Strela-1, the First Soviet Computer: Political Success and Technological Failure

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Which computer was developed first in the Soviet Union? Which one was first successful? Such questions are difficult to answer, but recently declassified archival material may hold the key. The story of the Strela illustrates how competing interests—as institutions and factions jockeyed to gain political advantage—helped determine the fate of this computer, a political success but a technological failure.

The "first" computer in the Soviet Union—the BESM (*Bystrodeistvuyushchaya Elektronnaya Schetnaya Mashina*—high-speed electronic calculating machine) had an official completion date of 1952, yet it was not actually completed until 1955.[1] Experimental work on the first BESM machine continued throughout 1953,[2] and the machine only passed the government's efficiency test in 1955. Another early Soviet digital computer, however, passed this same test a year earlier, in 1954, and was quickly put into operation.[3] That computer was the Strela (or Arrow). The designers of the first Strela (Strela-1) were awarded government prizes;[4] moreover, the Strela-1's chief designer, Yurii Ya. Bazilevskii, was recognized as a Hero of Socialist Labor, an honorary title of highest distinction for exceptional achievements.[5] Only two years later, however, the Strela project was abruptly abandoned with just seven machines completed.[6] We might well ask: What could have caused such a reversal?

In a 1999 article, Sergei P. Prokhorov provided an overview of the history of Soviet computer development and its institutional framework.[7] Earlier, in an extensive 1994 study, George D. Crowe and Seymour E. Goodman had revealed details of the BESM's development and the rivalry between the two primary institutions involved in developing Soviet computers.[8] More recently, science historian Slava Gerovitch offered an interpretation of that rivalry.[9] The problem of institutional rivalry, of course, centers on the importance of the respective institutions. So far, because we lack sufficient knowledge of the Strela and the institution that built it, the real explanation for the Strela's untimely demise remains unclear.

Drawing mostly on previously classified archival sources in Russia, it is my goal that this article shed new light on the history of Soviet attempts and efforts to build computers, focusing on the Strela-1's development background.

This article examines the interests and behavior of two groups—the engineers and the scientists—involved in the initial developments of Soviet high-speed, digital computers, which had been obscured by ideology. What I found was that a conflict of interests existed between the mechanical engineers and the mathematicians. The engineers were associated with the ministry producing the measurement and control instruments for the artillery, while the mathematicians were associated largely with the country's nuclear developments.

Soviet Union in retrospect

What is most distinctive in contemporary studies of the Soviet Union is that Soviet society's totalitarian model is being rapidly discredited. As early as 1977, economist Alec Nove wrote that,

> centralized decision making in a large, modern industrially developed economy sets up an unmanageably large number of micro-economic inter-relationships [Author's note: That is, relationships caused by the ministries' insufficient resources and authorities owing to bureaucratic overlapping of organizations].[10]

Nove commented further, "how the inescapable delegation (devolution, decentralization) in fact occurs" in the details that "central planners" should decide, and so, Nove

 Published by the IEEE Computer Society 1058-6180/06/$20.00

remarked, "ministerial empires, and upward pressures originating with them, are facts of economic and political life"[11] of the Soviet Union. Although originally confined to economic matters, Nove's concept of so-called centralized pluralism is receiving more attention in other Soviet studies, as research progresses based on newly declassified archival documents. We now know that in the Soviet Union's history, many conflicts and rivalries characterized the interrelationships of various agencies and institutions. The rivalries, which often resulted in conflicts, were rooted in politics as the different entities competed to win political advantage—and therefore financial advantage—to further their respective goals. For example, science historian Nikolai Krementsov suggested that,

> despite its totalitarian character, the Soviet state had a very complex internal structure, and the numerous agents and agencies involved in the state science-policy apparatus pursued their own, often conflicting policies.[12]

During the Cold War, both the Soviet Union and the US devoted enormous financial and human resources to military-related projects, one of which was the production of high-speed computers. This objective was supported financially and politically in both countries, and the creation of a successful computer technology became a highly competitive endeavor in both, as well. Analyzing the sophisticated computer technology development that was achieved in the US, historian Paul E. Ceruzzi suggested that to characterize it with the term "military" is misleading. He asserted that, "there is no single military entity but rather a group of services and bureaus that are often at odds with one another over roles, missions, and funding."[13]

Such an observation could apply equally well to the internal structure of the Soviet Union and, at the same time, to the military's crucial role as we review the history of the Strela-1.

Compared with that of the US, the Soviet initiative to produce a high-speed computer achieved only a little. As historians have rightly pointed out, the Soviet Union was highly successful in producing rockets, jet planes, and nuclear weapons, but its attempt to design a high-speed computer was perhaps its least successful undertaking.[14] Some researchers believe that an anticybernetics campaign, which emerged in Soviet computing's early days, "significantly delayed the development of Soviet computers."[15] Contrary to this belief, science

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historian Slava Gerovitch showed that "Soviet computing was shaped by the tension between the practical goal of building major components of modern sophisticated weapons and the ideological urge to combat alien influences."[16] He argued that while the "soldiers of the ideological front" were dismissing cybernetics as a "modish pseudo-science," the "actual soldiers in uniform" regarded Western military research on computing very seriously.[17] During my research, I, too, found hardly any evidence of Soviet ideology's influence on computer development.

Two Soviet institutions were engaged in developing the high-speed electronic digital computers. One was the Institute of Precision Mechanics and Computer Technology (ITMVT) of the USSR Academy of Sciences, which also developed the BESM computer (see Figure 1 next page). The second Soviet institution was Special Design Bureau No. 245 (SKB-245) of the Ministry of Machine and Instrument Construction (MMP), which later developed the Strela machines.[18]

To try to ascertain the facts behind the Strela's development, we will first reexamine the attitude of Soviet mechanical engineers toward computing technology. Initially, their focus was on the activities of the ITMVT and of the SKB-245, whose main clients were military: the army's artillery component and other military organizations concerned chiefly with aeronautics and artillery trajectories. At the same time, we must consider the internal discord between the engineers and mathematicians within the USSR Academy of Sciences, especially in its Department of Technological Sciences, and the consequences of that conflict. Finally, we will examine the response from the SKB-245, after losing its political advantage over a newly reorganized ITMVT. Then we will

Figure 1. BESM-1, the pioneer of a series of Soviet numerical electronic computers, designed by the Institute of Precise Machinery and Computer Technology. (From Akademiya nauk, Ordena Lenina Sibirskoe otdelenie [Russian Academy of Sciences, The Siberian Branch], *Vek Lavrenteva* [*The Time of Lavrentev*], Novosibirsk, Izdatelstvo SO RAN, 2000, p.61; ©2000 Presidium Siberian Branch, Russian Academy of Sciences.)

approach the major question: How should we interpret the complex intricacies of initial Soviet digital computer development?

