Anatoly Kitov and Victor Glushkov: Pioneers of Russian Digital Economy and Informatics

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Abstract. Recent work in the history of computing published in English might lead scholars to believe that there was little worthwhile research in computers during the cold war in the USSR. This article is devoted to the history of the development of the digital economy and automated information systems for managing the national economy in the Soviet Union. This history shows that the Red Book and OGAS projects were not failures given their impact on the development of the digital economy in Russia. Particular attention is paid to the contribution of two great Soviet scientists, Anatoly Kitov and Victor Glushkov, to the development of the automation of the Soviet economy, as well as the works of computer pioneer V. M. Glushkov in the field of informatics and the information society, artificial intelligence systems, and the creation of computers. The international renown of these scholars and the continuing work of their students to develop their ideas shows that Kitov and Glushkov's basic research had an important and lasting impact.

Keywords: Artificial intelligence systems · Automated management information systems · Digital automation of computer architecture · Digital economy · Informatics · Information society · Red Book · State automated management information system for the national economy (OGAS) · Unified State Network of Computing Centers

1 Introduction

At present, the world is experiencing an active penetration of digital technologies into all spheres of life, the information society and the digital economy developing rapidly. In 2017, Russia approved the federal program "Digital Economy of the Russian Federation", which later became one of the Russian national projects[1]. Also there is the Russian federal program "Information Society" (2011–2020)[2].

The digital economy and the information society in Russia, along with the corresponding models, methods and instruments, did not develop from scratch. They rely on

[1] https://strategy24.ru/rf/projects/project/view?slug=natsional-nyy-proyekt-tsifrova-ekonomika&category=communication.

[2] http://fcp.economy.gov.ru/cgi-bin/cis/fcp.cgi/Fcp/ViewFcp/View/2012/369.

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the achievements of Soviet science and technology, the experience of implementing in the USSR management information systems (MIS, in Russian АСУ - ASU), industry management information systems (IMIS, in Russian ОАСУ - OASU), and the draft State Management Information System (SMIS, or OGAS from the Russian ОГАС).

In this article, we tell about two great Soviet scientists, Anatoly Kitov and Victor Glushkov, and their contribution to the development of the digital economy, informatics, and the information society. The research uses a biographical approach based on an analysis of the scientific papers of Glushkov [1–9] and Kitov [10–14], as well as the works of well-known historians Gerovich [16], Peters [17], Malinowski [18, 19], Kapitonova and Letichevskii [20], Kuteinikov [21], Shilov [22–25], and Prihod'ko [26]. The authors used the materials of the funds in the State Polytechnical Museum of Russia, materials of the Virtual Computer Museum (http://www.computer-museum.ru), archives of the Institute of Cybernetics of the National Academy of Sciences of Ukraine, archives of Plekhanov Russian University of Economics, and the Glushkov and Kitov family archives. Family memories of the present authors also made a certain contribution to the research (V. A. Kitov is the son of A. I. Kitov, and O. V. Kitova is the daughter of V. M. Glushkov).

The names of A. I. Kitov and V. M. Glushkov are inextricably linked with each other. They were not only the founders of and fighters for the automation of the management of the Soviet economy. In their life they were connected by friendship and fruitful scientific cooperation, working on joint projects. In particular, they together created the industry management information system (OASU) of the Ministry of Radio Industry: Glushkov was the scientific leader of this project, and Kitov was the chief designer. This system became a model for the nine defense ministries of the USSR.

This article expands conclusions made in papers [16–27] about the successes of the Soviet school of computer science and about the problems in constructing of a nationwide computer network to drive the Soviet economy, caused by the reluctance of the Soviet bureaucracy to change existing management methods. The non-existence of a Soviet internet, what Gerovich [16] has described the "internyet", has been the focus of other work. Peters [17] also focuses on the uneasy history of the Soviet Internet not paying enough attention to the impact made by Kitov and Glushkov on the development of Russian IT industry and modern Russian projects in the field of digital economy and information society, to their influence on the modern computer science. Malinovsky [18, 19], Kapitonova and Letichevskii [20], Kuteynikov [21], Shilov [22–25], and Prihod'ko [26] also tell about Kitov and Glushkov's research and projects without proper connection with modern research and projects in Russia and worldwide. It is astounding that the obvious application of computing to maintain the Soviet state was not accomplished, and the fact that the project was promoted by two academics with strong research records makes it even more curious. Nevertheless, even if the project had been accomplished, it would not have been similar to CYCLADES, ARPANet, or any other cold war era network. Thus, to dismiss Soviet computing misses the point of basic scientific research and fails to explain how the Russian Federation succeeded in computing after the fall of the USSR. The article reveals the close connection of the Soviet school of computer science with the national scientific mathematical and technical schools, connecting biographical facts with the history of science and the history of the country. First, by understanding the biographies of Kitov

and Glushkov, and then by reviewing the wide scope of their research, one comes to appreciate how their work went far beyond what one might say was an effort to "network the nation".

