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Soviet Computer Technology: Little Prospect for Catching Up

An Intelligence Assessment

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Soviet Computer Technology: Little Prospect for Catching Up

Key Judgments

Information available as of 1 November 1984 was used in this report.

The United States leads the USSR in all fields of general purpose digital computer technology. This lead ranges from at least three years for internal memory devices to more than 10 years in high-performance magnetic storage systems. In general, the outlook for the remainder of the 1980s will be for the US lead to increase slightly, although, for some high-priority applications, the Soviets may be able to reduce or design around a particular technology gap

The Soviets have made progress both in computer technology and in computer production techniques; however, their progress has been overwhelmed by the rapid advances made in the West and Japan. The Soviets' status in seven important areas of computer technology is summarized in figure 1. These estimates are based upon the first delivery dates of functionally equivalent US and Soviet civilian computer products. If we were able to include computer production volume and quality in our measure of technology, then the United States would be at least several more years ahead

We believe there are many reasons why the Soviets trail the United States in computer technology:

- The Soviets' centrally planned economy does not permit adequate flexibility to respond to design or manufacturing changes frequently encountered in computer production; this situation has often resulted in a shortage of critical components—especially for new products.
- The extraordinary compartmentalization of information in the USSR—especially on technologies with potential military applications; compartmentalization not only restricts the flow of information, but also results in much duplication of work because of a lack of knowledge about other activities.
- The Soviet preoccupation with meeting production quotas, frequently at the expense of component and system quality control.
- The lack of adequate incentives for Soviet managers to take the risks associated with innovations or new technology.
- Poor coordination between separate design institutes and production facilities, sometimes resulting in products that have to be redesigned to fit a factory's production capabilities.

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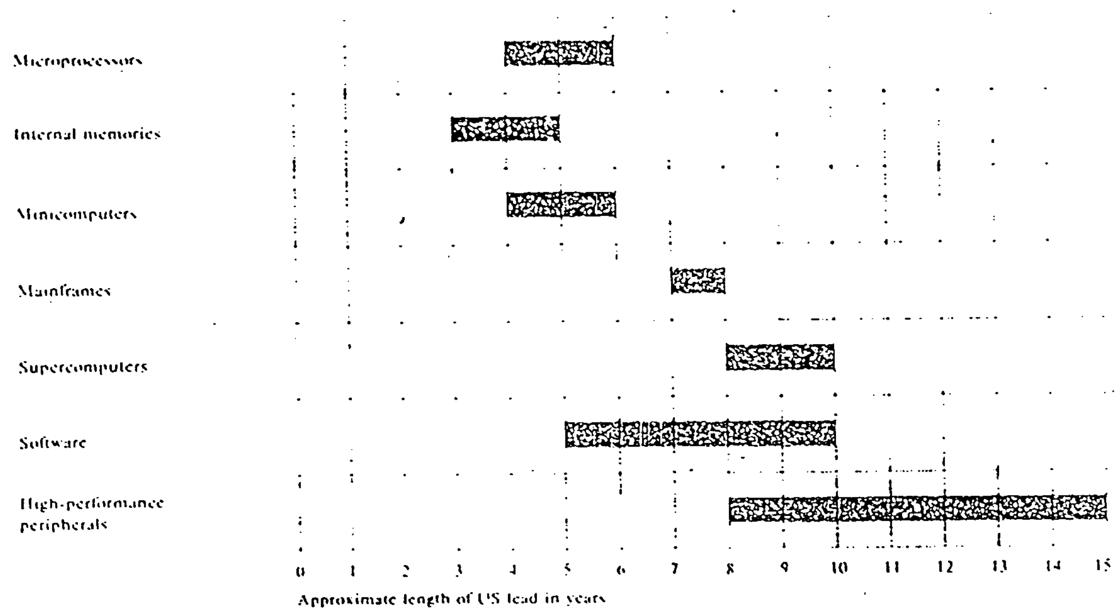
Figure 1
Computer Technology: United States Versus USSR



- The Soviets' lag in computer-aided design and computer-aided manufacturing techniques caused by a belated development start and also, ironically, by the Soviets' lag in computer technology.

- Concerns by Soviet officials that a computer is a powerful tool that could be used for antirevolutionary activity and that a proliferation of computers might reduce the tight control of information in the USSR; these concerns tend to restrict access to and firsthand knowledge about computers as well as their applications.

- Provincial disputes within and between ministerial and institutional organizations.

- Very poor customer support—including inadequate user feedback, poor installation support, and delayed maintenance—that frequently results in reduced efficiency and productivity for computers in use.

Similar reasons also account for the Soviet lag in microelectronics technology as well as instrumentation and test equipment: these technology lags in components and basic electronic tools that are essential for modern computers contribute directly to the Soviet lag in computer technology. In our view, the entrenched Soviet bureaucracy would probably find it difficult to take the necessary steps in the foreseeable future to correct many of these well-recognized problems

The Soviet lag in computer technology and production is resulting in a lag in both civilian and military computer applications. We believe that the Soviets have sufficient numbers of computers for high-priority, low-volume military and civilian projects. It is the remaining user community, including Eastern Bloc allies, who will experience shortages and delays in obtaining their desired computer systems. We expect the shortage of Soviet automation equipment to hinder seriously the modernization of their industrial base and also the growth of their economy

The Soviets apparently lag the United States also in the application of computers in their fielded military systems. Historically, there has been a tendency in the USSR to avoid the complex multimission military systems—for which computers are an essential subsystem—that are frequently preferred in the United States. The generally conservative Soviet weapon design philosophy has probably not taxed Soviet computer capabilities in the past. However, this may be changing. We believe that the Soviets will be forced to incorporate more-advanced technology into their weapon systems in order to stay competitive with Western military development.

The Soviets' most significant hardware deficiencies are in supercomputers and high-performance magnetic disk technology. We do not expect the Soviets to have a supercomputer until 1985 at the earliest, whereas the first US commercial supercomputer was delivered in 1976. In magnetic disk systems, the Soviets are about a decade behind the United States. Lags in these critical areas will constrain Soviet computer system performance for applications requiring high-speed capabilities, such as ballistic missile defense, and applications requiring high input/output data rates, such as large real time command, control, and communications systems. In the software arena, the number of experienced Soviet programmers who are also cleared for classified projects may still be insufficient to complete all priority projects on time.

We expect the Soviets' future progress in computer technology to be heavily dependent upon their advances in microelectronics and in secondary storage technology, and upon their continuing activity in legally and illegally acquiring Western and Japanese hardware and software. Judging from past performance and current technology assessments, we expect the Soviets to fall further behind the United States throughout the 1980s. If the Soviets obtained turnkey production facilities or detailed production know-how from the West or Japan—as they have done in the past—they would be able to narrow, at least temporarily, a specific technology gap. Also, if they made a major technological breakthrough in areas where they appear to be investing heavily, such as in optical computing or optical storage—and chances are about even that they will—the Soviets could overcome some of their computer deficiencies, for applications such as ballistic missile defense or real-time reconnaissance.

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Soviet Computer Technology: Little Prospect for Catching Up

Introduction

This report is an assessment of the state of the art of Soviet general purpose digital electronic computer technology. It is primarily a condensed version of a more detailed Technical Intelligence Report on the same subject.[1] The assessment is based on information about Soviet civilian computer systems; however, we believe that this information is indicative of Soviet capabilities in military general purpose computer technology

Microprocessors

A basic micro*processor* typically consists of the interconnection of an arithmetic and logic unit (ALU), a register set (very fast storage), a control unit, and interrupts. A micro*computer* consists of a microprocessor plus a main memory, an input medium, and an output medium

The current state of the art in Soviet microprocessor technology is a 16-bit single-chip capability in low-volume production and 16-bit chip-sets in serial production. The Soviets are four to six years behind the United States in microprocessor technology; however, we expect the US lead to increase in the near future as 32-bit monolithic processor technology matures.

We have been able to identify 20 types of Soviet microprocessors (table 1). Although 20 is a small number relative to the number of microprocessors commercially available in the West and Japan, the Soviets have judiciously spread their resources across a wide variety of semiconductor devices and fabrication processes. Thus, Soviet design engineers may choose a semiconductor device for a particular application on the basis of a wide variety of trade-offs in speed, power, radiation resistance, and cost

The Soviets can, however, be expected to make increased use of complementary metal oxide semiconductor (CMOS) devices in the next few years. The best known advantage of CMOS technology is its low power, both in the standby and in the operating mode. The high immunity of a CMOS device to noise encourages design engineers to use a lower voltage power supply. In addition, special processing techniques can make CMOS chips more resistant than the widely used negative-channel metal oxide semiconductor (nMOS) chips to a specified radiation dose rate or fluence. CMOS devices have other advantages over nMOS devices:

- Inherently faster switching times.
- Better resistance to "soft errors" caused by alpha-particle radiation.
- Higher tolerance to transistor-leakage problems.