Early Soviet development focus

Solving mathematical problems—of artillery, missiles, and aeronautics—was the main focus of postwar computing device developments. In a joint written statement in summer 1946, Nikolai G. Bruevich, N.E. Kobrinskii, L.I. Gutenmakher, N.A. Borodachev, and L.A. Lyusternik, all of whom later directed numerous ITMVT activities, declared:

> That which occupies a special position in computing techniques is the solution of a variety of mathematical subjects related to overland or oversea aeronautics, firing in artillery, precision bombing meters, anti-aircraft guns and firing of long-distance missiles. They will be realized with special devices (PUAO, PUAZO [*Author's note*: These are the names of the aiming and controlling devices for the antiaircraft guns.] and others) and other aiming devices. ... The research will be carried out with the purpose of the development of new calculating and solving machines, in which the integrators for the general differentiate equations, the machines for the algebraic equations, the electrical integrators for the frontiers in the partial derivatives with the application of the differentiate equations, the machines for the high-order algebraic equations, and the multi-purpose punch-card calculating machines, are to be included.[19]

The ITMVT was set up in July 1948, by an order of the Presidium of the Academy of Sciences, with approximately 60 researchers, most of whom came from the Institute of Mechanical Engineering, the Energy Institute, and the V.A. Steklov Institute of Mathematics.[20] The Ministry of Machine and Instrument Construction offered an 830-square-meter site of one of its factories to the newly founded institute.[21] The Academy of Sciences president, Sergei I. Vavilov, recommended Nikolai I. Bruevich, a technical specialist and lieutenant general, to be the ITMVT's first director.[22]

Reporting on the ITMVT's first-year activities in 1948, Bruevich wrote that,

> we embarked on the research for the development of general methods for tabulating of the multi-variable functions, which will be adapted for the subjects of ballistics, geodesy, radio-navigation and others. ... Moreover, a sample of Eli-

> 11, the integrator equipped with electronic tubes for a system of continuous differentiate equations, was developed and built up. ... Some of our achievements were adapted at the Ministry of Aircraft Industry and other specialized research institutes.[23]

An engineer who was present at the time, P.P. Golovistikov, said that Bruevich, in his capacity as acting director, brought up the matter of developing a general-purpose digital computer in a seminar held in early 1949. His proposal, however, met with strong objections from his colleagues. According to Golovistikov, Bruevich's colleagues raised three objections:

> First, the vacuum tubes were so unreliable and the quantity of tubes required for any potential machine was so great that the machine might not be so reliable, while analog machines had already proven quite reliable. Second, even if it were shown that universal electronic digital machines could function reliably, given the probable high cost of research and development, it would be more cost effective to continue to develop special-purpose machines. Finally, the expertise required to operate such machines seemed overwhelming.[24]

Therefore, the Institute's Plan of Scientific Research Activities for 1949 made no mention of a general-purpose digital computer.[25]

SKB-245 enters the picture

Soon after the ITMVT was established, the USSR Council of Ministers established the SKB-245 within the Ministry of Machine and Instrument Construction in December 1948. Its charter was to develop electrical analog calculators and precision instruments, and improve existing special-purpose calculating devices, specifically for designing rockets and jet planes. Beginning with only two engineers, within a year the SKB-245 had recruited as many as 144 people, of whom 97 were engineers, technicians, or men with technical expertise.[26] The others served in the administrative sections. At its peak, by 1951 the number of SKB-245 employees rose to 378.[27] By then, the Special Design Bureau was running 12 laboratories and an affiliated factory in Moscow.[28] Soon it began to operate a factory called the Penza SAM (for *Schetno-Analiticheskaya Mashina,* or Calculator-Analyzer). The Penza SAM itself helped establish an SKB-245 subsidiary, which employed 50 men, most of whom were specialists.[29]

Despite its growth, all did not go smoothly for the Special Design Bureau. For fiscal year 1949, its estimated budget was about 7 million rubles, but the amount it finally expended was far smaller: RUB4,636,600. At that time, the SKB-245 could not fulfill its full quota of work because of a shortage of specialists. Furthermore, the contractor-clients, all government institutions, were neither diligent nor well informed about computing devices, and so they often delayed submitting their specifications to the SKB-245.[30] Such delays meant difficulties in the SKB-245 financing, about half of which came directly from the contractors. For example, in 1952, the government's direct contribution to the SKB-245's total budget of RUB30,950,000 was about RUB16,150,000. The rest came from government contracts.[31]

The SKB-245's high productivity was largely due to its clients', especially artillerists' preference for special-purpose, rather than universal, computers.[32]

Objections from the mathematicians

The USSR Academy of Sciences led some of the crucial research in precise mechanics and computers in the Soviet Union.[33] However, according to the memoirs of mathematician Mikhail A. Lavrentev, who was later to be the academy's vice president, most scientists and engineers at the academy underestimated the potential of computers:

> After the appearance of computers in America, there arose a split in the opinion among our mathematicians, electric engineers and machinists. The majority of them considered a computer as an advertisement, without any prospects, and instead proposed to design more analog computing machines and mechanical calculators. For this end, a new research institution, the Institute of Precision Mechanics and Computer Technology, was established.[34]

As I have mentioned, the Institute's Plan of Scientific Research Activities for 1949 made no mention of a general-purpose digital computer.[35] This plan disappointed some mathematicians. Soviet scientists such as Lavrentev and Mstislav V. Keldysh, the latter a renowned mathematician who later became academy president, realized the need for faster machines than those available.

Ideas collide with ideology

Lavrentev, Keldysh, and other mathematicians were developing many complicated calculations needed for nuclear weapons development. The Institute of Mathematics, where Keldysh worked, kept numerous *brigades*

The Soviet Union's ideological campaign, however, made it hard for people to absorb foreign news, and adopt foreign ways and inventions.

of calculators busy with such calculations. The brigades, each consisting of more than 100 people (mostly young girls), worked 8-hour shifts and used German-made Mercedes calculators.[36] To coordinate the brigades' calculating tasks related to nuclear development, the government's First Chief Directorate, which was in charge of nuclear weapons development, set up an Interdepartmental Commission on Computing Technique.[37] The complexity of these calculations far exceeded the level required by Soviet artillery in trajectory research, so much so that the interdepartmental commission was nearing the limits of its ability. An ITMVT research associate known only as Neiman, reported at the 26–27 June 1950 Institute meeting that, "the mathematicians are now presented by the physicists with the tasks which are very difficult to solve."[38]

In addition, according to Gerovitch,[39] the mathematicians were increasingly aware of the computing developments achieved in the US and the United Kingdom. As early as 1947, Lavrentev cited the importance of developing computing mathematics at an Academy of Sciences discussion in the Department of Physical-Mathematical Sciences.[40]

The Soviet Union's ideological campaign, however, made it hard for people to absorb foreign news, and adopt foreign ways and inventions. To avoid ideological harassment, scientists and engineers like Lavrentev and Keldysh had to be cautious with their professional pursuits:[41] They had to prove the Soviet originality of their attempts. They were, however, close to reaching a milestone: A development test trial for a Soviet-made computer was already scheduled to be conducted in Kiev, where Lavrentev had long worked.[42]

Meanwhile, working independently of other engineers' efforts, Soviet electrical engineer Sergei A. Lebedev and his young colleagues devoted themselves to computer development in Kiev. Lavrentev, who also held the position of vice president of the Ukrainian Academy of Sciences, supported Lebedev's group.[43]

Lavrentev, in fact, was about to exert his political influence. For instance, as soon as Lebedev's group had completed the basic work for the first Soviet electronic-digital computer, named MESM (*Malaya Elektronnaya Schetnaya Mashina*, or small electronic calculating machine), in late 1949, Lavrentev had showed it to a group of top political leaders in the Ukraine. The group included Nikita S. Khrushchev, then secretary of the Central Committee of the Ukrainian Communist Party, and Andlei A. Grechko, commander in chief of the Ukrainian army (later minister of defense for the Soviet Union).[44] Khrushchev was to leave Kiev for his new position in Moscow in December 1949.

