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Digital computing technology in the USSR: Stages of science and technology policy

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Abstract. The paper is an attempt to systematize projects for the development of digital computing technology based on the science and technology policy adopted in the USSR. The socio-economic and technological imperatives that ensured the emergence of new computers, their production, element base and architecture make it possible to identify the periods with the characteristic features of science and technology policy in this area. These periods differ from the generally accepted division of computers into generations. We have taken into account two paradigms of technology development: "immanent-technical", or internal, and socio-economic, or external, and based on them have distinguished three stages in the development of computers in the USSR: the first, from their emergence in the late 1940s to the mid-1960s; the second, from the mid-1960s to the late 1970s; and the third, from the early 1980s to the early 1990s. In this paper, we will reveal the content and specifics of each stage.

Keywords: Electronic computing technology, science and technology policy of the USSR, catch-up development, computer generations, copying policy, Japanese challenge, Start VNTK

Introduction

What is the basis for our division into the stages of science and technology progress if it is not a modification of the element base? We propose a comprehensive approach that takes into account not only the evolution of the element base, but also the socioeconomic, political, and technological imperatives shaping science and technology progress in computing technology. Importantly, this discussion focuses primarily on computer applications in the national economy, science and technology, although the military-industrial complex also played an important role in the development of computer technology (at the time of the Soviet atomic project, missile defense, air defense, military office, etc.).

In the first period, from the late 1940s to the mid-1960s, when digital computer technology emerged in the USSR, the emphasis was placed on quantitative indicators like competing product lines, the organization of computer industrial production, and production of component bases. In the second period, from the mid-1960s to the late 1970s, as attention focused on the American IBM/360 System, there was a technological shift towards standardized computer production, software and hardware compatibility, as well as the wider use of computers in management, within the framework of A.N. Kosygin's economic reform. In the second period, the USSR Academy of Sciences lost its priority in computer development in favor of the three ministries, namely, the Ministry of Radio Industry, Ministry of Electronic Industry, and Ministry of Instrument Making. In the third period, from the late 1970s to the early 1990s, the USSR Academy of Sciences made an attempt to regain its former priority in computer development, an attempt that was only partially successful, as cooperation with the ministries remained quite close. At that time, Japan announced its intention to create fifth-generation computers, and a number of developed countries, including the USSR (Start Project), accepted the challenge.

It is worth noting a common trend across all three periods was the catch-up approach to computer development: from von Neumann's architecture, the quantity and quality of computers, influence of ideas from the IBM, Cray, Burroughs, and DEC to the call for fifth-generation computers. Even if these impulses originated within the country, they followed the global trend in digital computing. This is evidenced by numerous analytical reports made by various specialists and articles on the history of the subject, many of which are available to researchers [4–6].

1. Historiography and methodology

In a work on the history of computing technology in the USSR, it was rightly noted that in historiography, as a rule, the main attention of researchers "is focused on the details of biography or specific stories related to the creation of a particular machine or electronic system, while the policy of the Soviet state in this area is analyzed much less often" [29]. Basing on the materials of the Russian State Archive of Contemporary History, N.Yu. Pivovarov showed the role of the Communist Party Central Committee in the development and adoption of the decisions related to the development of computers in 1958–1962. The author attaches great importance to the then secret Resolution of the Presidium of the Communist Party Central Committee and the USSR Council of Ministers No. 1121/541 dated 06.10.1958 "On urgent measures for the creation and production of electronic computers". The historiographic review of this author, however, includes some articles, co-authored by him, which, even judging by their titles, contradict the aforesaid remark of focusing on specific details rather than on the Soviet computer technology policy [19, 20]. Important problems were formulated and solved by N.S. Simonov in his monograph, an objective of which is "to determine the key directions of the national science and technology policy for the development of the vacuum tube and semiconductor industry and budget for the development of basic technologies in radar and computing technology" [34, p. 54].

In 2023 a work was published that highlighted a shift in the USSR computer technology policy towards the mass production of computing equipment within the framework of the program to create a Unified Series of Computers (ES EVM Series). The program was implemented by copying ("redesigning") the American IBM System/360 [17]. In addition, there are some recent works revealing the main directions of the national science and technology policy in computing technology at the initial stage and a work that substantiates three technological impulses as an imperative for the development of computers [5, 18]. In general, the lack of research concerning the national science and technology policy can be explained by a lack of interest on the part of professional historians. Regrettably, Peter Wolcott's fundamental work, presented as a dissertation in 1993, is little known to specialists and is practically not cited. Having conducted a study and received a large number of testimonies from participants in the Soviet high-performance computing projects, P. Wolcott generalized this case for the period extending from the advent of computers in the USSR to the early 1990s [41].