In the light of these advantages, we expect the Soviet military to direct major Ministry of Electronics Industry (MEP) resources toward the advancement of their CMOS fabrication processes during the remainder of the 1980s

As in many non-Communist countries, US microprocessors have served as the model for many, and probably most, Soviet products (figures 2 and 3). In general, Soviet microprocessors reflect various degrees of similarity to US products (table 1, column 4). However, the Soviets have not copied US counterparts exactly, but rather have adapted the US designs to Soviet fabrication processes. We expect other US counterparts to be identified in time. The Soviets also have demonstrated an indigenous design capability in microprocessors, according to evaluations of a K587 device that was received by a US firm in 1978

Perhaps the most striking aspect of the list of Soviet microprocessors (table 1) is the preponderance of bit-slice[2] devices. We believe that the Soviets' preponderance of bit-slice devices resulted from deficiencies in

[2] Bit-slice devices and chip-set microprocessors implement the functions usually associated with a monolithic (single-chip integrated) circuit on many chips

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Table 1
Soviet Microprocessors

Designator	Technology/Width *(bits)*	Earliest Reference	US Counterpart	Microcomputers and Other Applications
K532	CMOS/4 ᵃ	1976		NTs-02
K536	pMOS/8 ᵃ	1979		Elektronika S5-02, -11, -12
K555	TTL/2 ᵃ ᵇ	1976		NTs-01
K580	nMOS/8	1978	Intel-8080A; 1973	SM-1800, SM-1803.05, Sport, K1-10, VEF-1021, -22, -23, military
K581	nMOS/16	1979	GI CP-1600; 1975	Elektronika-60
K582	IIL/4 ᵃ	1979	TI SBP-0400; 1975	
K583	IIL/8 ᵃ	1980		Ryad computer equipment
K584	IIL/4 ᵃ	1977		Specialized microcomputers
K586	nMOS/16	1980		Elektronika S5-21, S5-31
K587	CMOS/4 ᵃ	1978	None	NTs-03, NTs-80-01
K588	CMOS/16 ᵃ	1977	None	Military, NTs-03T, Agat ᶜ
K589	STTL/2 ᵃ ᵈ	1977	Intel-3002; 1974	Elektronika-60 bus formatter, SM minis, airborne processors, Ryad computer equipment, PS-315
K1800	ECL/4 ᵃ	1982	M-10800; 1975	
K1801	nMOS/16	1980		NTs-80-01D = NMS-11100.1, BK-0010
K1802	STTL/8 ᵃ	1981		NTs-03D
K1804	STTL/4 ᵃ	1981	AMD-2901; 1975	
K1810	nMOS/16	1983	Intel-8086; 1977	
ᵉ	SOS/?	1979		Military
?	nMOS/8	1983	Intel-80[illegible]	
?	nMOS/8	1983	Intel-8088; 1979	

ᵃ Bit-slice device.
ᵇ It is not certain that K555 is a microprocessor. Soviet open-source literature in 1977 identified it as a two-bit-slice microprocessor; but a 1984 open-source catalog equates the K555 family to the Texas Instruments (TI) SN74LS series, which does not have a microprocessor product.
ᶜ Soviet Agat is modeled after US Apple microcomputer architecture.
ᵈ May have been originally TTL.

ᵉ A G112 microprocessor was mentioned in a 1978 Soviet publication; we suspect that it is actually a microcomputer

MOS — metal oxide semiconductor
CMOS — complementary MOS
pMOS — positive-channel MOS
nMOS — negative-channel MOS
TTL — transistor-transistor logic
STTL — Schottky-clamped TTL
ECL — emitter-coupled logic
SOS — silicon on sapphire
IIL — integrated-injection logic

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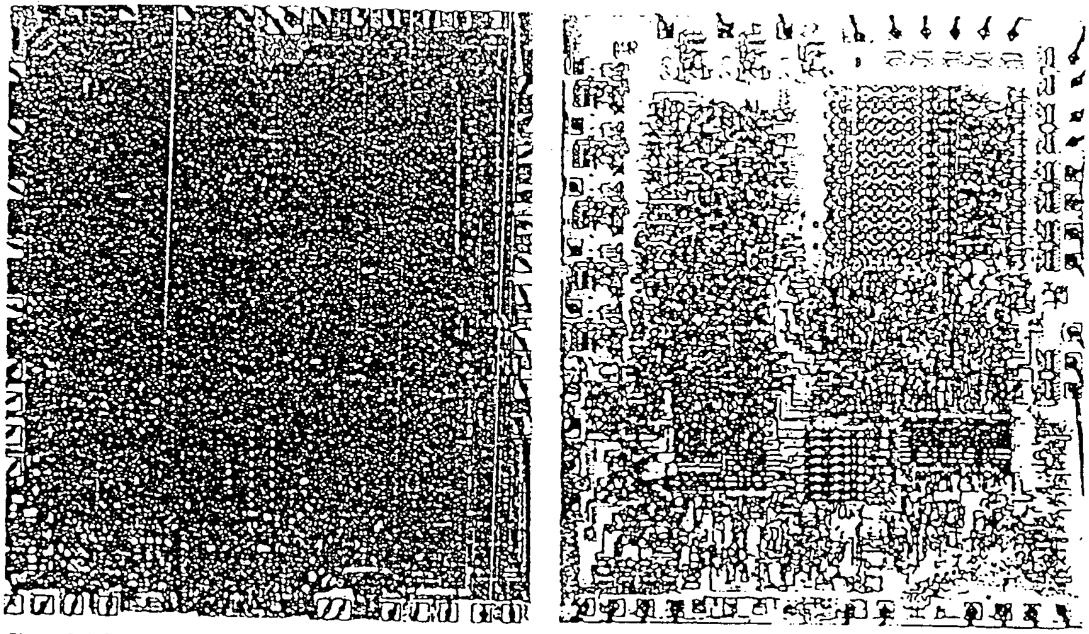


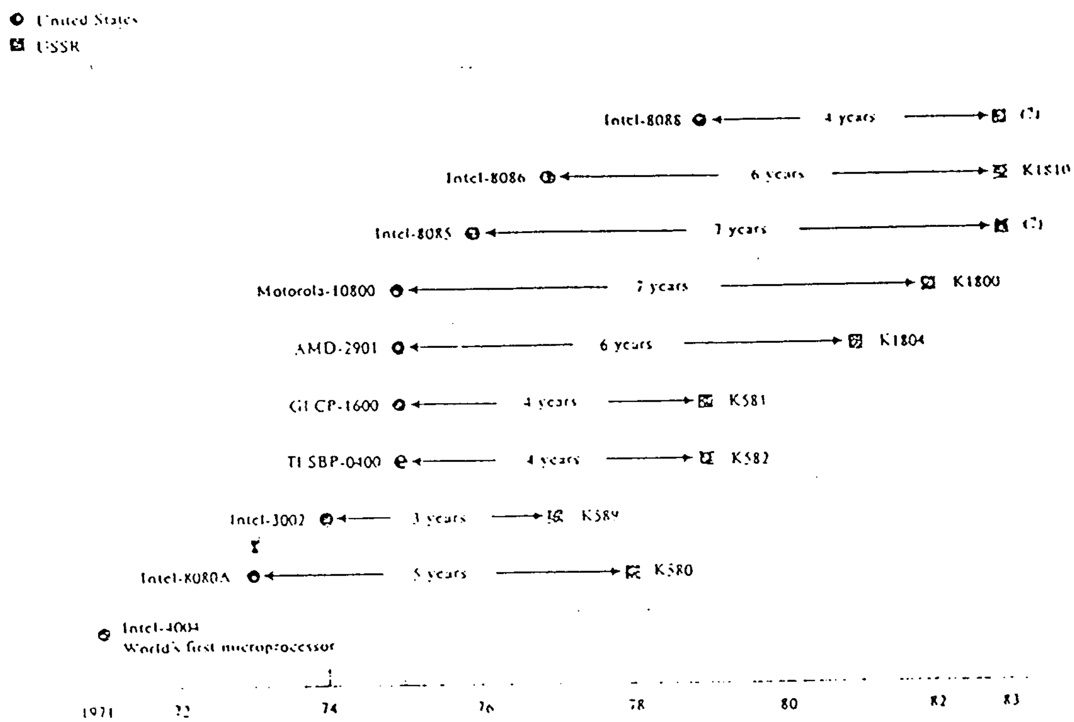
Figure 2. US Intel-8080A Microprocessor and Soviet K580. The K580 is a close, but not exact, physical copy.

Soviet microelectronic fabrication capabilities during the 1970s and early 1980s. Although single-chip microprocessors are cheaper, smaller, and more reliable, they also place more-stringent demands than do multichip microprocessors on the production equipment and the overall fabrication process. The Soviets' deficiencies in the production of semiconductor devices would also explain their usage of bit-slice architectures in metal oxide semiconductor (MOS) technologies—something that is not done in the West or Japan, because it is simply not efficient or cost effective.

We believe that all of the Soviet microprocessors listed in table 1 are in at least limited production. A US market analysis firm estimated that over 60 million microprocessors were shipped by companies in the non-Communist world during 1983. On the basis of fragmentary information, we suspect that the production volume of Soviet microprocessors lags this figure by two to three orders of magnitude. Ironically, low production volumes of microelectronic devices may hinder advances in Soviet microelectronic production technology. Major US manufacturers have attributed a significant portion of their high yield and production technology advances to their very large production volume, which quickly exposes the manufacturing processes that are the leading causes of rejection.

There are reflecting Soviet interest in or development of microprocessor applications for their military. We do not have information at this time that a Soviet microprocessor is currently deployed in or designed into any specific Soviet military system. There is a great potential for using small fast microprocessors with low power requirements in military applications, and we believe that it is simply a matter of time before we obtain firm evidence that the Soviets are so using them.