Furthermore, Lavrentev was anxious to interest "a certain highly authorized governmental organization" in his work, and sought a way to personally approach Boris L. Vannikov, director of the First Chief Directorate of the USSR Council of Ministers. In addition, Lavrentev wrote letters to the Central Committee and to the Council of Ministers, asking for favorable treatment for his Institute.[45]

Archival sources are silent about the details of the political maneuvers. However, the speculation is that in Moscow, Khrushchev worked for Lavrentev's advantage, which later led to the downfall of the ITMVT's acting director, Bruevich.[46]

Bruevich's downfall: Turning point

Lavrentev and others began criticizing the ITMVT plan for 1949, which did not include digital computer development. They later also succeeded in obtaining approval from many of the academicians enrolled in the Department of Technological Sciences of the Academy of Sciences for their proposal to inspect the ITMVT activities.

The Department of Technological Sciences set up a special commission, chaired by Keldysh, for this purpose and which included, for instance, A.A. Ilyushin, I.A. Oding, and Dimitrii Panov. The commission produced an official report, "The Conclusion,"[47] adopted with the approval of all the members except Oding. The report heavily criticized the ITMVT's disregard for developing general-purpose digital computers as well as its lack of focus. The commission's final report also included an "Opinion" that blamed Acting Director Bruevich for the ITMVT's lack of qualified computer specialists.[48]

Meeting on 6 July 1949, the Academy of

Sciences' Bureau of the Department of Technological Sciences discussed both the commission report and a reply from Bruevich and his colleagues.[49] The Bureau compromised, saying that the ITMVT should be tasked with developing general-purpose, high-speed computers as well as electrical, or mechanical, mathematical machines and other subjects.[50] The Bureau also adopted A.B. Chernyshev's proposal to add a phrase to its official report:

> Putting a special stress onto the development of digital, high-speed computers, [the Bureau] proposes that the Institute (ITMiVT) add the subject of the development of such machines to its plan and make progress in that subject, employing all possible means.[51]

Bruevich also took on the responsibility for developing digital high-speed computers, at least temporarily.[52]

Bruevich, not appointed full director, did remain as acting director for more than a year. Meanwhile, the ITMVT could not be fully established. In fall 1949, the Academy of Sciences withdrew its recommendation that Bruevich be made ITMVT director,[53] and instead, on 15 March 1950, Lavrentev was appointed director.[54] (It seems that Lavrentev's political maneuvering took a few more months. So, despite losing the directorship, Bruevich maintained his influence in the Institute for a while.) Even after Lavrentev's appointment as director, Bruevich remained as the Institute's chief of the Department of Precision Mechanics, until his later removal from the ITMVT in the fall of 1950.[54]

At Lavrentev's request, the Bureau appointed V.A. Ditkin acting deputy director in place of N.E. Kobrinskii on 11 April 1950.[55] Consequently, Lavrentev proposed new members of the Institute's Scientific Council, namely Lebedev as the chief of Laboratory No. 1, and Ditkin as chief of the Experimental and Calculating Laboratory. Such rapid reform by Lavrentev, however, raised questions.[56]

In its 13 July 1950 meeting session, the Bureau's Department of Technological Sciences examined the ITMVT's Five Year Plan and the Plan of the Scientific Research Activities for 1951, newly prepared under Lavrentev's leadership. Although Bruevich, who was not mentioned in it and so had no role, angrily denounced the plan, it was adopted anyway.[57]

Consequently, on 26-27 July 1950, the ITMVT conducted a major meeting[58] in which meeting attendees severely criticized the Institute's former activities. Ditkin read the questions submitted to the Institute leadership one after another:

> What are the causes of the miscalculations in the solutions of the problems with the calculating and the analyzing machines? How long can the calculations go on continuously without mistakes? What kind of miscalculations are there? What is the percentage of a working day when the machines are able to work without miscalculating? What is the ratio of the calculations not employing any mechanical means to those employing the help of cradle calculators and tabulators?[59]

Ditkin then revealed the low level of the Institute's computing technology, answering the questions himself:

> The rate of miscalculation is very high, at 2-5 percent; if the machine makes more miscalculations, we must give up using it. The ratio of the calculations without any mechanical means to those with mechanical helps is 1:8, or 1:10.[59]

Moreover, Ditkin discussed an example of a machine called D-11:

> Recently we obtained a calculator named D-11. That machine is a trophy. It lacks manuals. We cannot help learning it by practice. We don't know the mechanism of the machine. We don't know its maximum calculating ability, or how many relays can work at the same time.[59]

That meeting occurred approximately one year after the session of the Bureau of Academy of Sciences' Department of Technological Sciences in which the development of high-speed computers was initiated. The July 1950 meeting attendees adopted a resolution aimed at the "building-up of strong, high-speed digital computers."[60]

A shift in direction

In fall 1950, Bruevich, Kobrinskii, and their colleagues were removed from their positions in the ITMVT because their qualifications did "not meet the needs of the required project and the political requirement." They returned to the Institute of Mechanical Engineering, to which they had formerly belonged.[61] At the same time, Dmitrii Yu. Panov, a professor at Moscow State University, was recommended as the ITMVT's deputy director,[62] a position he accepted in late October.[63] Soon after that, Bruevich, who had long impressed Soviet scientists with his politically powerful connec-

tions, was virtually banished from the Academy of Sciences.[64,65]

Immediately after his appointment as the ITMVT's deputy director, Panov was asked to advise on the draft of the USSR Council of Ministers' Proclamation, which would list guidelines on the future development of computers. In a handwritten opinion that took him barely an hour to produce, Panov pointed out that the definition of "a high-speed numerical computing machine" in the Proclamation's draft was vague. Panov wrote that the draft mentioned so many subjects that he feared the Council was spreading its efforts too widely, and that the new subjects were too complicated for the Ministry of Machine and Instrument Construction to control, despite the major efforts by both the Ministry of Machine and Instrument Construction and the USSR Academy of Sciences.[66] Panov's advice was subsequently taken. In November 1950, the USSR Council of Ministers gave the ITMVT full responsibility for developing a universal automatic high-speed numerical computer. The Council of Ministers' Proclamation, dated 11 May 1951, designated the date of that machine's completion to be April 1953.[67]

In a competing development effort, Lebedev now moved to Moscow, where he directed the development of BESM, the first "successful" Soviet computer.[68] Yet although the 1955 State Commission had evaluated BESM very highly, the Commission reported that BESM was inferior to the American machines, for example to IBM's NORC (Naval Ordnance Research Calculator) machine. In addition, BESM had some serious defects. Nevertheless, the Commission recommended its commercial manufacture after some improvements were made.[69] The SKB-245, meanwhile, issued a report to the Commission that raised doubts about the originality of BESM. It claimed that BESM was "a mere copy of American machines or Soviet machines," and pointed to its shortcomings. The BESM, for example, did not use germanium or ferrite for the storage, and it was hard to solve the problem of automatic programming.[70]

