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SOVIET COMPUTING AND TECHNOLOGY TRANSFER:

An Overview

By SEYMOUR E. GOODMAN*

I. Introduction

BY the early 1950s, the United States had established itself as the leading developer of computer technology. The United Kingdom held a strong second place, and West Germany, France, Sweden, and the Soviet Union had each built working electronic digital computers. During the next several years, a dozen other countries developed their own machines, but the U.S. lead widened rapidly, and by the mid-1960s it was overwhelming.[1] Consequently, each of the non-communist industrialized states found it necessary to come to an accommodation with the dominant position of the United States. Such accommodations have taken the form of extensive interfaces with American research and development, products, and service. These countries have also allowed American firms to acquire significant shares of their internal markets. Several states have developed respectable indigenous industries of their own, and the strengths of these firms often reflect American technology or competition. Still, most of them have had trouble being competitive with U.S. corporations in their own countries (even with some government protection). Essentially, they were faced with a choice between an accommodation with the dynamic U.S. industry, or denying themselves some of the advantages of the technology.

The Soviets opted for a distant relationship with the U.S.-dominated international computer community. As a result, they denied themselves many of the benefits of computing that were available elsewhere, and the indigenous industry of the U.S.S.R. rapidly fell behind that of the United States. Soviet policy reflected both a desire to develop an independent capability in an important strategic technology, and a rational but somewhat shortsighted perception of computing and its value to the U.S.S.R. For a long time, the influence of the West, and particularly of the United States, was primarily technical. The Soviet pattern

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[1] O.E.C.D., *Gaps in Technology: Electronic Computers* (Paris: O.E.C.D. 1969).

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of development differed considerably in terms of time-scale, philosophy, institutional arrangements, capital decisions, and applications.

This Soviet perception slowly began to change in the late 1950s. During the next dozen years a major political, military, and economic reassessment of the value of computing took place as a result of internal economic and external military pressures. The overall Soviet view of computing and its applications moved much closer to that of the rest of the developed world. The new perception has been backed by large political and economic commitments. Apparently, the Soviet leaders are hoping that this technology will help to make the existing economic system more efficient and effective, and thus avoid fundamental, and politically unacceptable, reforms. In this context, it is worth noting that in the United States, computing has been so successful, both as a technology and in its applications,[2] precisely because of a cultural and economic environment that the Soviet leadership wants to avoid.

The U.S.S.R. has learned that the development of its national computing capabilities on the scale it desires cannot be achieved without a substantial involvement with the rest of the world's computing community. Its considerable progress over the last decade has been characterized by a massive transfer of foreign computer technology. The Soviet computing industry is now much less isolated than it was during the 1960s, although its interfaces with the outside world are still narrowly defined. It would appear that the Soviets are reasonably content with the present "closer but still at a distance" relationship.

This article presents a broad, nontechnical survey and analysis of the Soviet effort to develop a national computing capability in semi-isolation from the rest of the world. It will emphasize the role played by technology transfers from abroad, and the difficulties of trying to transplant a sophisticated and pervasive technology into a systemic

[2] It is difficult, perhaps impossible, to find a sector of the American economy with a more impressive technological performance record and deep and pervasive applications than the computer industry. This statement could also include the closely related semiconductor and communications industries. The data processing industry has been doubling in volume every five years and is expected to continue to do so until 1990. By then, it has been estimated that 20% of the U.S. labor force will require some functional knowledge of data processing. One industry executive has characterized cost/performance improvement as follows: "If we compare the automotive and computer industries over the last 30 years, we find that if there had been similar progress in the auto industry as there was in the computer industry . . . then the auto industry would today be able to offer us a Rolls-Royce for $2.50 with an E.P.A. gas rating of 2 million miles per gallon." "Computing for Business into the 1980s," *Fortune*, June 5, 1978, pp. 23-86, at 25. Other readily available and relatively nontechnical sources include: *Science* (special issue), March 18, 1977; *Scientific American* (special issue), September 1977; and *Information Processing in the United States: A Quantitative Summary* (Montvale, N.J.: A.F.I.P.S. Press 1977).

environment very different from that in which it originated and thrived.

At the outset, it is necessary to make a distinction between technology and its products. Technology is the *know-how* required to define, design, build, maintain, and use a product. It is not the end product itself. Thus the transfer of a product does not generally constitute a technology transfer, unless the product itself reveals some of this know-how. The term "technology transfer" will also be used on a higher level, to describe foreign influence on the overall Soviet perception of computing.

II. A History[3]

THE BEGINNING

The modern digital computer era originated in the United States and Germany during World War II.[4] After the war, a number of German electronics experts were taken to the U.S.S.R., but we know very little about their influence on Soviet work. The American ENIAC, the world's first large electronic digital computer, was completed in 1946. The Soviets tried to buy the ENIAC documentation and ultimately tried to purchase the whole machine. By 1950 they had built the EV-80, a punchcard calculator that was based on the design of the IBM 604.

The most important early Soviet achievements demonstrated a substantial indigenous capability. The U.S.S.R. was the first country in continental Europe to build a stored-program electronic digital computer. Work on this machine, the MESM, began in 1948; it was operational in 1951. The first computer of this type, the British EDSAC, had become operational in 1949; the American SEAC and BINAC followed in 1950. The MESM was thus an important achievement close to the technical state of the art. The Soviet Union was also the third country to put a machine into serial production (the STRELA in 1953).

Both the United States and the Soviet Union regarded their early

[3] The following articles should be consulted for summaries of technical details on early U.S., U.K. and U.S.S.R. computers: Saul Rosen, "Electronic Computers: A Historical Survey," *ACM Computing Surveys*, I (March 1969), 7-36; Willis H. Ware, ed., "Soviet Computer Technology—1959," *Communications of the ACM*, III (No. 3, 1960), 131-66; George Rudins, "Soviet Computers: A Historical Survey," *Soviet Cybernetics Review* (January 1970), 6-44. The journal *Soviet Cybernetics Review*, known earlier under the title *Soviet Cybernetics: Recent News Items*, was published by the Rand Corporation from early 1967 to mid-1974.

[4] F. L. Bauer and H. Wössner, "The Plankalkül of Konrad Zuse: A Forerunner of Today's Programming Languages," *Communications of the ACM*, XV (1972), 678-85; B. Randell, ed., *The Origins of Digital Computers* (Berlin: Springer Verlag 1973).

computers primarily as engines for doing scientific and engineering calculations. Neither country was using computers to any great extent for data processing or economic planning. The technology was not available for such applications.[5]

There was a legitimate technical controversy at that time as to whether analog or digital computers were most suitable for the scientific and engineering work that was being done. For the purposes of this article, which will be almost exclusively concerned with digital computers, it will suffice to distinguish digital and analog machines by the form in which they store and manipulate information. Digital computers use codes that represent alphanumeric characters as binary digit patterns. Analog devices use the values of electrical parameters such as voltages or currents to represent other variables. A digital computer can store and manipulate textual material more efficiently. However, a variety of arguments could then be made as to which was better for solving differential equations, one being that analog devices were usually simpler to build and operate.

The Soviets leaned toward analog technology because it served their purposes, they were good at it, and their electronics industry could support it more effectively. They did not have a well-developed business equipment industry: there were no Soviet counterparts to the salesmen for N.C.R., Burroughs, I.B.M., and so forth, who were running around the United States selling cash registers, adding machines, punchcard calculators, and typewriters. Nor did they have the established organizational structure or the bases of customer and sales support and of production talent that the American business-equipment industry would soon use to change the character of U.S. and world computing.

But the U.S.S.R. did not ignore digital computers. By 1953, the Soviets had built two new small models and the large BESM-1. The latter machine was, in some ways, comparable to the first American "supercomputer," the NORC. The BESM-1 was built earlier, but it was less powerful.

The level of technology transfer was weak during this period, even

[5] The commonly held view that the development of computing and cybernetics was politically suppressed under Stalin is something of a myth. There was, however, considerable and very serious ideological opposition to the use of economic theory and quantitative methods in economic planning, and thus indirectly to the use of computers for this purpose. For a discussion of the political pressures on the mathematically oriented economists, see Richard W. Judy, "The Economists," in H. Gordon Skilling and Franklyn Griffiths, eds., *Interest Groups in Soviet Politics* (Princeton: Princeton University Press 1971), 209-52.

though Soviet hardware designs showed a familiarity with Western work, and Soviet software was influenced by Western developments.[6] However, for the most part the agent of this transfer was the technical literature. There was little product transfer and hardly any use of the more active mechanisms, such as joint ventures, which transfer technology through very effective personal contacts. Innovative, lasting Soviet contributions to the technology were essentially nonexistent, although the Soviets seem to have reproduced some Western ideas independently, and it may not really be fair to expect them to have come up with totally different concepts.