Figure 3
Soviet Copies of US Microprocessors, 1971-83



Internal Memory Technology

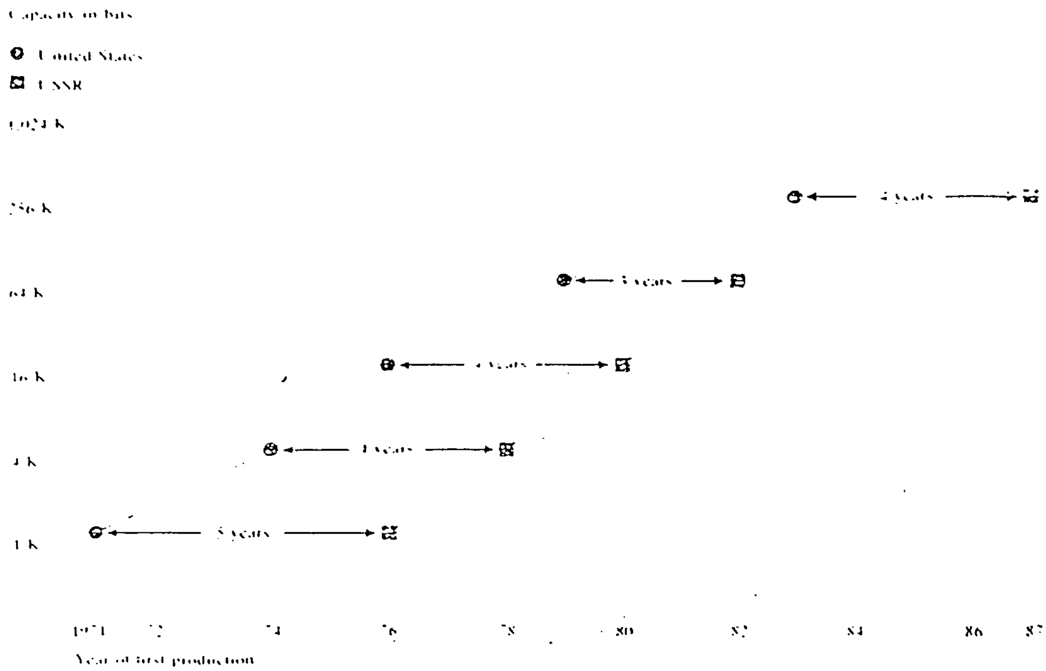
Semiconductor Memories

The Soviets are three to five years behind the United States in semiconductor random-access memory (RAM) technology (figure 4), but when production capability and quality are considered we assess that the US lead can be extended by at least several more years. The Soviets' literature indicates that they are even further behind the United States in read-only memory (ROM) technologies, including programmable ROMs (PROMs) and erasable PROMs (EPROMs)

Over 50 semiconductor RAMs and over 50 ROM-type memory devices, most in more than one version, have been identified in Soviet catalogs and open literature. As with their microprocessors, the Soviets have spread their semiconductor memories across a variety of technologies, including low-[redacted] CMOS and high-speed emitter-coupled logic

[redacted] the Soviets began using small-capacity semiconductor RAMs in the late 1970s. There were ". . . adequate supplies of acceptable quality . . ." of 16-Kbit (1K = 1,024) RAMs in mid-1980. [redacted]. The

Figure 4
Semiconductor Memory Technology: United States Versus USSR, 1971-87*

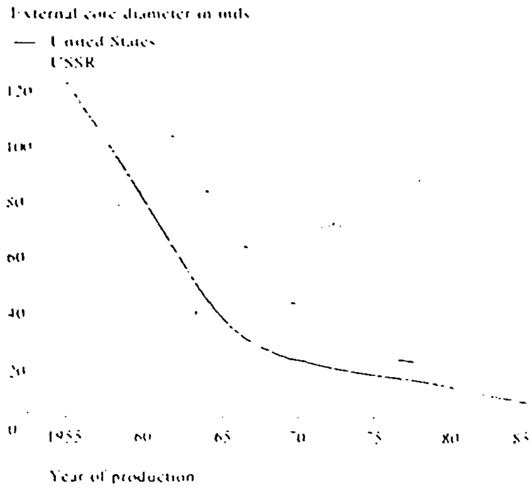


Soviets probably had a 64-Kbit dynamic RAM in sample production by the early 1980s. In the United States and Japan, the 256-Kbit RAM is now being produced and prototypes of a 1-Mbit RAM have been made with improved photolithographic techniques instead of X-ray or E-beam lithography, contrary to what was frequently forecast in the technical literature. We expect that the Soviets will not put 256-Kbit RAMs into production until the late 1980s.

Magnetic Cores

Magnetic core memories have several features that are attractive to the military. First, magnetic core is a random access memory, the time to retrieve data is the same no matter where the data are stored in the memory. Second, core memories are nonvolatile; when power is disconnected or interrupted, core memories do not lose their information as many semiconductor memories do. Third, core memories are available in systems that have been hardened against nuclear radiation. Fourth, cores require no power in order to retain data in a standby mode. On the other side of the ledger, core memories require much more physical space and more power to operate, and cost much

Figure 5
Magnetic Core Memory Technology:
United States Versus USSR, 1955-85



more, than a semiconductor memory of like capacity. The trend in US military applications is toward semiconductor memories, with backup or shadow memories in critical applications.

Magnetic core technology is frequently gauged by the external diameter of the basic ferrite toroid [a]—the smaller the diameter, the greater the memory capacity per unit of area. Using this core diameter as a figure of merit, we find that the Soviets lag the United States in magnetic core technology by about five years (figure 5). We believe that this lead was maintained during the 1970s, even though the emphasis on the development of magnetic cores in the United States decreased as fast as the popularity and usage of semiconductor memories increased.

Plated-Wire Memories

A plated-wire memory is a random-access memory that consists of a plane of parallel wires electroplated with a thin film of magnetic material and overlaid by a set of transverse word lines. One bit of information can be stored at each intersection of these wires. Plated-wire memories have several characteristics that are attractive to military-system designers. Plated-wire memories provide protection against electromagnetic pulse (EMP) and have good radiation hardening properties. These memories are nonvolatile and can be made with a nondestructive readout (NRDO), thus providing additional protection for the stored data. However, plated-wire memories are extremely expensive—on the order of $1.00 per bit, whereas most other memory technologies are just pennies per bit or less.

In the United States, plated-wire memories have been developed for the guidance computer in the Polaris and Poseidon missiles. Plated-wire memories have been used also in the US Minuteman weapon system computer as well as briefly in a few US and Japanese commercial computers. In a 1982 list of US space computers being used by the National Aeronautics and Space Administration, nine of 17 systems used plated wire for their main memory. It is reasonable to expect that the Soviets would also use their plated-wire systems in ruggedized mobile applications with modest memory capacity requirements.

[a] The small, doughnut shaped magnetic dev... that holds, or stores, the data in a magnetic core memory area.

Minicomputers

The Soviets are four to six years behind the United States in 16-bit minicomputer technology. They may realize their first 32-bit superminicomputer by the end of 1985.

Following along the lines of the successful CEMA cooperative program in mainframe computers, the Council of Principal Constructors of Minicomputer Systems was created in 1974 in an attempt to coordinate minicomputer development within CEMA countries. The Soviet Union assumed the major role and developed four new minicomputers: the SM-1, -2, -3, and -4. This group, and possibly the SM-5, constitutes the first generation of SM minicomputers, SM-I (table 2).

The SM-1 and the SM-2 are modeled after the Hewlett-Packard HP-2100 architecture and are primarily for process and production control as well as real-time applications. The SM-2 is essentially an SM-1 with an improved central processing unit and more main memory. These two machines are unusual examples of Soviet plagiarism in that the resulting Soviet systems are not compatible with HP software. The Impuls Scientific Production Association developed the SM-1 and the SM-2; the SM-1 is produced at the Ministry of Instrument Making, Automation Equipment, and Control Systems (Minpribor) plant in Orel, and the SM-2 is produced by the Impuls association in Severodonetsk. Impuls is currently promoting modernized versions called the SM-1M and the SM-2M. The great majority of the publicity has been given to the SM-2M, which has been identified in a Soviet brochure with 25 different configurations including 22 dual-processor versions. In an open-source article, the deputy general director of Impuls states that different computer architectures will be used to overcome the "disadvantages" of traditional minicomputers such as the SM-2. He then describes the SM-1210 multiprocessor and the PS-3000 array processor, which Impuls may now have in production. As in the United States, the trend in the USSR is toward multiprocessor systems to avoid the throughput bottleneck caused by sequential processing on a uniprocessor system

In 1981 the USSR State Prize in Technology was awarded to 10 Soviet managers and engineers for having developed the SM-3 and SM-4 minicomputers and for having put these machines into serial production. The SM-3 and the SM-4 are modeled after the low end of the US Digital Equipment Corporation (DEC) PDP-11 minicomputer line and are intended primarily for small scientific and engineering applications. The SM-3 and SM-4 can execute DEC software without modification. The newer SM-4 with 256 Kbytes of main memory can execute DEC's RSX-11M operating system. The popular UNIX operating system, which was originally writte . . . United States for DEC PDP-11 minicompu . rs, also is known to be available in the USSR. Copies of PDP-11 minicomputers a . . o being produced in Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Romania, and Cuba.

Being copies of US systems, the Soviet SM systems provide a good basis for a comparison of 16-bit minicomputer technology. According to the year of first installation for the SM-1 through the SM-5 (figure 6), the Soviets are about four to six years behind the United States in general purpose 16-bit minicomputer technology. However, if we were to go by the quality and quantity of production, several more years could be added to this US lead. In 1979 Soviet officials made an admission [redacted] that they were having "yield and reliability" problems in their SM production line. They hoped to resolve these problems and to be producing 1,000 SM units per year by 1982, the bulk of which were to be SM-3 and SM-4 models. In the fall of 1981 [redacted] 3,500 SM-4 units would be produced that year. Even the more optimistic forecast is quite modest, considering that the SM is the primary minicomputer series for the entire Soviet Union. By comparison, after about a decade of production, DEC had almost 100,000 PDP-11 minicomputers installed worldwide by the end of 1981. In late 1982 [redacted] the SM-4 would be replaced by the newer SM-1420—also called the SM-5—minicomputer in 1983 (figure 7).