Extensive collections of documents on the history of computing technology are presented in the fundamental publication “The USSR Atomic Project” on the website on the history of Rosatom [36, 37], in the Electronic Archive of Academician A.P. Ershov [2], and on the website of the Virtual Computer Museum [38]. The Institute of Informatics Systems of the Siberian Branch of the Russian Academy of Sciences maintains websites dedicated to the START Scientific and Technical Complex and to the creation of the Kronos processor family [35, 39]. Among other things, these resources are valuable for the recollections of the projects’ participants.

We would like to focus on a certain terminological aspect. N. Yu. Pivovarov writes: "One of the most important tasks of the Soviet government at the turn of the 1950s and 1960s was the implementation of the ideas of the science and technology revolution. Electronic computers (*EVM*s) became the symbol of this revolution." [29] However, there are temporal and semantic differences in the terms "science and technology revolution" and "science and technology progress." Yu. P. Bokarev noted that the signs of a post-industrial society in the West (after the World War) could be seen in the USSR, but they were treated "in a very peculiar way": the revolutionary social, institutional and organizational reforms could not be implemented in the USSR since they did not correspond to the Marxist-Leninist theory. The term "science and technology revolution" itself was replaced, after the July 1955 Plenum of the Communist Party, by the non-binding concept of “science and technology progress" [6, pp. 115-120]. On the one hand, the latent synonymy of these terms is noted; on the other hand, we can see the semantic difference attributed to the historical context. Moreover, until 1971, the term “science and technology revolution” is practically not found in the Communist Party documents relating to the development of the USSR national economy (except for the Resolution of the Central Committee and the Council of Ministers of the USSR "On the procedure and deadlines for developing the draft five-year plan for the development of the national economy of the USSR in 1971-1975" dated 29.12.1967). This term became quite widespread in the policy documents after the XXIV Communist Party Congress (1971). However, the study of the phenomenon of science and technology revolution in historical and philosophical terms began a little earlier [25].

Let us say a few words about the catch-up development paradigm. Apparently, the first research to dwell on it is the above cited work by Yu.P. Bokarev; the concept was developed further by E.T. Artemov [4]. Recently, this has been the topic of a number of publications, where the lag of Russian industry behind the world level, and, let us add, of its innovative component, poses the problem of choosing a model of strategy and tactics, and borrowing is considered as an economical option [3, 27]. The problems of catch-up modernization were considered by the team led by V.A. Krasilshchikov [14, 15]. As for the history of computing technology in the USSR, it is necessary to mention one of the latest works of the American historian of science L. Graham, who wrote about Russian science with great reverence. He not only noted the facts of Russia's primacy in the various fields of science and technology, but also identified and analyzed the reasons for the country's lag behind the leaders of the computer technology industry, including [8].

2. Science and technology progress in digital computing: Stage I, late 1940s – mid 1960s

On a global scale, digital computer design began on the eve of World War II. One may note the experimental systems of the German citizen Konrad Zuse (Z1, Z2, Z3 - 1938-1941) and Americans D. Atanasoff and K. Berry (ABC, 1939). In 1946, the first American programmable computer, ENIAC (Electronic Numerical Integrator and Computer) was created. The large volumes of calculations performed by the mathematicians of the USSR Academy of Sciences during the Great Patriotic War, their degree of awareness about foreign, in particular American and European, developments in the field of digital computing influenced the decision to create such equipment in the USSR. In all leading countries, including the USSR, first, enthusiasts conducted experiments, created mock-ups and working samples, and then government agencies involved industry. In 1950, the first experimental systems were created under the leadership of S.A. Lebedev (MESM, model of the electronic computing machine) and I.S. Brook (M-1). In their work on the history of domestic computer technology, the authors stated: "The idea of a program-controlled automatic digital machine came to the USSR from the United States in 1947." And further: "[S.A. Lebedev's – Auth.] initial ideas lay in the channel laid by the development of ENIAC" [7, p. 14].

An understanding of the critical importance of developing modern computing tools was forming within the scientific community – most notably, scientists such as N.G. Bruevich, I.S. Bruk, L.V. Kantorovich, M.V. Keldysh, M.A. Lavrentiev, S.A. Lebedev, L.A. Lyusternik, and S.L. Sobolev. Foundations were laid for the establishment of a specialized research institute devoted to computational mathematics and its technological base. As a result, the Institute of Precise Mechanics and Computer Technology was founded in 1948 on the initiative of the USSR Academy of Sciences.