EUPHORIA AND REALITY

The most visible form of Soviet computer-related activity during the next decade was the pro-cybernetic euphoria that had developed by the late 1950s. The death of Stalin brought an opportunity for more open philosophical discussion.[7] Soviet academics and the public media took this opportunity to become enamored with cybernetics to an extent that is without precedent in the history of science in the U.S.S.R.[8] In this new philosophical perception, cybernetics was not merely consistent with Marxist-Leninist thought, but somehow the communist state had become uniquely capable of developing and using this new science and its associated technology for the benefit of the human condition. The social-cybernetic visions imported from the United States soon paled before the abstract innovations of Soviet cyberneticists. While the Americans were losing interest in large-scale cybernetic applications, the Soviets were cranking out literature and creating institutes and long-range plans.

[6] Hardware consists of the physical devices of a computer system. Software is the control logic used internally to manage computer resources (operating systems), facilitate the use of applications programs (e.g., translators for English-related programming languages), and the applications programs themselves. The early influence of the Western literature on the development of Soviet software is described in A. P. Ershov and M. R. Shura-Bura, "Directions of Development of Programming in the U.S.S.R.," *Kibernetika*, XII (November-December 1976), 141-60.

[7] Apparently, Norbert Wiener's *The Human Use of Human Beings: Cybernetics and Society* (Boston: Houghton Mifflin 1950) was read by the Politburo; see Martin Dewhirst and Robert Farrel, eds., *The Soviet Censorship* (Metuchen, N.J.: Scarecrow Press 1973), 74. Unfortunately, the source of this information seems to have had no knowledge of the discussion that must have followed this group reading-assignment. Wiener's book became something of a best seller in the U.S.S.R. It should be noted that cybernetics and computing are not the same. The subject matter of the science of cybernetics is the dynamic control of complex (including social) processes. Cyberneticists see computing/communications as the technological means for implementing the practical application of cybernetic concepts.

[8] Loren R. Graham, *Science and Philosophy in the Soviet Union* (New York: Knopf 1972).

For the most part, technical leaders and government officials who were in positions to determine policy and capital investment ignored the popular and academic discussions. Of course, they did not come right out and denounce the academics as dreamers; but clearly, little effort was made to produce large quantities of suitable computer hardware intended for widespread general-purpose use. No great need for this was perceived in the industrial or military sectors; the cost would have been a severe strain on the limited capabilities available, and would have been out of proportion to the short-term benefits.

The foregoing does not mean that nothing was done. Quite a bit of serious research, development, and production of analog computers took place. Almost two dozen different digital computer models had been developed by 1961. Most of this work was done under the Ministry of the Radio Industry, one of the major defense-related ministries. Many of these models were one-of-a-kind research projects, and only a few hundred units were made of all the models that did go into serial production. Of these, the most important was the M-20, a machine that was used by the Soviet military and by high-priority industrial enterprises.

In the United States, there was also a certain amount of euphoria during this period, but it was more concerned with the practical applications of digital computers than with general cybernetic concepts. Americans and West Europeans were discovering that digital computers could be used for all sorts of applications besides small- and medium-scale engineering computations, and that analog computers could not be used to anywhere near the same extent. The most important of these applications was data processing.

This is not to say that the United States had a great deal of conscious foresight when it went primarily digital, and that the Soviet Union did not when it believed analog technology to be suitable for most of its needs. The market for business and government data processing by digital computer (rather than by simple punchcard devices) was at first not fully appreciated by the American computer industry—including I.B.M. Marketing forecasts grossly underestimated the rate at which Western commercial enterprises would utilize this technology. But the American computer industry was quick to take advantage of its unanticipated windfall. Service for the technically unsophisticated customer became a major part of the industry. The invention of the transistor made possible smaller, cheaper, more powerful, and more reliable computers.[9] By the early 1960s, the American industry had stopped manufacturing vacuum-tube machines, and had essentially replaced them with transistorized computers (although many models still had some vacuum-tube components). Data processing was a major stimulant for the development of new, larger, and more reliable forms of memory and input/output technology. Technological advances in the U.S. computer industry were frequently customer-inspired.

The U.S. military became interested in the digital computer for a variety of reasons.[10] One of its most revolutionary uses was in the area of command, control, and communications systems. By the end of the 1950s, the military potential of the computer had been significantly demonstrated by the SAGE air defense system and other developments. The military was also a major customer for computers for both scientific/engineering (such as nuclear weapons design) and data processing (such as logistics) applications.

The Soviets were not oblivious to what was happening in the West. They were busy collecting information and hardware through a number of overt and covert sources. The technology transferred during this period helped computer specialists produce better products in the U.S.S.R. But the use of computers for applications other than those that primarily involved numerical computation was much less common than in the West, resulting in a major long-term negative influence on the design and utility of Soviet machines.

The apparent attitude of the Soviet military is helpful in understanding the Soviet perception of computing during this period. Although the military had the capability to insist on the massive commitment of resources that would have been necessary to close the "computing gap" with the West, that task was clearly not near the top of its list of priorities. Design work on the M-20 (a vacuum-tube model) began in the mid-fifties, but production probably did not start until 1958–1959. A transistorized version, the M-220, did not appear until late 1964. Perhaps 3,000 of these units were produced during a combined production period that lasted about 15 years. By comparison, I.B.M.

[9] The transistor was developed in 1948, but it was not until 1954–1955 that it became technically and economically possible to use it as the component base for computers. The first large-scale commercial transistorized computer was the Philco S-2000 (1958). Transistors had been used in military computers before then. By the mid-sixties, all new Soviet computers were based on transistors, although many vacuum-tube machines were still in use.

[10] R. Turn and others, "Computers and Strategic Advantage: II. Capability-Enhancing Applications," *RAND Corporation Report R-1643-PR*, February 1976 draft.

built over 14,000 of the 1400 series second-generation discrete transistorized computers between 1960 and 1963.[11] The technical secrets of the transistor were quickly diffused throughout the Western world.[12] The Soviet military could have had second-generation computers more powerful than the M-220 before 1964 if it had felt the need and had pressed hard for them. In view of its awareness of what its U.S. counterparts were doing, there must have been a conscious policy decision. This is not to say that the Soviet military could have technically matched American products and service, but there is little doubt that it could have done better with an additional investment of resources that was within its means.

The relative lack of interest in the general-purpose use of computers certainly affected the volume and effectiveness of technology transfer from the West. Entire Western computer systems were acquired. The first machine to go to the U.S.S.R. was a British Elliott 802 in 1959. Several other models were obtained by the Warsaw Pact countries. Although East European specialists read the Western literature and could have had more contact with West European and American technical people, they did not get as much technology as they could have, nor did they use what they got particularly well. Travel restrictions imposed by the Soviets on their own citizens effectively prevented technology transfers, while other political restrictions also prevented the widespread internal diffusion of the computer technology that was obtained.

The net result was that the Soviets were more or less following the Western technical pattern, but their development was spread out over a longer period of time. Several individual Soviet scientists and engineers came up with some imaginative new ideas, but most of these were theoretical. They produced no new major practical contributions, and essentially seemed content to do little more than build functional equivalents of selected Western products at a rate slower than they had been produced originally in the West. The traditional gap between Soviet theoretical science and technology remained wide. Neither the euphoric academic visionaries nor the managers at the computer factories seemed to be seriously interested in the hardware (such as alphanumeric line printers) and software (such as simple data-processing

[11] O.E.C.D. Report (fn. 1), 64, 176.

[12] John E. Tilton, *International Diffusion of Technology: The Case of Semiconductors* (Washington, D.C.: Brookings Institution 1971).

languages) that made possible the use of digital computers for a wide variety of dull applications by people with little technical training.