In the spring of 1983 [redacted] the Ministry of Electronics Industry (MEP) has decided to develop, manufacture, and sell its own line of minicomputers in the Soviet

Table 2
Characteristics of Soviet SM-I Minicomputers

Characteristic	SM-1	SM-2	SM-3	SM-4	SM-5
Average speed in kops [a]	130	155	135	215	400
Main memory, Kwords	4 to 32	32 to 128	16 to 28	16 to 124	128 to 2,097
Instruction time in microseconds					
Fixed point					
Addition	2.5	2.2	5	1.2	--
Multiplication	36.6 [b]	10	16 [c]	10.8	-
Division	--	17	19.5 [c]	12.7	--
Floating point					
Addition	33	18 to 40	320 [c]	28.7	--
Multiplication	110 [b]	23	410 [c]	34	-
Division	—	40	...	52	--

[a] These speeds, except for the SM-5, whose speed is estimated, were cited in Soviet literature and seem to be more realistic than the 250 kops for the SM-1 and 800 kops for the SM-4 which are frequently quoted in open literature.
[b] Probably implemented in software.
[c] Implemented in software.

kops: 1,000 operations per second.
Kwords: 1,024 words with 16 data bits per word.
-- Not known.

Note: Soviet open literature has placed the SM-5 in the SM-I family; however, a Soviet export brochure (circa 1983) claims that the SM-5 is in the SM-II family of minicomputers.

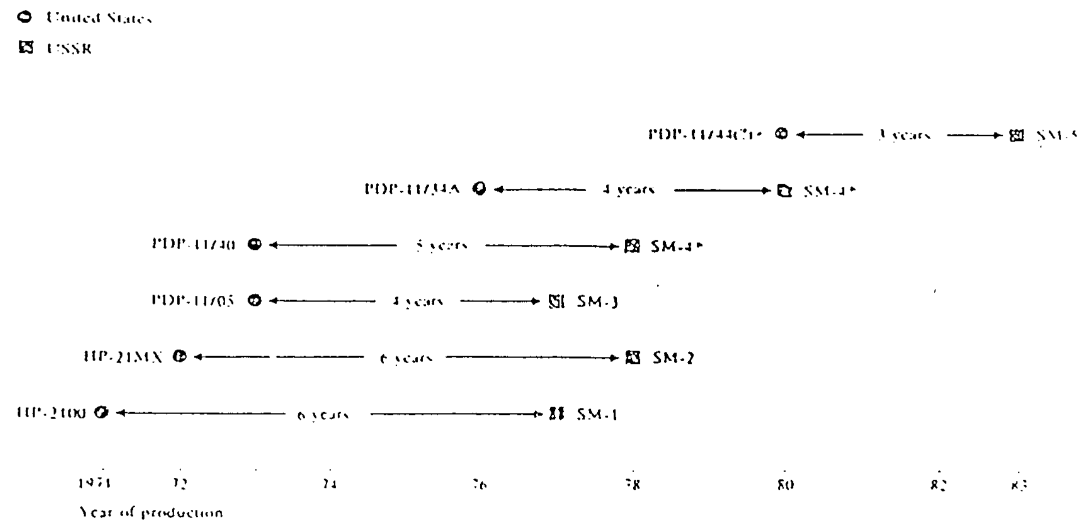
Union. The Soviet official said that MEP had made "exact replicas of the DEC minicomputers." We do not know at this time whether the Soviet official was referring to DEC's 16-bit PDP-11 minicomputer line or to its newer 32-bit VAX superminicomputer family. Minpribor has been the primary manufacturer of minicomputers in the USSR to date. If MEP begins producing minicomputers, serious interministerial conflicts could easily arise between MEP and Minpribor, because MEP is also the primary (possibly the sole) source of microelectronic components for Minpribor minicomputers.

At an international conference in 1981, [ ] stated that the Soviets were developing a minicomputer that would be compatible with software for DEC's VAX superminicomputer. Although information is very sparse, we believe, on the basis of past Soviet accomplishments, that the Soviets will produce their first 32-bit minicomputer by the end of 1985, and that this machine will be compatible with DEC VAX software. DEC's first VAX, the 11/780, introduced in 1978, is a complex machine requiring 23 printed-circuit boards for its central processor. We believe that the Soviets will have an easier time copying the DEC VAX 11/750, which, with its four-board processor, is much less complicated than the 11/780.

Nairi-4 Minicomputer

Although the SM series has no known special versions for military applications, at least one civilian general purpose minicomputer, the Nairi-4, has been modified

Figure 6
Soviet Copies of US Minicomputers



a May be a copy of PDP-11/44, less the cache memory.

b The SM-4 is known to have been a copy of DEC's PDP-11/34A since at least the early 1980s. The original SM-4 may have been a copy of the PDP-11/40.

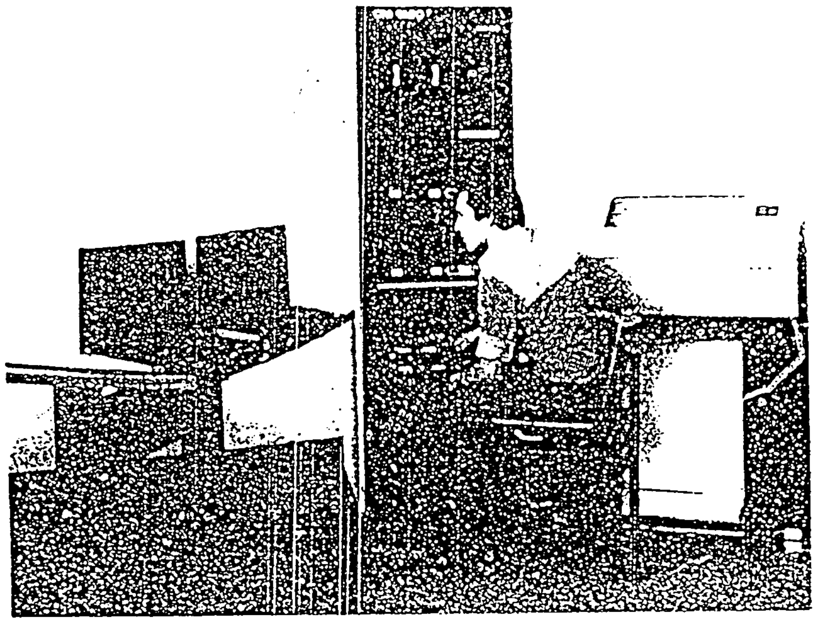
for such use. [ ] reported that a special Nairi-4 with gold contacts was being built in 1977 for the Soviet military. Indeed, the Nairi-4 has several other conspicuous characteristics that would make it useful for many fixed land-based military applications. One is the use of plated wire to provide a nonvolatile main memory having a nondestructive readout. Plated-wire memory also has good radiation-resistance characteristics

The Nairi-4 minicomputer has used a magnetic drum for bulk storage. Magnetic drums were used in many early automated subsystems for the US military, but they have largely been replaced by fixed-head magnetic disk systems, by core memories, and, more recently, by semiconductor memories. The physical size of the Nairi-4 computer would limit it to applications at fixed ground-based sites or on large mobile platforms. A new version called the Nairi-41 was briefly mentioned several times in the open literature in 1982. A nonoperational Nairi-41 was displayed at the 1983 Leipzig Spring Fair (figure 8). According to a technical brochure, the Nairi-41 has a 540-nanosecond cycle time for register-register instructions and up to 256 Kbytes of semiconductor memory

PS-2000 Array Processor

The PS-2000 is a microprocessor-based array processor system developed in the late 1970s at the Control Problems Institute, Moscow, in coordination with the Impuls Scientific Production Association in Severodonetsk (figure 9). With Impuls' involvement, it is likely that the PS-2000 will operate only with the SM-2 and the SM-2M minicomputers. Soviet literature states that the PS-2000 consists of eight, 16, 32,

Figure 7. Soviet SM-1420, SM-5 Minicomputer



or 64 "processing elements" that can be dynamically rearranged. In Soviet literature, "processing element" usually refers to a bit-slice microprocessor component. The word lengths in the PS-2000 (12, 16, or 24 bits) suggest a 2-bit or a 4-bit device as the basic building block. This hypothesis, in conjunction with the operational speed of the PS-2000 and the time at which it was developed, suggests that the K589 or the K584 microprocessor is used in this machine

A Soviet article announced that the PS-2000 was able to halve the computation time of a modeling problem executed on a uniprocessor minicomputer probably an SM-2. This increase in performance seems more realistic than the extraordinarily high speeds claimed in the Soviet press since 1981. Even so, the PS-2000 is important because it reflects the Soviets' interest and progress in array processor technolog

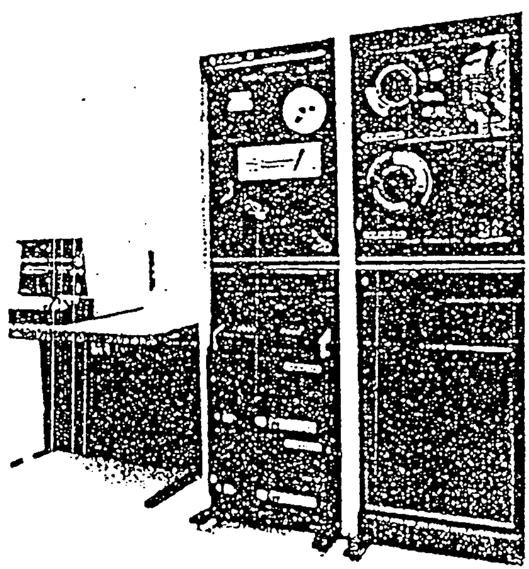
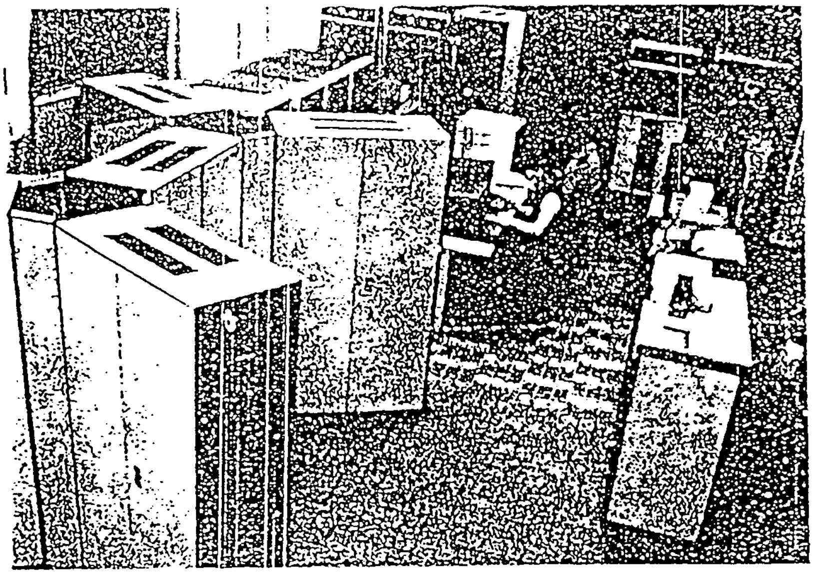


Figure 8. Soviet Nairi-41 Minicompute

General Purpose Mainframes

The term "mainframe," which originally referred to the central processing unit and sometimes the main memory, is now generally used to describe a class of computers exemplified by the IBM large computer line. Although far surpassed in numbers by the

Figure 9. Soviet PS 2000 Array Processor



microcomputers and minicomputers sold today, the mainframe class still accounts for over 50 percent of the dollar volume in computer sales worldwide.

