A RAND NOTE

A NEW FORCE IN THE SOVIET COMPUTER INDUSTRY: THE REORGANIZATION OF THE USSR ACADEMY OF SCIENCES IN THE COMPUTER FIELD

Simon Kassel

August 1986

N-2486-ARPA

Prepared for

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PREFACE

This Note was prepared in the course of a study of Soviet computer research and development, as part of an ongoing Rand project sponsored by the Defense Advanced Research Projects Agency under the auspices of Rand's National Defense Research Institute, an OSD-sponsored Federally Funded Research and Development Center. The work was carried out in the Applied Science and Technology Program. The project undertakes the systematic coverage of selected areas of science and technology in the USSR as reflected in the Soviet technical literature.

The present Note evaluates recent developments at the Academy of Sciences, USSR, designed to stimulate and improve the performance of Soviet R&D and production in computer technology. It is intended for analysts of the computer industry, U.S. government decisionmakers concerned with advanced technology, and students of Soviet science and technology.

SUMMARY

A major effort by the Soviet Academy of Sciences is under way to accelerate the development of Soviet computer technology. The effort has been spearheaded by Ye. P. Velikhov, Vice-President of the Academy of Sciences and long-time supporter of pulsed-power, fusion, and directed energy development in the USSR. The timing of the event and Velikhov's background strongly suggest space defense as a primary objective. It is likely that the Soviet leadership has been persuaded that the present quantitative and qualitative inferiority of Soviet computer technology is incompatible with the demands imposed by the prospect of high-technology competition with the West.

While the past Soviet attempts to improve the computer situation were aimed solely at the industry, the Soviets have now turned, for the first time, to the Academy, i.e., to science, for the decisive effort to solve the computer problem.

The Academy's response has been an extensive reorganization, initiated in 1983 and consisting of the establishment of a new Department of Informatics, Computer Technology, and Automation, the creation of four new research institutes in the computer field, the transfer of other institutes and computer centers to the new department, and the activation of a large network of R&D projects involving the new department, other departments of the Academy, and the computer industry.

These measures are said to pursue several aims: to develop supercomputer architecture and software; to accelerate the development and production of small (micro-, mini-, and personal) computers for mass use; to develop a new generation of integrated chip fabrication methods; and to secure a native scientific and technological base "capable of eliminating the national computer deficiency in the shortest possible time."

Regarding the last objective, the establishment of an R&D technology base, the Academy took a strong position against technology transfer from the West as a solution to the Soviet computer problem. It argued that, first, this would imply a dangerous dependence on the

United States, and second, in view of the highly advanced state of the art in the computer field, the acquisition of foreign computer technology is pointless without a well-developed native technological infrastructure.

The reorganization of the Academy of Sciences, and the acquisition by the Academy of an R&D technology base consisting of pilot plants and related facilities, means that the control over a substantial portion of the research-production process in the computer field now passes from industry to the Academy. Nevertheless, production and some development stages remain under industrial authority, independent of the Academy of Sciences. This fragmentation of the R&D cycle has been frequently noted by Soviet analysts as a major cause of the poor performance of high-technology enterprises. These analysts point to the U.S. experience, where the entire research-production cycle in large companies is maintained under one administrative roof.

The Soviet solution to the problem of the fragmented R&D cycle depends on various structures bridging the gap between the Academy and industry, such as science-production associations and other cooperative groups involving the participation of Academy institutes and industrial enterprises. However, these measures fail to resolve the basic conflict of interest between the performers of R&D and industrial producers; the conflict is likely to remain while the Academy of Sciences controls the R&D process.

The weakness of Soviet computer technology extends to all high technologies for which the Academy of Sciences is the principal performer of R&D and where it encounters problems interacting with the industry. The progress of this latest attempt to upgrade the Soviet computer technology, therefore, will be a good indication of the prospects that may be expected for a broad spectrum of Soviet high technologies.

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I. INTRODUCTION

In 1983, the USSR Academy of Sciences established a new top-level administrative unit in its table of organization: the Department of Informatics, Computer Technology, and Automation. The creation of the new department, involving the transfer of research institutes from other departments of the Academy, the founding of new institutes, and the planning of a complex network of research projects embracing the Academy and the computer industry, amounts to a major reorganization of the Academy of Sciences in the computer field.

The reorganization has obviously been undertaken in answer to a pressing national need to upgrade the weak Soviet computer technology. Its weakness, a subject of vigorous discussion in both the Western and Soviet press, is manifested by a substantial time-lag behind Western developments, and appears to involve the quality and quantity of practically the entire range of existing computer types and sizes, the rate of computer utilization, and the extent of computer literacy. The various efforts to improve the situation undertaken by the Soviets during the past two decades were confined exclusively to the computer industry; the 1983 reorganization marks the first time the Academy of Sciences has entered the field of computer technology as a major player in an attempt to deal with the problem on a significant scale.

This Note provides an assessment of this reorganization, its probability of success in affecting the future progress of Soviet computer technology, and its implications for the development of Soviet high technologies in general.

Computer technology can be regarded as a species of advanced, or high, technology. Under Soviet conditions, the development of advanced technology has been hampered by the twin burdens of jurisdictional boundaries cutting across the research-development-production cycle and economic disincentives inherent in the innovation process. The future of Soviet advanced technology, and of computer technology in particular, thus critically depends on effective solutions to both problems, each requiring radical changes in the organizational and economic structure

of Soviet R&D and industry. The main focus of this Note is the boundary problem stemming from the Soviet Academy of Sciences assuming control of a significant part of the R&D cycle in the computer field.

The Note begins with an analysis of the role of the Academy of Science as the principal performer of R&D leading to advanced technologies and as a participant in the process of planning and coordinating the Soviet R&D effort. Next, it presents an overview of the debate that has been taking place within the Academy of Sciences about the origins and aims of the Academy's computer reorganization. This is followed by an account of the reorganization itself and its new linkages and structures within and outside the Academy of Sciences system. A more detailed description of the new organizational structure is given in the Appendix. Section V, "Conclusions," provides the results of the assessment and discusses the prospects of the Soviet computer improvement effort in the general context of Soviet high technology.

II. PROBLEMS OF SOVIET HIGH TECHNOLOGY

In the industrialized West, two categories of institutions are generally involved in R&D: universities performing basic research, and the industry, which takes care of the remaining stages of the R&D cycle, including the work required for the effective transfer of R&D results to the production stage. The Soviet Union adds a third category of R&D performer: the research institutes of the Academy of Sciences. Since the Academy organization, with its network of R&D-performing institutes, represents an autonomous system independent of the industry, any contribution that this system may make to the industrial innovation process, beyond basic research, must overcome profound jurisdictional boundary problems. Much of the following discussion deals with the effects of these problems on the performance of the Soviet computer industry.

Speaking in broad terms, the Soviet R&D establishment consists of university research institutions, the Academy of Sciences system, a relatively small number of research institutes of other independent institutions such as the State Committee on Atomic Energy, and industrial R&D. The latter includes the bulk of Soviet research organizations, such as research institutes, design bureaus, and production plant laboratories, all operating under the industrial ministries. The number of industrial research institutes is probably an order of magnitude higher than that of the Academy system, and the two groups differ, at least nominally, in the kind of research they perform. The Academy research is supposed to be concentrated in basic science and the early stages of R&D, while the industrial institutes are active in the later stages, closer to actual production. However, the role of the Academy of Sciences in Soviet R&D transcends the limits of size and nominal function for at least two reasons: First, the Academy institutes employ the elite of Soviet scientists, in terms of talent, reputation, and the sheer concentration of advanced academic degrees, leaving the industrial institutes far behind. Second, the Academy institutes are responsible for much of what is known as advanced, or

high-technology research, and are the depositories of high-technology expertise, which Soviet industry does not possess in the same degree. Even in the case of Soviet defense R&D, projects involving advanced technology include the participation of the Academy [1]. This fact is insufficiently appreciated in the West, where the conventional wisdom has the Soviet Academy of Sciences primarily dedicated to basic research.