2 Anatoly Ivanovich Kitov

Fig. 1. Colonel Anatoly Ivanovich Kitov (1957).

Pioneer of Russian informatics Anatoly Ivanovich Kitov (1920–2005) spent his school years in Tashkent (now in the Republic of Uzbekistan). At school, he was the best student. In the sixth grade Anatoly chose the brilliant French scientist Blaise Pascal as a model for imitation. It was then that Anatoly told his family that he was going to become a scientist in the future. He regularly compared his actions and achievements with the biography of Pascal, constantly asking himself the question "Did Pascal know this and did he know how to do it when he was at my present age?" (Fig. 1).

In Tashkent, the Kitov family, in which there were five children, lived very poorly. From the age of 13, Anatoly began to earn money by tutoring children of high-ranking Communist officials of Tashkent in various disciplines. Anatoly regularly became the winner of republican and city competitions in mathematics, physics, and a number of other disciplines. Another of Anatoly's passions was sports. He played tennis and volleyball, and also participated in city swimming and chess competitions. He was the champion of Tashkent in gymnastics among schoolchildren. He was engaged in the section of aircraft modeling, and he regularly made hiking or cycling trips to the Chimgan mountains.

In 1939, Kitov graduated with honors from high school and decided to become a nuclear physicist. He enrolled in the Central Asian University, where he studied for only two months, because he was called to the Red Army. Kitov was on the front lines of World War II from June 1941 to May 1945. He moved from anti-aircraft gunner to the commander of an anti-aircraft battery, and he was wounded twice. In the intervals between battles he studied higher mathematics, physics, and other university

disciplines. In 1943, twenty-two-year-old senior lieutenant Kitov came up with a new method of shooting enemy aircraft. This was his first scientific work.

After the war in 1945, Kitov entered the Artillery Military Academy and began immediately on the second course. In the academy, in addition to studying, Kitov was actively engaged in scientific work. He was the author of a number of articles on missile ballistics and a patent for the invention of a new type of jet weapon. Kitov participated in the creation of the first Soviet R-1 rocket. Kitov graduated from Artillery Military Academy in February 1950 with a gold medal and was appointed to work as a scientific consultant to the President of the Academy of Artillery Sciences, Chief Marshal N. N. Voronov.

In 1951, after reading Norbert Wiener's book *Cybernetics* in the secret library of the Academy, Kitov immediately appreciated the enormous potential of this science, which at that time communist ideologists officially proclaimed "pseudoscience".[3] He wrote a fundamental article "The Main Features of Cybernetics", the first positive work on cybernetics in the USSR. This article, of which Academician S.L. Sobolev and professor A. A. Lyapunov were co-authors, was published in 1955 in the main ideological journal of the Central Committee of the CPSU, *Questions of Philosophy* [10]. This article was broadly discussed, and it was the beginning of recognition and further development of cybernetics in the USSR. At the same time, the journal *Radio* published another article by A.I. Kitov, "Technical Cybernetics". These publications were preceded by public lectures by Kitov and his associates in Moscow and Leningrad.

In 1952, Kitov was appointed the head of the first department of computers in the USSR created by him in the Academy of Artillery Sciences. In the same year, Kitov defended his Ph.D. thesis on programming called "Programming Problems of External Ballistics for Long-Range Missiles". In 1953, he published pioneer scientific article "The Use of Electronic Computers" (Fig. 2).

In May 1954, Kitov headed the first computer center in the USSR: Computing Center No. 1 of the Ministry of Defense of the USSR. He implemented Strela, one of the first computers, in the center and in some other organizations of the Ministry of Defense of the USSR. In 1954–1960, Computing Center No. 1 provided all the computer calculations necessary for the flights of the Soviet satellites.

In 1956, Kitov published the first in the USSR book on computers and programming, *Electronic Digital Machines* [11]. The final third of the book is devoted to non-arithmetic use of a computer for managing production processes, solving problems of artificial intelligence, machine translation, etc. The book was translated into several foreign languages and was published in the U.S., China, Poland, and Czechoslovakia.

At that time, Kitov developed the basis for building automated information systems for defense purposes and formed a new scientific direction, the development of information retrieval systems. He published a number of articles in the field of military cybernetics and computer science: "The Military Value of Computers", "Mathematics in Military Affairs", "Electronic Computer Science and Its Military Applications", "Cybernetics in Military Affairs", etc.

[3] See Doležel and Smutný, "The Emergence of Computing Disciplines in Communist Czechslovakia", this volume.

Fig. 2. A. I. Kitov, pioneer of Soviet cybernetics, head of the Computing Center No. 1 of the Ministry of Defense.