Historically the Soviets, together with their CEMA partners, have placed great emphasis on, and have invested significant resources in, the development and production of their series of software-compatible mainframes known as the Unified System (ES: Edinaya Sistema) or as the Series (Ryad). We know, from a variety of sources, that the Soviets patterned the first Ryad family after the highly successful IBM System/360 line; Ryad-2 developers used the IBM System/370 as a design basis. The adoption of a proven commercial system was a low-risk decision enabling the Soviets to circumvent much of the R&D costs associated with the development of new computers as well as most of the software development costs. In both Ryad-1 and Ryad-2, Soviet models were first installed approximately seven to eight years after their IBM counterpart (figure 10). Several improved versions of the Ryad-1 series were put into serial production during the 1970s in Bulgaria (ES-1022B) and the USSR (ES-1022, -1033, and -1052). Other Ryad-1 machines included the Czechoslovak ES 1021, which was not compatible with IBM System/360 software, and the Polish ES-1032 (o r

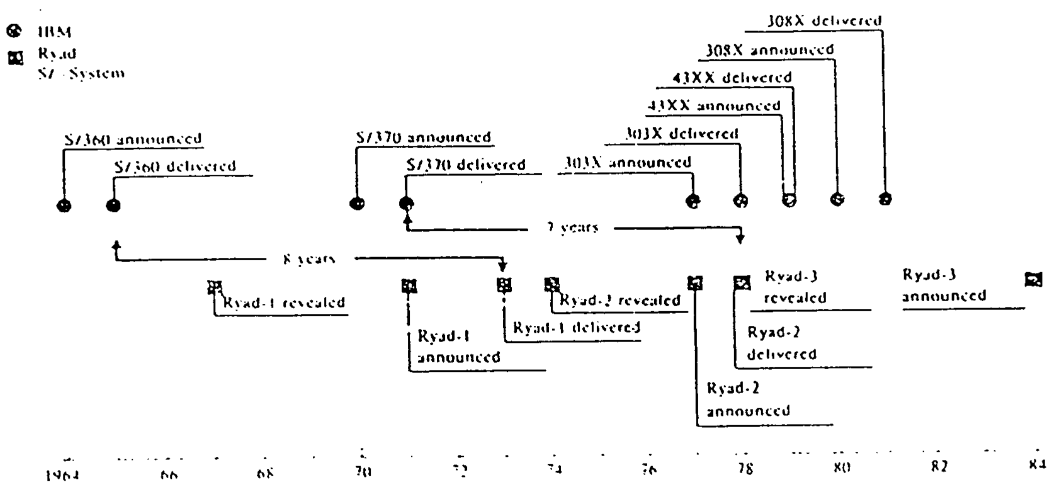
The Ryad-2 family initially consisted of five members that entered production in the late 1970s—the ES-1025 (Czechoslovakia), ES-1035 (USSR, Bulgaria), ES-1045 (USSR), ES-1055 (GDR), and ES-1060 (USSR)—plus a sixth, the ES-1065 (USSR), which was in production by 1982.[4] The ES-1060 slipped from the Ryad-1 program because of technological problems including overheating of its fast integrated circuit logic, and is now considered part of the Ryad-2 series (figure 11). Three improved Ryad-2 models were in or nearing production in 1984: the Czechoslovak ES 1026, the East German ES 1056, and the Soviet ES-1061.

Figure 12 shows a performance comparison of Ryad-2 mainframes and some IBM System/370 computers. The values for the speed (operations per second[5] (ops)) and the memory size are taken from Soviet and Western literature. Although lagging US mainframe

[4] Hungary produces the ES-1015 minicomputer, which is also listed as a Ryad [illegible] line but is not compatible with IBM System/370 software.

[5] Operations per second and other single measures of effectiveness are an oversimplification, as system performance is actually a complex function of many factors, especially the specific application.

Figure 10
Timetable: IBM and Soviet Ryad Mainframes, 1964-84



technology, the Ryad-2 family still offers the Soviets and their allies a fairly wide range of computing capability. Table 3 shows some Ryad-2 technical specifications. We believe that the Soviets are producing Ryad-2 machines in sufficient numbers to satisfy at least priority users. However, when one considers quantity, quality, and performance/cost ratios realized by the general-user population, the Soviets are about four years further behind the United States than the seven to eight years indicated by the dates of first delivery

Based on open literature, figure 13 illustrates those IBM system software products that we believe are in use, with some name changes, in the Soviet Bloc. Open literature suggests that the Soviets are using most IBM system software products released prior to 1978; the most notable exception is Multiple Virtual Storage (MVS

In November 1981 the Soviets announced a new Ryad mainframe, the ES-1036; a scale model of this computer was exhibited at the Budapest Spring Technical Fair in 1983. A Soviet export brochure [ ] in 1984 states that the ES-1036 represents the first stage in developing Ryad-3 computers. According to open literature, the ES-1036 can execute up to 400,000 operations per second, has a main memory of 2 to 4 megabytes, has an 8-kilobyte buffer (or cache) memory, and will have a virtual machine operating system. We suspect that Ryad-3 computers will be copies of the IBM 43XX and 303X families. In the spring of 1982, the Soviets also briefly mentioned that they were developing a prototype ES-1061 computer, which will be a modernized version of the ES-1060. The ES-1061 was to enter serial production in 1984; according to Soviet open literature. Other new Ryad designators include:

- Hungary: ES-1016, -1017.
- Czechoslovakia: ES-1026, -1027.
- Poland and/or USSR: ES-1034, -1047.
- GDR: ES-1056, -1057.
- USSR: ES-1046, -1066, -1067, -1077, -1087.

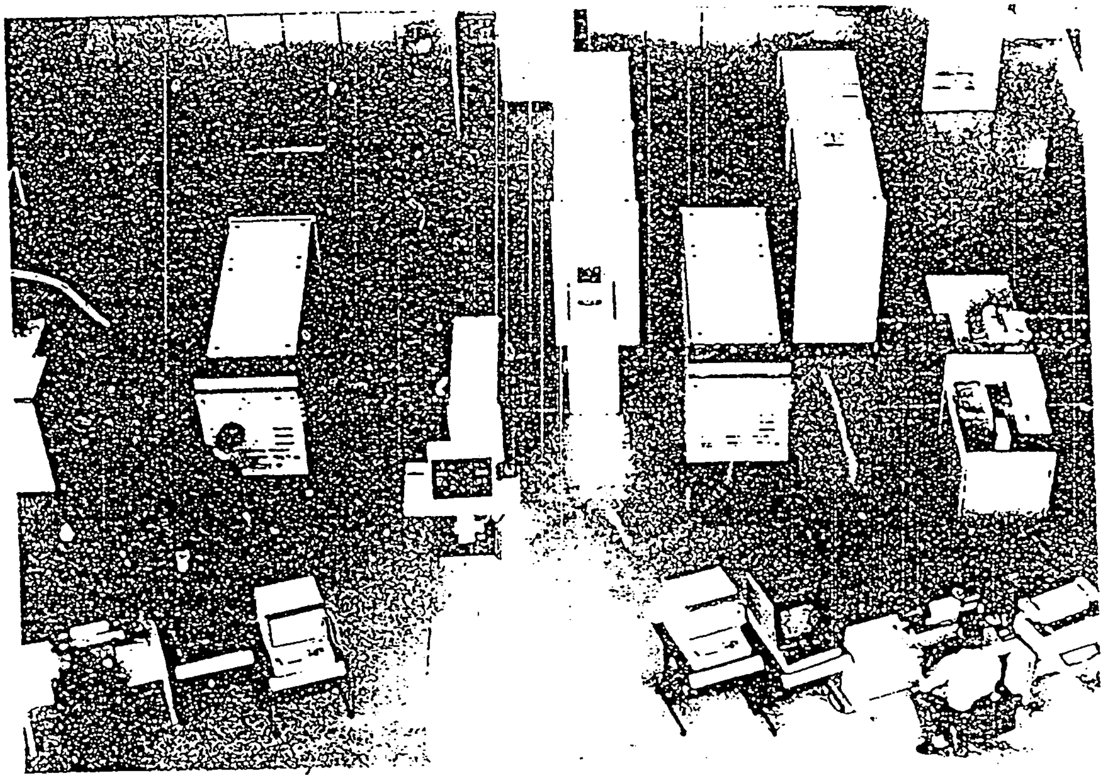


Figure 11. Soviet ES-1060 Twin Computer Comple

We believe that at least the ES-1036 and -1061 were in production in 1984, and that most of the machines listed above will enter production over the next two to three years