The Soviet Academy of Sciences has been the planner, coordinator, and performer of a broad range of R&D projects pursued well beyond the basic research stage, sometimes all the way down to the construction of prototypes and small-batch production [2]. The Academy has concentrated in its research institutes the top scientific and engineering talent in many areas directly relevant to advanced technologies [3, 4, 5]. These areas include automatic computer design methods, solid-state and microelectronics technology, advanced material processing and metallurgy technology, genetic engineering, magnetohydrodynamics, and pulsed power, or high-density energy technology. The latter drives the development of lasers, high-power microwave devices, and high-current particle beam generators, and is essential to the realization of controlled fusion reactors, directed energy weapons, and many aspects of space defense objectives.

The Academy of Sciences therefore appears as a key factor responsible for the development of Soviet advanced technologies and hence as a significant contributor to the Soviet defense potential.

The effectiveness of the Academy of Sciences in discharging these responsibilities depends heavily on the way in which the Academy's achievements are translated into manufactured products. However, the organizational independence of the Academy system from the industrial ministries inhibits the Academy-industry interaction essential to the successful operation of the R&D process. The result is a break in the R&D cycle, between the last stage performed by the Academy and remaining development work required for industrial production. We see here a curious paradox: Soviet society characterized by pervasive centralization tolerates a fragmented R&D cycle in an area as important as advanced technology.

The problem of impervious administrative boundaries inherent in the fragmented advanced-technology R&D is compounded by the problem of economic incentives affecting all Soviet industrial R&D. The absence of competitive market forces, the rigid production quota system, the steady excess demand for current production, and the highly centralized industrial management, all serve as a powerful disincentive to industrial innovation. Both problems are systemic in that their solution requires profound changes of the organizational and economic structure in which they are embedded, and both must be solved if Soviet technological innovation is to be significantly improved.

In the computer field, if the Academy of Sciences assumes a major role in the R&D process, the boundary problem will be directly involved. However, any gains the Academy may achieve in integrating the R&D cycle will be offset if the system fails to address the disincentives affecting the production organizations participating in the process.

The boundary problem has been the subject of extensive debate in the Soviet press for over two decades. Its persistence is striking: Many arguments currently figuring in the debate are verbatim repetitions of the paradigms of a decade ago. Recent writers at the top levels of the Academy note that the problem is the fault of both the industry and science [16]. The fault is, of course, due to a host of economic, social, and political factors shaping the environment in which Soviet science and industry must develop and interact and which retards technological progress.[1]

Soviet analysts often note the foreign industrial experience, which shows that a better interaction between fundamental science and technology is the main condition for improving the effectiveness of

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[1]A recent Soviet example cites the case of the pipe industry. The Soviet Union now consumes a quantity of steel pipes equal to that consumed by the United States, Japan, FRG, Britain, France, and Italy combined. In those countries the consumption of steel pipes is steadily declining, and they are used only where they cannot be replaced by nonmetallic pipes. The Soviet need for such pipes is particularly aggravated in gas transportation, water supply and irrigation. Plastic pipes should save a large quantity of metal, since 1 metric ton of plastic pipe replaces 4 to 5 tons of steel pipe. However, the plan specifies a plastic pipe production level for 1990 that is five times lower than that reached by the United States in 1984. The reason given is lack of polyethylene and of production capacities [6].

science. They conclude that effective research requires a single organizational structure, a unified scientific-technological complex, designed to minimize the effect of bureaucratic barriers [4].

The Academy writers impose two significant requirements on such a unified complex: First, it must be broadly supported by a network of industrial-type facilities, and second, it must be operated by the Academy of Sciences [4, 7].

The main components of the unified complex would be industrial-type pilot plants specialized in the various areas of advanced technology, where they would smoothly mesh with the development stage of the R&D process. This structure would make it possible for the Academy to proceed beyond exploratory research and development to the point of finished experimental prototypes, and would eliminate the need of industrial ministries to repeat much of the Academy's research work [4].

The second requirement addresses the question of who will control the major part of the R&D cycle in advanced technologies, involving the problem of conflicting interests between the Academy and the industry. The Academy of Sciences has no developed network of specialized pilot plants at this time. If placed in control of the R&D cycle, the Academy would have to procure the plants from the industry. The industrial ministries would certainly resist a large-scale transfer of such assets to the Academy.

On the other hand, the leadership of the advanced technology R&D cycle could be vested in the industry, where it would much more readily merge into the production stages. However, the scientific expertise of the industrial ministries is limited and the Academy of Sciences would resist equally strongly any mass transfer of its scientists to the industry.

It appears, therefore, that problems involved in the operation of the advanced-technology R&D cycle have much deeper ramifications than the discontinuities due to administrative boundaries, and extend to the problem of control of the R&D process itself.

The problems of Academy-industry interaction in the advanced technology area may be less acute in the military sector. Nevertheless, they must affect that sector as well. Military technology is developed

in the mode of demand economy, in which certain well-defined and relatively narrow topics are given high priority. The Academy of Sciences had responded to such priorities in the past, the most notable being the early development of nuclear weapons pioneered by the Academy. But the demand mode, however well endowed with enforcing resources, fails to develop a broad scientific and technological infrastructure that would transcend the narrow objectives of military projects. In the West, this infrastructure was generated on the grass-roots level by Western mercantilist economies. In the USSR, it is expected to be developed by the Academy of Sciences.

This bleak picture of Soviet advanced technology is moderated somewhat by other factors. Not all technologies depend on the Academy-industry interaction to the same extent. For example, pulsed-power technology had reached a high level of development in the hands of the Academy's institutes, partly because it did not require intensive industrial support. The end products of pulsed-power research were generally one-of-a-kind devices, however complex and large, that had been built mostly by the Academy's own resources. Here, the military may enjoy direct benefits without Academy's handicaps. Pulsed-power and related devices have an extensive potential application to space defense; a series of such devices developed by the Academy of Sciences are already being utilized within the U.S. space defense effort. It is probable that the impressive experience accumulated by the Soviets in this area has led them to conceive of their own, idiosyncratic system of space defense that may turn out to be quite different from the proposed U.S. system.

Another moderating factor emerges from an entirely different dimension, involving a second paradox of the Soviet system: In the collectivist Soviet society, individual dedication and initiative often spell the difference between failure and success. There are several technologies whose success is directly traceable to extraordinary efforts of individuals, such as Korolev, who has been responsible for Soviet rocketry, Kurchatov for nuclear weapons, Mikoyan and Gurevich for fighter aircraft, Paton for electrowelding, and Gaponov for high-power microwave devices. One can surmise that, if the current attempts at

economic reform succeed, they will be also largely due to the efforts of another dedicated and energetic individual, Gorbachev.

Computer technology is one of the advanced technologies critical to Soviet defense. It is a technology that happens to depend profoundly on both scientific and industrial support and is thus not immune from the constraints of the Soviet R&D system. For the past three years, computer technology has been the subject of what amounts to a major reform in the Academy of Sciences in its bid to bring that technology up to the world level. If the Academy succeeds in this attempt, it will be, again, due to the efforts of yet another dedicated individual, Ye. P. Velikhov.