In 1956, Kitov published the co-authored book *Elements of Programming*. In the brochure "Electronic Computers" (1958), he described how to use computers in mathematical calculations, automation of production management, and the solution of economic problems [12]. In this brochure for the first time in the USSR he outlined the prospect of integrated automation of information processing and administrative management processes in the country on the basis of the Unified State Network of Computing Centers (USNCC; in Russian, ЕГСВЦ or EGSVTS). In the same year, in co-authorship with N.A. Krinitsky, he published another book, *Electronic Computers*, which was also published in a number of foreign countries.

In 1959, the State Commission adopted M-100, a specialized computer developed under the leadership of Kitov, working at a speed of 100,000 operations per second, which was at that time the fastest in the Soviet Union and one of the most powerful in the world. In this computer, for the first time, an arithmetic device with conveyor processing of machine instructions was realized, which was patented in the same year. Also in 1959, Kitov, in co-authorship with N.A. Krinitsky, published a classic textbook-monograph *Electronic Digital Machines and Programming*. This was the first textbook in the country on the computers and programming officially admitted by the Ministry of Education of the USSR for training in technical universities. The book was published in many countries of the Central and Eastern Europe. In November of that year at the All-Union Conference on Mathematics and Computer Science, Kitov presented the first in the Soviet Union report on the creation of computer-based management information systems.

In 1967, A. I. Kitov published a monograph "Programming Information-Logical Problems" and in 1970 a book *The Automation System for Programming ALGEM*, written by the team he led. In 1971, he published another fundamental monograph, "Programming of Economic and Managerial Tasks".

Starting in 1971, Kitov began to engage in a new field of activity, the creation of computer information systems for healthcare. From 1976 to 1983, Kitov published

monographs “Automation of Information Processing and Management in Healthcare” (1976), “Introduction to Medical Cybernetics” (1977), and “Medical Cybernetics” (1983). From 1980 to 1997, Kitov worked as head of the Informatics Chair and professor at the Moscow Institute of National Economy (now the Plekhanov Russian University of Economics).

Kitov had a reputation that extended beyond the USSR. In the 1970s, he was the official representative of the USSR in authoritative international organizations in the field of medical informatics. He was an official member of Technical Committee 4 of IFIP, which later became the International Federation of Medical Informatics (MedINFO) . Kitov also represented the USSR in MedINFO. Kitov was one of the seven leaders of the International Medical Informatics Association (IMIA). He participated in the organization of IFIP forums in Sweden (1974), Canada (1977), and Japan (1980). At the forum IFIP-1977 he was the chairman of section T2 (Biomedical Research General). He took an active part in organizing the MEDIS’78 conference (Tokyo-Osaka). He was a member of the MedInfo-1980 program committee.

Overall, Kitov was the author of 12 monographs, which have been translated into nine foreign languages. Over forty of his Russian and foreign students completed their dissertations. He was an outstanding man, full of bold scientific ideas, burning with a high desire to benefit his homeland. Kitov is one of the founders of Russian cybernetics, computer science and programming, the creator of the first computers and management information systems, the author of the first textbooks and monographs on computer technology and programming. Particularly noteworthy is the scholarly and civilian courage of the scientist, who boldly and with risk for his career put forward projects on new approaches to the management of the troops and the national economy of the USSR.

Some books and articles by Kitov are presented below [10–14]. Biography of A. I. Kitov and his scientific achievements are reflected in a number of works [19–24].

3 Victor Mikhailovich Glushkov

Computer pioneer Victor Mikhailovich Glushkov (1923–1982) was born on 24 August 1923 in Rostov-on-Don to the family of a mining engineer. Glushkov graduated with honors from Middle School No. 1 in Shakhty on 21 June 1941. His mother was shot by the Nazis in 1941. After the liberation of the city of Shakhty, Glushkov was mobilized and participated in the restoration of the coal mines of Donbass. He graduated from the Novocherkassk Industrial Institute and in parallel from the Rostov State University in 1948 and moved to Sverdlovsk, where he worked at the Ural Forestry Institute. V. M. Glushkov solved the generalized fifth problem of Hilbert, which was the subject of his doctoral dissertation, “Topological Locally Nilpotent Groups”. As is known, in 1900 Hilbert formulated 23 major and complex problems of mathematics, the solution of each of which became a world sensation in science (Fig. 3).

After the successful defense of his doctoral dissertation in 1955, Glushkov received several appointments, among which he chose the sphere connected with computer science. He moved to Kiev, where, starting in 1956, he was the head of the laboratory of Computer Science and Mathematics at the Institute of Mathematics of the Academy of Sciences of Ukraine. Later, the laboratory that he headed turned into the Computing

Fig. 3. Computer pioneer Victor Mikhailovich Glushkov (1964).