The need to make powerful computers increased with the launch of the Soviet Atomic Project (SAP). The number of operations required to solve complex problems demanded that slow manual labor be replaced with high-speed electronic computers. SAP became a catalyst for the development of new types of computer technology, although basically it was not viewed as a "major project." A broader approach was demonstrated by the initiators of computer technology development at the Academy of Sciences and the USSR Ministry of Mechanical Engineering and Instrument Making, who continually created new types and varieties of machines, increasing their power and, over time, expanding their intended scope of use beyond the needs of the military-industrial complex and for non-arithmetic applications.

The Soviet Atomic project, especially the creation of the hydrogen bomb in 1950–1955, played a decisive role in the development of digital computing. It was substantiated by the decree No. 1358 of the USSR Council of Ministers issued on April 6, 1949 "On the Mechanization of Accounting and Computing Work and the Development of the Production of Calculating, Analytical, and Mathematical Machines". The decree generally concerned the development of the analog technology, but it contained two secret clauses (3 and 4). Their contents are disclosed in the letter from Minister P.I. Parshin to L.P. Beriya dated April 30, 1949. Parshin wrote: "In accordance with the Government Decree, the Ministry of Mechanical Engineering and Instrument Making is beginning to organize the design and production of calculating, analytical, and mathematical machines. The significant advances achieved in recent years in the development of pulse electronics have created the preconditions for the implementation of new computing equipment – high-speed automatic digital machines capable of performing calculations at a rate of a thousand or more arithmetic operations per second. Machines of this type are intended for the country's major computing centers, and the demand for them in the coming years will be estimated at *two or three units* (italics added – *Author*). The need for rapid solutions to problems related to the development of nuclear physics issues requires the installation of such an electronic digital machine in one of the research centers of the First Main Directorate under the Council of Ministers of the USSR" [36, pp. 652–653]. Parshin proposed that Beria participate in drafting the technical specifications for the design of the machine and in preparing, jointly with the USSR Ministry of Mining and Metallurgy, a draft Resolution of the USSR Council of Ministers on this issue.

The development of events in SAP reveals a "counter-movement." On February 26, 1950, the USSR Council of Ministers adopted the Resolution "On the Work on the Creation of the RDS-6," which laid the foundation for the state program aimed to create a hydrogen bomb in two versions: the RDS-6s – the "*sloika*" – and the RDS-6t – the "pipe." During the research, it became clear that the calculations of L.D. Landau's group (RDS-6t) could not meet the deadline (July 1951), since "the methods typically used by theoretical physics and which KB-11 and Landau relied on to estimate the deadlines have been tried but proved unsuitable [...]" [37, pp. 392–393].

To rectify this situation, on May 9, 1951, the USSR Council of Ministers adopted the Resolution "On the Work on the RDS-6t" [37, pp. 397–403], which was important for the further development of Soviet science and technology policy in computing. This document concerns the creation of appropriate structures within SAP that would be responsible for organizing computations. The operative part stipulated that, in parallel with the work at the Institute for Physical Problems, another computational and theoretical group should be organized at the Steklov Institute of Mathematics under the leadership of Academician M.V. Keldysh, who was appointed head of the Department of Applied Mathematics at the Steklov Institute of Mathematics. Clause 4 of Appendix 3 contained an instruction on the organization of a *Section of Mathematics* (*Section 7*) (italics are the *Authors*') within the Scientific and Technical Council of the First Main Directorate (STC FMD) of the USSR Council of Ministers. The main task of Section 7 was scientific guidance in developing the design of high-speed computers and methods for their operation. The Section chairman was Academician M.V. Keldysh, and its members were Academician I.G. Petrovsky, Academician S.L. Sobolev, Corresponding Member N.N. Bogolyubov, and Corresponding Member A.N. Tikhonov. On computing machine issues, the members of the Section were Academician M.A. Lavrentyev, Corresponding Member S.A. Lebedev, engineers Yu.Ya. Bazilevsky and M.A. Lesechko. Section 7 was tasked with reviewing plans for research, experimental and design work, as well as mathematical machine designs and work plans for the bodies performing computations related to the FMD topics. We believe this resulted in a unification of the concept of digital computing technology and the specific need for it.