Velikhov has had a highly successful career since the 1970s. During that time, he was a promoter of pulsed power and concepts of interest to space defense. Notable is his 1974 paper on the application of underground thermonuclear explosions to drive magnetohydrodynamic generators of very-high-current pulses, and his role in the development of transportable rocket-driven MHD generators for seismic exploration. He is also known for his support of research on controlled fusion reactions, focusing on inertial confinement fusion reactors based on high-energy, high-current, charged-particle beams and high-energy laser beams. Another research project that attracted Velikhov's interest was crystal channeling of electron beams with a potential for X-ray lasers.

In 1977 Velikhov became Vice-President of the Academy of Sciences, USSR, and a year later was appointed board member of the State Committee for Science and Technology. In the early 1980s, Velikhov became directly involved in the problems of Soviet computer technology and began a campaign to create a new division in the Academy dedicated to this area.

Velikhov's campaign reached its goal in 1983, when the General Meeting of the Academy of Sciences established a new division of the Academy, the Division of Informatics, Computing Technology, and Automation. The Central Committee of the Party supported this decision. Velikhov was made head of the new division, chairman of the Scientific Council for the Complex Problem "Cybernetics," and leader of all computer development operations of the Academy of Sciences.

III. THE COMPUTER TECHNOLOGY DEBATE

The creation in 1983 of a new organizational entity in the Academy of Sciences, USSR, named the Department of Informatics, Computer Technology, and Automation, was an event of major importance to the Academy and to Soviet R&D establishments in the computer field. Departmental changes in the Academy of Sciences have been very rare, the previous one of a similar nature having occurred two decades earlier, involving the establishment of the Department of Mechanics and Control Processes.

The recent change amounts to a profound reorganization of the Academy's research activities in the computing field. Its significance is reflected in the ambitious scope of the proposed activity of the new Department. According to Velikhov, the driving force behind the reorganization, the term "Informatics" in the name of the new Department covers areas associated with the development, creation, utilization, and servicing of information processing systems, including machines, equipment, software, and organizational aspects, as well as the complex of industrial, commercial, administrative, social, and political influences. He also defined informatics as the "Branch of national economy that includes electronic computer technology and electronic industry" [7]. B. N. Naumov, the director of one of the new institutes of the Department, defined informatics as embracing both hardware and software in computer technology [8].

Velikhov has announced that the basic mission of the Department of Informatics, Computer Technology, and Automation is to secure a scientific base "capable of eliminating in the shortest possible time the computer technology deficiency that threatens the development of the entire national economy." The immediate task is to develop and provide new computer technology in the deficient areas, or in what Velikhov calls the blank areas on the chart of Soviet computer technology. These are the supercomputers and their software, small efficient computers for mass use in research, design, and automation, and personal computers [9].

The creation of the new Department has been accompanied by an extensive debate, which started about 1980 and continues to the present, regarding the role played by the Academy of Sciences and its relations with the industry in the computer field, and regarding the factors responsible for the present state of Soviet computer technology. The participants of the debate were Academy leaders, such as its president, A. P. Aleksandrov, vice-president Velikhov, vice-president V. A. Koptyug, G. K. Skryabin, chief scientific secretary of the Academy's Presidium, B. Ye. Paton, president of the Ukrainian Academy of Sciences, Yu. A. Osip'yan, director of the Institute of Solid-State Physics in Moscow, V. M. Tuchkevich, director of the Ioffe Physico-technical Institute, A. N. Skrinskiy, director of the Institute of Nuclear Physics in Novosibirsk, and key members of the new Department, such as B. N. Naumov, director of the Institute of Informatics Problems, A. V. Rzhanov, director of the Institute of Semiconductor Physics in Novosibirsk, and A. P. Yershov of the Novisibirsk Computer Center.

The speeches of these scientists and administrators, delivered mainly at the general meetings of the Academy of Sciences, and the articles published within the framework of the debate in the Academy's house organ, the Vestnik Akademii Nauk, provide considerable insight into the basic issues facing the Academy in the computer field.

Perhaps the most curious aspect of this debate is the number of references to a loss of computer research institutes that the Academy of Sciences has allegedly sustained in the past. However, these references omit, with one exception, the names of the lost institutes and the period in which the loss occurred.

According to Heather Campbell, "Information about computer research institutes transferred in 1963 or later is almost totally lacking. Most of the computer research institutes were transferred to the Ministry of Radio Industry" [31].

Alexandrov, Velikhov, and Koptyug asserted that when the USSR began the development of computer technology, the Academy's institutes working in this area had been transferred to other agencies. As a consequence, the Academy's research in this area was largely discontinued, except for a few interested mathematics institutes [10, 11]. Among the transferred

institutes was the Institute of Precision Mechanics and Computing Technology (the developer of BESM-6), capable of carrying their R&D process to the point of prototype construction, and probably the Institute of Electronic Control Machines [7]. Campbell confirms that the former was one of the institutes transferred from the then Department of Technical Sciences of the Academy. She also has it under the joint control of the USSR Academy of Sciences and the Ministry of the Radio Industry [31]. The available directories list the Precision Mechanics Institute under the Academy of Sciences, USSR, as late as 1985 [12].

Osip'yan attributed the inadequate development of Soviet computing technology to this loss and held that the industrial institutes which took over computer R&D from the Academy were unable to solve the problems of contemporary computing technology [3].

At the same time, Velikhov and Koptyug insisted that the Academy must now recreate the structure necessary to improve the present situation, i.e., regain the lost institutes, and organize its scientific technology base [11, 7]. According to this viewpoint, no progress can be achieved without the Academy's development of the necessary theoretical and experimental research in solid-state physics, semiconductor physics, and radiophysics [3]. In Velikhov's words, "When the development of computers was in the hands of the Academy, operating in the context of a broad scientific interchange, things were much better than now, in spite of the fact that the number of workers engaged in computer technology is now much larger" [7].

According to Osip'yan, the "relative neglect" of the computer field by the Academy of Sciences, associated with the loss of institutes, changed into a more active participation in about 1980 [13]. Prior to that time, even the existence of the Coordinating Committee on Computer Technology in the Academy of Sciences failed to compensate for the Academy's inaction. In 1981, Velikhov asked that the Academy become more involved in this problem [5]. Two years later, Velikhov again stated that the Academy must recreate the structure necessary to improve the present situation and to organize the scientific technology base [7].

The past neglect of computer technology by the Academy was also discussed by Rzhanov. In his account, the participation of the Academy in the development of microelectronics has been, until quite recently, limited to individual pieces of research either of purely theoretical interest, or devoted to the solution of particular problems encountered in development. However, Rzhanov attributed this to the unsatisfactory relations between the Academy and the computer industry, rather than to the loss of facilities.

Rzhanov offered a comprehensive analysis of Soviet difficulties with the transfer of R&D results to industrial production. He stressed the serious organizational problems in the solution of long-range research projects that have been initiated and carried through early phases by fundamental science and that require, for practical realization, the contribution from highly developed technology and extensive technological support structure. Thus, according to Rzhanov, the results of research initiated from basic theoretical considerations, that turn out to have practical applications, either cannot be realized in practice at all or wind up as incomplete laboratory prototypes that cannot attract serious attention of the industry. On the other hand, Academy research performed on contract with the industry is, as a rule, duplicated by industrial institutes because of the sharp difference in the technological support between the Academy and the industry. The cases in which design development is performed directly from Academy's results are rare exceptions [4].

This viewpoint was supported by other participants of the debate. Complaints were made that too many ministries are working on the computer problem. Making computers is a profitable business, and no ministry wants to surrender its share of the project [14]. The organizations producing computer hardware and software are too diverse. Soviet computers are produced by as many as four ministries, and about 30 more ministries and agencies produce various computer accessories. Each industrial branch has its own technology policy and its own standards, which are not always compatible with the standards of other branches and with the needs of the users [8].

