six months later he was dispatched to serve with a rifle division near Tula. Two weeks later they were mobilized to Nevel where our troops were partially surrounded by the Germans. He memorized the words from a German propaganda leaflet: "You are in a ring; we are in the ring; lets see what the end will bring." Up until December 1943, the division was on the defensive; then after regrouping with other troops, took the offensive and advanced to Vitebsk. In one of the battles, a mine fell at Brusentsov's feet but fortunately did not explode. "According to my mother I was born with a silver spoon in my mouth" – he recalled. The difficult conditions at the front slowly improved after several successful offensives in Belarus,

[58] *Editor's note:* Vyacheslav M. Molotov was the Soviet Union's foreign minister at that time. In 1939 he had signed the Nazi-Soviet Non-Aggression Pact with Hitler.

the Baltic Republics, and East Prussia. Brusentsov was awarded a medal for bravery and the Red Star Order in 1945. Out of the twenty-five 18-year-old soldiers, who were initially drafted to form his division in August 1943, only five remained.

In 1946 Brusentsov's entire family moved to Tver, Russia, where his stepfather had been transferred to work. Brusentsov began studying simultaneously at a conservatory and at a school for young workers. He graduated from the 10th grade in 1948 with excellent marks, and on the advice of a friend from Moscow, applied to the Radio Department at the Moscow Energy Institute.

During his first year at the Energy Institute he battled tuberculosis, but managed to overcome it and stayed in school. His room in the dormitory was next to Mikhail Kartsev's room and the two often studied together. Neglectful of his own health, Kartsev also came down with tuberculosis, which was a very common disease among the MEI students at that time.

Radio technology captivated Brusentsov. While preparing his diploma project during his last year at the Institute, Brusentsov came up against the problem of calculating complex tables. After investigating a number of calculation methods, he put together diffraction tables on an elliptical cylinder, now known as Brusentsov's tables.

After graduating from the Institute in 1953, Brusentsov was sent to Moscow University's SKB, where they promised to help him find an apartment. At that time, the Bureau was just established and projects were assigned randomly. At first, they asked Brusentsov to build a new type of vacuum tube amplifier. Even though he handled the job well and completed the task, he received little satisfaction from it, and moreover, could not see himself doing such work in the future. He casually complained about this to his friend Kartsev, who by now was working in Brook's laboratory. Kartsev invited him to see the M-2 computer, which was already operational. It was the first time Brusentsov had seen such a modern and promising device, and he immediately fell in love with it. As luck would have it, the computer also caught Sobolev's eye; he arranged to have it moved to the University, and Brusentsov was sent to Brook's laboratory to familiarize himself with the machine prior to its transfer. Unfortunately, at the Soviet Academy of Sciences elections, Sobolev voted for Lebedev to be nominated as an Academician instead of Brook. Isaak Brook was offended and canceled the transfer of the M-2 to the University.

Brusentsov recalled what Sobolev said upon hearing the news, "Maybe it's for the best. We need to create our own laboratory at the Moscow University computer center to develop computers for use in our schools." So he decided to transfer Brusentsov to the Mechanics-Mathematics Department at the University.

Brusentsov recalled his first meeting with Sobolev:

> When I first came to Sergei Sobolev's office, it seemed as if I was enveloped in sunlight – his face looked that kind and open. We hit it off immediately and I will be forever grateful to providence for leading me to this remarkable man, a bright mathematician and knowledgeable scientist, one of the first people who understood the significance of computers.

Sobolev wanted to develop a small computer suitable for use in university laboratories. He organized a seminar in which he, Shura-Bura, Konstantin Adolfovich Semendaev, and Zhogolev participated. They analyzed the disadvantages of existing computers, looked at instruction systems and architecture, and considered various plans for technical implementation – they were leaning towards using magnetic components because there were no transistors yet, but magnetic rods and diodes were available. They had excluded vacuum tubes right away because they could not be integrated into a small computer. The tasks for designing a small computer and its fundamental technical requirements were assigned at Sobolev's seminar on April 23, 1956. Brusentsov was appointed as the supervisor and executive designer of this machine, which would be based on magnetic elements and have a binary system.

Sobolev had agreed with Gutenmakher to send Brusentsov to his laboratory at the Institute for Precision Mechanics to gain experience with this sort of technology. Sobolev's clout opened doors for Brusentsov that were closed to everybody else. "They showed me their computer and supporting documentation, but to me it seemed technically weak," recalled Brusentsov.

That is when Brusentsov decided to use a trinary number system. It allowed him to create very simple and reliable elements, plus he needed seven times fewer elements than Gutenmakher. The power source requirements were significantly reduced as well because a smaller amount of magnetic rods and diodes was used. However, the main advantage was in using a natural number-coding system instead of direct, reciprocal and supplementary number coding.

Sobolev strongly supported the project and brought in many young assistants to help. By 1958, Brusentsov's 20-person team assembled by hand the first model of the computer. They named the computer Setun, after a river near Moscow University.

Brusentsov discussed the roles of the participants in the Setun project:

> Sobolev was the heart and soul of this project. Unfortunately, his participation in our creative work ended in the early 1960s when he moved to Novosibirsk. All of his later involvement revolved around perpetual fighting with bureaucrats for the right to do the work we believed in.
>
> Zhogolev was our main programmer and together with him I developed what we later called "computer architecture." He would come up with what he wanted the computer to do and I estimated how much it would cost and offered alternatives. When we settled on the trinary system, all of the architectural problems were simplified. It was important not to complicate our design, and we used to troubleshoot our ideas during the seminars with Sobolev, Semendaev and Shura-Bura.
>
> A small team completed the project in a very short period of time. In autumn 1956 – when the idea of the trinary code emerged – the lab had four engineers and five technicians plus me. The mechanical manufacturing work on the units, frames, and the circuit boards where the elements were mounted, was done partly in the computer center workshop and partly in the workshops of the Physics Department. In addition, this was the first version of memory storage on a magnetic drum, where initially a gyroscope was employed with tube electronics. It was later replaced by a magnetic semiconductor unit with a drum from the Ural computer.
>
> The whole team worked inside one 60 square-meter room, filled with laboratory tables. We designed and assembled all of the devices ourselves – put together the research stands, sorted the ferrite elements and diodes, tested the cells and blocks. The workday began with "morning exercises:" everybody,

> including the chief, started with five ferrite cores and made preliminary tests on a stand. Using an ordinary sewing needle, they wound fifty-two coils of wire onto each core. Then the cores were passed to the assistants and technicians, who wound power-supply and control cables with five to twelve coils onto them, mounted the cells on printed cards, soldered the diodes, and provided a personal inspection mark. Then, the cells were mounted on the blocks; the signal and power-supply cables were produced next, according to the assembly schemata. After this, the testing of the block logic functions (adder, decoder, control pulse distributor, etc.) was carried out on a stand. Smaller blocks were installed on the larger blocks, and then their functions were tested. Finally, the blocks were installed onto a frame that we made and connected with an inter-block mounting cable. As a rule, everything worked fine after that. If something did go wrong, it was easy to detect and correct.

In accordance with a decree from the Soviet Cabinet of Ministers, the Kazan Mathematical Machines Factory was put in charge of mass-producing the Setun computer. The first model built at the factory was displayed at the National Exhibition in Moscow, but the second one was sent back because plant managers and officials from the Radio Ministry Industry maintained that the computer was not yet reliable and therefore not ready for mass-manufacturing.

"We were forced to manually adjust the second model of the computer made at the Kazan factory in accordance with our original documentation," Brusentsov recalled. "During testing it demonstrated 98% operational effectiveness. The only registered failure was the breakdown of a teletype diode. It also performed well in climate testing and supply-line voltage variations. On November 30, 1961, the director of the Kazan factory was forced to sign an act which ended his attempts to thwart the production of the computer."

Still, the leadership at the Kazan plant was not interested in large-scale computer production and they made only about fifteen to twenty computers annually. Soon they refused to do even that: since the Setun sold for 27,500 Rubles, they did not have sufficient financial incentive to continue. Setun's reliability spoke for itself, operating in different climatic zones: from Kaliningrad to Magadan; from Odessa and Ashkhabad to Novosibirsk and Yakutsk. It worked without any support and essentially, without spare parts. The Kazan plant issued fifty Setun computers, thirty of which worked in higher education establishments in the Soviet Union.

Setun attracted significant interest from abroad. The Ministry of Foreign Trade received many orders from East and West European customers, but none of them were filled, an anathema for the "supply and demand" oriented western minds.[59]

Between 1961 and 1968 based on their experience with Setun, Brusentsov and Zhogolev developed the architecture of another new computer, at that time called the Setun-70. Its functioning algorithm was comprehensively described in expanded Algol-60. The first model was operating by April of 1970. Brusentsov recalled:

> A year later, the modernized Setun-70 had been transformed into a structured programming computer, designed for very effective software development in

[59] *Translator's Note*: Neither the development nor future sales of Setun were part of the Soviet State economic plan: first, Setun was a university-initiated project, and second, all employees at the Foreign Trade Ministry had fixed salaries and could not receive pay increases or bonuses for such sales. On top of this, the Soviet government discouraged the sharing of technology during the Cold War.

> which the trinary system played a key role. It had no instructions in the traditional sense, but consisted primarily of syllables: syllable-addresses, syllable-operations. The syllable's length is equal to 6 trits, or one tryte – a trinary analog of the binary byte. The command length and addresses vary according to need, beginning with the zero-address instruction. In fact, the programmer does not think about instructions but simply writes the expressions that describe the calculations as a stack of operands. These algebraic expressions are program-ready for the processor, but the algebra is supplemented by testing, control and input-output operations. The user can add his own operations to the set of syllables by inputting his own procedures, which do not reduce the computer's performance, but instead provide the ideal conditions for structured programming. As a result, the programming time is reduced by five to tenfold, with unprecedented reliability, clarity, modification possibilities, compactness, speed, etc. It is clearly the most progressive architecture, and eventually will be developed.

Unfortunately, after the Setun-70 project, Brusentsov's lab was relocated from the Computer Center at Moscow University to a windowless attic in a student dormitory and was deprived of any serious support. The new university rector considered computer design a pseudo-science. Brusentsov's original Setun computer, an experimental prototype that had faithfully worked for seventeen years, was barbarically destroyed and carted off to the dump. Brusentsov's laboratory coworkers took the Setun-70 to their attic laboratory and used it as a basis for developing the Master Work Station – an educational computer system.

To this day, Brusentsov maintains that the trinary system is superior to binary, but only time will be able to tell whether or not he is correct. Today, Brusentsov manages the computer laboratory of the Computing Mathematics and Cybernetics Department at Moscow State University. Brusentsov runs several projects connected with microcomputer education systems and programming systems. He has published over 100 scientific works, received 11 invention certificates and was awarded the Sign of Honor Order and the Large Gold Medal of the Soviet Union National Exhibition. He is also an award-winning Laureate of the USSR Council of Ministries.