The analysis of this period revealed the shortcomings and lagging behind in computer production and offered recommendations for overcoming them. The leading argument in favor of focusing on the development of electronic computers was a comparison with the advanced Western experience, which had already taken root in the Soviet practice of promoting ideas and technologies ("Catch up and surpass America"). In September 1951, an employee of the Department of Applied Mathematics of the V.A. Steklov Institute of Mathematics, USSR Academy of Sciences, K.A. Semendyaev analyzed the use of various automation means designed to speed up labor-intensive computations as of the early 1950s. The study demonstrated, among other things, a lag of the domestic industry in the manufacture and application of electronic computers with automatic control [33, Col. 17. Inv. 133. F. 174. Sh. 136.]. Similar information is contained in the scientific report by M. Keldysh, S. Lebedev and D. Panov "Large Computing Mathematical Machines" (1952) [10. Col. 1939. Inv. 2. F. 2.], as well as in the classified "Brief Review of Mathematical Machines" prepared by the spring of 1953 by the SKB-245 of the USSR Ministry of Communication Equipment Industry [31. Col. 8123. Inv. 8. F. 524]. In March 1955, a review of computing machines, prepared on the instructions of the Institute of Scientific Information, USSR Academy of Sciences, was sent to the Department of Science and Culture of the Communist Party Central Committee, signed by the deputy director of the Lebedev Institute of Precision Mechanics and Computer Engineering (IPM I.S. Mukhin [32, Col. 5. Inv. 17. F. 512]. In September 1958, Chairman of the State Committee of the USSR Council of Ministers on Radio Electronics V.D. Kalmykov drew up a memorandum on the plans for the development of radio engineering industry for 1959–1965. These efforts found support from the Chairman of the Military-Industrial Commission of the USSR Council of Ministers and Deputy Chairman of the USSR Council of Ministers D.F. Ustinov. Their joint note (together with V.D. Kalmykov) on the expansion of the production of Soviet computers was sent to the Communist Party Central Committee at the end of September 1958 [5].

On October 6, 1958, the Presidium of the Communist Party Central Committee approved the resolution "On Urgent Measures for the Creation and Production of Electronic Computers." According to N. Yu. Pivovarov, this document played a key role in the development of Soviet computers. We refer the reader to his work [24]. The main bodies in charge of the development of "scientific problems in the field of creating electronic computing equipment" were declared to be the USSR Academy of Sciences and the Academies of Sciences of Ukraine and Georgia. Prior to the end of this stage of the science and technology progress, a number of decrees were adopted by the USSR leadership, aimed at organizing the production of computers and their component base and at expanding the scope of their application. It should be noted that during this period, the machines in operation were vacuum tube computers of the 1st and 2nd generations; the USA ceased their production in 1959 [10]. At this time, the production base for making computers was being created in the form of specialized design bureaus and factories. The BESM-6 computer production began in 1968 at the Computing and Analytical Machines Plant, Moscow and lasted until 1987 (all in all, 355 computers were made).

3. Science and technology progress in digital computing: Stage II, mid-1960s – late 1970s

We associate the next period of the science and technology policy in computing with the attempt to optimize the Soviet economy during the Kosygin reforms of the mid-1960s. The increasing complexity of the USSR national economy required better management methods: management organizations needed appropriate computer-based technical equipment of [1]. Similarly to the advanced countries, the problem of computer production was expected to be resolved through the software and hardware compatibility and standardized computer production.

Interestingly, ideas for standardized computer production were first proposed in the 1950s by D. Yu. Panov in the plenary report presented at the conference "Development

Paths of Soviet Mathematical Engineering and Instrumentation," held at Moscow State University on March 12–17, 1956. While praising domestic achievements in computing technology, Panov emphasized the crucial contribution of American and British scientists to the development of automatic computers with program control, beginning with the inventions of Charles Babbage. Panov stated: "Recently, the type of modern electronic computer has become quite clearly outlined. This is a machine constructed on a block principle, from standard blocks, the number of different types of which designers strive to keep as small as possible. Standard blocks are assembled into standard racks or cabinets, to which input and output devices are added, and a certain number of such racks or cabinets compose a machine. Using such standard elements, large companies build entire series of machines that differ from each other in their capabilities and adaptation to one or another type of work" [28]. The USSR, however, was not yet ready for this technology, since in the previous period the focus was on making computers in general, and the original production base was semi-artisanal.

The search for a prototype for standard production ruled out domestic developments. Analysts offered various arguments for the need to increase computer production and expand computer applications. However, this desire led to the policy of "copying prototypes." In the first half of the 1960s, the West transitioned to the third generation of computers (IBM-360, PDP-8, ILLIAC-IV). These computers used integrated circuits and disk drives; the software was written in high-level programming languages.