A well-known complaint attributed the problems of Academy institutes in realizing the results of their research to industrial enterprises that observe adherence to innovation plans much less closely than adherence to production plans [15]. Thus the industrial ministries, as a rule, focus on short-term problems at the expense of long-term research.[1]

The uncompromising dedication to the continuity of production on the part of the industrial ministries was said to hamper the conclusion of contracts between the Academy and the industry involving global problems, such as computing technology, to slow down basic research, and to increase the share of applied research. This situation was particularly aggravating in the Siberian Department of the Academy of Sciences, where the share of industrial contract work was much higher [11].

Another problem was the virtual monopoly that leading (golovnyye) industrial research institutes have established over individual research projects. Following this policy, the industrial institutes resisted accepting research results from off-line organizations, such as the Academy or VUZ [16].

Velikhov and his supporters regarded these policies of the computer industry as typical examples of bureaucratic interagency barriers and as a key factor inhibiting the development of Soviet computer technology [7, 17, 18].

The Academy's position that emerged from this debate can be summarized as follows:

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[1]The following case cited at the Academy debate provides a good example of the Academy-industry problems: The Institute of Solid-State Physics has developed the technology of producing sapphire tubes for street lighting. Their efficiency was such that if all illumination of Moscow were converted to these tubes, the electricity saved would be sufficient to light up Leningrad. The Institute proposed that the Ministry of Chemical Industry provide for the Academy a small plant to set up the production of the sapphire tubes. Although this plant was manufacturing obsolete equipment and had low productivity and poor working conditions, the Ministry refused the Institute's proposal, because nobody could take over the production plan of the plant [3].

1. The Academy of Sciences should not be held responsible for the present unsatisfactory situation in Soviet computer technology, since it largely withdrew from the necessary R&D, following the loss of some of its institutes taken over by the industry.
2. The industry that was in charge of computer R&D and production has been unable to equal the advanced standards of Western computer technology and has been beset by incompetence, shortsightedness, parochialism, and excessive diversity.
3. The only way to improve Soviet computer technology is for the Academy to take an overall charge of planning, coordination, and R&D in the computer field, reacquire its research institutes and facilities, and establish its own technological base, including pilot plants. These measures should be accompanied by a substantial increase in funding for the Academy.

The Academy's claims may not be entirely justified: The Academy of Sciences had not been as detached from computer R&D in the recent past as it now claims. Its Coordinating Committee on Computer Technology, chaired by G. I. Marchuk, was expected to direct the overall work of the program performed by the industry and by the Academy of Sciences [7]. The Scientific Council for Cybernetics, established in 1959 under the Presidium of the Academy of Sciences, has been active ever since [31].

It was also an exaggeration to say that the Academy's research in this area was largely discontinued, except for a few interested mathematics institutes, when significant work was being done in the computer field for over two decades by the Glushkov Institute in Cybernetics in Kiev. Medium-size computers were built by the Armenian Academy of Sciences and other republican academies [31]. Elsewhere, Velikhov claimed that many Academy institutes have traditionally been performing research in computing technology [23].[2]

[2]For example, the annual reports of the Academy of Sciences, USSR, listing projects pursued by its institutes during 1980 included the development of LSI and VLSI technology using electron, X-ray, and ion lithography techniques and the development of computer memory systems based on cylindrical magnetic domains and other submicron memory

On the other hand, since the inception of Soviet computer industry, the Minradioprom and Minpribor performed a major share of the R&D work. Production of computer hardware was controlled mainly by the two ministries [31].

Nevertheless, these claims served as a strong argument in favor of the Academy's bid to solve the Soviet computer technology problem. More important to the Academy's claim for leadership was the indisputable fact that the Academy concentrated the top scientific personnel and possessed the necessary theoretical and experimental expertise in the computer field.

Most significant, however, was the Academy's argument that science, rather than industry, holds the key to the problems of Soviet computer technology.

In Velikhov's words, "A major cause of the present situation is that the solution of computer technology problems requires the most advanced basic research in many areas, research that is being performed by the Academy of Sciences. The revolution in electronics and computer technology is mainly due to micro-miniaturization which, in turn, requires a good understanding of solid-state physics and, in particular, surface physics. . . . Informatics, as a branch of national economy that includes electronic computer technology and the electronics industry . . . requires the establishment of special relations with science, or what we call science leadership; this is a subject to which the Academy of Sciences pays very close attention" [7].

Aleksandrov called for the preferential development of fundamental research, the strengthening of ties between academic, industrial, and VUZ science, and the enhancement of the role played by the USSR Academy of Sciences as coordinator of all research work in the country. According to the president of the Academy of Sciences, the acceleration of the practical implementation of scientific results in the national

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domains [19]. This work must have begun well before 1980. In 1981, Velikhov mentioned three institutes, FIAN, IRE, and the Leningrad FTI, doing important research in the physical principles of computer design [5]. In 1984, Academy of Sciences institutes were reported to have been working on robotics "for the past 15 years" [20].

economy and the improvement of the forms of science's integration with production remain a most important problem [21].

The unique advantages of the Academy over the industry have been emphasized by Rzhanov and Osip'yan, who claimed that the majority of highly qualified Soviet specialists in mathematics, physics, and chemistry, that define the quality of microelectronics research, is concentrated in the Academy of Sciences system. On the other hand, the purely scientific capabilities of the industrial ministries are limited. For example, the number of PhDs throughout the entire Ministry of Electronic Industry is lower than that employed at the Academy's Institute of Chemical Physics alone [3, 4].

Velikhov advanced two basic reasons for the establishment of the new Department of the Academy to take charge of computer development: The first was that many scientists active in the area of computing technology have now been elected full and corresponding members of the Academy of Sciences. The second was his claim, noted above, that many Academy institutes have traditionally been performing research in computing technology. Thus, according to Velikhov, the Academy had the main prerequisites to create the new Department: an existing base, a major mission, and scientific personnel which can join the Department without losing contact with other parts of the Academy [7].

The mission of the new Department, concerned with solving the problems of Soviet computer technology "in the shortest possible time," involved several basic issues that demanded resolution if the mission were to be feasible. By far, the most important was the issue of industrial utilization of the Academy's research results and the attendant problem of technological facilities that would bridge the R&D gap between the Academy and the industry. The second issue was the perceived need of a comprehensive national program for the development of computer technology. The third addressed the problem of technology transfer from the West. Each of these issues has been considered in the debate.

The first issue, concerning the interaction of basic and applied research with industrial production, was considered to be particularly aggravated in the case of microelectronics, acoustoelectronics, optoelectronics, integrated optics, lasers, etc. In these areas, the

novelty and complexity of the principles involved and the need to create special technology for research and for the transition to production, were regarded as the principal factors preventing the paricipation of industrial institutes. Velikhov recognized the need for the intermediate technological support facilities, consisting of experimental production lines or pilot plants, that would serve as a bridge between R&D and industrial production.

The most effective solution of the problem, to place the entire research-development-production cycle under one administrative roof, was noted by Rzhanov, who observed that the overwhelming majority of discoveries and inventions in microelectronics have been made in the United States, where the organization of scientific research in large companies has avoided the gap between science and technology [4].

However, no such solution is possible in the Soviet R&D system, which includes the Academy of Sciences as an active performer independent of the industry. Since the Academy could neither acquire its own production facilities nor control industrial production, the only practical approach available to the Academy was to seek the acquisition of the intermediate technological support structure.