The Founder of Non-Traditional Computer Arithmetic

Israel Yakovlevich Akushsky was born on July 30, 1911 in Dnepropetrovsk, Ukraine, into the family of the city's head rabbi. While still a student at Moscow State University, Akushsky started working as a data analyst at the University's Mathematics and Mechanics Scientific Research Institute and later under Lazar Aronovich Lusternik – the creator of functional analysis – at the Steklov Mathematics Institute. At that time, calculation technology attracted few people, so Lusternik was an exception among mathematicians. However, the approaching war forced the rapid development of calculation technology, and the Steklov Institute received a government order to compute trajectory tables for artillery and navigation tables for military aviation. In 1939, when the Soviet Union's first calculation laboratory was founded at the Steklov, Akushsky was ordered to manage it. The volume of planned calculations was enormous, so naturally the question emerged – what instruments do we use in order to complete these tasks on time? Back then, arithmometers, abacuses, and slide-rules were the primary tools: the Soviet Union had only just begun to manufacture punch-card calculating machines. By then, IBM had already developed reliable punch card analytical machines (PCAMs) and in 1940 brought a set to Moscow to display at the State Polytechnical Museum. IBM did not produce the machines for sale, only for lease. Since the Soviet government could not buy them at that time, Akushsky managed to have some of the machines moved from the Polytechnical Museum to the Steklov Institute, where he established the country's first mechanical calculation laboratory – the precursor of electronic computer centers.

Akushsky recalled:

> In 1942, the IBM Company asked the Polytechnical Museum to return the machines to the United States. Naturally, the Museum managers sent a letter to the Mathematics Institute and I was forced to come up with an answer. Returning the machines was out of the question, because it would deprive the Institute of the ability to perform important defense work.
>
> I replied that due to wartime conditions, the government had ordered to have all valuable equipment evacuated to the far regions of the Soviet Union, were it would be safe from bombings, and at this time, we were not able to determine exactly where the equipment was located.

After the start of the war, the greater part of the Institute *was* evacuated, but some of the staff, including Akushsky, remained in Moscow and worked for the Army, computing navigation tables for aviation.

Mikhail Gromov – the comrade-in-arms to the legendary pilot Valery Chkalov[60] – visited the institute on several occasions, going directly to Akushsky for the latest results. When it was suggested that he visit the institute's top managers instead, he jokingly answered that he had enough managers of his own and would obtain the results directly from Akushsky. Sometimes, Gromov took Akushsky on short unexpected business trips; they would go out to the airfield and fly to a meeting near Saratov, the latest site for calculations. Akushsky would consult with the data analysts, check their work, and then return to Moscow the next morning.

Yet these were dangerous times. Once, in the middle of the night, Akushsky was arrested and taken to Lubyanka, the infamous KGB headquarters and prison in Moscow. His department manager had been taken there as well and they were both subjected to a ruthless interrogation:

"Are you responsible for the creation of the navigation tables for aviation flights?"

"Yes," they answered.

"Well, several days ago in the Far East, an aircraft didn't return from a special mission. We lost all radio contact with it, and if it's not found soon, you will be held responsible in accordance with war-time law."

When he got over the shock, Akushsky asked, "In the Far East?"

"Yes."

"Most likely, the navigator did not consider that crossing the 180th meridian requires a correction using the opposite sign! Do you have their flight plan?"

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[60] Chkalov made the first non-stop Moscow to Vancouver flight.

As soon as he received it, Akushsky calculated the possible trajectories of the aircraft, and using this data, the wreckage of the plane was found. The scientists were released with apologies.

Akushsky and his colleagues performed a tremendous amount of work right up to the end of the war. For example, they were given a special order to calculate fifty different round-trip flight plans between Moscow and Teheran. Later, they understood that it was for Stalin's flight to the "Big Three" (Stalin, Churchill, and Roosevelt) Teheran meeting in 1943. The relatively reliable American IBM equipment helped the laboratory successfully create the tables for flight plan angles and distances, especially for long-distance bomber aviation.

Akushsky worked with great enthusiasm, giving his all to his beloved work without any regard for time. The tables were published secretly by the Soviet Academy of Sciences. From the first months of the Great Patriotic War he became an indirect participant, assisting aircraft navigators to fly bombing missions over Berlin. A few months later, he was sent from besieged Moscow to the blockaded and starving city of Leningrad. There, he and his colleagues finished the work that they had started in Moscow, preparing calculation tables for the Naval radar systems.

At the end of 1943, Akushsky returned to Moscow. He briefed the Steklov Institute Director, Ivan Matveevich Vinogradov, about the work that they had done, and added that he would be like to quickly prepare for his Candidate's thesis on the problems of using analytical calculating machines for the solution of mathematical tasks (he was the first in the nation to propose and implement the binary system for calculations, which later became the basis for all computer technology, plus he developed the theory and calculating methods for radar navigation, surveillance and detection problems).

Vinogradov somberly replied, "I cannot release you from your laboratory duties right now. However, I'll inform you as soon as it is possible." Vinogradov always kept his word, and in February 1945, he called Akushsky to his office, saying, "I had a meeting with Marshal Zhukov[61], and the war is coming to an end. Now you can work on your dissertation!" He then ordered for Akushsky not be disturbed during day, with the exception of the first hour in the morning.

By May Akushsky's thesis was ready, and he informed the Director. Their conversation was brief, as usual:

"Well, it will be considered at the staff meeting. Your opponents will be Academicians Lavrentiev and Semendaev."

"But Lavrentiev takes a year to answer his letters. He'll delay the response preparation!"
"Don't worry. He'll do everything on time."
"But Semendaev is very jealous of me. I've already heard what he said about my work."
"He was speaking in the corridor. I dare him to try and say the same thing at the staff meeting."

At the end of June, the responses to his thesis came in; both were positive. Professor Semendaev furnished his response in person; he wanted Akushsky to read it immediately and then asked, "So, what do you think?"

Akushsky replied: "You have praised me too much!"

[61] Marshal George Zhukov was the Soviet chief military commander, responsible for most of the major Soviet victories during the Second World War, including the final capture of Berlin.

Akushsky's thesis defense was set for July 5, 1945 and was very successful, although not without some initial concern, because the board members were preparing to leave for their summer holidays. A few days before the defense, Akushsky shared his anxieties with Vinogradov, who smiled and slyly replied, "I promised that you'd have your Candidate's degree by the summer and I intent to keep my word, so calm down. Our accountant was given strict orders to delay holiday pay until July 5th!"

Academician Kolmogorov was one of Akushsky's strong supporters and was present at his thesis defense. During the war, Kolmogorov had been corresponding with the famous American scientist and cybernetics pioneer, Norbert Wiener. A short while after the defense, Kolmogorov asked Akushsky to prepare a paper based on his thesis and sent it to Wiener. In 1946, when Wiener visited the Soviet Union for the first time, he was already familiar with Akushsky's work, thanks to the article. Wiener spent all of his time at the Steklov Mathematics Institute speaking with Vinogradov and Akushsky and giving lectures on cybernetics. He pointedly ignored the invitation to visit the Institute of Philosophy, where at the time, they considered cybernetics a pseudo-science.

Even during the war, Lusternik organized and ran scientific seminars on calculation theory, in which Akushsky took an active part. At that time, Bruevich was the Board Secretary of the Academy of Sciences, and regularly led seminars on precision mechanics. At the end of the war, the two seminars were combined to serve as a forum for questions regarding the development of computing machines. Participants discussed the necessity for organizing a new, separate institute. Soviet-made punch-card machines were not reliable enough, and suitable only for accounting work. Analogous computational means could not provide for the advancing requirements of science and technology. Since the ideas of creating digital computers were already circulating in both the Soviet Union and abroad, the President of the Academy of Sciences at the time, Academician Sergei Vavilov, passionately supported the idea of establishing an institute. Once he published an article about it in *Pravda*, the plan was promptly approved by the government. In 1948, when the Institute for Precision Mechanics was established at the Academy of Sciences, it initially included Lusternik's department from the Steklov Institute along with Akushsky's laboratory, Academician Bruevich's department from the Precision Mechanics and Machine Building Institute, and Isaac Brook's department from the Power Engineering Institute, although Brook did not formally move to the new institute.

Academician Bruevich was appointed Director of the new Institute for Precision Mechanics. One year later he was followed by Lavrentiev, and in 1952 upon Lavrentiev's recommendation, the institute's directorship was turned over to Lebedev.

Yet soon after this time, the artificially concocted "Jewish problem" began surfacing in the Soviet Union.[62] Akushsky remembers this meeting with Andrei Alexandrovich Zhdanov, the Communist Party Central Committee's Science Supervisor:

"How's the work going?" Zhdanov asked Akushsky.
"Somewhat …uncomfortably," he answered.

"Why not pursue your research at another Republic's Academy? If you would like, I could

[62] The "Jewish Problem" refers to a period when the KGB and the First (Security) Department at every institute began to unofficially ban Jews from having access to all military and top-secret projects.

recommend you to the President of Kazakhstan, Kunayev, as a very promising specialist who could lead the development of computational mathematics in the republic."

Akushsky understood this "recommendation" as a clear order to leave Moscow. He replied, "Thank you. I agree." And that is how the Alma-Ata period of his life began.

At the Academy of Sciences of Kazakhstan, Akushsky organized the laboratory of machine and computational mathematics that later became the Institute of Mathematics and Mechanics. At the same time, he lectured on the mathematics of calculations at Kazakhstan State University.

Between 1954 and 1956, Akushsky came up with an idea for creating a special computing system that would considerably accelerate the calculation process in computers. He dedicated the rest of his life to its realization. Back in Moscow late in 1956, Akushsky met with Mikhail Lesechko, the Minister of Industrial Machinery and Device Building whom he knew from before. Lesechko was very interested in computer technology and asked:

"What are you doing in Kazakhstan? You should return to Moscow and work at SKB-245."

Akushsky happily agreed. At SKB-245, Akushsky was appointed as a senior scientific staff member and later a lab manager of the mathematics department. At first, Akushsky worked on developing a computer that used a conventional system of calculation. However, his preference was to develop a system based on remainders [in Russian: *Sistema schisleniya v ostatkakh*, or SOK] and use it to create a computer.

In 1961, he met the Czech scientist Antonin Swoboda at a mathematical conference in Leningrad. They spend a lot of time discussing the contents of their respective presentations on the SOK. Akushsky quickly understood that he was much further ahead in his work than the Czech scientist. Obviously, Svoboda realized this also, because he replaced his original report with another one on the trinary system of calculation.

By 1957 the SKB-245 team consisted of Bazilevsky, Rameev, Yuri Schrader and Akushsky, who together started developing a computer based on a system of remainders. However, the project did not get very far, mainly because Akushsky was the only member of the team who strongly believed in the remarkable possibilities of the SOK; in 1960, when he was invited to lead a similar project at the Scientific Research Institute of Long-Distance Radio Communication, he agreed without hesitation.