In the USSR, the need to equip the national economy with more powerful and standardized computing technology was recognized at various levels, including the leadership of the military-industrial complex, USSR Academy of Sciences, and State Committee for Science and Technology under the USSR Council of Ministers (SCST USSR CM, established in 1948). They were the driving forces behind the initiatives, preceded by analytical studies and followed by government directives. The use of computing technology for information processing in production and management was seen as a means of further economic development. This required specialized technology focused on management tasks, whereas in the USSR the technology focused primarily on solving scientific, technical, and research tasks.

The lag behind Western countries was recognized as critical. In 1966, in his report to A.N. Kosygin, Keldysh justified the need for the "unification of systems of elements, taking into account their block structure" and "programming compatibility". Regarding the acquisition of foreign products, Keldysh urged to acquire licenses for the production of the best foreign models of external devices, as well as... licenses for the production technology... of magnetic tapes, disk drives, and drum drives." To speed up the creation and implementation of computer hardware, it was necessary to take into account the experience of foreign countries. To this end, it was necessary to organize business trips of "integrated teams of specialists; regularly acquire design materials, technical documentation, and specialized literature, especially branded literature" [10]. The call was heard.

In the second half of the 1960s, several temporary scientific and technical commissions were formed under the State Committee for Science and Technology of the USSR Council of Ministers. They collected and analyzed information on the status and trends in the relevant fields and prepared proposals for rectifying the situation. These included the Scientific Council on Computer Engineering and Control Systems under the USSR SCST and the USSR Academy of Sciences, led by Academician V.M. Glushkov; the Interdepartmental Commission on Computers Mathematical Support (CMS), led by

Academician A.A. Dorodnitsyn; and the expert group for preparing a report on the situation with CMS, led by Doctor of Physics and Mathematics A.P. Ershov (by the resolution of the SCST USSR CM, December 1967). In December 1966, by the resolution of the State Committee for Science and Technology, a commission was formed under the chairmanship of Doctor of Engineering A.N. Myamlin, which prepared the report "On the Status and Development Trends of Universal Computers" (December 1967). The 300-page report showed that our country's lag behind the United States "is so significant that it can be eliminated only through fundamental changes in the financing and management of this important branch of the national economy" [31, Col. 9480. Inv. 9. F. 638. Sh. 87].

The commissions called for a fundamental overhaul of science and technology policy in the areas of military hardware and defense, which meant reforming, among other things, their organization, finances and personnel. Following the example of the American company IBM, the commissions proposed standardizing computer hardware and software; in other words, making a single series of computers using the same command set and identical interfaces to connect standard peripherals, input/output devices, modular design principles, etc.

During the discussion of A.N. Myamlin's commission report, a number of comments and suggestions were made. In particular, head of the G.K. Ordzhonikidze Minsk Design Bureau, G.P. Lopato, wrote that transition from individual to serial products, i.e. to a family of software and technologically compatible computers, required an enterprise that would be capable of developing such a family within a reasonable time frame and that there was no such enterprise in the USSR. It was hence necessary to combine the efforts of a number of enterprises under a single administrative and technical controlling body [31. Col. 9480. Inv. 9. F. 638. Sh. 98]. Similar proposals on organizational issues were made by A.P. Ershov in the report prepared by his expert group. He believed that the creation of computing technology and CMS should be singled out as a separate industry and "led by a committee or ministry", or reinforced by political leadership in the person of a candidate or member of the Communist Party Central Committee [2].

When developing a unified technical policy, many experts (Dr. of Engineering A. Ya. Lerner, for example) believed that the fastest solution would be cooperation with a Western firm [31, Col. 9480. Inv. 9. F. 638. Sh. 103]. In particular, they drew attention to the above-mentioned approaches of the IBM (Candidate of Engineering Sciences E.V. Evreinov) [Sh. 87]. Doctor of Engineering A.D. Smirnov, Director of the Computing Center with the Central Aerohydrodynamic Institute, wrote that it was necessary "to use experience in eliminating the backlog in computer technology by purchasing licenses and entering the world market as a manufacturing country (similarly to Japan and Bulgaria)." He believed that unification should be based on a domestic architecture, while Dr. of Physics and Mathematics M.R. Shura-Bura was critical of the idea of using a "domestic series of compatible machines," which was what the Ural-11, -14, and -16 were called [31. [Col. 9480. Inv.9. F. 638. Sh. 108]. According to A.D. Smirnov, before urgently eliminating the backlog, it was necessary to purchase samples of foreign equipment for trial operation and CMS development [31. Col. 9480. Inv.9. F. 638. Sh. 113–114]. A solution to the problem could have been scientific and technical cooperation with the ICL[1],