At this time, the Academy of Sciences has an inadequate system of pilot plants, both in the quantitative and qualitative sense. According to Osip'yan, the number of such plants is insufficient not only to support the expected level of research of the Academy, but also to maintain its actual level. Furthermore, since the industrial wage system has been extended to the Academy, the pilot plants operate on the production quota system and do not readily support research [13].

The establishment of an adequate technological support at the Academy thus became a principal objective of its campaign. The plan was ambitious and broad in scope, calling for a well-developed experimental, design, and pilot production base capable of supporting all R&D stages down to the design of technological and production processes [6, 7, 17].

The second issue, concerning the lack of a unified national plan for computer development, was important to the Academy as part of its rationale for assuming leadership in this area.

The planning, management, and organization of development, production, and use of computer technology has been carried out in the USSR by a number of organizations such as Gosplan, the State Committee for Science and Technology, and the Main Statistical Administration, and by the main industrial producers of electronics technology represented by Minpribor, Minradioprom, and Minelektronprom.[3] However, these organizations pursued no unified coherent, statewide program plan, and no single agency was appointed to take the entire responsibility of the realization of such a program [22].

Velikhov proposed that the Academy of Sciences, USSR, play the role of such an agency. The unified program, which would include mathematical methods and applied and system software, would then be a key element of the new Department's mission [23].

Finally, technology transfer as a means of enhancing Soviet computer technology was rejected in favor of indigenous technology development that would make the Soviet Union equal to and independent of the West in this field. The Academy's belief was that computing technology should not be dependent on scientific and technical relations with other countries.[4] Neither should simple technology transfers from foreign experience be expected to solve the national problem. It was stressed that no matter what modern specimens of foreign computer

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[3]Minpribor: Ministry of Instrument Construction, Automation Equipment, and Control Systems; Minradioprom: Ministry of Radio Industry; Minelektronprom: Ministry of Electronics Industry.

[4]Alferov cited the following anecdote to illustrate this point: In the mid-1970s, the Soviet Academy of Sciences wanted to order a large CDC computer from the United States for the Leningrad Scientific Computing Center. One of the prospective users of this machine was the Ioffe Physico-technical Institute. However, the U.S. State Department excluded that institute from access to the computer on the grounds that it might be used for military purposes. In response to the Soviet protest, the United States sent a group of experts to the Ioffe Institute to survey the work of a number of its laboratories. At the end of the visit, one U.S. expert stated that "the physics and technology of semiconductors is a subject of national pride in the U.S.; the work of the Ioffe Institute has deprived the U.S. of priority in many areas of this field. This was done without our computer technology and there is no sense for us to contribute to your progress further with our computers" [17].

technology might be procured, the current world-wide state of the art precluded any improvement in Soviet technology level without the development of a native infrastructure [3, 17].

The 1983 General Meeting of the Academy adopted a resolution to establish the Division of Informatics, Computing Technology, and Automation. Ye. P. Velikhov was appointed the organizer and head of the Division, as well as the leader of all work being carried on at the Academy in the computer field [9, 10].

IV. THE REORGANIZATION OF THE ACADEMY OF SCIENCES

The Department of Informatics, Computing Technology, and Automation was established at the 1983 General Meeting of the Academy of Sciences [9].

The Presidium of the Academy of Sciences, USSR, has subordinated twelve research institutions to the new Department. Of these, four represent newly created institutes, seven are institutions transferred from other departments of the Academy of Sciences, USSR, and one has been transferred from Gosstandart, USSR. Table 1 shows the institutions under the jurisdiction of the new Department, the cases of shared jurisdiction, and their former affiliations. A more detailed description of these institutions and their missions is given in the Appendix.

Within the Academy of Sciences, USSR, these changes amounted to considerable losses for the Department of Mathematics and the Department of Mechanics and Control Processes, which were deprived of major computing centers and research institutes, and to shifts in jurisdiction for the Departments of General Physics and Astronomy, Physical Chemistry and Inorganic Materials Technology, Biochemistry, Biophysics, and Chemistry of Physiologically Active Compounds, and Physical Chemistry and Inorganic Materials Technology, which now share supervision with the Department of Informatics, Computer Technology, and Automation over several of its newly acquired institutions.

The individual research institutes of the Academy were not affected by the reorganization. The institutes and computing centers of the new Department were transferred intact, retaining their former directors and deputy directors, with a few new deputy directors added after the transfer. An exception was the Institute of Problems of Microelectronics Technology and High-purity Materials, created out of a part of the Moscow Institute of Solid-State Physics whose deputy director, Ch. V. Kopetskiy, and senior researcher, V. V. Aristov, became director and deputy director, respectively, of the new institute.

Table 1

INSTITUTIONS SUBORDINATE TO THE DEPARTMENT OF INFORMATICS, COMPUTER TECHNOLOGY, AND AUTOMATION [24]

Name of Institution	Jurisdiction Shared with	Former Jurisdiction
Moscow Computing Center		Department of Mathematics
Keldysh Institute of Applied Mathematics		Department of Mathematics
Institute of Informatics Problems		New institution
Institute of Cybernetics Problems		New institution
Institute of Problems of Microelectronics Technology and High-purity Materials	Department of Physical Chemistry and Inorganic Materials Technology	New institution
Institute of Microelectronics	Department of General Physics and Astronomy	New institution
Institute of Computing Technology Problems		Unknown
Institute of Information Transmission Problems		Department of Mechanics and Control Processes
Leningrad Scientific Research Computing Center		Department of Mechanics and Control Processes
Pushchino Scientific Research Computing Center	Department of Biochemistry Biophysics, and Chemistry of Physiologically Active Compounds	Unknown
Commission for Computing Technology		Unknown
All-Union Scientific Research Center for the Study of Surface and Vacuum Properties	Department of Physical Chemistry and Inorganic Materials Technology	Gosstandart, USSR

It would appear that the computer technology reorganization has been confined to the USSR Academy of Sciences only and did not affect its Siberian Department or the republican academies. A significant indication of this is the fact that the Computer Center in Novosibirsk and the important Glushkov Institute of Cybernetics of the Ukrainian Academy of Sciences have not been affected administratively. The case of the Glushkov Institute is particularly striking, because it is a key research institution in the computer field and it should be expected to play a leading role in any major developments in that field.

According to Velikhov, the research base of the new Department consists of two existing and the four new institutes. The two existing institutions are the Moscow Computing Center of the Academy of Sciences and the Keldysh Institute of Applied Mathematics, which have traditionally led the development of computer technology and accumulated considerable experience in solving major problems [9]. However, it is the four new institutes that have, so far, defined the key R&D objectives of the new Department. These objectives concern small computers for mass use, large supercomputers, and advanced microelectronics materials, devices, and their fabrication methods.

The missions of the four new institutes have been allocated as follows:

The Institute of Informatics Problems: Development of computers for mass use, including small, high-capacity computers for scientific research, production automation and design work, microcomputers, personal computers, and their software [9].

The Institute of Cybernetics Problems: Development of billion ops supercomputers and their software, and automatic design of advanced super VLSI and associated components [7].

The Institute of Problems of Microelectronics Technology and High-purity Materials and the Institute of Microelectronics: Development of advanced fabrication methods, such as submicron optical and ion lithography, research instrumentation, and magnetic storage devices [9].

In the agendas of the new institutes, one can thus discern three basic aims of the new Department: (1) to catch up with the Western proliferation of mass-use small computers, (2) to maintain a position at the leading edge of research in supercomputer R&D, and (3) to provide the necessary materials and techniques for the first two aims.