Center of the Academy of Sciences of Ukraine, and in December 1962, the Institute of Cybernetics of the Academy of Sciences of Ukraine was established. with Glushkov as it permanent director. Today, it is known as the V. M. Glushkov Institute of Cybernetics of National Academy of Sciences of Ukraine. Under Glushkov's leadership, the Institute became the largest center in the Soviet Union and one of the largest in the world in the field of computer science, cybernetics, computer technology, and management information systems (MIS). More than 5,000 employees worked with him in this center.

The scientific activity of Glushkov in the period 1956–1982 was connected with the theory of informatics, cybernetics, computer technology, programming, and automated management information systems and was based on a powerful foundation of the national mathematical schools.

In 1961, Glushkov published the famous monograph "Synthesis of Digital Automata" [1], later translated into English and published in the United States [2] and other countries. It created the basis for the work on the theory of automata with the use of algebraic methods. In 1964, for a series of works on the theory of automata, Glushkov was awarded the Lenin Prize. The value of these works cannot be overestimated, as the use of the term "machine" as a mathematical abstraction structures and processes inside computers, opened up entirely new possibilities in the technology of computers.

Glushkov built the necessary mathematical tools and showed how the components of a computer can be submitted by algebraic expressions. With the help of this theory, the Kiev Institute of Cybernetics became the leader in the development of computers on a scientific basis. Modern computer-aided design systems of computers use these ideas everywhere. A number of interesting computers were designed in Glushkov's laboratory. From his department came a number of famous scientists (Yu. V. Kapitonova, A. A. Letichevsky, etc.), who became the core of Glushkov's school in the field of digital computers.

Based on Glushkov's theoretical research, a language was developed at the Institute of Cybernetics to describe the algorithms, computer structures and the computer design methodology that were implemented in a number of unique PROJECT systems (CAD systems). With the help of these systems, different computers were developed for both general and special purposes (e.g., military computers) (Fig. 4).

Fig. 4. Glushkov and Kapitonova study a computer block created with the help of the PROJECT system

Glushkov made a great contribution in the development of new architectures of computers and systems. Under his leadership, the computers Dnepr, Kiev, Promin, MIR-1, MIR-2 and MIR-3, ES-2701 and others were created.

In 1974, at the IFIP congress in Sweden, Glushkov made a presentation on a recursive computer. He expressed the opinion that only the development of a fundamentally new non-von-Neumann architecture of computing systems would solve the problem of creating supercomputers whose performance could increase unlimitedly with the build-up of hardware. The idea of constructing a recursive computer, supported by a powerful mathematical apparatus of recursive functions, was ahead of its time and remained unrealized due to the lack of the necessary technical base.

At the end of the 1970s, Glushkov proposed the principle of the macroconveyor architecture of a computer with many command and data streams (MIMD architecture according to the modern classification) as a principle of realization of the non-von-Neumann architecture and received the patent for this invention. The development of a macroconveyor computer was carried out at the Institute of Cybernetics under the leadership of Glushkov by team of scientists. Machines ES-2701 (in 1984) and the computer system EU-1766 (in 1987) became the most powerful computer systems in the USSR with a nominal capacity exceeding the boundary of 1 billion operations per second. They had no peers in the world and were the original development of the ES series of computers in the direction of high-performance systems.

In the field of programming theory and systems of algorithmic algebras, Glushkov made a fundamental contribution in the form of the algebra of regular events. In the framework of the development of this theory, Glushkov anticipated the well-known concept of structural programming proposed by the Dutch scientist Dijkstra in 1968, and proved a fundamental theorem on regularization (reduction to the structured form) of an arbitrary algorithm, in particular a program or microprogram [9].

Glushkov saw ways to improve the technology of program development in the development of algebra of algorithmic languages. In this problem, he invested the general mathematical and even philosophical sense, considering the creation of the algebra of the language of a specific area of knowledge as a necessary stage of its mathematization. Glushkov claimed that the development of common algorithmic languages and the algebra of such languages would lead to the fact that today's computer programs will become as familiar, understandable and convenient as today's analytical expressions. In this case, the difference between analytic and general algorithmic methods will virtually disappear, and the world of computer models will become the main source of development of new modern mathematics, as it is now.

Outside the USSR, Glushkov was recognized as leader in the field of cybernetics. He formed – on the basis of the works of N. Wiener, K. Shannon, A. I. Kitov, S. L. Sobolev, and others – his own understanding of cybernetics as a scientific discipline, its methodology, and structure of research sections. Cybernetics was interpreted by Glushkov broadly as a science on general laws, principles and methods of information processing and management of complex systems. Computer technology was considered as the main technical instrument of cybernetics. This understanding was reflected in the first in the world Encyclopedia of Cybernetics, created on the initiative of V. M. Glushkov and published in 1974 under his editorship [28].