A PERIOD OF REASSESSMENT

Between the late 1950s and the early 1970s, a combination of internal economic and, to a lesser extent, external military pressures produced major changes in the Soviet attitude toward computing. Economic planners were distressed by falling growth rates, poor factor productivity, the rising percentage of nonproductive (e.g., clerical) workers, and increasing difficulties with the centralized control of the economy.[13] The military began to recognize that the Soviet Union's small, isolated computer industry was increasingly incapable of keeping pace with that of the United States, or even with the less demanding Soviet perception of the military value of this technology.[14] The high-prestige space program was being run on a computing shoestring—one of the reasons it was being increasingly overshadowed by American achievements.

During this period, the leadership of the Communist Party of the Soviet Union (CPSU) gradually came to see that an enhanced national computing capability was essential. Public endorsements of the development and use of this technology and its products became more frequent and were made more prominently.[15] Computers became the obvious means for the practical implementation of many concepts of the scientific-technological revolution,[16] which was perhaps the most important ideological extension of Marxism-Leninism since the early days of the U.S.S.R. This rhetoric began to be increasingly supplemented by serious commitments and practical measures.

[13] See, for example, Gertrude E. Schroeder, "Recent Developments in Soviet Planning and Incentives," in J. P. Hardt, ed., *Soviet Economic Prospects for the Seventies* (Washington, D.C.: Joint Economic Committee 1973). *Soviet Cybernetics Review* (fn. 3) regularly carried articles concerned with the use of computers for these problems.

[14] One of the few nontrivial, unclassified comparisons of U.S.-U.S.S.R. military-related computing capabilities is R. Turn and A. E. Nimitz, "Computers and Strategic Advantage: I. Computer Technology in the United States and the Soviet Union," *RAND Corporation Report R-1642-PR*, May 1975. Given the conservative nature of the Soviet military, it is not unlikely that changes in the military's perception may have been partially the result of pressure by the Party.

[15] See, for example, Wade B. Holland, "Party Congress Emphasizes Computer Technology," *Soviet Cybernetics Review*, July 1971, 7-14.

[16] See Erik P. Hoffmann, "Soviet Views of the 'Scientific-Technological Revolution'," *World Politics*, xxx (July 1978), 615-44, and Hoffmann, "The 'Scientific Management' of Soviet Society," *Problems of Communism*, xxvi (May-June 1977), 59-67.

Some of the earliest, and most important, evidence of a real change in attitude and commitment came in the early 1960s, when record-keeping and data-processing tasks began to require suitable equipment at all levels. Furthermore, any rational approach demanded that the equipment and methods used at lower levels also be useful at higher levels without major modification. An upward-compatible family of computers was therefore needed. Simply stated, an upward-compatible series consists of a sequence of increasingly more powerful computers that have been designed so that programs and data which can be run on any one machine can also be run, without modification, on all the larger models in the family. Thus, the same management programs and data formats for keeping track of rolling stock at a small railroad yard on a small computer model can be used at a larger yard using a larger machine. Such compatibility is very important to future growth. An enterprise that outgrows its current computer is able to switch to a larger one without the time-consuming, error-prone, and disruptive experience of rewriting all of its programs and reformatting all of its data.

The first Soviet attempt to produce an upward-compatible family was the Ural-10 series of three machines, Soviet-designed and manufactured in Penza under the Ministry of the Radio Industry. This series was difficult to program and had design features that were poorly suited for data processing. It is doubtful whether more than 1,000 of all versions of all three machines were ever produced, although the production period extended from 1965 to at least 1972. The failure of the Ural series to satisfy Soviet needs influenced later decisions that determined the course of computing in the Soviet bloc.

In 1964–1965, essentially the same time that the U.S.S.R. announced and began to produce the Ural-10 series, I.B.M. announced and began to produce its System 360 (s/360) family. In spite of some technical and organizational difficulties,[17] I.B.M. had built more than 35,000 units of over a dozen models by 1970.[18] This family was a monumental technological achievement that consolidated I.B.M.'s dominance over

[17] T. A. Wise, "IBM's $5,000,000,000 Gamble," *Fortune* (September 1966), 116 ff.; Wise, "The Rocky Road to the Marketplace," *Fortune* (October 1966), 138 ff.

[18] "IBM System/360 Models 22-195," *Datapro Reports*, 70C-491-03, January 1974. The early s/360 units were based on hybrid circuits that represented a transition from discrete transistors to integrated circuits. The first large-scale commercial use of integrated circuits was in the R.C.A. Spectra 70/45 in late 1965. Many people consider the integrated circuit as the most important characteristic of third-generation hardware. The first Soviet computer to use integrated circuits was the small Nairi-3 (1968–1969), but it was not until 1972–1973 that this technology was really successfully used on a medium-scale Soviet computer.

both the domestic and the non-communist international data-processing markets.

By any standard, the Ural-10 series was very limited in comparison with the IBM s/360, or with the products of a dozen other Western vendors.

Although the Ural-10 series appeared concurrently with the s/360, it can be argued that its real counterpart was the IBM 1400 series which appeared in quantity in 1960–1961, and was an immediate success. Prominent Soviet computer scientists had been advocating the development of a compatible family since at least 1959. The decision to go ahead with the Ural family probably followed in 1961–1962, and was most likely based on this American success. Technically, the Ural machines—though not close copies of the 1400s—were much more comparable to them than to the 360s. The apparent policy of minimizing technological risk by using an already proven U.S. system as a model for their own efforts has characterized Soviet computing developments.

In 1966–1967, the Soviets began working on another upward-compatible family. The M-1000, M-2000 and M-3000 were developed under the Ministry of Instrument Construction, Means of Automation and Control Systems (Minpribor). Production was announced in 1968; these are the earliest models of the ASVT (the transliterated abbreviation of the Russian for Aggregate System of Computer Technology) family intended for industrial automation and data processing. The M-2000 and M-3000 used the IBM s/360 instruction set. This effort represents the first serious attempt by the Soviets to copy serially the architecture of a Western computer at a level intended to provide actual program compatibility. However, inexperience and the use of an inadequate circuit technology doomed this first effort to achieve compatibility with the s/360.

The Soviets were not doing particularly well in scientific/engineering computing. They produced a number of undistinguished, small-scale machines. The BESM-6 (which had many of the features of the British Atlas) had a CPU (Central Processing Unit) performance that, until 1973, was more powerful by at least a factor of ten than any other serially produced Soviet computer. Over 150 of these machines were built between 1965 and 1977, but they fell short of their American counterparts. Comparable to the CDC 3600 in CPU speed, they were much less powerful than the CDC 6600 (1963–1964), and were soon to be dwarfed by several other U.S. computers by the early 1970s. The performance of the BESM-6, like that of all Soviet computers, was severely degraded by a slow and inadequate core memory and by a lack of suitable and reliable peripherals (magnetic secondary storage and input/output devices).

The use of computers in industrial automation suffered further from a lack of commercially available devices that could connect computers with the manufacturing processes to be controlled.

The hardware situation in the Soviet Union, aggravated by the lack of customer service by hardware vendors, crippled the development of software. The users themselves had to write all but the most basic utility programs. The fact that they also had to maintain the hardware themselves eventually led to local engineering modifications that made it difficult or impossible to share software, even with users who had the same CPU model. Soviet computer systems were not large or complex enough to necessitate the development of modern operating systems. Most machines were so small, and so poorly equipped with peripheral devices, that only one application program could be in memory at any one time. With some simple utility programs for input/output and a few other functions, an intelligent Soviet scientist or engineer could manage the memory resources and supervise execution for his own program. By contrast, American vendors—in order to make efficient use of all the hardware power and flexibility they were selling—supplied huge operating systems which could manipulate several concurrently resident applications programs and their data. An operating system itself took up a large volume of memory, and much of it had to be quickly accessible in core or from disk.

Communicating with the computer was another software problem. Every computer has its own basic set of "built in" instructions, known as the machine language. Writing programs directly in machine language generally involves writing lines of a numeric or cryptic symbolic code that requires a detailed knowledge of the internal structure of the computer. Such programs tend to be difficult to read and debug; but writing small machine language programs is within the capabilities of most scientists and engineers. Since the mid-fifties, American and West European computer scientists have been developing so-called high-order languages (HOL), which use stunted English syntax and standard mathematical notation. Programs written in a HOL are easier to read and correct than those in machine language, and the detailed management of memory locations and register contents is done by the HOL translator and other software that is supplied to the user. It is thus possible for relatively unsophisticated users to write large applications programs in a HOL, enter the program via some convenient means, and let the systems software (translators, operating systems, etc.) handle it from there. Hardware limitations forced Soviet programmers to write most of their programs in machine language until the end of the early 1970s: core memory was in short supply and a good HOL translator could take up most of what was available. Furthermore, until the mid-to-late sixties, high-performance line printers that could handle alphabetic and other non-numeric characters were not widely available in the Soviet Union.