The reorganization of the Academy of Sciences in the computer field was not confined to the establishment of the new Department, but also involved the setting up of an extensive network of projects to be pursued jointly by the institutions of the new Department and other departments of the Academy, the industrial ministries, and universities. The scope of the reorganization is graphically apparent in Fig. 1, which shows the institutions involved and in which bold lines trace the project linkages spun within the Academy system, and beyond, to the industry, and, so far, to the Moscow State University. Nevertheless, the network in Fig. 1 probably represents only a rudimentary, initial state of the reorganization, and the new Department may now be involved with a much larger number of performing institutions.

Among the projects of the Department of Informatics, Computer Technology, and Automation, the development of supercomputers appears to involve the most extensive interaction with the industry. The design of supercomputer architecture and software in the Institute of Cybernetics Problems extends beyond the Department to the Glushkov Institute of Cybernetics, the new regional center of computing technology in the Siberian Department, and the enterprises of the ministries of Electronics Industry and Radio Industry.

On the other hand, the development of small computers entrusted to the Institute of Informatics Problems appears, at this stage at least, to be confined entirely to the new Department of the Academy and no direct industrial linkages have been specified by Velikhov.

The advanced materials and fabrication technique projects of the two new microelectronics institutes extend to a block of Academy institutes outside the new Department, but beyond the Academy involves only the Ministry of Electronics Industry. The block of Academy institutes, assembled for the purpose of developing a new generation of microelectronic devices based on new physical effects and new

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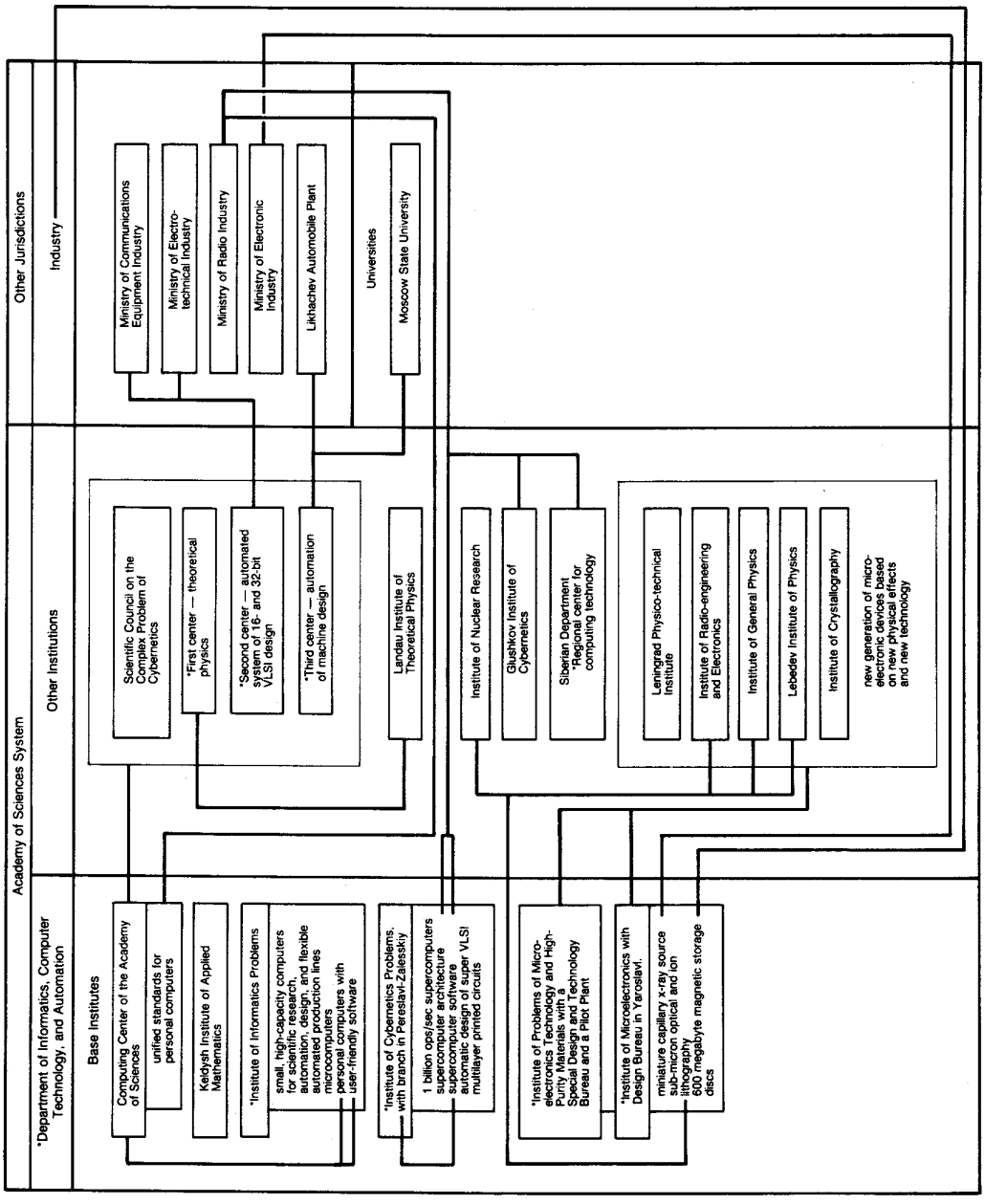

Fig. 1—Reorganization of the Academy of Sciences, USSR, in the computing technology area: participating organizations and activities

technology, consists of the Leningrad Physico-technical Institute, the Institute of Radio-engineering and Electronics, the Institute of General Physics, the Lebedev Physics Institute, and the Institute of Crystallography [9].

The development of advanced lithographic techniques appears to involve the largest number of participating institutions, including the Institute of Nuclear Research in Novosibirsk, which has three electron storage rings as synchrotron radiation sources that in the X-ray range have lithographic applications. The Institute is now operating a complete production line for X-ray lithography and, together with enterprises of the Ministry of Electronic Industry, it is developing the technology of mass-producing microelectronic circuits with sub-micron elements. The next objective is to reproduce masks, while the main mission is the development of ultra-large and ultra-fast VLSI with sub-micron elements [25].

Another major project of the Institute of Problems of Microelectronics Technology is the development of 600-megabyte magnetic storage discs, of special importance to the Institute director, Ch. V. Kopetskiy, who leads the work on vertical magnetic recording, which should increase disc density by an order of magnitude [9].

A commission has been set up to coordinate the joint action of the new Department with the other institutes of the Academy and the industry [9].

The Moscow Computing Center is cooperating with the Institute of Informatics Problems and with the ministries of Communications Equipment Industry and Electrotechnical Industry in establishing uniform standards for personal computers. The Computing center also serves as a base for the Scientific Council on the Complex Problem of Cybernetics,[1] which has set up three new research centers, one of which works with the above ministries.

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[1]The newly reorganized Council on the Complex Problem of Cybernetics was elevated to the rank of a scientific research institute. The Council is chaired by O. M. Belotserkovskiy, deputy director of the Moscow Computing Center, and is under a general management of Velikhov, who was nominated to this position by the Presidium of the Academy in 1984 [24].

The first center is intended to support theoretical physicists and has established a cooperative linkage with the Landau Institute of Theoretical Physics. The second center is dedicated to the development of an automated VLSI design system in cooperation with the Ministry of Communications Equipment Industry and the Ministry of Electrotechnical Industry. The third center consists of Moscow State University and the Likhachev Automobile Plant and deals with automation of machine design [9].