Strela: Development begins

Despite the fact that the internal structure of the Institute of Precision Mechanics and Computing Technique was now radically reformed, the SKB-245 remained unchanged: The Special Design Bureau just went on producing analog or mechanical calculators for its clients. Yet a few years before, in August 1948, a young SKB-245 employee, Bashir I. Rameev, had drafted a design for a digital electronic computer in collaboration with Isaak S. Bruk,[71] who had been involved in designing computers in the Energy Institute and who later designed small, limited computers such as the M-1 and M-2.[72] Nevertheless, the SKB-245 did not initiate a high-speed computer project until the Academy of Sciences had reorganized the ITMVT, and by the time it did begin such a project, the Bureau had to first recall Rameev from his army service in the Far East.[73]

Around that time, L.I. Gutenmakher proposed building a high-speed computer equipped with electromagnetic non-contact relays in the place of vacuum tubes. His proposal attracted the attention of the Minister of Machine and Instrument Construction, Petr I. Parshin, perhaps because the Soviet Union was then suffering from a shortage of vacuum tubes.[74] Gutenmakher's proposal was, however, denied in a meeting of the Technical Council of the Bureau in 1950.[75] Later, a dispute arose between Rameev and Yuri Bazilevskii, who proposed developing a relay-type high-speed "computer" instead of a computer equipped with vacuum tubes. But Bazilevskii's proposal was also rejected.[76]

At any rate, in 1950 the Bureau's new direction was confirmed: it would make a digital high-speed computer. The USSR Council of Ministers, on learning of the SKB-245's plans, then named the SKB-245 along with the ITMVT as the organizations responsible for developing digital computers, in its Proclamation of May 1951.[77] In so doing, the government effectively enabled the MMP to monopolize development of all kinds of mathematical machines. The SKB-245 and the ITMVT were now in a race to see which organization would be first to develop a high-speed computer.

At one point, minister Parshin invited Lavrentev to his office. Lavrentev, accompanied by Academy of Sciences president Sergei I. Vavilov, visited Parshin, who stated that,

> I will make the machines. I have the ability. I called you, the Academy of Sciences, for help; you shall cover up the project with a scientific appearance, taking advantage of your scientific authority—by writing scientific papers when needed.[78]

Parshin's statement left Lavrentev and Vavilov with no doubt as to the Ministry's determination to be the sole developer of computers.

The SKB-245 began designing a universal electronic digital computer, which was the *Strela* (see Figure 2). The government set the timetable for this project, which was supposed

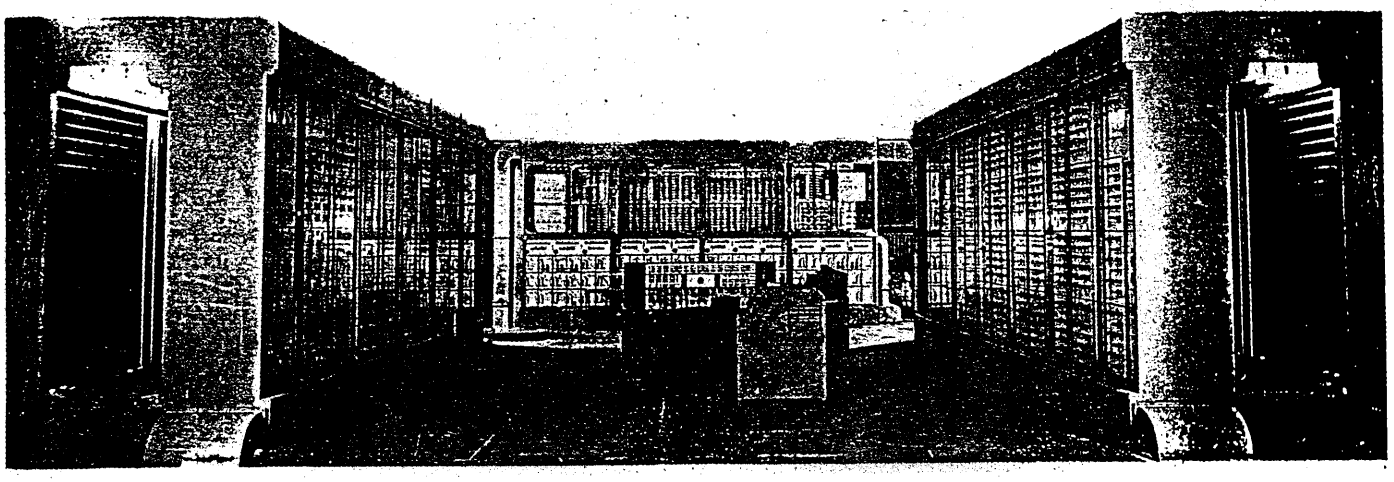

Figure 2. A general view of the Strela-3. (Courtesy of RGAE [Russian State Archive of Economy], collection 8123, group 8, file 619, p. 218.)

to be ready in the first quarter of 1953.[79] From an October 1952 letter from the SKB-245 director, we learn that the Strela's design was to include the following:

- an external input mechanism consisting of a keyboard unit, a punch-card device, monitoring indicators and entry device for magnetic tapes;
- a magnetic-tape external storage unit;
- a magnetic-drum internal storage unit;
- an arithmetic operating device;
- a controlling and signaling system;
- an output mechanism consisting of a punch-card device and a printer-reader; and
- an electric power supplier.[80]

Because the SKB-245 lacked sufficient experts, however, the Strela's development faced long delays. In addition, whenever the scientists and engineers learned of technological progress in computers that had occurred in the US, that knowledge often forced frequent changes in the design. The changes, which slowed the Strela's development, primarily involved two areas: the use of electron-beam (cathode-ray) tubes as recording devices for the storage unit, and the use of germanium diodes.[81] As late as 1953, the Bureau received additional design change requests for the Strela.[82] In addition, the organization—Scientific Research Institute No. 160 of the Ministry of Industry for Communication Means—that had been asked to develop the Strela's electron-beam tube declined, on the grounds that it lacked experience.[83] The delays meant that the Strela-1 would not be completed until late 1953.[84] The first trial, conducted before a State Commission headed by Keldysh, occurred in spring 1954, and it was impressive. In roughly 10 hours, the Strela-1 processed an integral-differential equation requiring approximately 70 million calculations to solve, which would otherwise have taken a mathematician about 100,000 days' work.

The new additions to the Strela-1 hardware included electron-beam tubes in the high-speed recording device, 125-mm-wide magnetic tape for the external storage unit, and germanium diodes. The Strela-1 was able to process 2,000 arithmetic operations per second. Its internal storage unit stored 1,023 words. It dealt with the numbers in a range of 10^{-19} to 10^{19}, and the external storage unit's capacity was about 200,000 words. The State Commission recommended that the Strela be put into operation.[85]

The SKB-245 had taken several orders for Strelas by the date of the machine's first trial. Its clients included powerful military departments and institutions, such as the Ministry of Defense. A year before the Strela's test, there had already been plans to establish six Computing Centers to be situated at the Chief Directorate of Artillery, the Naval Academy of the Ministry of Defense, the ITMVT, the Ministry of Aircraft Industry (for the Central Institute of Aeronautical Hydrodynamics), and at two other organizations whose names were deleted from the official documents. The SKB-245 took charge of supplying Strelas for five of them, with the exception of the ITMVT.[86] By the time of the Strela's first trial run, the SKB-245 had taken eight orders.[87] As the initiative to establish the computing centers gained momentum, the Special Design Bureau moved to take advantage of this opportunity, expanding its organization and hiring as many as 1,300 personnel. The Bureau required the additional expertise because of its backlog of projects it needed to complete.