Glushkov was elected academician of the Academy of Sciences of the USSR (1964) and Academy of Sciences of the Ukrainian SSR (1961); he was a member of the Deutsche Akademie der Naturforscher Leopoldina; a foreign member of the Academy of Sciences of Bulgaria, the GDR, and Poland; an honorary doctor of the University of Dresden, and an honorary member of the Polish cybernetic society. From 1962 until the end of his life, he was vice-president of the Academy of Sciences of Ukraine. He was a member of the USSR State Committee for Science and Technology and the Committee on Lenin and State Prizes under the Council of Ministers of the USSR.

In 1963, Glushkov became chair of the Interdepartmental Scientific Council on the introduction of computer technology and economic and mathematical methods in the national economy of the USSR under the State Committee of the Council of Ministers of the USSR on Science and Technology. He was a consultant to the governments of Bulgaria, the GDR, and Czechoslovakia in the field of computer technology, computer science, and automated systems for managing the national economy.

Glushkov was a member of the 8–10 convocations of the Supreme Soviet of the USSR. He had the titles of Hero of Socialist Labor (1969) and Honored Scientist of the USSR (1978). He was winner of the Lenin Prize and two State Prizes of the USSR. He was awarded many government orders and medals, including three Orders of Lenin, the Order of the October Revolution, the Order of the People's Republic of Bulgaria, the Order of the "Banner of Labor" of the GDR, and others.

Glushkov was the author of over 700 works on algebra, computer science, cybernetics, philosophy, the digital economy and the information society, dozens of patents for inventions, the creator of several scientific schools in the field of computer design and artificial intelligence, programming, automated management information systems, under his leadership more than a hundred dissertational works were defended. He was an ideologist and scientific leader of the automated management information systems industry in the USSR and the creator of the project of the State Automated Management Information System for the Soviet economy (in Russian, ОГАС or OGAS).

At the IFIP Congress in 1974 in Stockholm, Glushkov, on the decision of the General Assembly of IFIP, was awarded a Silver Core Award. Thus, the scientist's great contribution to the work of this organization was noted as a member of the Program Committee of the Congresses of 1965 and 1968, and also as Chairman of the Program Committee of the Congress of 1971. Glushkov was an adviser to the UN Secretary-General for Cybernetics.

The international organization IEEE Computer Society in 1996 posthumously awarded Glushkov a Computer Pioneer medal "for digital automation of computer architecture" [29].

Glushkov was an encyclopedically educated person, fluent in English and German, loving poetry and music, and was an excellent orator. He was also a sportsman: a master boxer and a swimmer of long distances. He was devoted to science, was a patriot of his country, and selflessly served it.

Some books and articles by Glushkov are presented below [1–9]. Biography of Glushkov and his scientific achievements are reflected in a number of works of historians and experts in the field of computer science [16–21].

4 The Works of A. I. Kitov on the Use of Computers in the Economy: The Red Book Project

In the second half of the 1950s, Kitov, with his initiatives and scientific publications, strongly insisted on the state necessity of using computers for making calculations when solving problems of economic management and planning the activities of Soviet enterprises. Already in the first positive Soviet article on the cybernetics, "The Main Features of Cybernetics" [10] S. L. Sobolev, A. I. Kitov, and A. A. Lyapunov pointed to the possibility of using computers in various fields of the economy. The last third of Kitov's book *Electronic Digital Machines* [11], which he named "Non-arithmetic Applications of Electronic Digital Computers", was devoted to prospects of using computers in the economy. In his brochure *Electronic Computers* [12], published in the USSR in mass circulation, he outlined the basic directions of using computers in industry and other areas. In this work, Kitov talks about the urgent need to create a number of computing centers in the country for carrying out production, economic, and planning calculations and that in the future it would be expedient to combine these many computing centers into the Unified State Network of Computing Centers (USNCC, EGSVC in Russian).

Being passionate propagandist of new approaches in the economy, Kitov on January 7, 1959 addressed a letter to the head of the USSR, N.S. Khrushchev, in which proposed a radical restructuring of the management system of the entire Soviet economy by moving from the administrative-command style of leadership to a scientific one based on the widespread use of economic and mathematical methods and computers that would be gradually combined in the USNCC. Kitov's proposal for the creation a national computer network on the basis of the USNCC (the prototype of the modern Internet) was the first in the world. Consideration of Kitov's letter to Khrushchev was assigned to L.I. Brezhnev. Brezhnev favorably treated this letter and created for its careful consideration the Governmental Commission chaired by A.I. Berg, well-known specialist in cybernetics. All the proposals of this letter by A.I. Kitov were approved by the leaders of the USSR with the exception of his proposal for the establishment of the USNCC. The historians of Soviet informatics believe that this letter was a catalyst for expanding the production and use of computers in the USSR and played an important role in preparing further decisions of the Government of the USSR on computers [16, 21, 24, 25]. Unfortunately, the main proposal of Kitov on the creation of a nationwide network of computer centers (USNCC) for managing the economy of a large country was not perceived as necessary by the Soviet leadership (Fig. 5).