Large Scientific Computers

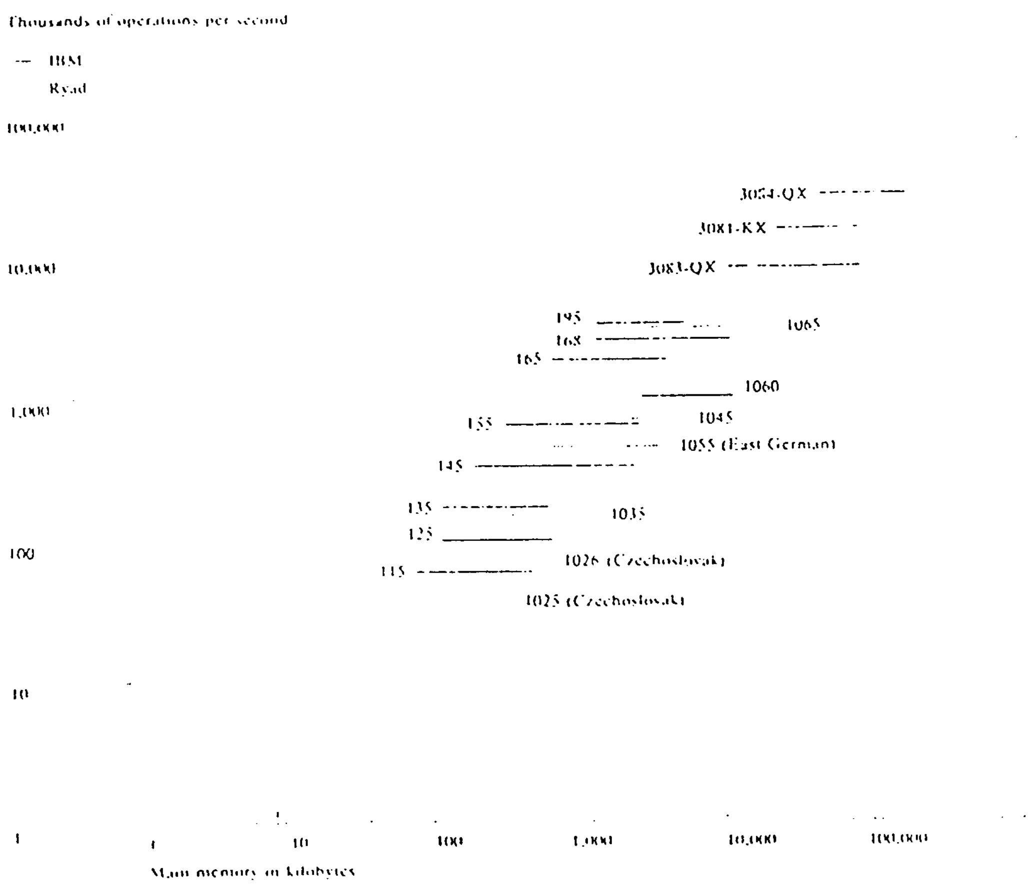
Status

We believe that the Soviets will not develop their first digital electronic supercomputer until 1985 at the earliest. T[illegible] odern supercomputer can restrict [illegible] advan[illegible] R&D programs as well as civil and military applications, such as energy exploration and strategic missile defense, that require a huge number of computation

Elbrus Computer

The USSR does not have a supercomputer in a class with the US Cray-1 or Cyber-205. The machine most likely to become the first Soviet supercomputer will probably come from the Elbrus project at the Institute for Precision Mechanics and Computer Technology (ITMiVT) in Moscow. The Elbrus-1 multiprocessor computer was created and fostered during the 1970s by V. S. Burtsev, the director of ITMiVT. The Elbrus-1 system employs a tagged architecture with a stack organization and an addressing structure similar to those of the Burroughs B-6700 system first delivered in 1970, in the United States. However, Elbrus-1 is much more ambitious in that it reportedly has from

Figure 12
Mainframe Performance: United States Versus USSR



one to 10 central processing units (CPUs) operating asynchronously [7] with up to four input/output processors and 32 memory modules interconnected through a series of crossbar switches (figure 14). In 1982 [ ] stated that "all" of the Elbrus-1 computers of which he was aware are single-processor models except one machine that has two CPUs. We suspect that this small number of processors in Elbrus computers being delivered may be due to the lack of a generalized operating system or to troubles with such

[7] An asynchronous multiprocessor assigns tasks to different processors using a set of indicators to designate which processors are free and which are busy. Typically, a processor will operate on a task until it has completed the task or until it is interrupted by the system.

Table 3
Technical Specifications for Soviet Ryad-2
Mainframe Computers

Model	ES-1025	ES-1035	ES-1045	ES-1055	ES-1060	ES-1061	ES-1065
Estimated date of first delivery	1980	1977	1979	1979	1978	1984	1982
Production plant	Cakovice	Minsk-Brest/Sofia	Kazan	Dresden	Minsk	Minsk	Minsk
Country	Czechoslovakia	USSR/Bulgaria	USSR	GDR	USSR	USSR	USSR
Processor							
Speed (*1,000 operations/second*)	35	160	650	450	1,000	2,000	3,000
Fixed add time (*μs*)	5-13	4.5	0.7-0.85	0.6-2.7	0.25-0.30	•	0.12
Fixed multiply time (*μs*)	95-220	23	2.8-3.4	3.4-5.[illegible]	1.5-1.8	•	0.6
Floating point add time (*μs*)	50.0	95.0	1.9	1.6	0.80	•	0.24
Floating point multiply time (*μs*)	9.7	19.8	2.8	2.7	2.3	•	0.30
Main memory							
Capacity (*Mbytes*)	0.1-0.5	0.25-1	1-4	0.25-4	0.5-8	1-8	2-16
Cycle time (*ns*)	1,250	800	840	1,140	800	•	•
Access time (*ns*)	500	5[illegible]0	650	•	•	•	870
Bytes fetched per cycle	8	8	8	8	8	•	•
Microprogram control memory							
Capacity (*Kbytes*)	•	48RW	7RO + 1RW	8	48	•	•
Cycle time (*ns*)	380	200	120-380	135	•	•	•
Access time (*ns*)	•	•	•	140	65	•	•
Length of word accessed (*bytes*)	•	•	8	8	16	•	•
Cache (scratch pad) memory							
Capacity (*Kbytes*)	X	X	8	X	8	•	32
Cycle time (*ns*)	X	X	120	X	135	•	•
Access time (*ns*)	X	X	72	X	65	•	•
Length of word accessed (*bytes*)	X	X	8	X	8	•	•
Channels							
Maximum number	2	5	6	5	7	8	•
Total transfer rate (*kbytes/s*)	•	1,200	5,000	6,000	9,000	•	15,000
Selector channels							
Maximum number	1	4	(5)*	(4)*	(6)*	•	(16)
Transfer rate (*kbytes/s*)	33	740	(1,500)*	(1,500)*	(1,300)*	•	(1,500)
Byte-multiplex channels							
Maximum number	1	1	2	2	2	•	•
Transfer rate (*kbytes/s*)	24	40-280*	40-160*	40-1,500*	110-670*	•	110-[illegible]

Table 3
Technical Specifications for Soviet Ryad-2
Mainframe Computers (continued)

Model	ES-1025	ES-1035	ES-1045	ES-1055	ES-1060	ES-1061	ES-1065
Block-multiplex channels							
Maximum number	X	X	5	4	6	[a]	[a]
Transfer rate (*kbytes/s*)	X	X	1,500	500-3,000 [c]	[a]	[a]	3,000
Class, per State Standard GOST 16325-76	II	III	III	IV	V	V	V

[a] Data not available.
[b] On these models the block-multiplex channel can be operated as a selector channel.
[c] Speed varies depending on numbers and types of operational channels in system.

μs = microsecond = 10^{-6} second; ns = nanosecond = 10^{-9} second.
Byte = 8 bits (8 binary digits); Kbyte = 1,024 bytes; kbyte = 1,000 bytes. Mbyte = 1,048,576 bytes.
X = equipment not available on model; RW = read/write; RO = read only.

Note: Specifications for Ryad computers vary, sometimes greatly, in CEMA literature. None of the values in this table have been confirmed by direct access to a Ryad-2 computer, and we believe that they tend to be overly optimistic. Ryad-2 systems introduced in the late 1970s had ferrite-core main memories; these were upgraded to semiconductor memories in the early 1980s. Operational parameters for semiconductor devices are used in this table. The performance of the ES-1065 is based upon a uniprocessor configuration.