The expected performance of the SOK computer was about 1.25 million operations per second, and it was successfully used in the national air defense system. This computer received a second life and was used up to the 1990s, thanks to integrated circuits.

In Czechoslovakia, the Epos computer was developed under Svoboda's supervision. It also used SOK technology, although it had lower operational speed and was practically never used.

Akushsky spent the latter part of his career working at the Zelenograd Scientific Center for Microelectronic Technology – just outside of Moscow, and I got to know him in the 1970s.

I visited Akushsky at his home several times, and met his wife Galina Petrovna, who was very involved with all of her husband's students and associates. They had no children of their own, and were like surrogate parents to all the young people who visited their home.

However, not all aspects of his life were pleasant, despite being able to patent many computational inventions in such leading countries as England, America and Japan. After

Akushsky had already relocated to Zelenograd, an American became interested in collaborating to build a computer based on Akushsky's ideas and the latest cutting-edge American technology. Preliminary negotiations were underway and K.A. Valiyev, director of the Institute of Molecular Electronics, was preparing to work with modern microchips from the United States. Suddenly, Akushsky was called to meet with the "experts" (the KGB), who stated that "Zelenograd Scientific Center was not going to contribute to the intellectual enrichment of the West!" With this, all the work stopped. Unfortunately, it was not the only time when rudeness, ignorance or intrigue impeded the progress of technology and Akushsky's innovative ideas.

Dealing with his problems took their toll – he suffered a stroke, was hospitalized, and was forced to walk with a cane for a prolonged period of time. During my frequent visits, we took walks near his home and he told me lots of stories about the creation of Zelenograd, and the kindness of F. V. Lukin, Valiyev, and Malinin. He considered them the real "founders of the city," excellent scientists and planners. The only person, about whom he spoke with restraint, was Phillip George Staros.

Akushsky had the ability to find a common language and mutual understanding with all kinds of people – from the engineers to scientists at the Academy Presidium. Although he was not a Communist party member, he had a very good relationship with the party leadership in Zelenograd, even with the city administrators.

Akushsky was very disappointed that the Soviet computer technology was falling further and further behind their foreign competition, especially in the pace of development. At the same time, he understood that he and other Soviet scientists would not be able to help the Party machinery in this matter.

Akushsky died somewhat unexpectedly. On the night of April 2, 1992, as he got up from his bed, he fell and badly injured his head and leg. An ambulance took him to the hospital. Later in the day, when his wife visited, he seemed to be doing well. At the end of that day, he said he was tired and wanted to sleep. But by midnight, his condition had worsened. The head nurse called the doctor on duty, who wanted to perform an emergency surgery. But the head trauma turned out to be a mortal wound and they were not able to save him. His funeral at the central cemetery in Moscow was attended by many of his students and close friends.

Chapter 6: The Soviet Scientist from America

The Beginning of Soviet Microelectronics

One of the most notable periods in the history of Soviet computer development began in Leningrad in the late 1950s, with the work of a group directed by Philip Georgievich Staros and his closest assistant, Iosef Veniaminovich Berg. They were the first ones in the Soviet Union to achieve significant results creating computer models with microelectronic controls and were instrumental in organizing the Zelenograd Scientific Center for Microelectronics with branches in several cities in the Soviet Union.

In 1956, one of Leningrad's scientific development organizations established the special secret laboratory, SL-11. There, scientists created experimental models of film microcircuits, integral multi-hole ferrite plates for memory devices, and computer logic units with low energy consumption. After visiting SL-11 in 1959, Dmitri Ustinov – he was the chairman of the Military Industrial Commission of the USSR Cabinet of Ministers back then – organized an independent construction bureau under Staros. By 1961 it was christened Construction Bureau-2 (KB-2) of Electronic Technology.

KB-2's first major project was the record breaking two-year development of the UM1-NX control computer.

In 1962, the UM1-NX was approved by a State Commission headed by Academician Dorodnitsyn and slated for mass-production. The computer became the forerunner of a new class of technology – microelectronic control computers. Although the logic part of the UM1-NX and read-only memory (ROM) of constants and instructions used discrete elements, it was the first computer that realized the principals and technical advances of microelectronics. The essential distinguishing features of this computer were its low cost and high reliability in industrial conditions. For example, during the first 12,000 hours of operation in metallurgical production control system at the Cherepovetsk Metallurgical Factory, the machine's failure-free index registered over 1500 working hours.

The Americans recognized UM1-NX as the world's first mini-computer. In a review of Soviet computers published in *Control Engineering*, (no. 5, 1966) with the title "Desktop Model," the UM1-NX was described as "remarkable" for its size and low energy consumption.

According to a resolution of the Central Committee and the Soviet Cabinet of Ministers, the UM1-NX was manufactured at the Leningrad Electromechanical Plant [in Russian: *Leningradskii elektromekhanicheskii zavod*, or LEMZ]. Using variable units designed for the UM1-NX computer, the LEMZ filled many industrial orders for control complexes.

In November 1969, Staros and his co-workers were awarded the Soviet State Prize for their work on the UM1-NX control computer complexes and their usage in the first digital control system in various branches of the Soviet economy. Simultaneously, KB-2 was researching microelectronics, creating experimental models of micro-miniature logic and storage elements for computers, and developing ideas and methodologies for construction of microelectronic equipment.

Soviet leader Nikita Khrushchev visited KB-2 on May 4, 1962. He was accompanied by Defense Minister Ustinov, Senior Naval Commander Sergei Gorshkov, Electronic Industry Minister A. I. Shokin, and a number of other high-level managers from the military-industrial complex. Staros presented a succinct report (Khrushchev loved reports of this style) about the significance of microelectronics for the national defense and general scientific-technical progress in the Soviet Union. During Staros' report, working models of microelectronic computing technology were demonstrated: UM1-NX microchips and integral storage devices, and prototypes of equipment for simulation of fighter aircraft maneuvers and pilot decision-making during air battles. The report concluded with Staros' proposal to build a Scientific Microelectronic Center.

Within a month after Khrushchev's visit, the Central Committee and Soviet Council of Ministers (without a doubt, setting a record for bureaucratic brevity), passed a resolution to construct the Zelenograd Scientific Center for Microelectronics with branches in Kiev, Minsk, Riga, Vilnius, and a few other cities. The project envisioned intense development of all microelectronic components for various branches of the economy, especially for science and electronic machine building.

During his first two years at Zelenograd, Staros was the Deputy General Scientific Director of the new center, while remaining the Chief Designer at the KB-2.

Under Staros, the UM-2 microcomputer was developed at the KB-2 in 1964. This computer was designated for aerospace applications. Besides an advanced structure, UM-2 had an original circuit scheme and other technological features, which greatly influenced the development of on-board computing devices in later years.

The design of the UM-2 computer, with its elegant architecture and technology, later found applications in these two areas: the Electronika K-200 control computer, which weighed about 120 kg and had an operating speed of 40,000 operations per second, and the Electronika K-201 control complex, with upgraded input-output peripheral devices. They were both manufactured in the late 1960s at the Rubin plant-complex in Pskov. During the 1970s, the Electronika K-200 and the systems based on it, were widely used in industrial control, specifically in the electronics industry.

The UM-2 computer also was used in the Uzel multi-purpose control system for small Naval submarines.[63] The Uzel system successfully passed state testing and was produced at the Pskov Rubin Complex. It was delivered to various naval installations during the 1970s and 1980s.

In the early 1970s under Staros' management, KB-2 created the first large integrated circuits for micro calculators, which were manufactured by the Svetlana Industrial Amalgamated Complex. They achieved this months before other microelectronic enterprises, due to the use of CAD-systems based on mini-computers and a powerful topological design system, which at the time was based on the BESM-6 computer.

The development of large-scale integral circuits for micro calculators became the basis of the Electronika-S5 – the first Soviet-made family of single-circuit board, multi-board and single-chip microcomputers for control of industry processes. Particularly noteworthy is the single-chip microcomputer S5-31, developed in cooperation with the Glushkov Institute of Cybernetics. Its originality was noted by American scientists.

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[63] *Translator's Note:* The Russian word "uzel" means "node."

After Staros' KB-2 complex merged with Svetlana in 1974, Staros moved to Vladivostok to work at the Far East Scientific Center, where he managed research on artificial intelligence using modern microelectronic technology. He died in 1979; almost every pioneer of Soviet microelectronics and microcomputers attended his funeral in Moscow.

Philip Staros was Alfred Sarant

I met Philip Staros at his Leningrad institute only once, while I was there on business. At that time, I didn't think that I would ever write about him so I did not try to remember every detail of our meeting.

Staros was a popular personality among computer specialists. The UM1-NX (developed at his institute) was the first microelectronic control computer. Even though I and other designers of control computers were familiar with the machine, very few people (including myself) knew that its designer was born, educated, and received his initial microelectronics experience in the United States.

Vitaly Valkov, Staros' colleague of many years, shared with me some details of the relationship between Staros and another American engineer, Iosef Berg.[64] They were, respectively, the Chief Designer-Constructor and Chief Engineer of KB-2, one of the primary computer design bureaus with strong ties to the Soviet military. It is almost certain that someone in the Soviet government, perhaps Khrushchev himself, helped both Staros and Berg to come to the Soviet Union from Czechoslovakia; both arrived around late 1955, early 1956. Staros came with his American wife and four children; Berg – with his Czech wife.

Valkov suggested that Staros' success in the Soviet Union was due to three factors: the Soviet military managed his work starting in 1956, he had the bearings of a man educated in the United States along with Western engineering experience, and he was a gifted researcher and a skilled manager of large teams.

The military had direct access to the highest levels of the Soviet bureaucracy, thus military projects received high priority and stood a better chance of successful realization.

Although it is not clear who invited Staros to come to the Soviet Union, there is very little doubt that Soviet authorities held him in great regard from the very beginning of his career. His monthly salary was significantly higher than any other scientist's at Zelenograd and even higher than that of many Soviet ministers.[65]

According to Valkov, Alfred Epaminodas Sarant received his bachelor's degree in electronics from Cooper Union University in New York City in 1941. He worked in communication systems design in Fort Monmouth, New Jersey, and at a nuclear physics laboratory at Cornell University, where he participated in the construction of a cyclotron. In 1950, he went to work for Bell Laboratories gaining experience in communication systems and radar technology; he also gained some knowledge about the first American computers and electronic equipment for the cyclotron. Until 1944, Sarant was a member of the American Communist Party and he, Berg, and Julius

[64] Iosef Berg's American name was Joseph Barr, born in New York City in 1916.
[65] *Translator's Note*: At present, it is common knowledge in the former Soviet Union that both Staros and Berg were KGB agents while they lived in America. Until the end of his life, Berg, who returned to the United States, insisted he never worked for the KGB. Staros' given name was Alfred Sarant.