Figure 3. A group of engineers involved in the Strela's development (with A.N. Myamlin at the center, front). (Reprinted with permission from *M.V. Keldysh: Tvorcheskii Portret po Vospominaniyam Sovremennikov* [M.V. Keldysh: Creative Portraits in Memories by His Contemporaries], A.V. Zabrodin, ed., Nauka, 2002, p. 344; ©2002 Russian Academy of Sciences.)

What is interesting, however, is that the Bureau now evidenced strong hostility toward the USSR Academy of Sciences. The Bureau persuaded the USSR Council of Ministers to have the Academy transfer some of its personnel and equipment to the Bureau.[88] Clearly, the Bureau was exploiting its military connections to promote its prestige and success, as well as to hide its technological failure, about which I will explain later. It appears that the Bureau even tried to get the military to blame the Academy of Sciences for the Soviet Union's lack of success in computer technology. For example, in June 1955, Section No. 14 of the Scientific-Technical Council of the Ministry of Defense, headed by academician Aksel I. Berg, who also served as deputy-minister of defense, adopted the official "recommendation" to blame the Academy of Sciences for the serious failings and long delays that threatened the completion of the USSR's high-speed computers. It was prepared by Anatolii I. Kitov, director of the Computing Center of the Ministry of Defense.[89] Taking advantage of this opportunity, the Ministry of Machine and Instrument Construction was soon appealing to the USSR Council of Ministers to call the Academy to account for the matter.[90]

Strela success: Mixed results

The Strela's success resulted partly because of the high regard with which Keldysh's Commission was held, and partly because of the delays experienced by the Strela's rival, the BESM, thanks to tactics taken by the Ministry of Machine and Instrument Construction. According to the Ministry's records, an experimental model of the BESM machine achieved a speed of only 600 to 800 operations per second in 1953.[91] The Ministry hoarded the supply of electron-beam (cathode-ray) tubes for calculators in the Soviet Union and refused to share them with the ITMVT, which—because it lacked an industrial basis—was forced to rely on the largess of the Ministry of Machine and Instrument Construction.[92] In 1954 when, finally, the Ministry of Machine and Instrument Construction and the Ministry of Radio Industry negotiated to jointly develop electron-beam storage for the BESM, the BESM ultimately reached a speed of 7,000 to 8,000 operations per second,[93] making it one of the fastest computers in Europe (although not the world).[94] Its memory was now built mainly with electron-beam tubes and ferrite magnetic cores rather than the supersonic wave devices with which the BESM had been equipped previously.

The Strela's much-touted success, on the other hand, was greatly exaggerated. Anatolii N. Myamlin, an engineer who contributed to the development of Strela (see Figure 3), confessed that the Strela, which had been installed in the Institute of Mathematics, "worked very badly."[95] Most of the Strela's hardware had to be replaced after only a year, apparently, except for the arithmetic operating device. Mikhail R. Shura-Bura, a pioneer of Soviet computer science, stated that "The machine very often failed and did not work properly."[96] What was worse, this machine was unable to solve the mathematical tasks required for the study of nuclear fission, for which it had been designed. Aleksei V. Zabrodin, in recalling that Yurii B. Khariton, a leading scientific expert of a Soviet nuclear development center, had visited Keldysh to discuss complicated quadratic equation solutions, witnessed the fact that the Strela was unable to solve these equations.[97]

Why, then, had the Strela been so highly evaluated by the State Commission? One possible reason was that, simply, Strela was visually a nice-looking machine. It had hundreds of lamps, most of them blinking. A witness described it as a "beautiful machine in a beautiful hall."[98] The Commission's Keldysh made use of that beautiful physical appearance of the machine to hide its failings. Now Keldysh, who had been aligned with Lavrentev and his Institute, had to pretend to be satisfied with the Strela's success, because the initial failure of the

computer's development would have been a political disaster. This was undoubtedly a matter of prestige for him and for his institution, so he worked hard to conceal the technological inadequacy of the first Soviet computer from the central planners and, in so doing, enabled the Strela's brief political success.[99]

Conclusion

A pivotal moment came when, in July 1955, physicist Igor V. Kurchatov, a scientific leader of Soviet nuclear development, and Sergei L. Sobolev, his colleague and leading mathematician, asked the Ministry of Machine and Instrument Construction to provide BESM computers for their Laboratory of Measurement Instruments.[100] This laboratory was the successor to Laboratory No. 2, the first research center for the Soviet Union's atomic bomb development, and now known as the Kurchatov Institute. The net effect of the BESM's having been officially requested for such an important government endeavor meant the end of the Strela project. As a result, the Ministry of Machine and Instrument Construction cancelled the Strela project.[101]

The Soviet military itself, especially its artillerist parts, was content with the mechanical calculators and the analog machines, provided by the Ministry of Machine and Instrument Construction, which was a familiar agency to the artillerymen as a supplier of trench mortars, rocket launchers, and other projectile weapons.[102] Moreover, the military seems to have preferred the special-purpose analog calculators because they were easier to operate and a lot cheaper: The planned price of the Strela (in September 1954) of RUB9,800, far exceeded the RUB1,350 price of an analog calculator or the RUB1,000-3,000 for a special-purpose computing machine.[103]

In addition to the military's preference for the cheaper, analog machines, which did not bode well for the Strela, another factor was the delay in installations. The completion of Strelas was delayed in many cases; for example, the machines for the Ministry of Medium-sized Machine-Building and for Moscow State University were installed only in 1955, almost a full year late.[104]

The primary force behind the desire for faster computers was a group of scientists and mathematicians, such as Lavrentev, many of whom were actively involved in the Soviet nuclear project. These are the specialists who felt a genuine need for general-purpose, electronic, digital computers to process, for example, the advanced and complicated calculations that nuclear physics required. In the Soviet bureaucratic culture, this group had to seek political patronage in order to eliminate obstacles to computer development. At the same time, such political maneuvering inevitably affected the scientists' interrelationships.

The SKB-245 took countermeasures against Lavrentev's group—the development of its own computer. With such actions, the Bureau gained success, however transitory.

All of these processes shaped the Soviet quest for high-speed computers into a complicated and discordant process. Without any question, they greatly delayed, and altered, Soviet computer development.

Acknowledgments

This study was carried out with financial support from the Japan Association for the Promotion of Science (Grant-in-Aid for Scientific Research: A basic research, type C-2) and the Nomura Foundation for Social Science. The author thanks Oksana Danirovna Simonenko, other colleagues of the Institute for History of Natural Sciences and Technology of the Russian Academy of Sciences, Elena Aleksandrovna Tyurina, Andrei Viktorovich Kurakin (the Russian State Archive of Economy), Masanori Kaji, Yakup Bektas (Tokyo Institute of Technology), M. Ludwig (Technishce Universitet, Berlin) for the reference concerning Mercedes calculators, Anne C. Fitzpatrick (Federation of American Scientists), referees of the *IEEE Annals of the History of Computing* for scientific advice, Martin Ward, and Louise O'Donald (for the extensive correction of the author's English writing).