[1] A British computer hardware, software, and services company that operated from 1968 to 2002. It was formed by the merger of International Computers and Tabulators (ICT), English Electric Computers (EEC), and Elliott Automation. ICL was acquired by Fujitsu in 2002.

a U.K. company. For a number of reasons, this cooperation did not take place. The decisive argument in favor of "copying" the IBM/360 was the situation in the GDR, where the concept of the Robotron-400 (R-400, the machine very similar to the IBM/360 system (System/360)) had been under development since the second half of the 1960s [17]. Let us recall that the copying policy was applied to the development of the 3rd generation computers designed for the national economy. We cannot say that there were no domestic developments at that time [40, 41]. However, Soviet engineers striving to make high-performance machines were inspired by the projects developed by Burrous, Cray, DEC, Lilith and others, [42].

It is still debated whether switching to the unified ES EVM line and subsequently to the PDP-11 (SM EVM, Elektronika) line (both in terms of control computers and minicomputers) was justified. On the one hand, the "borrowed" technologies covered a broad spectrum of developments–from the element base, design, and basic architecture to basic and applied software. On the other hand, domestic computer engineering schools, which had grown within the USSR Academy of Sciences and in collaboration with ministries, were deprived of incentives for further growth and development, as well as of technical resources. Enormous efforts were made to copy and master the technologies only to produce a good but outdated model. This gave grounds to claim that we had "fallen behind forever." Unlike the Atomic Project, the management and development of the computing technology ended up in a number of government organizations, and inter-industry barriers and intra-departmental interests hindered and unnecessarily duplicated the efforts.

4. Science and technology progress in digital computing: Stage III, late 1970s – early 1990s

The USSR Academy of Sciences sought to strengthen its influence on the development of fundamental research in computer technology. As a result, the Coordinating Committee of the USSR Academy of Sciences on Computer Technology (CCCT) was set up under the leadership of the Vice-President of the USSR AS, Academician G.I. Marchuk, by Resolution of the Presidium of the USSR AS No. 1307 of October 12, 1978. The CCCT was entrusted with coordinating the fundamental research conducted by the institutes of the USSR AS and the Academies of Sciences of the Union Republics aimed at creating high-performance computing technology, including the architecture of computing systems and complexes, system mathematical support, organization of data banks and information retrieval systems, computer networks and centers of collective use, a new element base for computing equipment, and requirements for computers and mathematical support.

The USSR was not the only country concerned with updating and improving its computer fleet. At the meeting of April 26, 1982, the plenum of the CCCT considered the issues of making and using supercomputers. In his opening remarks, Academician Marchuk outlined a challenge to make computers of the 5th generation – the project prepared by the Japanese Committee for Research and Development of Computing Machines in 1979–1980 [22, p. 9]. It was assumed that the 5G would be based not on the VLSI, but on the created on their basis devices with artificial intelligence elements. The ultimate goal of the project was the introduction of computers into all spheres of society.

This addressed the realities of the information society, where the cybernetization of economic processes came to the forefront: automation and production management, modeling of production processes, processing of experimental data, long-term planning, development of an industry for the accumulation and use of knowledge based on computer technology, etc. [30]. The USSR responded to this challenge, in particular, by creating the Start Provisional Scientific and Research Group (1985–1988), with its management center in the Computing Center of the Siberian Branch of the USSR Academy of Sciences (SB AS), Novosibirsk.

Creating the architectures for multiprocessor high-performance systems was of interest to the employees of the Computing Center SB AS [22, 23], and not only to them [41, 42]. At a meeting of the CCCT devoted to the problems of making and using supercomputers, where Academician Marchuk reported on the Japanese fifth-generation project, representatives of several supercomputer projects made presentations on relevant developments. A.N. Myamlin emphasized that increasing performance through continuous development of the element base had been exhausted [22, p. 21], and the promise lay in the development of architectures allowing parallelization of computations at the software level. Supercomputers with, for example, one instruction stream and multiple data streams were ILLIAC-IV, and among domestic ones, M-10 (M.A. Kartsev) and MVS PS-2000 (V.V. Rezanov)[2]. Myamlin classified Cray-1 (Cray Research) and the Soviet MVS PS-3000 (V.V. Rezanov) as pipeline computers. These machines demonstrated a certain departure from the SIMD[3] architecture and transition to the MIMD architecture concept. The MIMD[4] structure was also characteristic of the Elbrus family of computers (V.S. Burtsev) [22, p. 31]. Relevant developments were carried out at the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR. It is also necessary to mention the vector-pipeline supercomputer Elektronika SS BIS (V.A. Melnikov, 1989) and the modular-pipeline processor (MKS, A.A. Sokolov). In the second half of the 1980s, V.S. Burtsev and his team began research previously announced by the American company AT&T (within the program of the USSR Academy of Sciences "Main Directions of Fundamental Research and Development for the Creation of an Optical Supercomputer (OS)"). The OS project was presented in 1994 but it was not implemented. Thus, Soviet engineers were at various stages of doing research and developing high-performance supercomputers.