Rosenberg belonged to the same communist party group and spy ring.

Just after the Rosenbergs' arrest in the summer of 1950, the Federal Bureau of Investigation interrogated Sarant. After the interrogation, he received permission to visit his relatives in New York. Shortly after, using false documents, he crossed the American-Mexican border and later appeared in Czechoslovakia; the name 'Sarant' disappeared from publication. Five years later, the American engineer Phillip Staros arrived in the Soviet Union.

The calculation and control computers designed by Philip Staros received high praise both in the Soviet Union and in the West. In 1964, the popular magazine *Soviet Union* featured UM1-NX computer, where it was described to weigh 65 kg, and have operating energy consumption of only 100 watts; it consisted of eight thousand transistors with approximately ten thousand resistors and capacitors. During its testing period, it performed failure-free for 250 hours.

A small circle of people close to Staros joked that "NX" stood for Nikita Khrushchev, so it could be said that the computer was named in honor of the benefactor of Staros' construction bureau.[66]

Another control computer developed by Staros that gained attention in the West was the Electronika K-200. It weighed approximately 120 kilograms and could performed 40 thousand operations per second. The American critics who reviewed this machine remarked, "Many of its features would not be considered original in the West, but the appearance of such features in a Soviet computer is extremely uncommon. The K-200 was the first Soviet-produced computer that may be considered well-designed and amazingly up-to-date." They even complimented the use of contemporary English technical jargon that accompanied the description of the machine. Naturally, had the critics known that the machine's designer was an American electrical engineer who followed American developments in this field, they would not have been so surprised or generous with their praise.

Whatever the source of his knowledge, it must be recognized that Staros was able to achieve many significant accomplishments during his time in the Soviet Union.

One of Staros' Soviet colleagues, who now lives in the West, claims that Staros was first in the Soviet Union to draw attention to the new field of computer technology, which is now called microelectronics. Staros took the first step in this direction during a presentation on microelectronics in November 1958. All of the principal developers and leaders of design bureaus, representing the entire Soviet electronics industry, were present at this meeting.

In 1961, a new powerful State Committee was formed. In 1965, it was followed by the Ministry of the Electronic Industry, headed by Alexander Shokin. The purpose for creating this ministry was to increase the production of basic electronic components without which it was impossible to make radar equipment or computers. The government pinned enormous hopes on the Ministry of the Electronic Industry and its placement in the middle of the so-called "nine sisters" – nine industrial ministries, most of which were involved in defense production. Shokin's position was very strong and vulnerable at the same time because he was under constant pressure to produce practical results. This explains why he was so willing to support Staros and his plans. But by encouraging Staros to expand his design bureau, he inadvertently allowed Staros to experience the limits of Soviet patience when dealing with foreigners. Creating the Center for Microelectronics Zelenograd, which is a part of Moscow now, a kind of "Silicon Valley" in the suburbs, was the most dangerous step taken by Staros during his tenure in the Soviet Union.

[66] *Editor's note:* NX are the Russian letters for the initials of Nikita Khrushchev.

A colleague of Staros recalled:

> The designing of the Microelectronics Center was a project undertaken by a group of 5 to 6 people under Staros' supervision. It was very well thought out and planned, not some hare-brained idea. We were young and enthusiastic; Staros knew important people, had a great deal of authority, and a permission from Khrushchev to act freely.
>
> Khrushchev visited our bureau in 1962; he saw with his own eyes the possibilities that the advancement of microelectronics was opening. As a result, he supported the decision to develop the Microelectronics Center.
>
> Several decisions, made together by the Central Committee of the Communist Party and the Council of Ministers of the USSR, supported the creation of the Microelectronics Center. All of these resolutions were secret; they were never published in the Soviet press. They also allowed for the establishment of the Center for Electronic Engineering in Zelenograd; and later, bureaus in Riga, Minsk, Yerevan and Tbilisi. The Center was modeled after American companies such as IBM, Texas Instruments, and Raytheon. Its founder's native tongue was English; he took American journals home with him every day. No one dared to ask for a meeting with him without first studying the American scientific literature related to the theme of the discussion.

The Microelectronics Center was supposed to include six to seven research institutes, a design bureau, and a training institute. The Center's functions had to be coordinated by the General Director. Staros was appointed as the assistant to the General Director of science, while simultaneously keeping his post as the chief designer of his design bureau in Leningrad. This situation became troublesome for Staros. On one hand, he needed to stay in Leningrad to fight off the criticism of the local party bureaucracy, which was directed against his design bureau. On the other hand, the Zelenograd Center was developing so successfully that Staros' associates decided that they wanted to manage its development without him. In 1964, Staros found himself under attack on two fronts. The secretariat of the Leningrad Regional Committee was very unhappy that the director of an important research organization, which served the military, was a foreigner. In particular, the Secretary of the Leningrad Regional Committee, Grigoriy Romanov, objected to Staros' personnel recruitment policy. Staros hired specialists based solely on their level of expertise. As a result, a politically "unreliable" group of very strong professionals formed inside a Soviet military organization. Among these professionals were many Jews and non-party members. Sensing the unfavorable situation in Leningrad, Staros also became aware that his chances to move to Zelenograd were diminishing as well.

Just as he had in 1950, Staros decided to cut the Gordian knot of his fate with one bold move. He wrote a personal letter to Khrushchev, explaining his problems and complaining about the lack of support from Shokin – the new Electronic Industry Minister. Khrushchev's office received the letter in early October 1964. Unfortunately for Staros, Khrushchev was forced into early retirement a few days later, and the letter ended up on Shokin's desk. His reaction was quite predictable, and in his ensuing conversation with Staros, he warned, "Phillip Georgievich, it seems to me that you suffer from a misconception that you are the creator of Soviet microelectronics. That is simply wrong. The real creator of Soviet microelectronics is the Communist Party, and the sooner you understand this, the better off you will be."

It was clear that Staros could no longer play an independent role in the development of the center he had founded. The following year he was dismissed from his post as the Deputy Director at Zelenograd. In 1973, Staros' design bureau in Leningrad was closed and he spent his remaining years in Vladivostok.

I would like to add a story here that I heard from Burtsev.

In the late 1960s, Petr Stepanovich Pleshakov – who was the Radio Industry Minister back then – called Burtsev to tell him that Staros finished the development of UM1-NX and that he (Burtsev) would be appointed as the Chairman of the State Commission for reviewing the computer.

"Please note," said the minister, "Khrushchev is convinced that this is a remarkable computer, so you have to accept it! The national economy needs it!"

When the Commission began its work, Burtsev prepared a simple test for the computer. The test failed and this delayed the computer's acceptance for six months. During the second trial period, some of the elements burned out. The circuits and the design had to be revised and reworked. On the third try, the Commission – which was headed by Dorodnitsyn now – finally accepted the computer. With Burtsev's help, Staros was able to vindicate himself in Khrushchev's eyes and later received the State Prize for the design of the UM1-NX.

We don't appreciate things until they are gone.[67]

Development of the Computer Industry in the Soviet Union

The Soviet government and its leaders made significant strides in computer development during the period immediately following the end of the Great Patriotic War. They considered this issue to be the most critical for the national economy, despite the acute need for capital investments in rebuilding the war devastated country and philosophical polemics on the role of cybernetics in society.

The Central Committee and Council of Ministers established the ITMVT, SKB-245, and the Schetmash by 1948. At the same time, the government's budget was expanded to accommodate economic growth. One should remember that in the early 1950s the Soviet Union was producing only a small number of punch-card calculators: electronic calculating technology was in its infancy and lacked production resources for basic components.

The development of a modern computer production base came at the end of the 1950s, after the successful completion of the first industrial models of electronic computers: the M-20, the Ural-1, and the Minsk-1, the forerunners of the semiconductor computers M-220, Ural-11, 14, Minsk-22 and -32, which were issued in the 1960s. These were the basic models available in the Soviet Union before the third generation of computers began production in the early 1970s.

Beginning in the early 1950s, the Moscow SAM plant and the Penza EVM plant were the main producers of those machines, later joined by the Minsk Mathematical Machine factory, the Astrakhan Progress plant, and several other factories. In 1955-56, there was a significant

[67] *Editor's note:* In the original Russian version of this book, Malinovsky refers to the well-known Russian aphorism, *Chto imeem – ni khranim, poteryavshi – plachem*, which literally means "What we have we don't keep, but having lost it, we cry."

expansion of scientific research and construction bases across the Soviet Union. By the end of the 1960s, they were all prepared to mass-produce semiconductor computers. By 1964, the manufacturing of the first generation of computers stopped and in 1965, the production of semiconductor computers commenced with Ural-11, Ural-14, Minsk-22, Minsk-23, BESM-4, Razdan-3, and others.

Notably, most of this developmental phase coincided with the fact that the Soviet national economy consisted of regional economic councils, or Sovnarkhozes, which dealt with all basic production issues in the Soviet Union.[68] At the same time, all computer scientific research was managed by the State Committee on Radio Electronics, governing scientific research institutes for electronic machine construction (SRIs), and electronics construction bureaus (KBs).

This separation of science and manufacturing into different departments was not the most efficient method of production, although it had positive aspects – the operational assistance to companies involved in mass-production was approved much faster and implemented more efficiently.

In 1965-1966, the national economy was restructured again to a branch control system and all SRIs and KBs for computer technology came under the control of two ministries: the Soviet Ministry of the Radio Industry, responsible for universal and specialized computers, and the Ministry of Machine Construction, responsible for Automation and Control Systems. This restructuring of the Soviet economic system coincided with the beginning of work on the third generation computers based on integral microchips.

The difficulties of this period consisted not only of solving scientific and technological problems (ranging from general architecture to the element base of the new computers), but also complex problems of creating a new branch of computer technology based on new methods and never before manufactured equipment. Shifting of economic policy from a defunct regional control system to an internal branch structure only contributed more problems. In many cases, the development of the next generation of computers happened simultaneously with the construction of production plants and training of personnel.

Due to the economic restructuring and high production quotas demanded by the Soviet government, we had to solve all of these problems in three to five years, more than triple the volume of computer production, and make many internal components and peripheral devices. This required the development and implementation of mass-production of a universal family of software-compatible computers that would be constructed at a single technological installation.

The drastic reduction in research and development timetables was predicated on the assumption that we would be able to sign contracts with leading Western firms to legally obtain their expertise, as well as utilize all of the available domestic experts to design and manufacture these new computers. On December 30, 1967, the Communist Party of the Soviet Union along with the Council of Ministers issued a government decree, Resolution No. 1180/420. This was an order for the creation of domestic computer technology collectives that would offer solutions to every problem – from development and implementation of production materials and base components to the guaranteed production of a new generation of computers and the increased effectiveness of their integration into the national economy. The order provided for:

A budget increase in the production means for computer manufacturing from 304 million rubles

[68] *Translator's Note:* These were regional economic councils established by Khrushchev.

in 1965 to 1 billion rubles in 1970 and 3 billion in 1975.