Thus, by the early 1970s, Soviet software existed primarily in the form of many isolated pockets of machine language programs. There was very little portability between installations. Computer centers were essentially on their own once the hardware had been delivered. Many applications, especially those of a non-numeric nature, were out of the range of the hardware. Little experience had been built up in the development of large, modern software systems. And, most important, computers were not accessible to users who had not had much technical training.

Although Western hardware imports continued to trickle into Eastern Europe and the U.S.S.R.,[19] the Soviets did not use the available computer technology transfer sources and mechanisms to the extent that they might have. They also did not use their own college-trained computer specialists effectively. Many seem to have been merely duplicating work done elsewhere (both at home and abroad), or working on trivial refinements of earlier developments. The vast majority of Soviet managers and administrators had little or no perception of the practical and potential value of computers.

The most important condition for upgrading the state of general-purpose computing in the U.S.S.R. was the creation of a modern, upward-compatible family of computers with adequate quantities of primary memory, a suitable assortment of peripherals, and the systems and applications software necessary to enable people with little technical training to use computers effectively.

The Soviets made the decision to start work on a new upward-compatible family of general-purpose data processing computers as soon as the success of the IBM s/360 series became apparent. The first official statement concerning the Unified System (known as ES or Ryad),[20]

[19] Ivan Berenyi, "Computers in Eastern Europe," *Scientific American* (October 1970), 102-8. This reference contains a listing of many of the Western computers in Eastern Europe and the U.S.S.R. before 1970, but Berenyi's estimate of the total number of computers in the U.S.S.R. before 1970 is much too low.

[20] G. Kazanskiy, *Moscow Nedelya*, No. 43 (December 4, 1967), 7. Kazanskiy was a

in December 1967, implied that it was a Soviet project. However, by 1968 the U.S.S.R. was hard at work trying to persuade its CEMA allies into joining the effort.[21] Hungary, Bulgaria, and the German Democratic Republic were the most amenable. Poland wanted to continue its ODRA program, which was based on that of England's International Computers Ltd. Czechoslovakia also had a program of its own and proved to be less than wholeheartedly committed to the Unified System. Romania remained especially obstinate, preferring to look to the West, and France in particular, for help.

Since the 1950s, the Soviet Union had attempted to organize cooperative efforts in computer technology as part of a more general effort to increase technological integration within CEMA. Technical prestige and the hope of eventual export opportunities were important goals. In general, cooperation was desirable as a means of solidifying economic and military ties through technical interdependence. The Warsaw Pact countries appreciated the value of computers for military purposes. A compatible family of computers and related equipment would be an invaluable asset for combined Warsaw Pact activities—particularly for command, control, and communications systems.

The computer industries of the G.D.R., Hungary, Poland, and Czechoslovakia were much smaller than that of the U.S.S.R., but in some ways they were more sophisticated. Because they had been more in contact with the Western computer community, their experience proved to be a valuable asset for the Ryad project. They also had more advanced capabilities in some aspects of peripheral technology and software development.

The decision on the basic architecture of the new system was made only after some discussion both within the U.S.S.R. and among the CEMA partners. National pride was an important factor in the argument favoring the use of a design of CEMA origin. The G.D.R. wanted to use the IBM S/360 architecture and to make the Ryads compatible with the I.B.M. computers. The East Germans were already pursuing

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deputy minister of the Radio Industry. Ryad, the Russian word for "row" or "series," is the popular name for the Unified System of Computers. ES, an abbreviation of the transliterated Russian for Unified System, is used as a prefix to designate equipment numbers. N. C. Davis and S. E. Goodman, "The Soviet Bloc's Unified System of Computers," *ACM Computing Surveys*, X (June 1978), 93-122, presents an extensive description of Ryad. It should also be consulted for references to the Soviet technical literature.

[21] The Council for Economic Mutual Assistance includes Bulgaria, Czechoslovakia, the German Democratic Republic (G.D.R.), Hungary, Poland, and the U.S.S.R. Cuba, Mongolia, Romania, and Vietnam are also affiliated.

this approach on their own—probably aided by either direct or indirect access to I.B.M. and other U.S. technology in Western Europe. For this reason, plus the availability of vast amounts of I.B.M. software and favorable experience with imported I.B.M. products in Eastern Europe, the I.B.M. architecture was finally adopted.

The potential for problems in this arrangement was enormous. There were language barriers, the difficulty of trying to duplicate sophisticated foreign technology, poor telecommunications and long physical distances, weak support industries, assorted international bad feelings, and an untested control structure that supervised many development and production facilities which had never worked together before.[22]

Perhaps with these problems in mind, or at least in anticipation of delays in the ES program, the Soviets and their partners chose to continue developing their other projects, such as the production and upgrading of several second-generation computers.[23] Minpribor proceeded with the development of the ASVT family, and work continued on specialized military projects and computers for scientific applications, as well as on several East European programs.

Before investigating the current consequences of this period, it is worth summarizing the role of technology transfer from foreign sources. Technology transfer was important at two levels, even though Western influence was for the most part at a distance. At the policy-making level, it is clear that the Soviets were conscious of what was being done in the West, and decided that some of their problems could be alleviated through the emulation of the Western pattern. At the technical level, it is equally clear that Soviet computer scientists were much influenced by Western technical progress. The Soviets' substantial efforts, through both overt and covert channels, to obtain Western technical information and products had relatively little effect on the overall development of Soviet computing except in an extremely narrow technical sense. Even there, Soviet hardware and systemic constraints made it impossible to use Western technology to the fullest extent.

[22] The basic effort involved 70 to 80 R & D and production enterprises and several hundred thousand workers, engineers, and scientists. M. Rakovskiy, "Control and Cybernetics," *Pravda*, May 31, 1973. Rakovskiy is a deputy chairman of U.S.S.R. Gosplan, and head of the CEMA commission supervising the development of the Unified System.

[23] V. A. Myasnikov, "Results and Priority Tasks in the Field of Automation of Control Processes in the National Economy of the U.S.S.R.," *Upravlyayushchie sistemy i mashiny* (January-February 1977), 3-6.

III. Progress and Problems

A NEW ERA

The Ryad program represents a new era in Soviet computing. With the development of the Unified System, the Soviets have begun to follow the West in the production and installation of complex general-purpose computer systems that are intended for widespread general use. Ryad is the most important concrete manifestation of their commitment to the use of computers in their economy. The entire project has been based on a massive transfer of Western technology.

The first Ryad computers, prototypes of the small ES-1020 model, were seen on display in Bulgaria and Poland in 1971.[24] Only a small batch were made for initial production, and within two months they were back at the Minsk Ordzhonikidze Plant for "redesign."[25] It was not until May 1973 that six of the seven Unified System models could be put on display at the Exposition of Achievements of the National Economy in Moscow.[26] (All seven machines had been described in 1970 in a detailed set of design specifications.) The two largest models were in considerable technical trouble. Of the six models exhibited, only the Hungarian ES-1010 and the Soviet ES-1020 and ES-1030 were said to be actually in production.[27] By early 1974, the Czech and East German models had gone into production. Four new Ryad models appeared between 1975 and 1977.

Neither the Hungarian nor the Czech model has much compatibility with the other Ryad models. The first is based on a small French computer, itself a licensed version of an American model. The second is a modification of a Czech design to incorporate some S/360-like Ryad features. The inclusion of this machine represents a political compromise with Czech interests in order to obtain their participation in the Unified System project.

Peripherals—input-output devices and auxiliary storage—are the weakest part of the Unified System. In 1973, orders were being accepted for only about half of the announced peripherals. Many of those not

[24] Wade B. Holland, "Ryad Arrives—And So Does the Party," *Soviet Cybernetics Review* (May 1972), 7-11. Production was formally announced in 1972: N. Novikov, "Computers: Third Generation," *Pravda*, January 21, 1972, p. 3; M. Shimanskiy, "All-Powerful Electronics," *Izvestiya*, January 22, 1972, p. 5.