The ES-1026, -1056, and -1061 are modernized Ryad-2 versions of the ES-1025, -1055M, and -1060, respectively.

an operating system for Elbrus-1 computers having more than two processors. By analogy, the first US commercial supercomputer, the Cray-1, initially was delivered in 1976 with only the most primitive software support for system management

Table 4 lists four Elbrus configurations identified as "standard" in a Soviet brochure. All of the throughput values are quite optimistic; and the maximum main memory capacity is modest relative to US state of the art. On the basis of comments by Soviet scientists and the size of the Elbrus machine, we estimate that between five and 10 Elbrus computers have been built each year since 1979. Cray Research Corporation in the United States delivered an average of seven Cray supercomputers each year between 1976 and 1984)

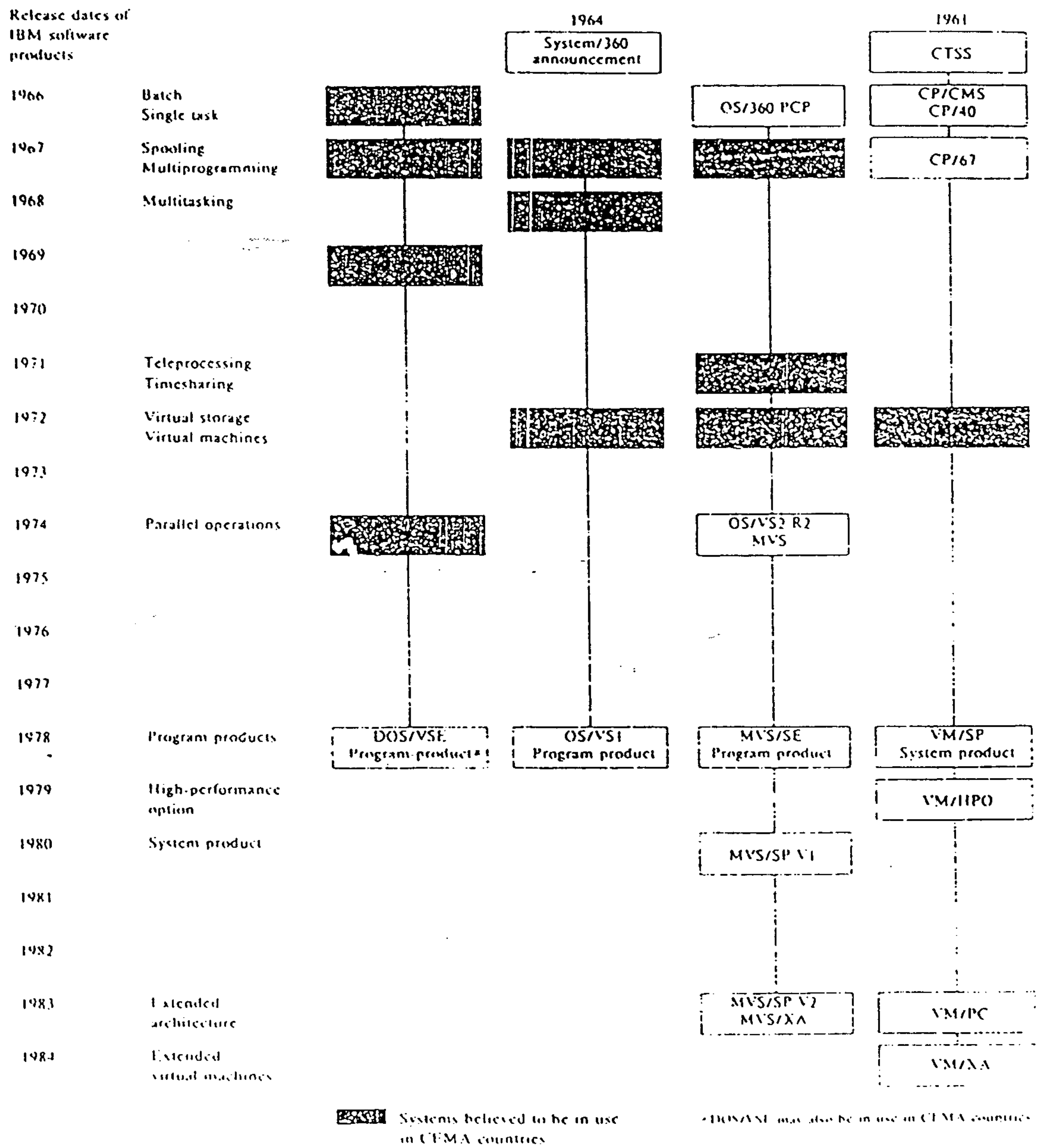
[ ] connecting the Elbrus computer with the Soviet military. [ ] Burtsev had said that there would be two versions of Elbrus: one for civilian use, and one for the military. According to Burtsev, the only difference between these two computers would be the method of testing. Ballistic missile defense is an application [ ] for the Elbrus computer. It was rumored in Soviet scientific circles around 1978 that an Elbrus was to be installed on an aircraft carrier.

A new model, Elbrus-2, has been under development at ITMiVT. According to Soviet literature, this machine will exceed 100 million operations per second. Elbrus-2 was mentioned as early as 1977, but we suspect that Burtsev has been busy debugging Elbrus-1 and is still trying to perfect an Elbrus-2 prototype. [ ] in September 1983 that no Elbrus-2 machines had been produced as of that date. If Elbrus-2 is realized, it will be, we expect, the Soviets' first entry into the supercomputer realm.

M-10 Computer

In May 1979 M. A. Kartsev published a description of a synchronous multiprocessor system called the M-10 that he had designed at the Institute of Electronic

Figure 13
IBM System Software in Use in CEMA Countries



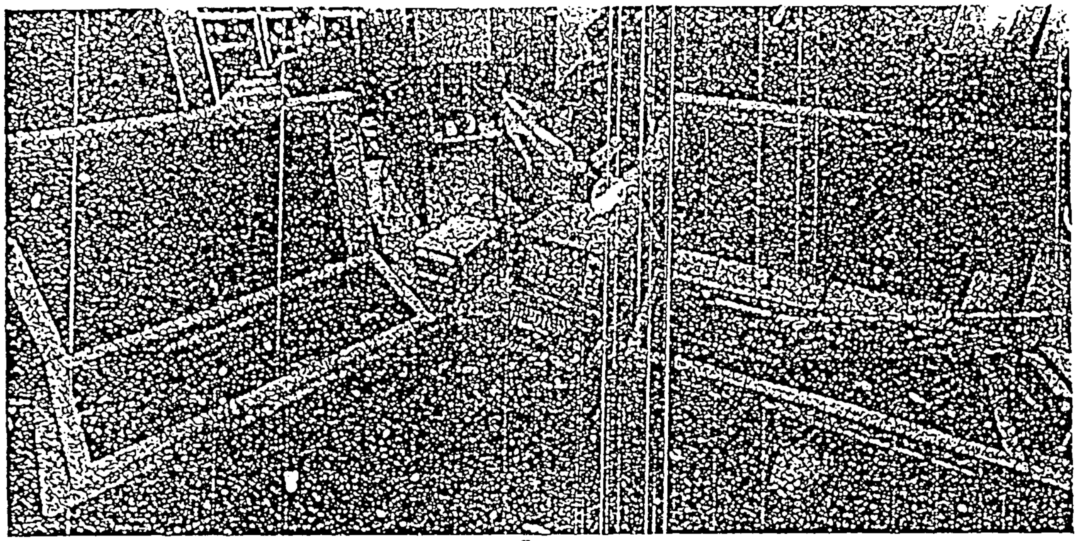


Figure 14. Soviet Elbrus-1 Computer Complex, Circa 1986

Table 4
"Standard" Soviet Elbrus-1
Configurations

Number of CPUs	1	2	4	10
Throughput in Mops	1.5	3.0	5.5	12.0
Storage capacity Kbytes	576	1,152	2,304	4,608
Memory blocks	1	2	4	8
Memory commutators	1	2	4	8
Input output processors	1	1	2	4
Data communication processors	(1)	1	2	16

CPU = central processing unit
Mops = millions of operations per second
Kbyte = 1,024 bytes = 8,192 bits
( ) = optional

Computers (ITCM) in Moscow. Kartsev said that up to seven M-10 computers can be joined together in a single synchronous complex. Another open source states that Ryad peripheral equipment can be used with the M-10. According to Kartsev, this 32-bits/word computer has an average speed of over 5 million operations per second.

Kartsev described the control unit of the M-10 as being able to dynamically adapt the number of processors under program control as a function of the word length. This approach is similar to a technique used in the US Illiac-IV supercomputer, which made it possible either to execute with 64 processors on word lengths of 64 bits or to use 128 processors on 32-bit words. Having these alternatives is useful in applications that are suited to parallel algorithms and have variable numerical range requirement.

Although the new Ryad-2 ES-1065 computer may be faster, the M-10 may have been the most powerful computer available in the Soviet Union during the late 1970s. Kartsev's lengthy association with classified military projects, especially air defense systems, makes the M-10 computer a reasonable benchmark

In a synchronous multiprocessor system, the processors operate in a lockstep manner usually timed to a worst-case operation. This procedure greatly reduces the management [illegible] associated with asynchronous systems but can lead to [illegible] short operation.

for Soviet military systems requiring such capabilities at fixed ground sites. Although Kartsev died in April 1983, we suspect that the design philosophy of this domineering personality is well entrenched at the institute that he directed. We expect that improvements and variations on the basic M-10 architecture will continue through the 1980s [redacted]

New Activity

[redacted] Ye. P. Velikhov, vice president of the USSR Academy of Sciences, stated in late 1983 that he was the focal point for an accelerated program on the development of supercomputers. This pronouncement is interesting because Burtsev's institute and the Elbrus program are under the control of the USSR Academy of Sciences. Until now, Burtsev seems to have had an autonomous reign in pursuit of his high-performance Elbrus computer. Many sectors of Soviet society, especially the military, are known to be anxious for a supercomputer [redacted] Velikhov's appointment as the focal point for managing a supercomputer program may be the first step in opening up the development of these machines to other organizations within the academy

Software

We estimate that, in general, the Soviets are five to 10 years behind the United States in the implementation of large multiuser and real-time software systems as well as in computer-aided techniques for various industries

There are numerous causes that contribute to the Soviet software lag. Some of the problems frequently cited by Soviets [redacted] are:

- The Soviet hardware lag.
- A belated appreciation of, and belated emphasis on, software.
- A poor or nonexistent vendor-user feedback loop in the USSR.
- Low pay for programmers relative to other technical personnel.
- Poor software development tools.
- A Soviet preoccupation with meeting quotas usually at the expense of quality control.
- Duplication of work due to the excessive compartmentalization of software routines written at many facilities

The number of experienced Soviet software programmers who also are cleared for classified projects may still be insufficient, thus probably leaving many military projects not completed on time