An increase in computer output (income) from 2.47 billion rubles in 1966-1970 to 7.5 billion rubles in 1971-1975. Growth of annual computer output from 5,800 in 1966-1970 to 20,000 computers in 1971-1975.

The order called for the construction of up to 28 new plants and the expansion of 22 existing plants – their operational-industrial space during 1968-1975 increased by more than 2 million square meters.

Appropriate decisions were taken for the development of computer components, practically starting from zero to 65 million integral circuits (microchips) per year.

The program outlined above was, of course, "top of the line." It was not fully realized, but supported the expansion of production resources, and enabled the Soviet Union to nearly double its computer output capacity. Thanks to this resolution, during 1968-1985, manufacturing plants for computer devices and components were built in Kiev, Boyarka, Kanev, Vinnitsa, Kamenets-Podolskii, and Odessa. And this was just in Ukraine. The production potential at other existing plants throughout the Soviet Union, in cities such as Minsk, Brest, Kazan, Kishinev, and others, increased significantly.

When the government decided to build the ES system, nearly 100 organizations and enterprises including 200,000 scientists, engineers and technicians, as well as about 300,000 workers from the Soviet republics, Bulgaria, Hungary, Czechoslovakia, and Poland were involved in the project.

One leader who made a huge contribution to the Soviet computer industry was Mikhail Kirillovich Sulim. He served as Deputy Minister of the Radio Industry and was a close associate of Glushkov, with whom he worked to save the development of the domestic computer technology. After our long conversation and reading the documents that he shared with me, I realized that the Soviet past still haunted him, but no less than the complexities of the present day in the Commonwealth of Independent States.

The Godfather of the Soviet Computer Industry

Mikhail Sulim belonged to the generation of the eighteen-year-olds most of whom did not return from the battlefields of the Great Patriotic War. When the war began, he was studying in Kiev, at a school that specialized in artillery training. At first, the students were evacuated to Dnepropetrovsk, and then to the city of Elek (now Orenburg, Russia) in the Chkalovsky region.

In January 1943, the 18-year old Sulim received his first battle experience near Voronezh. He was serving as the intelligence division commander of the Army's 152-mm howitzer artillery regiment; at the Kursk encirclement, he distinguished himself in the fierce battles near Ponyry and was awarded a First Degree Order of the Patriotic War. Together with the artillery regiment, he reached Berlin in 1945.

After demobilization, he was accepted into the Electro-Technical Department of Kiev Polytechnic Institute and in 1951 graduated with honors, receiving recommendations for post-graduate studies. Naturally, there was no work in the field of digital computer technology yet. Even at Kiev Polytechnic, there were no lectures or research in this discipline, although the

MESM was already operational in Kiev. Since the work on MESM was conducted in secrecy, only a very small circle of people knew about it.

Sulim might not have become involved with computers if not for the Deputy Director of Scientific Work at the Moscow Schetmash, who had visited Kiev Polytechnic that year to look for young specialists. He captivated Sulim with his story of the unusual technology that was being developed at an institute in a Moscow – also behind closed doors – where work on Strela, Ural-1, and other computers was underway. Sulim insisted that they send both him and his wife to work at SKB-245. For a long time the couple did not have an apartment and rented a room barely big enough for a bed, a table, and two chairs.

One and half years later, Sulim completed the design for a digital differential analyzer. At the time, the manager of the digital computer department, Rameev, was transferred to Penza where he began manufacturing the Ural-1.

Sulim, who already had the reputation of being a motivated and qualified specialist, was appointed as the manager of Rameev's former department, which had its own construction bureau and workshop for prototypes, where about 150 people worked. By the order of the government, the Schetmash and ITMVT were commissioned to build the M-20 computer. Academician Lebedev had been appointed Chief Designer of the computer and Sulim his deputy.

The research and development of the first four models of the M-20 computer required four years (1955-1959), instead of the projected 2 to 3 years. Managers Lebedev and Sulim set the tone, actively participating in the computer's adjustment. The work pressure grew daily. It is impossible, of course, to convey in a few sentences the agitation and difficulties that accompanied the design of one of the first computers in our nation. Ultimately, it was the enthusiasm of the young specialists that carried the project through. The M-20 computer was the world's champion in operational speed for only three months: such was the price for inadequately developing the element base.

After the M-20 vacuum tube-based computer, Sulim designed the M-220 and M-222 semiconductor models, which had increased storage volume and were software compatible with the M-20. For many years they were mass-manufactured and used in computer centers all over the Soviet Union.

In 1959 when the regional Sovnarkhozes were organized, the 35-year old Sulim was appointed Chief Engineer of the newly founded Soviet State Committee on Radio Electronics. A year later he had become the committee's Operations Manager and Board Member. For five years he supervised the SRI and KB as they developed specialized computing technology and controlled the factories manufacturing computers in various Soviet cities. When in 1965 the Sovnarkhozes were transformed into national branch Ministries – Radio Technology, Electronics, Electro-Technology Industries and others – Sulim was first appointed Manager of the Main Administration of Computer Technology and Board Member of the Soviet Union's Ministry of Radio Industry and then promoted to Deputy Minister. He spent six years in this vital high-level government position, dedicating all of his time to the development of computer technology.

When the Soviet Council of Ministers prepared the resolution to build new and expand existing factories for computer and related component production under the wings of the Ministry of Radio Industry, Ministry of Electro-Technology Industry and the Ministry of Machine Construction, Sulim was given the responsibility for creating a Scientific Research Center for

Computer Technology and a series of other institutes.

After the resolution went into effect, Sulim spent most of his time on business trips overseeing the project. Many new plants sprang up and the old ones were rebuilt. Through Sulim's efforts, Moscow's SKB-245 was rapidly transformed into the leading construction bureau in the Ministry of the Radio Industry, while the Scientific Research Center for Computer Technology became the largest computer center in the country.

Sulim was a huge proponent of cooperating with the West in designing the ES project, but Director Krutovskikh of the Scientific Research Center for Computer Technology – who was also appointed General Designer of the ES – did not support Sulim's proposal to collaborate with Western European firms on the design and production of the computer. In fact, he became a strident supporter of copying the American IBM-360 system. During the controversial discussion about the future of the ES computers, Sulim and his followers suffered defeat.

Although I have already discussed some of the details of this meeting, the view I present here is of the person at the epicenter of this political battle, Mikhail Sulim:

> Looking back on the discussion regarding the development of Soviet computer technology in the late 1960s and early 1970s – about which much has been written in the foreign press, and unfortunately, almost nothing in our own – I have to say that of the two possible paths of development, we chose the wrong one.
>
> As an innovator and an adamant supporter of our domestic computer technology, who was interested in attracting European companies to work on a new generation of computers, I still consider this the right path. If we had collaborated with the leading European firms, we could have achieved world-class level for mass-produced goods and a solid base for further development of computing technology in a very short time.
>
> The events of recent years have confirmed the correctness of this approach. Moreover, our desire to join the 'civilized' world would have been strengthened by our practical achievements – we would have already been integrated into the global 'civilized' society. Regretfully, I consider the past two decades as the years of 'missed opportunities.'
>
> Today (in the post-Soviet era), we are once again trying to make our way into the 'civilized' world, but with one significant difference. Back then, we were invited as equals. Now, however, we are trying to get in by any means available, with nothing to offer, driven only by our wish to be 'civilized.'
>
> In 1970, one of the West German market research institutes wrote a review of the future of computer technology development in the USSR: 'The Soviet Union possesses enormous scientific and technical potential, but uses it poorly. Their progress in computer science is proceeding very energetically, but, in order to be competitive in the world market, it is necessary to make large investments in this area, and there are very few firms capable of doing this.'
>
> Signing contracts of cooperation between the USSR and the leading European firms would have enhanced technical progress in European countries. Soviet specialists would have received modern equipment without unnecessary

> competition, because back then, the USSR had too many internal economic problems. Our predictions were accurate – there was interest in working with the USSR, the contract proposals, the desire to give assistance and train people. The only problem is, these agreements were never realized. Due to the events of recent years, we lost our great scientific-technical potential and hence, our foreign would-be partners have lost interest in collaborating with us. At the same time, our needs for advanced technology have only multiplied. It is still possible to rectify this situation today; tomorrow, it will be too late – what's left of our great potential will disappear into the chaos.

Protesting the Soviet government's decision to copy the IBM-360, Sulim resigned as Deputy Minister and was appointed Director of the Moscow Schetmash. Working there, he successfully defended his Candidate and Doctoral theses, while the Soviet computer industry slowly collapsed on itself.

Instead of an Epilogue

Lebedev, Glushkov, Brook, Rameev, Matyuhin, Kartsev, Brusentsov, Akushsky, Staros, and Sulim were indeed the prophets in their own country. Under the harsh conditions of a command-administration system, these individuals and their followers were denied adequate understanding and support from weak and corrupt leaders who destroyed scientific and technological progress.

Will a renaissance ever come to the Commonwealth of Independent States, where the science, technology and economy will flourish as they once did in the years immediately following the Great Patriotic War?

There is nothing More Precious . . .

Memories, according to the Russian writer Fyodor Dostoevsky, are a person's most precious possessions. The more pivotal they are – the most tragic ones or the ones requiring tremendous strength and stamina – the more dear they seem. This is why Glushkov, in the last nine days of his life, dictated his last testament to his daughter. For this same reason Rameev, Akushsky, Brusentsov, and other Soviet computer pioneers readily shared their memories with me. My life presented me with a series of challenges as well, as if it trying to prove the truth of Dostoevsky's great words.

In 1939, I enrolled at the Leningrad Mining Institute. Like the rest of my friends and peers, I dreamt of getting a higher education, which was considered at that time to be more important than material possessions. But I was soon drafted into the Army and had to put my educational goals aside.[69] Two years later, just as I was awaiting demobilization and hoped to return to the institute, the Great Patriotic War started and the young draftees were at the forefront of battle – soldiers, sergeants, and lieutenants. They were the closest ones to the enemy and suffered the

[69] *Translator's Note:* At that time in the Soviet Union, two years of Army service was mandatory for all healthy male students; 3 years were required of other young people (4 years for the Navy). In 1967, the Army service was shortened to 2 years (3 years for the Navy) and to 1 year for students in 1967. Today, military service is still obligatory for males in all former Soviet countries.

largest irreplaceable losses. I am one of the lucky ones who survived, but my older brother – a tanker – was among the thousands who now rest in countless common graves beneath the former fields of battle. I still have his Orders of the Great Patriotic War of the 1st and 2nd degree that were removed from his combat uniform, along with some of his photos and letters from the front.

I am sure that the readers, who have attentively studied the previous chapters of this book, have noticed that nearly every one of my computing colleagues participated in the war. By describing the first post-war decades in the Soviet Union, this book also documents the lives of the people who were touched by the war.