References and notes

1. See, for example, M.V. Keldysh, "Matematika—Vychislitelnaya tekhnika" ["Mathematics—Computer Technology"], *Bolshaya Sovetskaya Entsiklopediya* (v. 2) [*Great Soviet Encyclopedia*], vol. 50 , p. 438 (in Russian).
2. *Rossiiskii gosudarstvennyi arkhiv ekonomiki* [Russian State Archive of the Economy], collection 8123, group 8, file 560, p. 239. In citing documents from the archives, I have listed the archives by their abbreviations, the document classifications, and the document filing numbers, omitting the full titles. I cited mainly documents kept in the Branch of the Russian State Archive of Economy [*Filial Rossiiskogo gosudarstvennogo arkhiva ekonomiki* (RGAE)], the Archive of the Russian Academy of Sciences [*Arkhiv Rossiiskoi Akademii Nauk* (Arkhiv RAN)], and the Russian State Archive of Socio-Political History [*Rossiiskii gosudarstvennyi arkhiv sotsial-*

no-politicheskoi istorii (RGASPI)], all located in Moscow.

3. RGAE, collection 8123, group 8, file 560, p. 204.
4. B.N. Malinovskii, *Istoriya vychislitelnoi tekhniki v litsakh* [*History of Computer Technology in Personalities*], Kiev 1995; see chapter 6, at http://lib.ru/MEMUARY/MALINOWSKIJ/7.htm (in Russian).
5. I.M. Makarova et al., eds., *Istoriya informatiki v Rossii: uchenye I ikh shkoly* [*History of Informatics in Russia: The Scientists and Their Schools*], Nauka, 2003, p. 186 (in Russian).
6. Virtualnyi kompyuternyi muzei [Virtual Computer Museum], *Istoriya otechestvennoi vychislitelnoi tekhniki* [*History of Russian Computer Technology*]; http://computer-museum. ru/histussr/18htm.
7. S.P. Prokhorov, "Computers in Russia: Science, Education and Industry," *IEEE Annals of the History of Computing*, vol. 21, no. 3, 1999, pp. 4-15.
8. G.D. Crowe and S.E. Goodman, "S.A. Lebedev and the Birth of Soviet Computing," *IEEE Annals of the History of Computing*, vol. 16, no. 1, 1994, pp. 4-24.
9. S. Gerovitch, *From Newspeak to Cyberspeak: A History of Soviet Cybernetics*, MIT Press, 2002, pp. 131-149. In noting that the Ministry of Machine and Instrument Construction objected to disclosing BESM information to a group of scientists from India, Gerovitch said that the Soviets' policy of secrecy "was not solely the product of Soviet isolationist ideology, but could sometimes be induced by interagency rivalry and used as a weapon of bureaucratic competition." (pp. 148-149). On the other hand, I.V. Kurchatov and B. Vannikov jointly wrote to Vice-Prime Minister V.A. Malyshev, an army general involved in developing the Soviet atomic bomb, to demand that a paper not be published about the Strela because of "an unnecessary citation," RGAE, collection 8123, group 8, file 623, pp. 271-272.
10. A. Nove, *The Soviet Economic System*, George Allen & Unwin, 2nd ed., 1988, p. 62.
11. Ibid, p. 65.
12. N. Krementsov, *Stalinist Science*, Princeton Univ., 1997. p. 5. Krementsov said, "The war forced the party-state bureaucracy to rely on the expertise of military, industrial, scientific, and technical specialists, thus loosening party control and increasing local autonomy and initiative"(p. 65). He directed his attention to such consequences of war as the background of the symbiotic relationship between political power and scientists. Asif Siddiqi, however, clarified that even in the prewar period, internal discord among the specialists might have affected the political treatment they received through their political relationship: A. Siddiqi, "The Rocket's Red Glare: Technology, Conflict, and Terror in the Soviet Union," *Technology and Culture*, vol. 44, no. 3, 2003, pp. 471-501.
13. P.E. Ceruzzi, *A History of Modern Computing*, MIT Press, 1998, p. 7.
14. For an early perspective, see, for example, M. Boretsky, "Comparative Progress in Technology, Productivity and Economic Efficiency; U.S.S.R. versus U.S.A.," *New Directions in the Soviet Economy*, U.S. Congress Joint Committee, 1966, pp. 172-175. M. Cave, "Computer Technology," *The Technological Level of Soviet Industry*, R. Amann, J.M. Cooper, and R.W. Davies, eds., Yale Univ. Press, 1977, pp. 377-390.
15. S. Gerovitch, *From Newspeak to Cyberspeak: A History of Soviet Cybernetics*, p. 7.
16. Ibid., pp. 7-8.
17. Ibid., p. 131.
18. Besides these two organizations, we can refer to the effort by I.S. Bruk in the Energy Institute of the Academy of Sciences: see B. Malinovskii, chap. 5, http://lib.ru/MEMUARY/MALINOWSKIJ/6.htm (in Russian).
19. RGASPI, collection 17, group 125, file 447, pp. 29-30.
20. Arkhiv RAN, collection 1559, group 1, file 3, p. 1.
21. Arkhiv RAN, collection 395, group 1-50g., file 1504-62-613, p. 87.
22. RGASPI, collection 17, group 132, file 36, p. 29. Bruevich taught at the Military Aviation Academy from 1929-1961. He was a lieutenant general during World War II (N. Krementsov, *Stalinist Science*, pp. 98 and 300).
23. Arkhiv RAN, collection 1559, group 1, file 3, pp. 3, 4.
24. Cited in G.D. Crowe and S.E. Goodman, "S.A. Lebedev and the Birth of Soviet Computing," p. 14.
25. RGASPI, collection 17, group 132, file 36, pp. 48-49.
26. RGAE, collection 8123, group 8, file 308, p. 31.
27. RGAE, collection 8123, group 8, file 402, p. 1.
28. RGAE, collection 8123, group 8, file 524, p. 27.
29. RGAE, collection 8123, group 8, file 523, p. 11.
30. RGAE, collection 8123, group 8, file 308, pp. 29-31.
31. RGAE, collection 8123, group 8, file 482, p. 85. The major client contracts at that time were the Ministry of Armed Forces (later Ministry of Defense) RUB1,091,600; Moscow State University, RUB3,201,600; and Factory No. 293 of the Ministry of Aircraft Industry, RUB623,300.
32. For example, even in 1953, the Bureau built analog machines, such as *Polyet* (or *flight*, a computing machine specialized for testing automatic piloting systems of aircraft), Operator (an analog computer for modeling with changeable variables), Integral VI (with 6 integrators), and an analog calculator for discrete differential equations (RGAE, collection 8123, group 8, file 402, pp. 94-109). At the same time, the Bureau

developed MDA, a high-performance differential analyzer with 24 integrators; a high-performance electrical integrator; a high-speed relay calculator; and two types of high-resistance germanium diodes (ibid., pp. 153-156). The Bureau planned to develop four new machines for the Chief Directorate of Artillery of the Ministry of Defense from 1955 to 1957: *Korund* (designed to calculate the atmosphere's influence on trajectory caluclations), *Plyut* (designed for geological survey calculations), *Granit* (to verify results of correlative functions), and *Udar* (for integrations of the probability of warhead strikes); RGAE, collection 8123, group 8, file 629, pp. 181-184. Even in 1955, the Central Institute of Aeronautical Hydrodynamics recommended a calculator with an analog mechanism for complex simulations of jet flights; RGAE, collection 8123, group 11, stock unit 11, pp. 181-188.