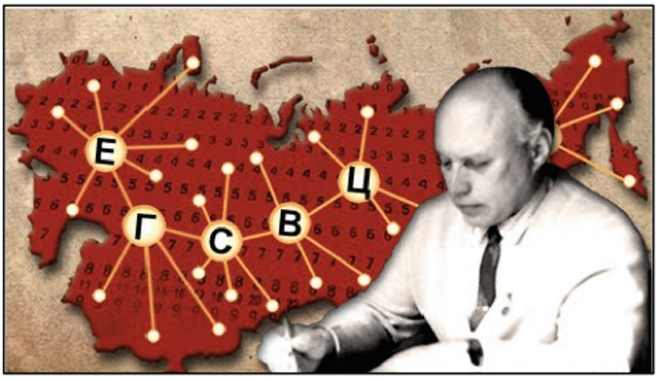

Fig. 5. Kitov and his project of Unified State Network of Computing Centers.

At the same in 1959, Kitov spoke at the All-Union Conference on the use of computers with a report "On the Possibilities of Computerization of the Management of the National Economy". This was the first report on the need to create in the country a statewide automated system for the management and planning of the national economy.

In the fall of 1959, Kitov sent a second letter to Khrushchev, containing the innovative project he developed, which consumed his time for several decades. It was called "The Creation of a National Network of Computer Centers to Improve Governance in the Armed Forces and the National Economy", otherwise known as the Red Book project on the creation throughout the Soviet territory Unified State Network of "dual-purpose" computing centers for managing the economy and the Armed Forces.

The project was rejected, and its author was expelled from the Communist Party and removed from the prestigious position in Computing Center No. 1 of the Ministry of Defense because of the criticism of the existing management system and proposals for its change based on use of scientific methods and digital technologies.

Nevertheless, Kitov continued to fight for the recognition of his ideas of restructuring the Soviet economy management on the basis of the establishment of the USNCC and mathematical methods. In 1961, Kitov published a fundamental article, "Cybernetics and National Economy Management", in which it was proposed to create a large number of regional computing centers in order to collect, process and reallocate economic data for effective planning and management. The unification of all these centers in a nationwide network would, he said, "lead to the creation of a single centralized automated system for managing the national economy of the whole country".

In the 1960s, Kitov was the chief designer of the Industry Automated Management System of the Ministry of Radio Electronics Industry, which was recognized as a model industry automated management system for all defense ministries, he and published the basic scientific articles on management of the country's economy on the basis of computers and economic and mathematical methods. He developed a new method,"associative programming", which was an effective way of solving information-logical problems. He led the creation of a new algorithmic language, ALGEM, for programming the economic and mathematical problems used in hundreds of enterprises of the USSR and countries of Eastern Europe. The results of these works were reflected in Kitov's book *Programming Information-Logical Problems* (1967) and the book *Automation Programming System ALGEM* (1970), written by the team led by him. In 1971, he published another fundamental monograph, *Programming of Economic and Managerial Tasks.*

In addition to military cybernetics, Kitov stood at the origins of Russian medical informatics. He laid the foundations for automation of information processing and management in healthcare and carried out a lot of work on the practical implementation of these systems. The results of this pioneering work were described in his monographs *Automation of Information Processing and Management in Healthcare* (1976), *Introduction to Medical Cybernetics* (1977) and *Medical Cybernetics* (1983), which were recognized in the USSR and abroad.

5 Victor M. Glushkov, a Theorist of the Information Society and the OGAS Project

Beginning in the 1960s, Glushkov was the chief ideologist, scientific leader and one of the main creators of the automated management information systems (AMIS, in Russian АСУ or ASU) industry in the USSR. Glushkov and his school developed a wide range of applications: automated process control systems (APCS), systems for automation of scientific research and testing of complex industrial facilities, automated management information systems (AMIS).

Together with his students and associates, Glushkov made a great contribution to the formation and implementation of the ideas for the creation of an automated process

control system, the development of an appropriate theory, mathematical, software and special technical means for managing technological processes in microelectronics, metallurgy, the chemical industry, and shipbuilding. Automation of experimental scientific research in the early 1960s was associated with the automation of measurements and processing of information obtained with the help of the Kiev and Dnepr computers. Computers from Kiev managed steel smelting in the Bessemer converter at a metallurgical plant in Dneprodzerzhinsk and a carbonization column at a soda plant in Slavyansk.

Then, Glushkov proposed to develop automated problem-oriented laboratories, which had to include measurement systems, computers (micro- or minicomputers), and measurement processing programs. He planned five or six such standard laboratories for X-ray analysis, mass spectrography, and other methods of experimental research used in chemistry, physics, and biology. To process the results of complex nuclear experiments, such laboratories were connected to remote computers such as BESM-6 or ES-1060. Because most of the scientific experiments were not limited to the collection and processing of data, but required the exact adjustment of the experimental setup itself, Glushkov set the task of automating the tuning operations of these installations. The specialists of the Institute of Cybernetics automated the tests for mechanical fatigue of materials at the Institute of Strength Problems of the Academy of Sciences of Ukraine, experimental studies at the Institute of Geology and Geophysics, the Institute of Oncology Problems of the Academy of Sciences of Ukraine. Works on automation of testing of complex industrial facilities were carried out for the navy and aviation. For the future, Glushkov saw in this area the prospects for developing algorithms for deductive constructions so that the system not only processed the results of measurements, but also checked hypotheses and built theories on this basis, i.e., acted as an artificial intelligence system in a given domain.