My own experience was certainly neither the most difficult nor most tragic part of the war. But for me, it is the most poignant, the one that will always remain in my memory, the one that left scars on my body and soul.

Fifty years of the post-war life have placed other pages in my memory: studying, family, and the National Academy of Sciences of Ukraine, where my path continued from post-graduate student to Corresponding Member. During the 1950s and 1960s I worked very hard, sparing neither time nor health, but receiving enormous satisfaction from the results of my work. It was during those years that I developed Dnepr, the Ukraine's first mass-produced semiconductor control computer. Later I worked on designing numerous automation systems for technological processes and complex scientific experiments.

The 1970s passed more peacefully, but I continued to work hard. The experience and authority gained over the years by the teams at the Glushkov Institute helped immensely. The 1980s and 1990s were disappointing: the amount of energy I put into my work during this period could have produced more significant results. Many obstacles stood in the way of scientific research, especially in applying the results for industrial purposes. By contrast, the early years were successful, though not simple. The growth and initial development of digital electronic computing technology in the Soviet Union and the biographies of its remarkable creators have to become an integral part of the history of computing.

In 1988, when I found myself in the hospital after a heart attack, I tried to write about myself and my most important professional accomplishments in the post-war years. Much of it turned out to be a diary of sorts, in which I noted the state of my health, my ideas, and wrote down what I could remember about my path in science, including the period spanning the Dnepr's creation and implementation.

I decided to include that last portion of my diary in this book, partly as an addition to Glushkov's last testament, where he talks about the heroic period of the growth of the Institute of Cybernetics of the National Academy of Sciences of Ukraine. The technical part of my diary begins here:

November 21, 1998

Today is November 21, 1988, my last day at the hospital. It has been 2 months and 18 days since my heart attack on September 3rd. Tomorrow, I will be taken to the 'Zhovten' sanitarium near Kiev to begin my rehabilitation.

November 21 is a memorable date for me: 47 years ago, I was wounded on the bank of the Volga River near Kalinin. A piece of shrapnel tore through the front of my right shoulder, just missing the carotid artery, and exited, breaking my right shoulder blade. ‘You are a very lucky young man,’ the doctor in the regiment hospital told me, ‘A little further over and your carotid artery would have been severed. They would not have gotten you here alive.’

When my heart attack occurred a few months ago, the physicians were not sure that I would recover. If I had gone out to my dacha on the morning of September 3 – which I was ready to do despite not feeling well – then I probably would not be alive today.

During the period I have described in this book, I was very enthusiastic and highly driven to accomplish something significant in science, but not for the sake of personal gain or additional accolades – I thought nothing of that. I remember the end of the summer in 1956, when Boris Gnedenko, director of the Ukrainian Academy’s Mathematics Institute, which included our laboratory, phoned me:

“Come to my apartment. I want you to meet the new lab manager!”

He sent a car to pick me up and I was quickly transported from Feofania to Kiev.

In Gnedenko’s office sat a young man wearing glasses. Gnedenko introduced us – I was a communist party organizer in our lab back then – and asked me to take a ride out to Feofania with the new lab manager – mathematician and Doctor of Physical Mathematical Science, Viktor Glushkov. Gnedenko himself was obviously busy.

Glushkov and I arrived at the lab during the lunch break. Knowing the lab would be empty, I led him out to the sports field where workers were playing an enthusiastic volleyball game. We stood and watched for a while. I sensed that Viktor felt a little uneasy, so I introduced him to some of the people.

Almost immediately after his arrival at the lab, our scientific seminars got a big push. At that time, cybernetics was just beginning to gain acceptance in our country but not by many. In print, it was frequently referred to as pseudo-science, which attempted to substitute machines for human brains. Back then, Wiener’s remarkable books were unheard of in the Soviet Union. And when the first one arrived, it was kept at the Moscow SKB-245 in the department of secret documents!

November 26, 1988

Forty seven years ago today, I arrived in Moscow at the Timiryazev Agricultural Academy, which housed a military hospital at that time. After a brief medical examination and a change of my wound dressing, they put me in a tiny room on the eighth floor. I had an empty cot next to me where another Red Army soldier was soon placed. After the attendants left, the soldier sat up in bed and began checking himself for lice. As he squashed the odious parasites between his fingernails, his would frequently grimace and occasionally mumble unintelligibly. He was older, unshaven, his hair a mess: it was obvious that he had just come from the trenches. Back then I was still unaware of how much a human can suffer from lice. But later, on the Northwest front, where lice were eating us alive all summer long, I often thought of that soldier.

Our makeshift room was on the top floor of the hospital and the attendants accidentally forgot about us. They finally came back on the second or third day, fed us, then led us out to a truck. From there we were put on a train that transported the wounded soldiers to Tyumen, in Siberia.

Going back to my first meeting with Glushkov:

Glushkov's arrival changed the character to our lab and set a new tone for the way our communist party group operated. We decided to write a letter to the Central Committee of the Communist Party of Ukraine. In this letter we pointed out that the work in the field of computer technology in the Soviet Union, and especially in Ukraine, was developing much slower than in the United States, United Kingdom, and France. Moreover, our first computers were still in the embryonic stage. We concluded, "The condition of computer technology in Ukraine borders on being a crime against the state!" It was true.

Every member of the communist party-group at the laboratory signed the letter. Glushkov supported our position, but said that since he was not a communist, he could not sign it.

We could have never anticipated the response that our letter generated: many copies were made and sent to all members of the Ukrainian Politburo; a meeting of the Politburo was quickly organized and Glushkov was invited to attend. A number of important decisions were made at that meeting including reorganizing the laboratory into the Computer Center at the Academy of Sciences of Ukraine and erecting buildings to house the center itself and to provide living quarters for its engineers. Glushkov was appointed as the director of the center and he recommended me as the Deputy Director for Scientific Affairs.

After one of our visits to the Central Committee's Department of Science, as Glushkov and I were leaving the building, he suddenly asked me:

"Boris Nikolayevich, could you recommend me for membership in the Party?"

"Of course," I said; I was glad to do it. In the letter of recommendation, I wrote everything I knew about Viktor Mikhailovich: he was talented, modest, had quickly earned the respect of the team, he worked extremely hard, and was able to infuse the team with new creative energy in a very short time.

Once, when Glushkov and I met in the corridor of the Computer Center, he said, "We should design universal control computers. Now everybody is interested in specialization. But since designing a computer requires a lot of time, it could be obsolete as soon as it's created. Besides, it's practically impossible to change the design of a specialized computer. Original technology should always be universal, and then it can be specialized."

A few days later he met me again and asked:

"Have you started the work yet? If you don't like my proposal, I can talk to somebody else."

I said that I liked his proposal and was thinking about how to start such a project. By 1958 I had gained considerable experience in semiconductor computing devices and control computers. In 1957-1958, under my management, a secret project for a control computer for aircraft-bombers was developed in Kiev. The mathematical part of the work was done by a young Doctor of Technical Sciences Shamansky, a very qualified, intelligent and responsible man. The following areas required specialization: the navigational tasks that had to be solved in-flight aboard the bombers, on-board radar equipment, and issues with aiming of the aircraft's missiles. I can now write about this in the open because more than forty years have passed and the information is no longer secret.

We finished the work on time, the project was approved, and the prototype easily passed all tests.

In 1958, many graduate students from Kiev Polytechnic Institute were coming to the Computer Center, which was then still located in Feofania. The technical departments, including my specialized computer department, began filling up with top notch engineers. They immediately started developing the Universal Control Computer, which was later called the Dnepr.[70]

It was a very complex project that was wrought with problems. Exercising my authority as a Deputy Director, I had to take over the entire project a year or so later. I believed at the time that we needed a design-construction department and convinced Glushkov to create it. Yuri Mitulinsky, a man with great organizational abilities, was assigned to manage this department, which quickly began designing and building computers. This was the beginning of establishing a staff base for large-scale projects.

Meanwhile, we had to address the following questions: what kind of machine would the Universal Control Computer be? What design principles would we employ? What would be its main features, structure, and architecture?

Glushkov offered his ideas and general suggestions concerning how to make the machine and how it should function and control various processes. But he did not micromanage and trusted me to handle the details. The computer was designated to control of industrial processes and we also had to learn them.

I wrote letters to many scientific research organizations, universities and industrial enterprises, saying that we were designing a universal control computer and were looking for people interested in creating such a machine that could also envision its applications and would agree to work with us – helping to formulate the requirements for the computer. I sent out over one hundred letters, but we only received four positive responses, including the Kharkov Institute of Organic Chemistry. The other organizations either did not answer at all or sent meaningless replies.

I was forced to bury myself in books about measurement devices, regulators, servo-mechanisms and other technologies. At that time, no unified system of measurement technology existed. Generally, most measurement devices used only scales and pointers, where the position of the pointer on the scale would indicate the level of the parameter.

In a control computer, the data for a process had to be input automatically, in accordance with the computer's instructions. So there emerged the problem of connecting the computer with the control object. It was namely at our department of specialized computers that a unit was developed to execute those functions: the Unit for Communication with the Object, or USO [in Russian: *Ustroistvo svyazi s ob'ektom*]. The USO's designers quickly understood the need to standardize electrical output signals from 'measurement devices and input those signals to servo-mechanisms. This forced many measurement technology specialists to think about standardizing signal levels to and from sensors. At that time, hundreds of such devices existed. While attending conferences, seminars, and visiting various enterprises, I repeatedly discussed these problems with the concerned scientists in order to begin working on the concept of the future SO.

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[70] *Translator's Note:* Dnepr (Dnipro in Ukrainian) – is the largest river in Ukraine and flows through Kiev. It should be noted that the computer was given the Russian version of the river's name, reflecting Russia's dominance over the rest of the Soviet Union.

As far as the arithmetic unit, data storage, and the principles of their construction, there were no problems; however, many technological difficulties emerged because reliable transistors were still not available in the Soviet Union, and ferrite memory on miniature cores did not even exist yet.

December 2, 1988

The ferrite rod is a very reliable part and ferrite memory devices have existed for more than twenty years. They were eventually replaced with semiconductor memory devices. The Universal Control Computer's storage unit based on miniature ferrite rods was the first in our nation.

The human heart is not an oxy-ferrite rod that never wears out, but a piece of living tissue in an organism. Like everything living, it changes over time and grows old. However, the conditions in which a human being finds him or herself are the main contributors to aging, not time.

In the beginning of 1942 at Tyumen Hospital No. 3330, where I spent about two months after being wounded near Kalinin, an attending doctor asked me:

"Do you have any complaints? "
"Yes. My heart is beating too fast."

My heart, which was not used to me being active after being bedridden for such a long time, was beating loudly in my chest after I had to walk upstairs for my medical exam, and for some reason it did not slow down.

"Ah, this kind of thing happens all the time with young men. Next!"