[25] A. Reut, Director of the Minsk plant where the ES-1020 was built, in an interview in *Sovetskaya Belorussiya*, March 11, 1972, p. 2.

[26] The largest Ryad model, the Soviet ES-1060, was not on display. It would not go into production until 1977.

[27] A. M. Larionov, interviewed in *Pravda Ukrainy*, May 20, 1973, p. 4. Larionov was head of the main Ryad technical planning group in Moscow.

available were devices for auxiliary storage and servicing of remote users via telecommunications channels. Hungary was most successful in meeting its goals for peripherals; the Soviet Union was perhaps least successful. Most of the equipment was at the level at which I.B.M.'s products had been in the mid-sixties. The collection of Ryad peripherals includes some that were being produced under foreign licenses, but were added after modification to minimum standards. However, in some ways the peripheral situation is a major achievement. For the first time, a Soviet computer system provided for a little customer convenience. The ES card readers might be a bit slow; but what is that compared to the pre-Ryad situation where input had to be via papertape, or where the card readers were so sensitive to the poor quality of the cards that they would crush decks and jam so often as to be effectively out of commission half the time? Similarly, the ES tape drives may be slow and the tapes themselves not very densely packed, but they represent a substantial improvement when compared to paper or magnetic tape so unreliable that users had to use back-up tapes like chain smokers to avoid losing everything. For the first time, disk storage and alphanumeric printers with Cyrillic characters are generally available; ES peripheral quality and availability is such that they are being used with non-Ryad machines.

The CEMA countries have done reasonably well in achieving their goal of adapting the IBM S/360 operating systems to the Ryad hardware, thus placing themselves in a position to borrow huge quantities of systems and applications software that have taken I.B.M. and its customers several billions of dollars and tens of thousands of man-years to develop. There was no effective way to deny either the software itself or the documentation to the CEMA countries. Any serious effort to do so would have harmed the United States more than the Soviet Union. In any case, it was available from many other places. These include I.B.M. itself, with thousands of user installations all over the world, and other assorted sources, such as the open literature. Furthermore, several CEMA countries had legally purchased some small- and medium-scale S/360 systems, including the software and the opportunity to participate in SHARE, the major I.B.M. user group. Soviet and East European computer scientists could also legitimately talk to Western counterparts at meetings, use Western consultants, exchange visits, and so forth.

Some covert procurement was also helpful, but such activities are beyond the scope of this article. The information sought was not extraordinarily difficult to obtain. Determined efforts have regularly resulted in the acquisition of much better-protected U.S. defense secrets. The Soviets have demonstrated that, if they are willing to try hard enough, they can illegally obtain entire I.B.M. computer systems.[28]

The models of the Unified System are not a reverse engineering of the IBM s/360 machines in the sense that the CEMA countries have achieved quantity production, at reasonable cost, of exact (or nearly exact) copies of the I.B.M. equipment. That would imply duplication down to the level of circuit components and, if truly successful, interchangeability of parts between the original and the copy. This level of reverse engineering of a major computer system has never been carried out anywhere in the world. Ryad and other attempts to "copy" I.B.M. products might be described as an effective functional duplication. The architecture, instruction set, and data channel interfaces are the same, permitting the use of I.B.M. software and interchange at the CPU or major subsystem level with relatively little difficulty. Although there is no detailed copying of electrical or mechanical components or manufacturing techniques, the CEMA countries have achieved some limited compatibility of media, permitting the exchange of cards, magnetic tapes, and disk packs.[29]

It is important not to underestimate the achievements of the CEMA computer scientists. They have mastered the quantity production of reasonably modern hardware and succeeded in adapting the s/360 operating systems to this hardware. That is not to say that they did not have considerable help from external sources, or that they did a good, or fast, or imaginative job. In fact, the effort took them as long as it took I.B.M. in the first place, and they have yet to achieve the quality and reliability standards of the s/360 across the Unified System product line. Nevertheless, they had the talent and resources to achieve the basic goals and, relative to their own past, they have acquired a much enhanced indigenous computing capability. There is every reason to think that, as this capability improves further, they will use technology transfer more effectively.

The CEMA partners themselves are not unsatisfied with their progress, although there is evidence that they had hoped to achieve more, and that they seriously underestimated many problems.[30] The best

28 " 'Reexporting': How Peter Lorenz Shipped IBM Hardware to Russia," *Datamation* (January 1975), 92-93.

29 R. A. Koenig, "The Issue of 'Reverse Engineering,' " Control Data Corporation, memo, July 25, 1978.

30 Wade B. Holland, Comments on an article by M. Rakovskiy, *Soviet Cybernetics Review* (November 1971), 33. Ryad production may have only been a third of what was planned for the Ninth Five-Year Plan.

evidence that they are basically satisfied with the policy of copying the I.B.M. product line is their current effort to develop a new group of Ryad-2 models that are clearly intended to be a functional duplication of the IBM S/370 family. By early 1977 most of the new models were well into the design stage, and prototypes for at least three models existed by the end of 1978. The appearance of other prototypes and the initiation of serial production will probably take place between 1979 and 1982.

Currently, there is an unprecedented effort to instruct people in the use of the new computers. Programming courses are proliferating in both industry and the higher educational institutes. Not long ago, 10,000 copies of a programming or software text was a large printing; now books on the ES system are appearing in quantities of 50,000 to 100,000. Considerable efforts continue to be expended on software for second-generation machines.

Although most of what appears in communist publications relates to Ryad, the Unified System project has not absorbed the entire computer industry of the Soviet bloc. The focus is on Ryad because it is by far the largest project, and most of the others are officially classified. The known manufacture of ES equipment involves only a fraction of the U.S.S.R.'s known capacity for computer production. A good deal remains classified and is used to build military systems, scientific computers of all sizes, and other special-purpose machines. The same is true of the other CEMA industries. The influence of Western, and particularly of American, technology on most of the developments we know about is significant; but it is not yet possible, on the basis of publicly available information, to comment in any detail on the extent to which Western products have been copied.[31]

INTEGRATION

During the last decade, the Soviet computing community has moved from almost total isolation to substantial, but still restricted, integration with the outside world. Integration has been at three levels: with the worldwide community, with CEMA, and within the economy of the Soviet Union.

Current Soviet policy on computer development is very conservative: to a considerable extent, the goal is to try to re-create systems that have

[31] In addition to Ryad, other major efforts that seem to be based on U.S. products include large computers for scientific applications (the El'brus-1 and -2) and minicomputers (the M-6000, M-7000, and new SM series). The El'brus-1 appears to be patterned on the Burroughs B7700. The M-6000 and M-7000 are based on the Hewlett-Packard HP21XX. The SM minicomputers seem to be based on Hewlett-Packard and Digital Equipment Corporation designs.

been in use in the rest of the world. This policy reflects the leadership's perception of the important role assigned to computing as a means of improving economic performance, and their desire to fulfill their goals as safely and as expeditiously as possible. The performance of the Soviet computer industry during most of the 1950s and 1960s—admittedly highly constrained by limited goals and resources—provided little cause for confidence. An obvious course of action was to use well-tested systems from abroad, and the obvious choice for a general-purpose family was the s/360.[32]

In order to achieve their goals, the Soviets have had to widen their contacts with the worldwide computing community. In the United States, the development and use of computers is based on extraordinarily effective and dynamic relationships between vendors and customers. In the absence of such a mechanism, the Soviets appear to have little choice but to wait and see what has been done in the West before they can take their next step. Greater commercial and academic contacts partly account for the expanded intake. The atmosphere of détente has permitted more effective people-to-people technology transfers; in an indirect way, American users and manufacturers may have as much of an input into the Soviet decision-making process as their Soviet counterparts.

These first steps toward integration have been limited. They involve only a fraction of the Soviet computing community. Much of it is still very secretive. Covert efforts to acquire computer technology have never been more extensive than they are now. The Soviet commitment to a high level of sustained computer technology transfer has been going on for over a decade, but it is a matter of conjecture as to how long it will last. If the technology successfully fulfills the hopes of the leadership without giving rise to unwanted pressures for reforms, the present trends are likely to continue. Otherwise, there might well be a withdrawal after a certain level of indigenous capability has been reached.