The development of automated management information systems for enterprises (ERP-systems) was started under the leadership of Glushkov in 1963–1964. In 1967, the first automated management information system for the enterprise with a mass character of production “Lviv” was launched at the Lviv television plant “Electron”. In 1970, when the system was already successfully exploited, its creators Glushkov, V. I. Skurikhin, A. A. Morozov, V. V. Shkurba and others were awarded the State Prize of Ukraine. After the creation of the “Lviv” system, Glushkov set the task of creating not an individual, but a standard automated management information system for machine-building and instrument-making enterprises. In the early 1970s, work was completed on the *Kuntsevo* system (for the Kuntsevo radio plant), which Glushkov proposed as model for the creation of automated management information systems on enterprises of nine defense ministries.

In 1965, Glushkov developed the concept of a specialized operating system designed for systems with a regular stream of tasks, in contrast to IBM/360 universal computer operating systems that solve random task flows and were good for packet mode of computing centers. Glushkov’s monograph “Introduction to Automated Management Information Systems” [4], which was mainly devoted to the systems of organizational management, was published in the second edition in 1974. It systematized the original results he obtained in 1964–1968.

The work on the creation and implementation of the automated management information systems into practice had problems. The reasons for this phenomenon lay in the sphere of the planned socialist economy that was then operating in the USSR, forcing enterprises to "drive the product shaft", not caring about optimizing the technical and economic indicators of production, the quality of manufactured products, and scientific and technological progress.

In the late 1960s, the creation of industrial automated management information systems (IOMIS) became necessary. Glushkov, as the most qualified and authoritative expert in this field, became the scientific adviser and consultant of many large IOMIS projects in the 1970s, in particular in the defense industry. When the Interdepartmental Committee (IAC) of nine defensive ministries was established and the Board of Directors of the main institutes for management, economics and informatics of the defense industries was created, Glushkov became the scientific head of the Committee and of the Board of Directors.

In 1962, on the orders of A. N. Kosygin, at that time the Deputy Chairman of the Council of Ministers of the USSR, Glushkov began to develop a project, which later became the State Automated Management Information System for national economy (SAMIS, in Russian OGAS). Starting to create the OGAS project, Glushkov personally studied the work of more than a thousand objects of the national economy: plants and factories of various industries, mines, railways, airports, and higher management bodies (Gosplan, Gossnab, the Ministry of Finance, etc.). He worked on the application in OGAS of macroeconomic models and instruments to improve the methods of management, which was reflected in his monograph "Macroeconomic Models and Principles of Building OGAS" [5]. Glushkov proposed the concept of OGAS as a unified system for collecting reporting information on the national economy, planning and managing the national economy, and an information base for modeling various options for the development of the national economy.

The Unified State Network of Computing Centers (USNCC) was required to become the technical basis of the OGAS. In the draft design of the USNCC, Glushkov suggested and substantiated the construction of a network of approximately 100 large centers in industrial cities and centers of economic regions, united by broadband communication channels with message switching and connected with 20,000 centers of enterprises and organizations. It was planned to create a distributed data bank and to develop a system of mathematical models of economic management.

Of course, Glushkov understood that with his plan he challenged the Soviet canons in governing the economy. Indeed, the draft of OGAS, submitted to the government in 1964, met with sharp demagogic objections based on creation complexity and high cost from the leadership of the Central Statistical Administration of the USSR (V. N. Starovskiy), then for a long time was processed into the USSR Central Statistical Bureau, the State Planning Committee of the USSR, but it was never implemented. It has often been said that main reasons were the incompetence of the top management of the country, the reluctance of the average bureaucratic unit to work under strict control of computer systems, the unpreparedness of society as a whole, the imperfection of the existing means of computing and communication, the lack of understanding, or even opposition from the scientists-economists. In fact, the concepts of OGAS and USNCC, correctly reflecting in the technical plan the rigidly centralized structure of the Soviet

social system, met the resistance of the social system itself. Why was the project of Glushkov threatening? Party leaders – Brezhnev, Kosygin and others – could lose power, because they did not correspond to the new era. However, this points to an additional consideration: to administer the Soviet Union in the digital era, it was necessary to admit young technocrats. The structure of the state, formed in the early part of the twentieth century, no longer corresponded to the current processes in the economy. The ideology and political system of the country also needed serious renewal. In addition, the enemies of the USSR organized publications that ridiculed Glushkov and his idea of OGAS. They said he was going to replace the Politburo with a computer, and "the card would control the Kremlin" [21].