In 1984, the Academy of Sciences had been charged with formulating a national program for the development of microelectronics and computer technology up to 1990. The key areas of this development had been determined and emphasis was placed on the standardization of computer technology [26, 27]. However, it was not clear what should be the overall level of effort implied in the national program. For example, in 1985, Yershov argued that computerization should be elevated to a superproject status, coordinated at the Politburo level, and the computer industry should be restructured [14].

At this time, the efforts to facilitate the transition of Academy research results to industrial production have taken the form of science-production associations, interbranch science and technology complexes, and temporary technological laboratories established in some Academy institutes. The recently created State Committee on Computer Technology may serve the same purpose on the administrative level.[2]

There are probably not many science-production associations involving Academy institutes in the computer technology field. Rzhanov noted that the decision to establish Academy science-production associations is beyond the responsibility of the Academy of Sciences.

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[2]The All-Union State Committee on Computer Technology and Informatics of the USSR was established by the Presidium of the Supreme Soviet of the USSR in March 1986 [28]. In April, the Presidium appointed N. V. Gorshkov Chairman of the State Committee. Gorshkov had served in the management of the Ministry of Radio Industry since 1964, and was Deputy Minister of the Radio Industry since 1974 [29]. While his appointment to the chairmanship of the State Committee may reflect at least a nominal industrial control of this coordinating body, it may also indicate a desire on the part of Soviet leadership to make the industry more amenable to cooperation with the Academy.

However, he added that it should be possible to establish such associations at a modest cost, provided some existing industrial research institutes and pilot plants are transferred to the Academy [4]. Obviously, such a transfer would be subject to the uncertain agreement from the industrial ministries and would be feasible only within the framework of a major restructuring of the computer industry.

The creation of interbranch science and technology complexes has been recently approved by the Politburo [21]. Only one such complex known in the computer field, the "Personal'nyye EVM" (Personal Computers), is in the organization stage. The complex will be subordinated to the Academy of Sciences and, according to Naumov, is expected to overcome the bureaucratic diversity and to function according to a unified strategy of design, production, and mass dissemination of computers [8]. This formulation, reminiscent of the debate-arguments in favor of the establishment of the new Department, suggests that the complex has been created as part of the Academy reorganization.

The temporary scientific technological laboratories were approved in 1981 by a joint decision of the State Committee for Science and Technology and the Academy of Sciences, USSR. The laboratories were to be installed in institutes working in areas that require a sharp acceleration of research or promise considerable practical results. The State Committee for Science and Technology had the responsibility to determine annually the number of temporary laboratories, based on proposals of the Academy of Sciences [16]. According to Velikhov, the temporary scientific technological laboratories are to operate within existing institutes as inter- and intra-agency linkages, also including the science-production associations [30].

The initial such laboratories are said to have completed their tasks with considerable success [16]. The earliest and largest temporary laboratory was established at the Ioffe Physico-technical Institute in Leningrad, in Alferov's Division of Contact Phenomena in Semiconductors. The Division was already uncommonly successful with industrial approval of its work. The temporary laboratory was developing fiber-optics communications lines, working on a contract

financed by the industry. Workers at the temporary laboratory were given considerable material incentives. The laboratory was established for a period of three years and successfully accomplished its tasks [16].

V. CONCLUSIONS

The effort to reorganize the Academy of Sciences in the computer field appears to be the result of two factors: the perception that new and more effective measures are needed to improve the state of Soviet computer technology, and Velikhov's personal initiative. It is clear that computer technology has become the foundation of many new developments in the industry and defense, and that Soviet deficiencies in the computer field may critically retard such developments in the USSR. The creation of a new department in the Academy of Sciences is a rare and important event in its own right; when dedicated to the computer problem, such an event assumes national importance. Thus, the Academy reorganization probably required the approval of the Politburo, the State Committee for Science and Technology, and the Presidium of the Academy of Sciences. Nevertheless, the published evidence indicates that the initiative to justify and launch the reorganization has come from Velikhov. It was Velikhov who set the tone of the reorganization debate, proposed the establishment of the new Department, defined its mission, and insisted on the broadest possible scope of its agenda.

Velikhov's leadership of this venture suggests that its direct purpose might have been more specific than the general needs of Soviet industry and defense for computer technology. In the past, Velikhov had not been particularly active in computer development. Instead, he is known for his enduring interest in exotic technologies, some of which, such as pulsed power and directed energy technology, are applicable to space defense. The latter, of course, critically depends on a vigorous development of computer technology. One would be, therefore, justified in speculating that it was the consideration of Soviet space defense that prompted the reorganization of the Academy of Sciences. A poignant note in this respect is the fact that the Academy's decision to establish the new Department was practically simultaneous with President Reagan's speech on the Space Defense Initiative in 1983.

The thrust of Velikhov's efforts was directed at the spectrum of computer technology on both sides of the medium-to-large computers--the small computers and supercomputers--as well as at advanced chip fabrication methods. These technology areas have been under industrial development for some time, albeit with indifferent results. The creation of new Academy research institutes dedicated to these technologies is, in itself, a severe indictment of the past industrial performance, and particularly of the industrial R&D.

Velikhov's diagnosis of the reasons for the poor results obtained by the Soviet computer industry was the same as that offered in the past by many analysts of Soviet R&D in general: a lack of technological facilities and mechanisms for an orderly transition of basic and applied research results to the industry. His solution of the problem was to bring back the Academy to the computer field, provide such facilities and mechanisms, and place them under the control of the Academy.

In this, Velikhov followed Paton, the outstanding president of the Ukrainian Academy of Sciences, who has for years promoted similar views. In a recent speech, Paton said that "The main thing that scientists must ensure is that their R&D projects are carried far enough to accommodate the realistic potential of industrial enterprises to refine these projects and to launch them into series production. To do this, it is absolutely necessary that scientific establishments have a well-developed experimental, design, and production base." But Paton also added that "Much also depends on the attitude of industrial workers who must have a real interest in innovation, the ability and desire to undertake a justified risk, and courage not to shirk responsibility."

Velikhov skirted the issue of industrial incentives, partly because that would require a basic industrial reform, well beyond the purview of the Academy of Sciences. However, another reason appears to be the Academy's bid to control a major portion of the R&D cycle, including the key stages of development and prototype construction. Such a control contradicts the practice of Western industry, where much of the R&D cycle and production are held under one administrative roof. This practice has been hailed by Soviet analysts as a basic cause of Western success; for example, recall Rzhanov's praise of U.S. microelectronics,

where "The organization of scientific research in large companies has avoided the gap between science and technology." The Soviet Academy's activists seem to overlook the fact that in the Western model it is an industrial roof that unifies R&D and production.

Instead of considering the merits of industrial incentives and industrial control of the R&D process, the Academy proposed to solve the problem of the "gap between science and technology" by resorting to various bridging structures, such as the science-production associations, interbranch science and technology complexes, and temporary laboratories, always to be held under Academy's control. In this connection, the newly created State Committee on Computer Technology and Informatics may be helpful to the Academy by providing the needed authority from the top to coordinate the interaction between the Academy and the industrial participants of the research-production cycle.

The bridging structures have not operated effectively in the past, because they failed to resolve the divergent interests of the participating Academy institutes and industrial enterprises. The Academy scientists resented being held accountable for the shortcomings of industrial workers, who still had to observe the production quota schedules. There is no evidence to show that a better performance should be forthcoming from such structures in the computer field.

What can one expect from the Academy's bid to take over the leadership of the entire complex of computer R&D? From the American perspective, it looks as if Caltech and MIT were asked to bail out the Chrysler Corporation. Velikhov may share the drive and talent of Lee Iacocca, but he is in the wrong sector.