The level of integration with the other CEMA countries runs deeper. There are strong political, military, economic, and technical reasons for the Soviet Union to maintain a cooperative arrangement with its East European allies. The joint Unified System is regularly hailed as

[32] The CEMA countries were neither the first nor the most successful users of this policy. The first was R.C.A. with their Spectra 70 series. The most successful have been the Japanese. An important consideration for these non-communist companies was the possibility of capturing part of I.B.M.'s share of the market by using the architecture of the s/360 and s/370. Program compatibility was expected to make it easier for a customer to switch vendors.

one of the most important examples of "fraternal socialist cooperation" and a demonstration of the technological strength of the socialist system.[33] Ryad provides a broad base of common hardware and software that should do much to relieve many of the deficiencies that have limited the computing activities of the Warsaw Pact countries. There are now several thousand Ryads in operation, and the priority allocation practices of the centrally planned economies have presumably put most of these machines in places where they will have the greatest impact. There is also a fair amount of trade in computing equipment among the CEMA countries, and the hope that they might have some success as vendors in the international marketplace.[34]

The joint CEMA Unified System is not as tightly knit as the corresponding I.B.M. projects, and various Ryad hardware products and operating systems are not as family-compatible or interchangeable as the I.B.M. products. There is an Intergovernmental Commission of Socialist Nations on the Field of Computer Technology, under M. Rakovskiy, one of whose jobs is to enforce conformity to technical compatibility standards; but the fact that Ryad hardware and software are not as well matched as I.B.M.'s would seem to indicate that the CEMA countries had a fair amount of technical autonomy. To a considerable extent, the level of autonomy is determined by Soviet needs and desires. The Hungarian and East German contributions help to fill important gaps in the Soviet Union's indigenous capabilities. Around one-third of the production of these machines is exported to the U.S.S.R. As far as we know, not a single Czech-made Ryad CPU has left that country (for all sorts of reasons that may be conjectured), and most of the small output of Polish Ryads has stayed in Poland. The other CEMA countries' needs for computers in this performance range are filled by Soviet exports. The most extensive mixing of products occurs at the level of peripherals. Many of the Ryad-producing countries have developed peripheral specialities: e.g., the Poles in line printers, the Hungarians in graphics devices, the Bulgarians in disk units.[35] The con-

[34] Davis and Goodman (fn. 20), 118-19.

[35] At the start of the Ryad project, the Bulgarians had by far the lowest technological capabilities of any of the participating countries. It is thus surprising that they should become "masters" of this difficult technology. They may have received considerable help from the U.S.S.R., as they did in their production of the ES-1020. The Soviet Union seems to have something of a paternal interest in helping Bulgaria. During the last decade, the Bulgarians have built up a substantial export-oriented electronics industry. See, for example, *Vunshna Turgovia,* Sofia (No. 10, 1978), 9-12.

[33] See, for example, S. Kipnis, "Integrated Family of Computers," *Nauka i zhizn'* (No. 8, 1973), 2-11.

figurations of peripherals at virtually all unrestricted Ryad installations are of multinational manufacture.

With a reasonably common base of hardware and operating systems, one would expect a certain amount of integration in building and using applications systems among the CEMA countries. Some of this is going on, and there are visions of great efficiencies to be achieved from the partition of these activities among the member countries.[36] But since the various East European economies differ considerably at the microeconomic level, and there are differences in adaptations of the I.B.M. operating systems, one might entertain doubts as to how well this will actually work out. It seems likely that the various CEMA countries, and the installations within each country, will continue to be dependent on local resources for the great bulk of their applications software and systems.[37]

In spite of its assorted problems, the Ryad project apparently has been working well enough for the CEMA countries to undertake a similar unifying joint effort in the area of minicomputers. The new project, known as SM (transliteration of the Russian for Small System), currently consists of four models, and the announcement of two others is expected in 1979. The details of the participation of the various countries are not yet known. It is likely that Cuba will be an active participant.

The East European countries, particularly the G.D.R. and Hungary, are useful to the Soviets as conduits for technology transfer from the West, as sources of technology in their own right, and as models for institutional innovations that might be used in the U.S.S.R. The "per capita" capabilities of some of these countries may exceed that of the Soviet Union, probably as a result of many factors; one of the most important may be the greater contact these countries have with the Western computing community. Although one cannot go so far as to conclude that the ES project would have failed without help from Eastern Europe (especially from the G.D.R.), the role of these countries should not be underestimated. As communist countries using a common hardware base, they are the best external source the Soviets have for many industrial and management-related products, either in

[36] M. Rakovskiy, "According to a Single Plan," *Pravda*, February 3, 1978, p. 4.

[37] The adaptation of the huge number of applications programs available for the S/360 has not yet occurred to the extent that the CEMA countries might have planned. Reasons include the lack of adequate quantities of memory at most Ryad installations (actual deliveries seem to be running at not much more than half of what was planned), a shortage of trained people to make the adaptations, and the realization that much of the software may not be appropriate for their needs.

the form of licenses or of contracts for the development of new systems. Problems that inhibit active involvement with the West, such as travel restrictions, "cultural contamination," and a lack of hard currency, are much less important.

The integration of the Soviet and East European computer communities is asymmetric. The U.S.S.R. has access to anything it wants in most of Eastern Europe. On the other hand, the Soviet exposure is limited to the Unified System, the SM minicomputers, and a few other developments. Much of what the Soviets do within the U.S.S.R.—including some work on Ryad—is off limits to their CEMA partners. Conversely, some East European communist countries (Romania, Yugoslavia) have kept their computing activity separate from that of the Soviets.

Although the CEMA countries have not achieved the levels of integration and centralized control that I.B.M. has in its multinational operations, by their own past standards they have made considerable progress in the last decade. A reasonable case can be made that they now effectively possess the second-largest computer company in the world, and that their long-term prospects are fairly bright. The Soviet Union alone, and the CEMA countries together, have assets that no other computer organization except I.B.M. has: huge capital and personnel resources and centralized management control involved on a large scale with the full spectrum of computer-related R & D, products, and services.[38]

STRUCTURAL AND BEHAVIORAL PROBLEMS

The most basic and difficult problem of technology transfer has been that of taking a complicated, pervasive, and successful technology out of its original and nurturing environment, and attempting to transplant it into a fundamentally different one.

Although the Soviet Union has managed to acquire a fairly respectable base of hardware and systems software during the last decade, in terms of the U.S./West European/Japanese technological state of the art, the Soviets are still backward (particularly in the quality and availability of telecommunications). But it is important to distinguish between technology viewed in terms of technological frontiers, and technology as a means of providing functions and capabilities. The U.S.S.R. now has many of the hardware and systems software "pieces" that would enable it to get on with its ambitious plans. Its output of hard-

[38] Another possibility is Japan, but it is not yet clear, at least to this author, how unified the Japanese computer industry is.

ware is now behind only that of the United States and its multinational facilities abroad.

At this stage, most of the Soviet Union's pure technology and product needs are in software. One could argue that the number of computers per capita is still quite low by American standards, but this point is secondary and somewhat moot, since the U.S.S.R. is currently producing more machines than it can adequately support in the field. Of greater importance than pure technology and products is the problem of systemic integration: the users' perception of need, the acquisition of experience, the effects of institutional structure and economic-social practices, and so forth. It is obviously not possible to provide a comprehensive overview of these problems in a few pages. Accordingly, the present discussion will focus on software and customer services,[39] starting with brief, somewhat simplistic, reviews of the most relevant characteristics of the structures and behavioral patterns of the Soviet economic system and the American computer industry.

To a first approximation, the Soviet government/economy is organized in a hierarchical, tree-like structure.[40] At the topmost level is the Council of Ministers. The next levels represent a few score ministries, state committees, and other high administrative agencies. Then there are intermediate levels of Republic, branch, and departmental administration and management. Finally, the lower levels contain the institutes and enterprises that are responsible for R & D and the production and distribution of goods and services. This large bureaucratic hierarchy encompasses almost every economic aspect of Soviet society. As a result of this vertical structure, plus a very long and strong Russian bureaucratic tradition, much of the Soviet economy is unofficially partitioned into assorted domains or fiefdoms. These exist along ministerial, geographical, and personality divisions. As is frequently the case in large bureaucratic structures, people and institutions develop behavior patterns that please the higher levels of their domains. This behavior may or may not coincide with the goal of providing customers with products or services of high quality.