Let us return to the Computing Center of the Siberian Branch of the USSR Academy of Sciences. Undoubtedly, the Novosibirsk intellectual response to the Japanese challenge was due to the support of Academician G.I. Marchuk, who directed this institute from 1975 to 1980. In 1975, a laboratory for the theory of computational processes was set up in the Computer Science Department of the Computing Center; head of the laboratory was V.E. Kotov. The first major work of the new team was the MARS (Modular Asynchronous Developing Systems) project. In 1981, Kotov defended his doctoral dissertation on the topic "A model of asynchronous parallel computing and its linguistic and architectural implementation." It became the theoretical basis for further large-scale projects.

The concept of a modular asynchronous system (MARS) was based on a generalization of the global experience in computing system architecture. These issues were supervised by

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2 I.B. Virbitskaite analyzed the computers controlled by data flows. The results of the study were published in the preprint of the same title issued by the Computing Center SB AS in 1989.

3 SIMD – Single Instruction Stream, Multiple Data Stream.

4 MIMD – Multiple Instruction Stream, Multiple Data stream.

Academician G.I. Marchuk, who from 1975 to 1980 was Chairman of the Siberian Branch of the USSR Academy of Sciences (SB RAS) and Director of the Computing Center SB RAS. In 1980–1986, he was Deputy Chairman of the USSR Council of Ministers and Chairman of the USSR State Committee for Science and Technology (SCST). He lobbied for the START project, which encouraged its implementation: the Soviet high-performance computing sector was interdepartmental, and any progress required the coordination and cooperation of numerous administrative structures. Moreover, high-performance computing systems are a dual-use technology. However, as it was revealed by P. Wolcott , G.I. Marchuk and the START initiators tried to avoid cooperation with the military-industrial complex [40, p. 329] due to the complexity of bureaucratic procedures and negative experience [26]. The funding was provided by the SCST and the Academy of Sciences.

In V.E. Kotov and G.I. Marchuk’s concept set forth in 1978, the following essential principles of organizing the computing process were outlined and substantiated: parallelism of processing, access to data and control; decentralization of processing flows; asynchronous interaction of devices and processes; hierarchy, modularity and specialization of components. The analysis was based on the then new models of interaction of asynchronous processes, and the architecture was seen as a natural implementation of the computing model [23].

START research involved four laboratories of the Computing Center SB AS. The Parallel Systems Laboratory, led by Yu. L. Vishnevsky, worked on the creation of the MARS-M computer. V. E. Kotov's laboratory developed two parallel programming languages: BARS and Polar. A. G. Marchuk's laboratory focused primarily on the development of the 32-bit Kronos microprocessor and MARS-T parallel system based on Kronos. They also developed a computer-aided design system for the design of VLSI microcircuits, in particular, Kronos. A. S. Narinyani led the laboratory conducting research in artificial intelligence. In Moscow, at the Computing Center of the USSR Academy of Sciences, Yu. G. Yevtushenko and V. M. Bryabrin developed system and application software, primarily for personal computers. At the Tallinn Institute of Cybernetics, the Systems Software Department, led by E. H. Tõugu, developed object-oriented software development systems, program synthesis systems, and the PIRS object-oriented workstation based on the Kronos processor. The only formal industrial participant was the Novosibirsk Laboratory of the Impuls Research Association of the Ministry of Instrument Making (Minpribor) in Severodonetsk (led by E. P. Kuznetsov).

The concept of a modular asynchronous system (MARS) was based on a generalization of the global experience in computing system architecture, which subsequently played its role in involving Novosibirsk specialists in MARS fundamental research and development. These issues were supervised by Academician G.I. Marchuk, who from 1975 to 1980 was Chairman of the Siberian Branch of the USSR Academy of Sciences (SB RAS) and Director of the Computing Center SB RAS. In 1980–1986, he was Deputy Chairman of the USSR Council of Ministers and Chairman of the USSR State Committee for Science and Technology (SCST). He lobbied for the START project, which encouraged its implementation: the Soviet high-performance computing sector was interdepartmental, and any progress required the coordination and cooperation of numerous administrative structures. Moreover, high-performance computing systems are a dual-use technology. However, as it was revealed by P. Wolcott , G.I. Marchuk and the START initiators tried to avoid cooperation with the military-industrial complex [40, p. 329] due to the complexity

of bureaucratic procedures and negative experience [26]. The funding was provided by the SCST and the Academy of Sciences.