The weakness of Soviet computer technology is essentially an industrial problem and not a scientific one. While the Soviets have the capability to keep abreast of new scientific and engineering developments, their pressing task is to translate these developments into reliable mass-production techniques and ultimately to increase both the quantity and quality of computer production. The solution to this problem will have to be found within the industrial context. For this reason, the Soviets would do better if they placed the R&D process under industrial control, rather than vesting control in the Academy of

Sciences. This, of course, implies the need of industrial reform to eliminate the deleterious effect of rigid production quotas and misplaced incentives. Equally important in such a case would be the need of a large-scale shift of scientific talent from the Academy to the industry.

Short of these radical measures, the Soviet computer development program faces an uncertain future. Much depends on the efficiency of the Academy's links to the industry and the degree to which Velikhov's requirements are met by Soviet leadership. There are two indicators to watch that may presage a moderate success in this venture: The first is evidence of a significant strengthening of the Academy's computer technology base. The second is evidence of actual measures taken to improve the incentive system and remove the rigid production quotas in the participating computer industry.

These relationships between science and industry are not unique to the computer field, but reflect the entire spectrum of Soviet high technologies in which the Academy of Sciences plays a major role. The same problems of transferring research results to the industry are again traceable to the jurisdictional independence of the Academy from the production end of the R&D chain.

From the viewpoint of Western R&D organization, the Soviet Academy of Sciences appears as an anomalous phenomenon, without a counterpart in Western practice, which tends to distribute, rather than concentrate, scientific talent and to associate leading scientists with the industry without intervening organizational constraints.

While the Soviets are aware of the pitfalls inherent in their R&D system, they cannot, and probably do not wish to, change it to follow the Western model. To understand this, one must appreciate the Soviet stake in the Academy of Sciences as a priceless national resource and as the originator of technology. What could be regarded in a sense as a vice is turned into a virtue, and the very concentration of independent scientific capability is looked up to for solutions not only in matters of science, but also in problems of technology and industry itself.

In the long chain of measures undertaken to retain and bolster the existing system of Academy-industry cooperation, the latest is the establishment of the interbranch science and technology complexes. At a

first glance, this measure does not appear to be qualitatively different from its predecessors, and it remains to be seen if it is capable of contributing materially to the progress of Soviet high technologies.

Thus, even if the Soviets succeed in significantly improving the performance of their computer R&D and production sectors, due to the concentrated efforts of Velikhov and other Academy leaders, they may still fail to close the high-technology gap because of the systemic problems affecting high technology as a whole.

Appendix

MISSIONS OF THE FOUR NEW INSTITUTES OF THE DEPARTMENT OF INFORMATICS, COMPUTER TECHNOLOGY, AND AUTOMATION

The following are the stated missions of the four new institutes of the Department of Informatics, Computer Technology, and Automation:

1. Institute of Informatics Problems (Institut problem informatiki). B. N. Naumov, director; V. G. Zakharov, deputy director [8, 12].

   The main mission is the development of computers for mass use. These are small, high-capacity computers intended for scientific research, automation and design work, and use in flexible automated production lines. Their equivalents in the West are the VAX, MV-10000, and IBM-4300. Another objective of the Institute is the development of microcomputers and small computer systems. Together with the Computing Center of the Academy of Sciences, the Institute is also charged with overcoming a major deficiency of computer technology in the USSR, the lack of personal computers. This means the development of a universal mass-use machine on a scale sufficient to reach the Soviet equivalent of the Western production levels of 4 million units per year, and the corresponding software for users not familiar with programming [9].

   An interbranch scientific-technical complex, "Personal EVM," is being organized. The complex is expected to function according to a unified strategy of design, production, and mass dissemination of computers [8].

2. Institute of Cybernetics Problems (Institut problem kibernetiki) with a branch being established in Pereslavl-Zalesskiy. V. A. Mel'nikov, director [12].

   The main mission of the institute is the development of supercomputers capable of performing over 1 billion operations per second, and includes the development of a system of automatic design of super VLSI, multilayer printed circuits, and supercomputer architecture [7].

   The design of supercomputer architecture is to be performed jointly with the Institute of Cybernetics Problems, the Siberian Regional Center, the Glushkov Institute of Cybernetics of the Ukrainian Academy of Sciences, and Minelektronprom and Minradioprom [9].

   The software for the supercomputer will be developed by these organizations jointly with the Pereslavl-Zalesskiy Branch of the new Institute of Cybernetics Problems [9].

   The first-generation model of the supercomputer is expected to reach 300 million scalar and 150 million vector operations per second. The machine will require the development of totally new types of VLSI and a new overall design to deal with the large amount of generated heat. The supercomputer is intended for use in automated design and the development of systems larger than VLSI [9].

3. Institute of Problems of Microelectronics Technology and High-purity Materials (Institut problem tekhnologii mikroelektroniki i osobochistykh materialov) with a Special Design and Technology Bureau and a Pilot Plant. Ch. V. Kopetskiy, director; V. V. Aristov, deputy director [9, 12].

The Institute has been established on the base of a large scientific team taken from the Institute of Solid-State Physics [9, 13].

Current projects of the Institute include the following [9]:

a. Miniature capillary X-ray source, developed jointly with the Ministry of Electronic Industry.

b. Sub-micron optical and ion lithography, developed jointly with the Institute of General Physics, the Institute of Radio-engineering and Electronics, FIAN, and the Institute of Nuclear Research.

c. An instrument for the study of surface structures in diverging X-rays, scheduled for production by the Academy of Sciences.

d. Magnetic 600-megabyte storage disks, developed jointly with the industry. Kopetskiy is leading the work on vertical magnetic recording, expected to increase disk density by an order of magnitude [9].

4. Institute of Microelectronics (Institut mikroelectroniki) with a Design Bureau in Yaroslavl. K. A. Valiyev, director [12].

Some projects of the Institute of Microelectronics are shared with those entrusted to the preceding institute.

The Moscow Computing Center, together with the Ministries of Radio Industry and Electronic Industry, is charged with the development of unified standards for personal computers. At this time, standards of two computer types are being worked out. The first is intended for schools and universities to eliminate "computer illiteracy." The second is intended for scientific research institutions and industrial design bureaus [9].

The Scientific Council on the Complex Problem of Cybernetics of the Academy of Sciences has been reorganized. The Council chairman is O. M. Belotserkovskiy [9]. The Council, which now has the rank of a scientific research institute, is setting up three centers based on the Computing Center of the Academy of Sciences [9].

The first center is intended for theoretical physicists and cooperates with the Landau Institute of Theoretical Physics.

The second center operates jointly with the Ministry of Communications Equipment Industry and the Ministry of Electrotechnical Industry. Its mission is to develop an automated system of VLSI design in cooperation with the appropriate institutes. The VLSI will be based on 16- and 32-bit microprocessors required for the next generation of computers. This mission is assigned to all research involved in microelectronics and the Academy of Sciences.

The third center consists of Moscow State University and the Likhachev Automobile Plant and deals with automation of machine design [9].

A separate group of Academy institutes is scheduled to develop a new generation of microelectronic devices based on new physical effects and new technology [9]. The group consists of the following institutes: Leningrad Physico-technical Institute, Institute of Radio-engineering and Electronics, Institute of General Physics, Lebedev Physics Institute, and Institute of Crystallography. The group also includes the Institute of Problems of Microelectronics Technology and High-purity Materials and the Institute of Microelectronics, which are components of the new department.

While not subordinated to the new department of the Academy, this group is expected to work closely with it, and a Commission has been set up to coordinate that work.

A regional center of computing technology is being organized in the Siberian Department of the Academy of Sciences, USSR, as a separate measure [9].

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