Superimposed on this vertical hierarchy are a variety of horizontal relationships. The domains are not self-sufficient; in addition to directions from above, they receive supplies and services from units in other

[39] A more extensive discussion may be found in S. E. Goodman, "Software in the Soviet Union: Progress and Problems," *Advances in Computers*, XVIII (1979), 231-88. This source contains many references to the Soviet literature.

[40] See Morris Bornstein and Daniel R. Fusfeld, eds., *The Soviet Economy: A Book of Readings* (4th ed.; Homewood, Ill.: Irwin 1974); Joseph S. Berliner, *The Innovation Decision in Soviet Industry* (Cambridge, Mass.: MIT Press 1976).

domains, and in turn, supply goods and services elsewhere. The centralized planning apparatus, in collaboration with other levels in the hierarchy, specifies suppliers and customers for almost every Soviet institute and enterprise. Although there is some flexibility in establishing these horizontal relationships, they are for the most part beyond the control of lower-level management. One of the most important of the self-assigned tasks of the Communist Party is to expedite all sorts of governmental and economic activities; it intercedes to get things done. Although the Party organization is also subdivided into fiefdoms, it is more tightly controlled and operates across government/economic domains. Finally, there are the unofficial (sometimes illegal), horizontal arrangements that are created to enable an enterprise to function successfully despite bureaucratic handicaps.

In the centrally planned Soviet economy, there is no market or quasi-market mechanism to determine prices, mixes of products and services, rewards, and so forth. For the most part, these factors are worked out at high levels and by a centrally controlled haggling process, although since 1965 lower-level management has been granted some degree of autonomy by gradual reforms. Quantity is stressed over quality, and production is stressed over service. Enterprises are told what to do. Failure to meet the imposed commitments can bring stiff penalties. Success is rewarded, but there is little opportunity for the high-risk, big-payoff, innovative entrepreneurial activity that is common in the U.S. computer community. The central planners do not like much activity of this sort because it is hard to control.

Business practices that have evolved in this environment are oriented toward the basic goal of fulfilling the performance indices that are given to them. They usually consist of narrowly defined quantitative quotas. Thus, for example, a computer producer's most important index may be the number of CPUs manufactured; a less important index may be the number of peripheral devices built. Lists of suppliers and customers are provided by the planners. Plant management will obviously give first priority to meeting the CPU production norm; the next priority goes to the peripherals. Although rewards are paid for meeting the basic goals and for overfulfillment, the managers do not want to overdo things, because this year's successes may become next year's quotas. Furthermore, it is clearly in their own best interest to haggle with the planners for low quotas. Since customer satisfaction is of relatively minor importance (particularly if the customer is far away or under another ministry), management is not going to divert its resources to installation and maintenance unless it absolutely has to.

There is also an obvious incentive to try to retain the status quo. Once a plant operation has started to function smoothly, there is no market pressure to force innovation, improved service, new products, and so forth. These things would involve problems such as finding new suppliers, changing equipment, and retraining personnel—in other words, a serious risk; and local management cannot control prices or suppliers to balance the risk.

There are strengths in this system. Central control and the powerful expediting role of the Party allow national resources to be concentrated in high-priority areas. The differences between the Ural-10 and Ryad hardware show that much can be done on a respectably large scale once the high-level decisions have been made. Of course, the government and Party do not have the resources and cannot maintain enough pressure to exert control across the entire economy. Furthermore, it can be argued that some of the success of high-priority projects occurs precisely because these projects are really removed from the economic mainstream.

The American mainframe industry is dominated by I.B.M., which is the primary vendor for approximately two-thirds of the general-purpose installations at home and for approximately half of them worldwide. As a mainframe manufacturer, I.B.M. competes with about a half-dozen billion-dollar domestic "dwarfs" and another half-dozen companies in Western Europe and Japan. The industry is not a pseudo-competitive oligopoly. The other companies are not shy about the way they go after I.B.M. at the customer level, in copying products, in the courts, and in seeking government controls. I.B.M.'s position is not nearly as dominant in other hardware areas (minicomputers, microcomputers, peripherals, etc.); in some of these, it is not dominant at all.

The impressive record of technological innovation in computing hardware reflects the sense of competition that exists among hundreds of companies. This innovation has been widely distributed throughout the industry, and I.B.M.'s share is not anywhere near that of its percentage of installed mainframes.[41] That is not because it has not been trying—I.B.M. invests almost $1.4 billion a year in R & D, reflecting its perception of the quality of its competition and the influence of customer feedback.

The primary efforts of most American hardware vendors are in the areas of marketing, software, and customer-oriented service. Serious

[41] See, for example, Gerald W. Brock, *The U.S. Computer Industry* (Cambridge, Mass.: Ballinger 1975), 204.

concern for customer response—reflecting the business-machines origins of many of the most important companies—has, in fact, been a major stimulant to technological progress. I.B.M. does not owe its continuing large share of the mainframe market to the technical superiority of its products, but to the scope and quality of its customer services and its aggressive concern for its customers' needs.[42] Many organizations have entrusted much of their business to computerized information systems. The majority of users are afraid of their machines; they need to have their hands held and be shown how best to utilize computing capabilities. If the systems do not work right or go down for long periods, they are in trouble. So are computer vendors who do not deliver services.

The same applies to the software industry. In the United States alone, there are thousands of companies that provide professional software services for customers. They range in size from I.B.M. to one-man firms. Some build systems and then convince users to buy them. Others ascertain a customer's needs, and then arrange to satisfy him. They also offer a variety of other services. Basically, all of the companies try to make a profit by showing their customers how to make the best use of computers. To a considerable extent, the software vendors and service bureaus have created a market for themselves through aggressive selling and the competitive, customer-oriented development of general-purpose as well as tailor-made products.

Before Ryad, Soviet installations were pretty much on their own with respect to hardware service and maintenance: they had to hoard spare parts and employ their own engineers. This led to very inefficient use of resources; many places had trouble getting qualified people. Since the Ryad systems are more complex, and self-maintenance is much more difficult, some serious efforts have been made to provide for centralized hardware services along American lines, but this has not yet worked out well even for users in major metropolitan areas.[43] Repair or replacement of faulty parts that in the United States would take hours or at most days may still take a year in the Soviet Union.[44]

[42] I.B.M. itself has been realistic and frank in its assessments of the technical quality of its competition. See I.B.M., "Quarterly Assessment of the Product Line," March 16, 1971 (Telex vs. I.B.M., Plaintiff's Exhibit 224); Brock (fn. 41), 206-7.

[43] See, for example, V. Fadeyev, "Who is to Answer for Computer Servicing?" *Sotsialisticheskaya industriya*, September 4, 1977, p. 2; I. Perlov, "The ASU—Its Use and Return," *Ekonomika i zhizn'* (Tashkent; No. 6, 1977), 83-86; Yu. Taranenko, "How to Service Computers," *Sotsialisticheskaya industriya*, July 19, 1977, p. 2; *Izvestiya*, March 14, 1978, p. 2.

[44] "The First R-22 Has Been Started Up. Favorable Experiences at the ELGAV," *Szamitastechnika* (March 1977), 3.

The worst stories come from ordinary users who are not near major metropolitan areas. For example:

> At the Institute [Central Asian Scientific Research Institute of Agricultural Economics in the Uzbek S.S.R.] an expensive ES-1020 has been operated in an improperly prepared room for three years now. The room still does not have air conditioning and the computer goes down from overheating. The disk memory devices are not protected against dust. According to figures from the Central Statistical Association of the Uzbek S.S.R., the workload of the Institute's machinery last year was just three hours a day compared to a norm of fifteen hours. A similar situation has developed at the Institute's Bukhara division where a Minsk-32 computer has been idle since 1974.[45]

The service for software is at least as bad. Most users are pretty much on their own with respect to applications systems. American success in this area is partly due to institutional arrangements that allow a large number of companies and other organizations (e.g., professional societies, users' groups) to cut across industries and hierarchies of management to set up flexible, manageable, low-level, horizontal relationships and communications. Furthermore, American management has given computer-related personnel within their companies a great deal of flexibility and authority in dealing with these service organizations. The Soviets have no comparable arrangements; nor do they seem to be rapidly developing mechanisms that effectively provide similar results. Even maintenance of the centrally adapted and distributed Ryad operating systems appears to be poor. Simple arrangements, such as software libraries that collect programs and redistribute them among users, do not seem to work out. Most Soviet libraries with which Western observers are familiar have not been properly staffed, organized, indexed, or quality-controlled. Problems of organization and behavior severely retard almost all other forms of diffusion.