Software is one area where technology transfer from the West can help the Soviets close specific gaps with quantum jumps. Software programs are conveniently stored on relatively small media such as diskpacks, floppy disks, or magnetic tapes—or on solid state memory devices, which are even smaller. It is not just classified military software that is of interest to the Soviets; they also can use many commercial software programs to improve their industrial base or to implement military subsystems. Programs are available from thousands of commercial outlets in the non-Communist world. Thus, the United States has a major technology transfer problem. If the Soviets were able to obtain a microprocessor from the United States, a team of engineers and technicians would need from one to four years to reverse engineer the device. However, if the Soviets obtained just one copy of a software program, it would be a minor project for even a novice to turn out copies of this program immediately. With the increasing number of computers available to the Soviets that are functional equivalents of Western systems, we can expect the Soviets to continue, and probably to increase, their legal and illegal acquisition of Western software systems

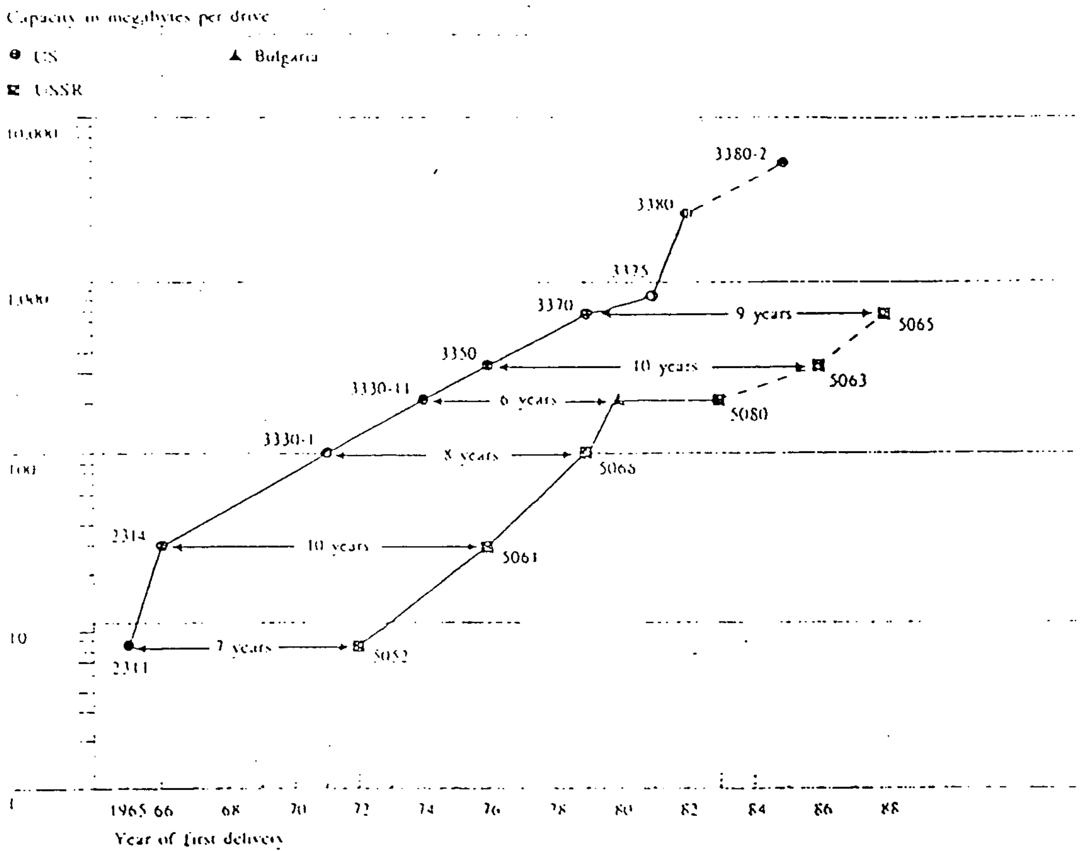
Peripherals

Magnetic Disks

The Soviets are about 10 years behind the United States in high-performance magnetic disk technology. This is one of their most serious computer hardware deficiencies and it is limiting the performance of their computer systems in many applications

Figure 15 illustrates the significant lead that the United States has in magnetic disk devices. The Soviets have announced their own 200-Mbyte disk drive (ES-5080)—about four years after the Bulgarians began low-volume production of comparable equipment (ES-5067) and about 10 years after the

Figure 15
Magnetic Disk Technology: United States Versus USSR, 1965-88



advent of IBM's 3330-11 counterpart. Bulgaria and the USSR have, however, been able to adopt some mechanical features of disk drives such as voice-coil motors, in a very timely fashion.

Although the low performance of Bulgarian and Soviet disk drives may impose some inconveniences now, Western engineers who integrate disk memories into computer systems believe that system performance above approximately 5 million operations per second would be severely hampered without further advances in disk technology. We believe that this situation is currently slowing or negating many applications on the Elbrus-1 multiprocessor system and will also hinder system performance on Ryad computers beyond the current top of the line, the ES-1065. [ ] that the Soviets are placing a high priority on obtaining know-how for the production of high-performance magnetic disks, probably via Western Europe or Japan. We believe that the Soviets also are seriously pursuing optical storage technology to alleviate this bottleneck in system performance

[ ] in early 1976 of the existence of a secret production plant for magnetic disks, possibly in Yaroslavl near Moscow. This plant reportedly produced a small number of high-quality magnetic disks solely for military use. Disks rejected as below military standards were destroyed to maintain secrecy, contrary to the usual practice of making them available to the civilian sector. Although we have no other evidence on this facility, the report is consistent with the basic policy of autarky for Soviet military programs. We consider it quite likely that such dedicated plants and pockets of expertise exist in the USSR for military applications—not only for disk technology but also for many other areas as well.

Magnetic Tapes

According to open literature [ ], the state of the art in magnetic tape drives in CEMA countries is 1,600-bits-per-inch (bpi) density with a data transfer rate of 189 kilobytes/second. IBM first released comparable equipment in 1966—an 18-year differential. A density of 6,250 bpi at 1.25 megabytes/second has been used in the United States since 1973. In March 1984, IBM announced its new high-performance magnetic tape drive, Model 3480, scheduled for delivery in 1985. The new 3480 will have a linear density of approximately 19,000 bpi, and a data transfer rate of 3.0 megabytes per second

Magnetic Bubbles

The Soviet Union possibly had a prototype 64-kbit * magnetic bubble memory (MBM) by 1980 and a 92-kbit prototype by 1981. By comparison, at the same time in the United States, 256-kbit MBMs were in production and 1-Mbit MBMs had been developed in the laboratory. MBM is an attractive storage technology for military applications because bubble memories exhibit very good performance in severe environments presenting extremes in dust, shock, heat, humidity, and radiation. Bubble memories are nonvolatile and have a reputation for high reliability relative to magnetic tape and disk equipment, which use electromechanical drives.

Technological and Military Implications

Today, the Soviets are trailing the United States in all aspects of electronic computer technology. If we include the quantity and quality of computer production, the US lead averages several years more than is indicated by just comparing the dates of first installation of functionally equivalent US and Soviet systems. As a result of the more advanced microelectronic technology and computer packaging techniques in the United States as well as the poor state of the art in Soviet peripheral equipment, we expect the US lead to increase by one to three years in all major electronic computer technologies by 1986

It is difficult to assess accurately the impact of the Soviets' lag in computer technology on their development of military systems, because of the sparsity of information on Soviet classified projects. It is rare that we receive reliable information when computer technology is hindering the development of a specific military program, such as we received in 1982 on the Soviet spaceplane project. However, at the high-performance end of computer technology, at least, we can speculate with reasonable confidence that military systems requiring high-throughput computers have been negated, delayed, or reduced in capability because of the Soviets' deficiency in this area. The impact would have been serious on large high-speed computational problems such as ballistic missile defense and on high-volume, high-speed data transfer applications such as real-time command, control, and communications systems requiring large data bases.

* MBM size has had a confusing evolution. Early MBM products used "bit" quite loosely, generally rounding a number to the closest 1,000 bits. Later products reverted to the "normal" powers-of-2 sizing for memories. In this MBM section, we use 1k as approximately equal to 1,000, 1K = 1,024, and 1M = 1,048,576

The Soviet scientific community has frequently expressed the opinion that the lack of a supercomputer is hampering many R&D projects, such as in computational physics and chemistr:

Apart from large scientific computers, the impact on military systems of the Soviet lag in computer technology is more difficult to judge; here the lack of information is more of a barrier. One may argue that the traditionally conservative design philosophy associated with Soviet military systems has not stressed their computer technology. Another possibility is that system requirements were kept modest in line with the Soviets' knowledge of the limitations of their computers. The truth is probably a mixture of both hypotheses

The Soviets tend to have less reliable computer systems than the United States or Japan because Soviet microelectronic components are less reliable and Soviet quality control is generally weaker. An example of how this reliability can affect a critical system is ICBM design. The Soviets use triply redundant computers on board their ICBMs [redacted] By contrast, the United States has used a single computer for navigation, guidance, and control functions on board its Minuteman and MX missiles. Ironically, today US contractors are reportedly going to redundant computer systems in many designs for increased reliability. For example, the F-16 flight control system and the navigation system on the Navstar satellite will both have triply redundant processors on board

The Soviets understand and appreciate the potential impact of high technology on weapon systems. Automation in the Soviet military sector will grow steadily and become an integral part of new system designs. We suspect that the Soviets during the 1980s are following the US approach from the 1970s; that is, expanding the use of mil-spec minicomputers for tactical military applications, while continuing to decrease reliance on special-purpose computers. As the reliability of Soviet microprocessors in severe environments improves, they will become more prevalent in Soviet tactical systems. Although automation in the Soviet military is expected to increase throughout the 1980s, the rate of increase is expected to be slower than in the United States, especially for mobile tactical systems. Over the next three years we expect that the Soviets:

- Will improve the quantity and quality of their semiconductor memory devices and microprocessors.
- Will phase in the production of Ryad-3 mainframes.
- Probably will build their first 32-bit minicomputer.
- Probably will build their first supercomputer.
- Will fall further behind in all areas of computer technology