They sent me back to the army and in May, I was transferred to a boggy Northwest front with its hard spring rains, its frigid January temperatures and the never ending artillery bombardment.

Even if there had only been one artillery shell daily – they flew over my head accompanied by a terrible whistling screech, or exploded nearby – the total would have come to 300, the number of days I was there. But there were many days when the ground was littered with shells, the snow turned black, and the mighty forests were reduced to charred tree stumps. My already weak heart had to endure all that without the benefit of a ferrite rod...

Today, for the second time the physicians did not let me walk the control distance of 1300 meters because my cardiogram was not normal. In fact, it was even worse than when I arrived at the sanitarium. My heart is still unable to cope with the endurance tests, although years ago, it could handle much more: during night marches to the Dnepr we tramped 50-60 kilometers so the enemy would not see us – and that was nothing. However, I do remember one old soldier who walked and walked with us, and then suddenly fell over dead – his heart simply gave out.

None of the soldiers complained about heart problems to the army medics. Some may have tried, but I never did. In February 1943, during the battles near Staraya Russa, after each 100-150 meters of walking I needed to rest, sit on a stump or lean against a tree. My left shoulder blade felt like an awl was being driven through it and the pain was intolerable. When I stopped, the pain subsided slowly, and then I walked on…

When the Universal Control Computer was ready for calibration, I tried to make sure that all the work on the machine would take place in my department. During all the years that we worked on it, I tried to base its construction principles and main features on the wide variety of proposed applications.

When the word about the Universal Control Computer got out in the Soviet Union, many organizations sent representatives to negotiate for its delivery. So we had a lot of choices. However, this was not a simple question. First, for every selected customer it was necessary to prepare and install the machine and match it to a specific technological process. Second, we had to be sure that the computer landed in skilled hands, so we asked customers to send their specialists to us for preliminary training. Third, we looked for customers capable of signing comprehensive contracts and supplying at least a portion of the transistors, diodes and other electronic parts, which were necessary to manufacture the computer.[71]

A wide introduction of the Universal Control Computer could only happen if it were mass-produced. At that time, the Sovnarkhozes acted as regional executive centers to help solve many complex issues by local authorities, and here I got lucky. When I came to P.I. Kudin, Director of the Department of Industry of the Kiev Sovnarkhoz, I told him about the Universal Control Computer: its applications, the great demand for it, and the need to mass-produce it. After some consideration, he recommended the Radiopribor Factory where Kotlarevsky was the director.

I did not want to approach the director of the factory alone, so I asked Glushkov to accompany me and we went together.

To our great joy, Kotlarevsky agreed to mass-produce the computer immediately. He only wanted to know one thing – the size of the computer. Since his plant manufactured oscilloscopes, we compared the two machines, saying that the UCC was five to six times larger than an oscilloscope. He was satisfied with our answer and promised to prepare the premises, hire the assemblers and, if necessary, provide the staff to finalize the computer's documentation. We left in a state of euphoria, delighted with this energetic director. I realized my mistake –comparing the computer with a simple oscilloscope – much later.

In order to begin the mass-production of the UCC, we needed to successfully demonstrate its broad applications, versatility and provide full documentation.

The primary control and administrative sites for demonstrating the Universal Control Computer's potential had already been designated: the Bessemer converter at the Dneprodzerzhinsk Metallurgy Plant; the carbonization column at the Slavyansk Soda Plant, the Sheet Metal Works at the 61 Communards Shipyard in Nikolayev; and a military academy in Kiev.

The following work was performed at the chosen sites: analyzing algorithmic systems, working with the computer interface, training of personnel, and adjusting the machine. The mass-production of the Universal Control Computer required enormous labor, persistence and the solution of a myriad of problems.

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[71] *Translator's Note:* Here the author hints at one of the biggest problems of the Soviet economic system, where a complete lack of parts and materials was common due to the inflexible of its central planning and distribution system. Nobody could buy products through a simple contract and payment if the product was distributed by the state plan. So, Malinovsky had to look at the actual situation of manufacturing under these conditions.

Of course, acknowledging the need for a universal control computer did not happen on its own. During that period, everybody was captivated by the special purpose computers such as Steel-1, Steel-2, and specialized on-board computers. I remember the article, "The General Purpose Universal Computer," which I wrote for the magazine *Automation and Telemechanics.* They returned it saying that the problem wasn't real. This was in 1958, when an American magazine described the RW-300 computer, noting multi-purpose usage as its main advantage.

In 1959, at the first national conference in Moscow for problems of control computers, I spoke about the Universal Control Computer. My report raised a number of questions and I was invited to be a part of a commission that prepared the recommendations. The beginning of our reports read: "to approve and support the development of universal control computers at the Ukraine Academy of Sciences." At the closing of the conference, Loskutov, who was the chief of the Department of Computer Technology at Gosplan, acted as if he was the Tsar himself. When he heard this phrase, he said:

"The universal control computers should be scrapped. They were created on some Academician's whim and nobody needs them. "

So the first phrase was deleted. It was pointless to argue with a self-enamored person who could wield such tremendous power.

December 5, 1988

Forty seven years ago, wounded soldiers lay ten to a room at the Tyumen hospital and listened to Yuri Levitan talk about our troops' offensive near Moscow: the Red Army regiments had forged ahead through the ice and snowstorms, forcing the Germans out of the cities, towns and villages, which they had captured earlier.[72] Lying next to me was an old soldier who was wounded near the same Kalinin grain elevator, where I had been hit in October of that same year. From our observation point, we could clearly see the grain elevator, about 700 to 800 meters away. Our infantry trenches were in-between. In 1941, our infantry had not yet started digging common ground trenches. In accordance with Red Army statutes, each soldier was supposed to dig his own hole in the ground and stay there, but sitting alone in a hole without communication was dangerous and inefficient. Later, we started to dig long common trenches that connected the many individual holes. For us, the ground hillocks in front of each hole were clearly visible. Inexperienced soldiers dug shallow holes, which made them easy targets for the German snipers, who were perched on the upper floors of the grain elevator tower. If any of our soldiers were to get up or even peek out of the holes to see outside, shots would rain down on them.

But I digress…

In a way, our Universal Control Computer was also caught in a war, though a bloodless one, caused by the bureaucratic reluctance to understand and support an innovative project. This forced us to work in as if we were at war – the adjustment of the machine went on around-the-clock.

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[72] *Translator's note:* Yuri Levitan was a famous Soviet radio announcer from 1940 through 1960, who had a fabulous deep bass voice. During the Great Patriotic War, he announced all of the official Soviet government messages from the Information Bureau.

I would come to work at eight o'clock in the morning, spend about an hour functioning as a Deputy Director – reading, preparing, and signing documents. The rest of the time was occupied working on the computer project. I typically returned home no earlier than midnight. On my way home, I usually reread the incoming mail. Such was my normal job mode – excluding business trips – for three years.

It was also very difficult to work with manufacturers. We were horrified when we received the first batch of computers from the plant. Every soldering connection – there were over a 100,000 of them – was abominable, causing permanent failure. Most of the 30,000 jack contacts were unreliable and constantly came loose. This computer was impossible to adjust, but the reasons for such poor quality became clear only after visiting the plant where the computers were assembled.

Because of my careless remark that the computer was five times larger than an oscilloscope, the director of the plant recruited young men and women fresh out of high school to work on the project. Armed with soldering irons, they "soldered" the computer together as best as they could, constantly breaking jack pins with their careless handling. When the deadline for the installation of the first computer in the Bessemer shop was approaching, we were forced to re-solder almost all of the connections, as well as change many of the contacts. Only then were we able to perform the adjustments.

I remember the difficult days when I gathered the whole team and everybody else who could help us, and said:

"I understand that the work is very difficult. But during the war, the conditions were even worse. Trust me, you are much better off now than our soldiers were!" This was my appeal to the young people – most of whom were 23-25 years old. I was 35, only 10 years older, but with wartime experience, which added independence and a greater sense of responsibility. My words produced results: everybody redoubled their efforts.

The State Commission managed by Academician Dorodnitsyn arrived to approve the first computer. The commission also included the manufacturers' representatives as well.

The trial tests of the computer began: performance testing, heat testing, reliability during element changes, etc. The members of the commission provided the problems and the testing went on day and night for a week. The commission rated the machine very highly, but also noted that since it was the very first semiconductor control computer in the Soviet Union, it would require additional testing at the installation points a year later.

At the time, the recommendation for mass-production was given, though the first models were very poor. The manufacturing technology remained inadequate because the plant employees continued to ignore all of our requests and advice. This was a very difficult year; I was forced to repeatedly visit the plant where the Universal Control Computer was being assembled. About five years later, I went to Sweden to give a speech at the IFAC-IFIP symposium on industrial implementation of computers. Upon my return, I met with Valentin Zgursky, who at the time was the senior technologist of the manufacturing plant. He asked me:

"Boris, why are you so gloomy?"

"In the United States and United Kingdom, computers are already available to those who need them, but here in the USSR…" I waved my hand, expressing my frustration.

"Well, I must confess," said Zgursky, "when you brought the Universal Control Computer project to our plant for mass-production, I did everything possible to make sure it would never succeed!"

I was speechless from this unexpected revelation.

"But now I am ready to kneel before you," he continued "I need your help to install it in the automatic galvanizing shop. I have finally understood its awesome potential!"

I remember that his request made me extremely happy. It meant that our computer customers had finally become aware of its possibilities. And if that was the case, then we could catch up to the developed capitalist countries!

After my meeting with Zgursky, it finally became clear why the beginning of mass-production had been so difficult: due to my naiveté, I believed that every new invention should receive immediate support, and that resistance to technological progress was not real and existed only in fictional stories.

At last, we finished manufacturing and fine-tuning the Dnepr models that were going to be installed at industrial enterprises slated for final testing of their capabilities and flexibility. These first sold models were only partially adjusted. The final complex calibrations were made by my department designers, with the assistance of customer specialists.

Many enterprises were preparing for the implementation of Dnepr computers at the same time. In the end, I was able to achieve high quality results and rapid completion of the project.

Dnepr's debugging was completed. The computers were manufactured according to customer contracts as part of their planned arrangement. Unfortunately, we greatly underestimated the expenditures. To be more precise, we did not expect that the manufacturers would ask such a high price for the completed computers.[73] We had a shortage of funds and were unable to pay for all of the computer models. The plant demanded that we fulfill our contractual obligations and sent angry letters to the Academy of Sciences and the City Committee Communist Party complaining that they were suffering losses. They threatened to stop production of the new computer series for new customers.