By and large, the users accept the poor service situation; their attitude is thus a major obstacle to progress.[46] Most complaints disappear into bureaucratic oblivion, and those that would get at the heart of the problem are politically unacceptable.[47] Soviet vendors ("manu-

[45] Perlov (fn. 43). V. Letov, in "Computer in the Basement," *Izvestiya*, August 22, 1975, p. 3, tells of mice eating a calculator in Kunya-Urgench.

[46] Of course, there is a hierarchy of users in the U.S.S.R. Special users, such as the military, KGB, and CPSU, are not in the habit of accepting poor service. Their peacetime consumer privileges are almost beyond comprehension in the United States.

[47] Some complaints that appear in the public press are quite outspoken (see fns. 43-45), but not effective. In theory, the Soviet legal system allows wronged parties to take their suppliers to court. In practice, however, the Party and military-industrial representatives get satisfaction for special customers (usually themselves); ordinary customers just complain in print.

facturers" and "distributors" are really more appropriate terms in the Soviet case) accept little responsibility (or even guilt feelings) toward their customers. Ordinary Soviet users have no choice but to do the best they can with whatever they have, and to wait passively in the hope that the leadership will get around to doing something about their problems. American computer users can vent their displeasure by hiring lawyers, not paying bills, not using poor vendors again, and by saying nasty things in front of vendors' stands at exhibitions and fairs. No comparably effective mechanisms exist in the U.S.S.R. The CPSU does not have the ability to exert pressure on behalf of each of the thousands of computer installations in the U.S.S.R., nor is it apparently interested in diluting its own unique strengths by letting non-Party organizations exert such pressures.

The introduction of computers into the structure of Soviet management has been limited. Conservative applications, such as systems for scheduling, process monitoring, and personnel files seem to be the rule. Although there is some research on the utilization of computer techniques for decision analysis and for the modeling of management problems, little seems to be put into practice. Soviet managers tend to be older and more inhibited than their American counterparts. The system in which they work emphasizes straightforward production rather than innovation and marketing decisions. Soviet economic modeling and simulation activity stress the necessity of reaching a "correct socialist solution," and are not oriented toward being alert for general and unexpected possibilities in a problem situation. Furthermore, Soviet industry has learned not to trust its own statistics; much information is controlled, and unavailable to many potential users, and there may be a big difference between "official" and actual business practice. What does one do with a computer system for the "official" operational management of an enterprise when actual practice is different? Does one dare use the computer to help manage "expediter" slush funds, under-the-counter deals with other firms, etc., which could leave a substantial trail for audits?[48]

The rate at which computing services and computer use are improving in the Soviet Union would be considered intolerably slow in the United States. Moreover, progress comes more slowly and less decisively as the technology broadens its impact on the Soviet social and economic system. Changes at the level and on the scale discussed here

[48] Difficulties of this sort seem to be at the root of the problems described in I. Novikov, "Follow-Up on a Letter: They Put Their AMS Up for Sale," *Pravda,* March 13, 1978, p. 2.

take longer than the time in which the leadership changes its perceptions and commitments, or in which hardware engineers can copy American products. Integrating computing into a large national economy is not like building army tanks. Users must have the motivation to go through all the trouble that is involved in learning to apply this technology effectively. They also need a great deal of help. The kind of motivation that has driven the desire to use computers in the United States, and the help that has made it possible, do not exist in the Soviet Union to anywhere near the same extent.[49] The guidance provided by the philosophy of the scientific-technological revolution is not much of a substitute.

IV. Conclusion: Pressure for Reform?

The Soviet Union's commitment to upgrade and expand its national computing capabilities is clearly dependent on a substantial and sustained transfer of technology from the West, and particularly from the United States. Although the Soviet industry has become more dependent on Western technology, it remains physically and institutionally isolated. The U.S.S.R. has no intention of integrating itself into the U.S.-dominated industry to the extent that Japan and Western Europe have. Its primary goal is to build up its indigenous capabilities. However, the pursuit of this goal has required it to become more involved with the outside world. The most important of these new international relationships are those that it has developed with its CEMA partners. Although the U.S.S.R. still insists on a high level of independence and autarky even within this group, the CEMA countries have put together a respectable international computing community. On a much smaller scale, the Soviet Union has become both a buyer and a seller in the non-communist international market.

At the level of national policy making, the Soviets have been slow to understand the potential of computing, and even slower to appreciate the difficulties involved in the development of this technology. In spite of the readily available Western example, the industrial, political, and military leadership of the U.S.S.R. has consistently made short-

[49] Military and other high-priority users probably come closest, but we know very little about how—and how well—computers are used at such installations. It is important to emphasize that we do not have a good, detailed, overall picture of how well the Soviets are using the computing capabilities (particularly in software) that they have recently announced, or even those they are known to have had for a long time. We have had limited access to Soviet installations. Most installations described in the open literature and those that have been seen by visitors from the U.S. are clearly much better than average; but it is hard to say how they compare to high-priority installations.

sighted decisions that reflect existing technical capabilities without showing any particularly deep and long-term perspective. As far as we know, the most important Soviet projects are only trying to recreate systems that have been well tested in the rest of the world. For all the high-level exhortations and the proclamation of the scientific-technological revolution that singles out the U.S.S.R. as the society that is uniquely capable of using computers, it is clear that the leadership has few innovative ideas on what to do with this technology. It appears to have little choice but to wait and see what the U.S. has done before deciding on its next step.

The problems of the leadership are reflected at the technical level. Extensive use is being made of Western products, but the Soviet industry seems satisfied with the short-term goals of re-creating selected Western systems at a rate that is slower than that at which the West built them in the first place. In spite of a great deal of technology transfer, in terms of in-depth understanding and the avoidance of repetition of mistakes in their own work, Soviet computer scientists do not seem to have profited much from foreign experience. They are making the same mistakes and suffering from the same growing pains—often exacerbated by difficulties they have created themselves.

Although the changes in high-level perceptions and technological development have been slow and not particularly impressive in comparison with what has taken place in the United States, from the Soviet point of view there has been substantial progress in both areas. They are no longer the critical, limiting factors they once were. The real problem is now more broadly and deeply systemic: the pervasive and effective integration of computing into the fiber of the national economy. Soviet society is poorly structured to support many of the practices that work well in the U.S. If the Soviets want to achieve their proclaimed goals, it will be necessary for them to solve some difficult problems themselves.

Although it is hardly feasible to speculate in detail on the variety of possible solutions to these problems, it seems appropriate to conclude this article with a few observations. A major problem, from the standpoint of the political leadership, is that development and use of computers on a national scale cannot be isolated socially like the more narrow military industries, or even like industries such as power, steel, etc., whose products are used relatively passively as compared with computers. In particular, it might not be possible to contain major reforms that would greatly improve the quality and availability of computing services. If changes were made to enable a Western-style service sector to exist among thousands of computer installations cutting across the domain of every ministry, then (if successful) how could there not be pressure to extend these changes beyond computing?

It would seem that the last thing the CPSU wants to do is create an environment that seriously erodes its own role in the economy; moreover, it would take decades for Soviet vendors and customers to learn how to play well by the new rules. A more realistic spectrum of possibilities exists. One conservative change, such as the consolidation of research institutes and production enterprises into corporation-like associations,[50] would seem to permit substantial improvements in computing services without greatly disturbing current practices. A more extreme, but not unlikely, development would be the gradual establishment of an unofficial trade in computer services among installations that have built up capabilities of one form or another. There are other possibilities, but all of these improvements would still appear to leave the computer development/user community of the Soviet Union short of the systemic advantages enjoyed by its American counterpart. The Soviets may be reasonably content with this. In light of what we know of their data-processing needs and capabilities, and of their political concerns, progress within these bounds is likely to be sufficient for at least another decade.

[50] Berliner (fn. 40); Alice C. Gorlin, "Industrial Reorganization: The Associations," in J. P. Hardt, ed., *The Soviet Economy in a New Perspective* (Washington, D.C.: Joint Economic Committee 1976).