Nevertheless, Glushkov did not retreat during the rest of his life. Convinced he was absolutely right, he proposed even more than 40 years ago the task of digitization and computerization of the country. At that time, he could not do anything without large-scale decisions of the government and the Communist Party Central Committee, which became a barrier on this path. In Glushkov's archive, there are copies of many notes to high party and government bodies on questions of the policy of development and use achievements in computer technology and automated systems in the economy, defense capacity, etc. On average, there is one note every two months in the period 1968 to 1980. Reviewing his notes, it is possible to compile a list of cases that could not be carried out within the functioning social system, e.g., using the decision-support system DISPLAN created by Glushkov and his team to manage Soviet economy [9]. This was a tragic component of his life. Like no one else, he understood and told to his relatives that this led to the death the social system and, as further historical events showed, the country as a whole.

Glushkov's academic position was active. His more than 250 publications in popular scientific and public journals and newspapers, as well as the regular cycles of lectures for the top management of the country and the public, testify to this (Fig. 6).

Fig. 6. V.M. Glushkov – pioneer of informatics and information society (1979).

Glushkov was not only the pioneer of digital economy but also a theorist of the information society, the author of works on the philosophy of scientific knowledge and the application of artificial intelligence systems in various fields. He came up and realized new ideas for building artificial intelligence systems such as "eye-hand", natural text reading, and an automation system for mathematical proofs. He worked on computer simulation systems for such intellectual activity processes as decision making in economic, technical, biological and medical fields. The approaches proposed by Glushkov for using natural language tools in information systems have been developed. Glushkov actively promoted a practical approach to the problem of artificial intelligence as a matter objectively evoked to life by the growing power of computers and their penetration into all spheres of human activity.

Even today, students and followers of Glushkov successfully develop his ideas and are engaged in research on structural pattern recognition, methods of analysis of images and speech signals, methods of structural analysis of scenes in the field of view of robots, are engaged in neurocomputer technologies and medical information systems.

Glushkov believed that the consistent accumulation of knowledge and effective ways of processing it, the development of intellectual capabilities of the computer, would provide a breakthrough in the development of civilization and ensure the transition of humanity to the information society. More than 40 years ago, he talked about the digital immortality of a human being. "Fundamentals of Paperless Informatics" is the name of his last monograph, published in 1982 [7]. This book described a mathematical apparatus and a set of ideas related to the problems of digitization of all aspects of life and the transition to the information society. He paid special attention to the digitization of education.

The OGAS concept largely anticipated the ideas of e-government and the digital economy in the world and in Russia. Fundamentally new approaches, methods, models and technical systems developed by Glushkov have made a great contribution to the development of informatics and the information society.

6 Conclusion

The foregoing analysis of the scientific biography of Anatoly Kitov and Victor Glushkov shows the successes of the Soviet school of computer science, which were based on strong connection with national scientific mathematical and technical schools, strong support from the state due to the importance of this field to national defense. Unfortunately, construction of a nationwide computer network to drive the Soviet economy and OGAS project were unsuccessful due to reluctance of the Soviet bureaucracy to change existing management methods and some other reasons mentioned above. Even though national networking was a success in other countries, it is simplistic to dismiss Soviet computing because it did not make a similar accomplishment. The many different developments of Kitov and Glushkov indicate that their work had a different focus. The Red Book and OGAS projects have influenced the creation of the Soviet IT industry, which employed about 700,000 people and the use of automated management information systems in major industries and agriculture. This was the basis for the development of informatics and IT in Russia and the creation

of the national project Digital Economy, which is ideologically connected with the works of Glushkov and Kitov. Indeed, the failure to build a nationwide computer network does not reflect a failure of their careers. Their many honors, their international reputations, and the legacy of work that continues into the present day demonstrate the richness of Soviet computing contemporary with networking projects in other countries.

The development of the digital economy and the information society in Russia is based on a powerful foundation laid by a glorious cohort of Soviet scientists, and Kitov and Glushkov are in the first row. Their work in the field of computer theory and practice, programming, mathematical modeling and computer applications in various fields of activity, their great projects of automation of the Soviet economy – the Red Book and OGAS – laid the foundations for the development of the digital economy. Their students continue to work in scientific centers around the world. The Glushkov Institute of Cybernetics of NAS of Ukraine continues its work, as well as created by V. M. Glushkov Department in the Moscow Institute of Physics and Technology, founded with his participation Faculty of Cybernetics in Taras Shevchenko Kiev National University, departments and faculties in other universities in the expanses of the former USSR. Some important ideas of A. I. Kitov and V. M. Glushkov in the field of computer science, artificial intelligence, the development of digital economy and information society are still waiting for implementation.

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