Lucky for us, we found a way around this problem. In my department, I had a man by the name Junkovsky. Previously, he had worked in the financial department of the Ukrainian State Planning Ministry. He invited the manager of the State Plan Ministry financial department to come and learn about the Dnepr. They were so impressed with the project and our youthful enthusiasm that the Ukrainian Cabinet of Ministers decided to give us a million rubles to complete the project.[74]

Thus the business was saved, along with the Dnepr. We started a comprehensive, round-the-clock work at the installation sites. The State Commission headed by Academician Dorodnitsyn

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[73] *Translator's Note:* Because the Soviet Union had a closed economic system, price setting was inconsistent. It depended more on personal contacts between manufacturing managers and state body leaders rather than on actual cost of the resources. Another problem that the Dnepr project faced – along with every other technical process in the Soviet Union – was a designer's inability to choose alternative manufacturers.

[74] *Translator's Note:* According to the official exchange rate at that time, this was equal to approximately $1.66 million dollars.

offered to investigate and test two systems – in Dneprodzerzhinsk and Nikolayev. I do not remember the details of the trips and or the testing, but they were quite successful. However, one incident comes to mind. During the meeting of the Commission, the director of the Dneprodzerzhinsk plant had shown little interest in the system's implementation. He was not impressed by Dorodnitsyn's words about the possibilities for future development and the use of a control computer at the plant. He yawned, fidgeted and appeared completely disinterested in the computer or its potential for the plant, barely tolerating the presence of the obtrusive academician.

In Nikolayev, things were just the opposite. The chief engineer of the enterprise, Mr. Ivanov, did not leave the Commission even for a minute. He proudly pointed out the improvements and the great value the implementation of computers had brought the plant. He clearly described the future prospects, which we found very charming.

I remember thinking: "That is why the work in Dneprodzerzhinsk was so hard and the Nikolaev project was so successful." The consequences were also very telling: in Nikolaev, a huge computer center of the Shipbuilding Ministry was soon created; it supported all Ukrainian shipyards. In Dneprodzerzhinsk, the computers were installed, but the systems developed slowly and worked badly.

Later, when Dnepr's mass-production had begun, proposals for joint work poured in. However, we were forced to restrict our service to advice and consultation only. I organized a seminar on control computers and systems, which quickly became very popular across the country, attracting representatives from dozens of cities and hundreds of organizations. One outcome of the seminar was the creation of the Ukrainian journal *Control Computers and Systems*.

December 9, 1988

Today, I remember December 1942, when I was with the 55th Infantry Division near Gorby, a village that had been completely obliterated during the war. I recall frigid temperatures of minus 30-40° C. Our division was thrown across the neck of the semi-surrounded 16th German Army, cutting off the Ramush Corridor and, together with other regiments, we tied the noose around the Germans. The enemy used all available artillery weapons against us, anything that could reach Gorby. After each artillery attack the ground turned black, as if the snow had been scraped from the field. As soon as our battery began to fire, the Germans responded almost immediately with return fire. We dug deep trenches in the ground for the guns and covered them with two or three layers of wood logs. At the battlefront, it was even more difficult; the frozen ground did not yield easily and we had to dig in the open, since the woods were annihilated by the hurricane of explosions…

Yesterday, doctors told me that I should not go outside if the temperature reaches below minus 10° C. Otherwise, I could have a vascular spasm that would be very dangerous. But long ago near Gorby, both my lungs and heart withstood not only the frigid cold, but also the hell of artillery fire, which nobody who survived that battle could ever forget.

Late in 1959, when Glushkov returned from a Moscow meeting with his doctoral thesis advisor Alexander Kurosh, he surprised me with a proposal to become his replacement as the Institute Director. Glushkov said, "Kurosh thinks that I am spread too thin and instead should be focusing my efforts in one scientific direction where I can really do a lot. In order to accomplish this, I need to delegate the organizational work to someone else and spend all my free time on research."

I told Glushkov that I could not accept the offer, but was willing to take on all of the organizational work. I felt the effects of this decision a year later:

"Boris, the staff wants to know which one of us is the director?" Glushkov once said.

I decided not to remind him about our conversation and the obligations I had promised to fulfill, but instead asked him to release me from my duties as deputy director. Being a department chief was enough for me.

About three years before his death, Glushkov surprised me again by nominating me as a corresponding member of the Ukraine Academy of Sciences.[75] He added, "Really Boris, there are very few directors who are brave and courageous enough to support their opponents!"

I remember feeling very uncomfortable hearing such a strange comment. Then I laughed, mumbled something, and tried to leave Glushkov's office as soon as possible. Our birth dates were the only thing we ever had in common, but I was born two years before him, on August 24, 1921.

December 15, 1988

Forty five years ago today my older brother, Lev Malinovsky, perished. He was a T-34 tank commander. Being a tanker was an extremely difficult and dangerous duty during the war, perhaps the hardest of all assignments. Tanks were always at the leading edge of the battle. They were bombed by aviation, shot at by artillery and damaged by anti-tank mines. In battle, losses among tank personnel were even greater than among the infantry. Tankers often died burning alive inside their tanks. It was an impossible miracle to come out alive from a tank that was hit and on fire.

After each shot of the tank gun, the inside of the cabin filled with smoke and fumes. When a tank was struck by infantry fire, the internal metal cover shattered and flying shrapnel could wound or kill the crew. Moreover, the sound of the explosions inside the tank felt like someone was beating your head with a hammer.

My parents informed me of Lev's death 4 months after it happened.

"This terrible wound is still bleeding" my father wrote to me when I was at the front. I still think about him and my wound continues to bleed to this day. I loved my brother very much; to me, he seemed fatherly in his appearance: almost 2 meters tall, eternally kind, with hands that could do anything. And he was gone at the age of 24 years and 13 days.

My parents loved each other and their children very much, but fate was very cruel to them. Their first child, Konstantin, died from scarlet fever when he was only 2 years old. The next eldest son, Lev, perished in the war. My sister Helen was born after me. She finished college with an advanced degree during the difficult war years and defended her Candidate's thesis a few years later. In February 1958, she died in my mother's arms from an incurable cancer. We saved the

[75] *Author's Note:* Becoming an Academician was an extremely prestigious position and one was rarely nominated by one's own institute director.

notebook where she wrote things she wanted to say to Mother, Father, and me because she could not speak.

When I was told of my brother Lev's death, I remember thinking: "If I die, that will be the end of the Malinovskys." My parents must have also thought about it and about me, especially since the war was still raging.

February 15, 1989

I have been home for two months now, but have not touched my diary. I am gradually getting used to life again – at home, on the street, and at work. The rehabilitation process is very slow. "You need very small, step-by-step changes," my surgeon Amosov told me. But at times I was just fed up. My wife and children help enormously, saving me with their love, care, and faith in me. I received many supportive letters from my wartime comrades. Every one of them wrote: "Keep your chin up. Do not give up. Take control of yourself and you'll beat this illness." When I returned to work, there again, I felt my colleagues' support, understanding, and desire to help in every way. I was going to get better, no matter what…

The mass-producing of the Dnepr went much better after its approval by the State Commission. Kotlarevsky took every measure to improve production technology and the shops worked at full capacity. Customers bought the computers like mad. During his report at a meeting of the city communist economy leaders, Glushkov glowingly described the industrial applications of computers and at the same time, complained that there were not enough Dneprs being manufactured. Evidently, someone caught wind of these remarks, or perhaps it was easier to solve economic management problems during the Sovnarkhoz period, because soon Kotlarevsky was given the job of creating a plant for control computers in Kiev. The plant was built in record time, just 3 years, and began to produce Dnepr computers. Kotlarevsky's wife, Olga, picked out the colloquial name Dnepr for the Universal Control Computer, and it stuck.

I would like to add an aside to my diary.

In the middle of 1962, Glushkov suggested that I prepare a Doctoral thesis for the degree of Doctor of Technical Sciences based on my published scientific work. I decided to make one book in which I compiled all of the articles I had written for various magazines. The thesis was published one year later under the title "Control Computers and Production Automation" (Moscow, 1963). My defense was in January 1964.

This is an excerpt from the stenographic notes of the scientific council meeting:

The Chairman: Academician Victor Glushkov has the floor.

Academician Glushkov: In Professor Temnikov's response, he mentions my contribution to the development of the computer. So first of all, I would like to say that although Boris Malinovsky and I managed things together, over ninety percent of the work, especially in the final phase, was done by Boris Nikolayevich alone. Therefore, all of the positive comments about the Universal Control computer rightfully belong to him.

… Cybernetics begins when the conversation stops and the real work starts.

… In a very real sense, Malinovsky's work has helped cybernetics to serve and support our economy and our nation.

It is no wonder that we have heard 43 responses of successful applications of the Control Computer. People in every corner of this nation have a keen interest in the computer itself and the variety of its applications.

The other value of this work is the fact that it stimulated a great deal of new research. In 1957, when the project started, there was great skepticism about its potential. In the beginning, any idea can easily be killed – and at that time, there were plenty of skeptics.

…The fact that we reached the end and implemented the mass-production of the computer is an enormous achievement.

…At the very beginning, people said that the team was relatively small, that it had virtually no experience in computer design. They cited many examples of various organizations where the development of computers was carried out by teams of one to two thousand specialists, using powerful experimental workshops, etc.

We could easily vote to not only award the degree of Doctor of Sciences, but the Hero of Socialist Labor as well, because of the supreme effort and amount of work done here. Just to explain this project to lay people – the blueprints alone weight more than the computer itself. It is a tremendous volume of work. There is enough material here to write several Candidate and Doctor of Sciences theses.

In conclusion, I would like to say that without a doubt, this work has had an enormous economic effect and was broad reaching in terms of its scientific significance; it required huge personal sacrifices and the endurance of highly stressful conditions. It deserves the highest approval on all counts, and its author/project manager should be awarded the degree of the Doctor of Technical Sciences.

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The Institute o f Cybernetics proposed that the Dnepr's designer team be awarded the Lenin prize, the highest public award in the Soviet Union. Simultaneously, Glushkov was nominated to receive the Lenin prize for his research on the theory of digital automatons, which he was awarded in 1964. We were enormously proud of Victor Mikhailevich and his accomplishment. It was the first high-level award for our institute.

Unfortunately, the Committee responsible for assigning the Lenin prize sent the materials about the Dnepr to a specialist in analog computers, who was a strong opponent of digital technology. He now lives in the United States and I do not mention his name here because that was old business.

After receiving a "negative" response, the Committee rejected the nomination.

About eight or nine years later, Academician Keldysh, who headed the Awards Committee for Lenin prizes in the 1960s, said to Glushkov:

"Back then, we didn't understand the value of the work done at your institute. You were ahead of your time."

After Dnepr's success, we embarked on many other computing projects. Some of them received awards, orders and recognition. Yet, the first Dnepr remains dearest to me; it is displayed in the Moscow Polytechnic Museum to this day.

I am grateful to fate for my life, for the many years I worked with the remarkable scientific team at the Ukraine National Academy of Sciences Institute of Cybernetics, and for the opportunity to publish this book about the extraordinary computer scientists in the former Soviet Union. And, finally, I am grateful that it was not my fate to lie in one of the countless common graves of the Great Patriotic War.

9 May 1994
Kiev