33. The Energy Institute of the Academy of Sciences, for example, had been striving to develop differential analyzers equipped with six integrators since 1936 (RGAE, collection 8123, group 8, file 524, p. 19). The Institute manufactured its first device between 1938 and 1939 (ibid., p. 23). The Institute had tried for 10 years to design electronic integrators for differential equations. From 1948 to 1952, the Academy of Sciences' pursuits included a small electronic analog computing machine (ibid., p. 19).
34. Rossiiskaya Akademiya nauk, Ordena Lenina Sibirskoe otdelenie [Russian Academy of Sciences, The Siberian Branch], ed., *Vek Lavrenteva* [*The Time of Lavrentev*], Izdatelstvo SO RAN, 2000, p. 54 (in Russian).
35. RGASPI, collection 17, group 132, file 36, pp. 48-49.
36. A.V. Zabrodin, ed., *M.V. Keldysh: tvorcheskii portret po vospominaniiam sovremennikov* [*M.V. Keldysh: Creative Portraits in Memories by His Contemporaries*], Nauka, 2002, p. 344 (in Russian). The calculator *Mercedes* was invented by Ch. Hamann in Zella-Mehris in 1905 and produced in eastern Germany. Unfortunately, I could find no documents confirming that young Soviet girls worked with calculations at that time. Girls' role in computing's early days is getting more attention since J.S. Light's article, "When Computers Were Women," *Technology and Culture*, vol. 40, no. 3, 1999, pp. 455-483.
37. A.N. Myamlin, "M.V. Keldysh i Vychslichelnaya Tekhnika" ["M.V. Keldysh and Computer Technology"], A.V. Zabrodin, ed., p. 343 (in Russian).
38. Arkhiv RAN, Collection1559, Group 1, File 15, p.15; Neiman's given name and his father's name (Russian middle name) are unknown.
39. S. Gerovitch, *From Newspeak to Cyberspeak: A History of Soviet Cybernetics*, pp. 132-133.
40. *Vek Lavrenteva* [*The Time of Lavrentev*], p. 77.
41. For a reconsideration of the campaigned "scientific discussions," see A.B. Kozhevnikov, *Stalin's Great Science: The Times and Adventures of Soviet Physicists*, Imperial College Press, 2004, pp. 186-216. For a reevaluation of the philosophical discussion in the beginning of this campaign , see Y.I. Krivonosov, "Srazhenie na filosovskom fronte: Filosovskaya diskussiya 1947 goda—prolog ideologicheskogo pogroma nauki" ["The Battle in the Philosophical Front: Philosophical Discussion in 1947—Prologue of Ideological Pogrom of Sciences"], *Voprosy istorii estestvoznaniya i tekhniki* [*Problems of History of Natural Sciences and Technology*], no. 3, 1997, pp. 63-86 (in Russian), and V.D. Esakov, "K istorii filosovskoi diskussii 1947 goda" ["For the History of Philosophical Discussion in 1947"], *Voprosy filosofii* [*Problems of Philosophy*], no. 2, 1993, pp. 83-106 (in Russian).
42. *Vek Lavrenteva* [*The Time of Lavrentev*], p. 58.
43. G.D. Crowe and S.E. Goodman, "S.A. Lebedev and the Birth of Soviet Computing," pp. 4-8.
44. *Vek Lavrenteva* [*The Time of Lavrentev*], pp. 59-60. Later, Khrushchev's patronage for Lavrentev became well known. As late as 1962, Lavrentev made sure to thank Khrushchev in his speech: "Although the world-wide center of mathematics has moved to the United States owing to the immigration of many mathematicians (John von Neumann and others), and many great mathematicians have been mobilized to the physics field in the Soviet Union, we have been able to gather a sufficiently talented collective. N.S. Khrushchev gave us the powerful and organizational support.", Nauchinyi arkhiv Sibirskogo otdeleniya Rossiiskoi Akademii nauk [Scientific Archive of the Siberian Branch of Russian Academy of Sciences], collection 27, group 1, file 76, p. 4).
45. *Vek Lavrenteva* [*The Time of Lavrentev*], p. 60.
46. Citing the minutes of the Party's Politburo meetings and other documents, Gerovitch affirmed that Khrushchev took action in favor of Lavrentev in the Party's top echelons (see S. Gerovitch, *From Newspeak to Cyberspeak*, p. 136).
47. RGASPI, collection 17, group 132, file 36, pp. 34-44.
48. RGASPI, collection 17, group 132, file 36, p. 47.
49. Arkhiv RAN, collection 395, group 1-49g, file 1503-62-613, pp. 149-172. In this "reply," Bruevich and his colleagues said "a series of the machines, based upon analogue principles, are younger. They have only appeared in the 20th century. The basic theories and the first example in the world of a differentiate analyzer were

developed by the late academician, A.I. Krylov (p. 156). ... The numerical machines cannot be massive computers for the solution of analytical subjects (p. 158). ... ENIAC has a large number of vacuum tubes. Up to 70% of these tubes may, however, come to a standstill, which is somehow undesirable in the results and needs an inspection by special testing. ... We must not repeat ENIAC (p. 160) ... Research considering the problems of digital, high-speed, automatic machines began in ITMVT in the fall of 1948 with the help of the correspondent member of the Academy of Sciences, I.S. Bruk. ... It became known that the subjects of the construction of such machines are so complicated that a special resolution is needed" (p. 162).