Later, Kotov, in agreement with the State Committee for Science and Technology, somewhat modified his expectations regarding the project's results. A year before its completion, he wrote that the project was aimed at "developing some basic elements of the 5G computer concept. The ultimate goal was to create a prototype of a new-generation computing system with intelligent software" [18, p. 52]. Naturally, the project implementation encountered difficulties. Some of them were minimized through collaboration with V.S. Burtsev, who provided the technical means and tools of the Institute of Computer Science and Technology: "The MARS-M developers gained access to components, subsystems, and computer-aided design systems. The Institute of Computer Science and Technology provided technical consultations, logic design, and development of a printed circuit board layout system. The institute also issued production documentation for the plant. Novosibirsk developers were able to use racks, boards, memory, microcircuits, power supplies, a cooling system, and the entire Elbrus input-output system" [42, p. 342]. START created a foundation, which allowed the team and management to expect interest from a number of ministries, such as the Ministry of Electronic Industry (*Minelektronprom*), Ministry of Medium Machine Building (*Minsredmash*), Ministry of General Engineering (*Minobshchemash*), and Ministry of Aviation Industry (*Minaviaprom*). The team was supposed to continue creating a set of domestic microprocessors and VLSI, supermini computers, multifunctional workstations and special-purpose control systems (on-board systems), as well as experimental samples of modular microprocessor computers with a transputer organization (up to 1 billion op/sec). The development of intellectualization tools was anticipated to lead to the integration of parallel architecture and artificial intelligence methods.

The results of the successful launch of this high-profile project featured prominently in the domestic and foreign press [11, 12]. Expectations were great: the Academy of Sciences was supposed to bring the USSR to the forefront of developing the computers of the next-generation. These hopes were dashed not because the tasks were poorly done, but because of the collapse of the state planning and implementation system in the late 1990s. At the time, the nascent private sector was unprepared to address challenges of national scale. Nevertheless, like many other breakthrough projects, Start became a significant learning experience for many of its participants–researchers and developers– who were able to solve highly complex problems in a short period of time and despite modest funding. Subsequently, most of the project participants achieved good positions in research and IT companies. In Novosibirsk, the Institute of Informatics Systems of the Siberian Branch of the USSR/Russian Academy of Sciences was established on the basis several departments of the Computing Center. The Institute has experienced all the vicissitudes of Russia's current scientific policy.

Conclusion

Research into the formation and development of the Soviet science and technology policy in digital computing is a complex problem. The difficulty lies not only in the abundance of technical aspects, but also in having to take into account political, ideological, social and administrative imperatives. This is a specific issue that must be considered in the context of our entire history.

Characteristic of the first stage of science and technology policy in digital computing was interdepartmental competition. The aim was to increase the number of the new machines to meet the needs of the USSR national economy, primarily of the military-industrial complex. However, this project was not considered "major," although it did not escape the attention of the authorities. In the next stage, the development of domestic projects continued, but the main resources were directed toward the implementation of the international ES EVM program, based on the copied IBM/360. Moreover, there was no intention of stopping this process. In the third stage, which coincided with domestic political changes (*perestroika*), when a certain degree of independence was granted to companies and scientific organizations, some intellectual achievements were made. Because of the difficult economic situation, these achievements were negligible at the state level; however, the people who made them and their followers are now advancing global science and technology.

L. Graham identified and named a number of reasons why, after a “promising start in the field of computing technology, Russia today lags behind the industry leaders.” He noted that “in the leading Western countries, the field of computing technology after World War II was formed under the influence of three main driving forces: scientific community, the state (in terms of military applications), and business circles. The role of scientific community and the government was especially important at the initial stage; business became important later. Computing technology in the Soviet Union was successful as long as its development depended primarily on the achievements of scientific thought and state support. The latter was unlimited if the computing technologies were used for the needs of air defense or nuclear weapons research” [8, p. 115]. In the West, computers became a commercial product thanks to the large-scale computerization of the banking and business spheres. The Soviet Union, with its planned economy, centralized, non-competitive market, and, we might add, departmental interests and barriers, could not keep pace with technological advances. L. Graham's conclusion, despite all his piety, sounds categorical: "The Soviet computing industry was not let down by a lack of knowledge in this area; it was undermined by the irresistible force of the market" [8, p. 116].

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