50. Arkhiv RAN, collection 395, group 1-49g, file 1503-62-613, pp. 2-4.
51. Ibid., p. 75.
52. Arkhiv RAN, collection1559, group 1, file 6, p. 11.
53. Ibid., p. 51.
54. Arkhiv RAN, collection 2, group 3-a, file 109 (microfiche).
55. Arkhiv RAN, collection 395, group 1-50g, file 1504-60-613, p. 3.
56. Although his proposal was eventually accepted in the Bureau session of 23 May 1950, some members of the Department of Technological Sciences showed hesitation. (Arkhiv RAN, collection 395, group 1-50g, file 1504-65-613, p. 31.) Moreover, inside the Institute Lavrentev met with strong resistance; the Scientific Secretary (D.N. Shakhsuvarov), who was removed from office by Lavrentev, accused him in court of unfair dismissal and won the trial in the lower courts (*Vek Lavrenteva* [*The Time of Lavrentev*], pp. 59, 60).
57. Arkhiv RAN, collection 395, group 1-50g, file 1504-69-613, pp. 59,63, 66,68. Bruevich said, "I cannot help referring to my right to carry out scientific research activities in the fields in which I have been engaged for a long time. I have been engaged in two fields—precision of machinery and computing techniques. ... I had carried out the task of computing continuous functions for a very long time. ... Although I was engaged in this task, i.e. the development of differentiate analyzers, for many years, why is it that we cannot find my surname in the Five Year Plan? ... This [Author's note: The direction which Lavrentev was taking.] means the adoption of a measure of exiling Bruevich. This is not a Soviet attitude towards the scientist. I think that I need to make a proper protest." (ibid., pp. 59,63). Lavrentev brought forth a counterargument to Bruevich's remark: "I won't refer to any personal matter of anyone without the direction of Boris Alekseivich (Vvedenskii). Not only Nikolai Grigorievich (Bruevich) is devoting himself to the task of differential analyzers. I don't regard Nikolai Grigorievich as the only specialist in this field" (ibid., p. 66). Bruevich tried again to make a counterargument against Lavrentev, saying, "Appointing the leader and removing the leader are quite different things. ... The matter would be different, if I had committed any mistake in leadership." No sooner had he said that than a Bureau member, A.A. Blagonravov, interrupted, saying, "I propose that the plans should be adopted." Thus the argument was stopped with Vvedenskii shouting, "Adopted!" (ibid., p. 68).
58. Arkhiv RAN, collection 1559, group 1, file 15, pp. 1-82.
59. Ibid., p. 28.
60. Ibid., pp. 76-81.
61. RGASPI, collection 17, group 133, file 174, p. 71, and Arkhiv RAN, collection 1559, group 1, file 14, p. 87.
62. RGASPI, collection 17, group 132, file 354, pp. 185-186.
63. Ibid., p. 187.
64. See, for example, his letter to V.M. Molotov, vice-chairman of the Council of People's Commissars, dated 7 August 1943 (RGASPI, collection 82, group 2, file 930, pp. 49-56). He, in the capacity of Academician-Secretary of the Presidium of the Academy, revealed some calumnious information about some candidates for membership of the Academy. For example, he says, "L. D. Landau is politically ineligible," "B. G. Kuznetsov is zero [Author's note: meaning totally useless]," "It is undesirable that two persons of German origin are nominated for the Presidium while we are fighting with Germany," and so on. Also in the postwar days, he sent a letter to the Party's Central Committee secretary, A.A. Kuznetsov (ibid, pp. 141-148) in order to inform him of the political careers and the nationalities of the scientific workers of the Institute of History, the Institute of Physics, and the Department of Biological Sciences of the Academy of Sciences.
65. Immediately after the dismissal of Bruevich from the ITMVT, at the suggestion of L.P. Beriya, Minister of Home Affairs, the Academy of Sciences carried out a survey on the activities for observation of secrecy in the Department of Precision Mechanics and Machines of the Institute of Mechanical Engineering. They found Bruevich and several colleagues leaving classified experimental data on the accuracy tests of the bombing-meters, which were carried out in Baku in 1944–1945 at the demands of the Navy, open on their desks. Consequently, five of them, including Bruevich, received official reprimands for carelessness, and senior associate Kobrinskii also received a dismissal notice (RGASPI, collection 17, group

133, file 174, pp. 64-66).
66. RGASPI, collection 17, group 132, file 354, pp. 188-191.
67. RGAE, collection 8123, group 8, file 524, p. 20.
68. G.D. Crowe and S.E. Goodman, "S.A. Lebedev and the Birth of Soviet Computing," pp. 8-9.
69. RGAE, collection 8123, group 8, file 560, pp. 113-114.
70. RGAE, collection 8123, group 8, file 623, pp. 89-91.
71. Malinovskii, chap. 6, p. 6; see http://lib.ru/MEMUARY/MALINOWSKIJ/7.htm (in Russian).
72. For his contribution, see Malinovskii, chap. 5; see http://lib.ru/MEMUARY/MALINOWSKIJ/6.htm (in Russian).
73. Ibid., chap. 6, p. 17; see http://lib.ru/MEMUARY/MALINOWSKIJ/7.htm (in Russian).
74. Ibid., chap. 2, p. 2; see http://lib.ru/MEMUARY/MALINOWSKIJ/3.htm (in Russian). D. Kipyatkov, Chief of 3rd Division of the State Planning Committee, said in his report dated 21 Feb. 1951, "Industry has a serious difficulty in gaining the necessary amount of vacuum-tubes."(RGAE, collection 4372, group 98, file 968, p. 25.) It was planned that a billion rubles would be invested in vacuum-tube manufacture from 1951 to 1955. The main purpose of this investment was, however, to enlarge the industrial basis of Soviet radar-building (ibid., p. 28).
75. Malinovskii, chap. 2, p. 4; see http://lib.ru/MEMUARY/MALINOWSKIJ/3.htm (in Russian).
76. Ibid., chap. 6, p. 19; see http://lib.ru/MEMUARY/MALINOWSKIJ/7.htm (in Russian).
77. RGAE, collection 8123, group 8, file 524, p. 20.
78. *Vek Lavrenteva* [*The Time of Lavrentev*], p. 60.
79. RGAE, collection 8123, group 8, file 481, p. 89: The initial proposal by the Ministry of Machine and Instrument Construction for the financial plan for this machine was denied by the Ministry of Finance and the State Planning Committee. The total development expenditure was reduced to only RUB200,000 (RGAE, collection 8123, group 8, file 523, p. 84).
80. RGAE, collection 8123, group 8, file 481, p. 89.
81. RGAE, collection 8123, group 8, file 402, pp. 1-2.
82. RGAE, collection 8123, group 8, file 523, p. 84.
83. RGAE, collection 8123, group 8, file 481, p. 102.
84. RGAE, collection 8123, group 8, file 402, p. 2.
85. RGAE, collection 8123, group 8, file 560, pp. 200-202, 205-208.
86. RGAE, collection 8123, group 8, file 524, p. 25.
87. RGAE, collection 8123, group 8, file 560, p. 192.
88. RGAE, collection 8123, group 8, file 560, p. 263, 295.
89. RGAE, collection 8123, group 8, file 623, p. 253. For the discussion itself, see RGAE, collection 8123, group 8, file 630, pp. 18-24.
90. RGAE, collection 8123, group 8, file 623, pp. 138-142.
91. Ibid., p. 138.
92. *Vek Lavrenteva* [*The Time of Lavrentev*], pp. 59-60.
93. RGAE, collection 8123, group 8, file 623, p. 112.
94. According to the news agency TASS (the Information Telegraph Agency of Russia) on 12 November 1955, a Dr. Dreier of the Darmstadt Institute of Applied Mathematics admired BESM as the fastest machine in Europe; I.M. Makarov et al., eds., *Istoriya informatiki v Rossii* [*History of Informatics in Russia.*], p. 74.
95. S.P. Prokhorov, "Computers in Russia: Science, Education and Industry," p. 4.
96. M.R. Shura-Bura, "Moi Keldysh" ["My Keldysh"], A.V. Zabrodin, ed., *M.V. Keldysh: tvorcheskii portret po vospominaniiam sovremennikov,* p. 359.
97. A.V. Zabrodin, "V nachale bolshogo puti" ["In the Beginning of the Great Way"], A.V. Zabrodin, ed., *M.V. Keldysh: tvorcheskii portret po vospominaniiam sovremennikov,* p. 370.
98. M.R. Shura-Bura, "Moi Keldysh ["My Keldysh"], pp. 358-359.
99. Ibid., pp. 359-360.
100. RGAE, collection 8123, group 8, file 623, pp. 271-272.
101. RGAE, collection 8123, group 8, file 623, p. 261.
102. This Ministry, then People's Commissariat, was temporary reorganized as the People's Commissariat for Projectile Munitions, during the war; see N.S. Simonov, *Voenno-promyshlennyi kompleks SSSR v 1920-1950-e gody: tempy ekonomicheskogo rosta, struktura, organizatsiya proizvodstva i upravlenie* [*The USSR Military-Industrial Complex in 1920's-1950's: Rates of Economic Growth, Structure, Organization of Productions and Management*], Rosspen, 1996, p. 139 (in Russian).
103. RGAE, collection 8123, group 8, file 551, p. 29.
104. RGAE, collection 8123, group 8, file 619, pp. 9,11.

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