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Total Soviet Computing Power

SUMMARY

We have estimated the total computing power of the Soviet Union for both general-purpose and scientific applications. In general-purpose computing, the USSR has the equivalent capacity of 50 to 500 Cray-1 supercomputers, or about 10% of the total US general-purpose computing power. If used for scientific computing, the Soviet computing inventory has a capacity equivalent to 1 to 10 Cray-1's, or about 1% of the total US scientific computing power.

To the Soviets, the acquisition of a single Western supercomputer would give a 10%-100% increase in total scientific computing power. Acquisition of a single VAX-11/780-class superminicomputer would give the Soviets only a tiny increase in total capability, roughly 0.01%, for either scientific or general-purpose computing. In terms of computational power per ruble spent, however, the Soviets certainly will find it highly attractive to acquire Western computers of all classes.

The large gap between the US and Soviet computing powers is a result of shortages of all classes of computers in the USSR. The Soviet shortfall is particularly large for scientific computing, due to the absence of true supercomputers in the USSR. Although smaller computers can be used for scientific computing, they are very inefficient for demanding tasks such as advanced weapons system design. The Soviet Union will probably not be ready to produce a large-scale scientific computer comparable to the Cray-1 before the early 1990s.

This memorandum was prepared by
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Comments and queries are welcome, and may be addressed to him or to

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GRAPHICAL SUMMARY OF RESULTS

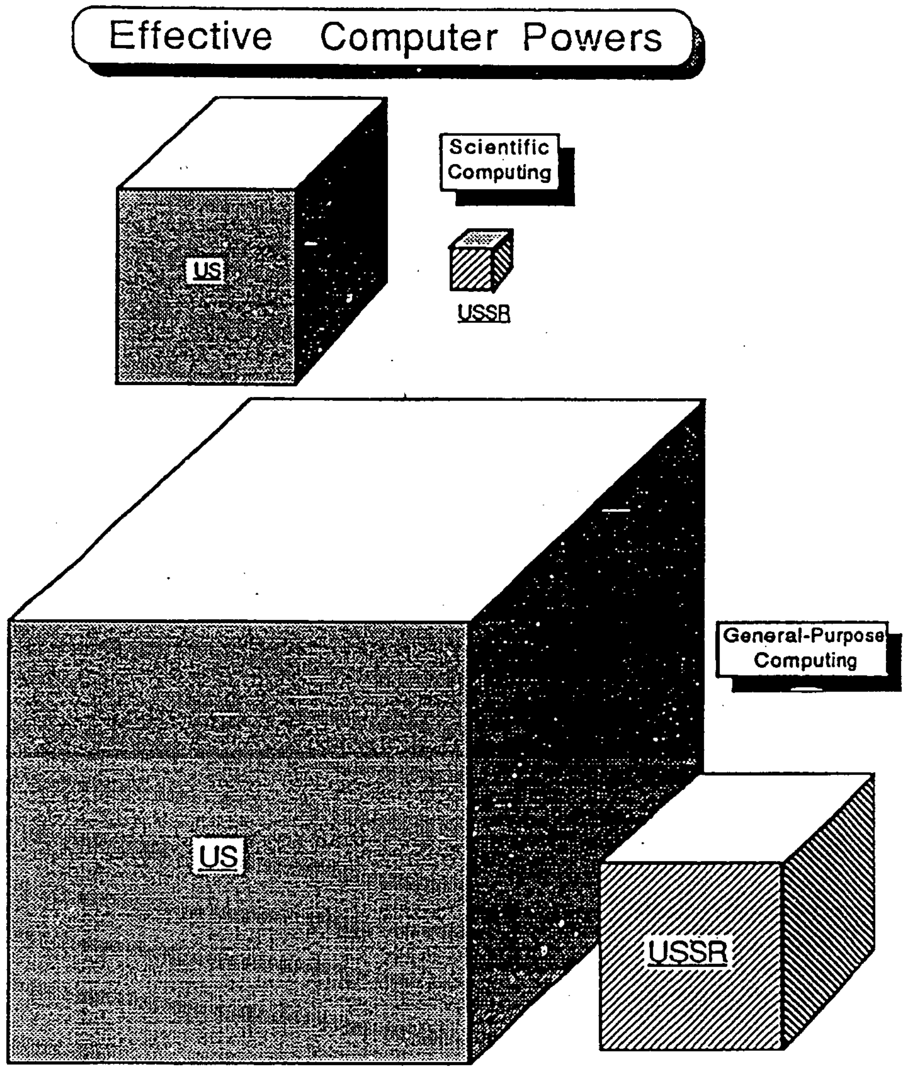

Figure 1: Volumes of the cubes represent the estimated relative computing powers of the US and the USSR, for scientific and for general-purpose computing. See text for definitions and details. (U)

Background

The total computing power of a nation places a fundamental limit on how much computationally intensive work that nation can do. Trade-offs are, of course, possible: a country can devote more computing power to nuclear weapons design and cryptography, for example, and less to weather forecasting and oil exploration. But the total computing power available limits this trading-off.

Quantitative estimates of the total computing power of the USSR are useful in many areas. In technology transfer it is important to know the effect of imports on computing power. For example, how does the sale of one VAX or 100,000 PCs affect Soviet computing resources? In weapons systems development, what computer power is available to designers of nuclear weapons, or aerodynamic vehicles, or armor penetrators, or low-radar-cross-section systems? How credible are Soviet contributions to the Nuclear Winter climatology debate? A knowledge of the total computing power in the USSR is a first step toward answering some of these questions.

Computers, and in particular high-performance scientific computers, are essential tools for many military and civilian applications. Typical large-scale scientific computing problems include modeling weather, nuclear bomb explosions, aerodynamic vehicle performance, and controlled thermonuclear fusion systems. Large-scale scientific computing is also central to seismic data analysis (for oil exploration), in quantum chemistry (for designing and understanding molecules), in astrophysics, molecular biology, and in many other advanced research fields. And there are numerous other computationally-intensive applications: signal processing, economic planning, battle management (for example, strategic ballistic missile defense), data base searching, cryptology, computer vision or image processing, and artificial intelligence research.

Units and Definitions

Total computing power is a broad, useful concept. It contains two important sub-classes: general-purpose computing power, and scientific computing power. General-purpose computing includes word processing, industrial record-keeping, process control, accounting, and so forth. The size of the computer system (above certain minimums) is frequently unimportant for general-purpose computing. Many users can effectively share one large system, or they can each have his or her own small system. In contrast, scientific computing tends to require large, powerful machines. Scientific computing problems typically cannot be broken down easily to be run on small computers without suffering grave penalties in speed or accuracy.

It is convenient to calculate the total computing power of a nation in Cray-1 Units. The Cray-1 is the archetypal supercomputer of the past decade. It has a processing data rate (PDR) of about 2,000 Mbits/s, a peak computational rate of about 200 Mflops (millions of floating-point arithmetic operations per second), and an average computing rate for realistic scientific problems of about 20 Mflops. A modern large general-purpose mainframe computer is about 0.1 of a Cray-1 Unit, and a typical superminicomputer (such as the VAX-11/780 from Digital Equipment Corp.) is about 0.01 of a Cray-1 Unit. An IBM-PC/AT or an Apple Macintosh is about 0.001 of a Cray-1 Unit, depending on the details of the programming language being used, the problem under attack, etc.

Relative Computer Powers

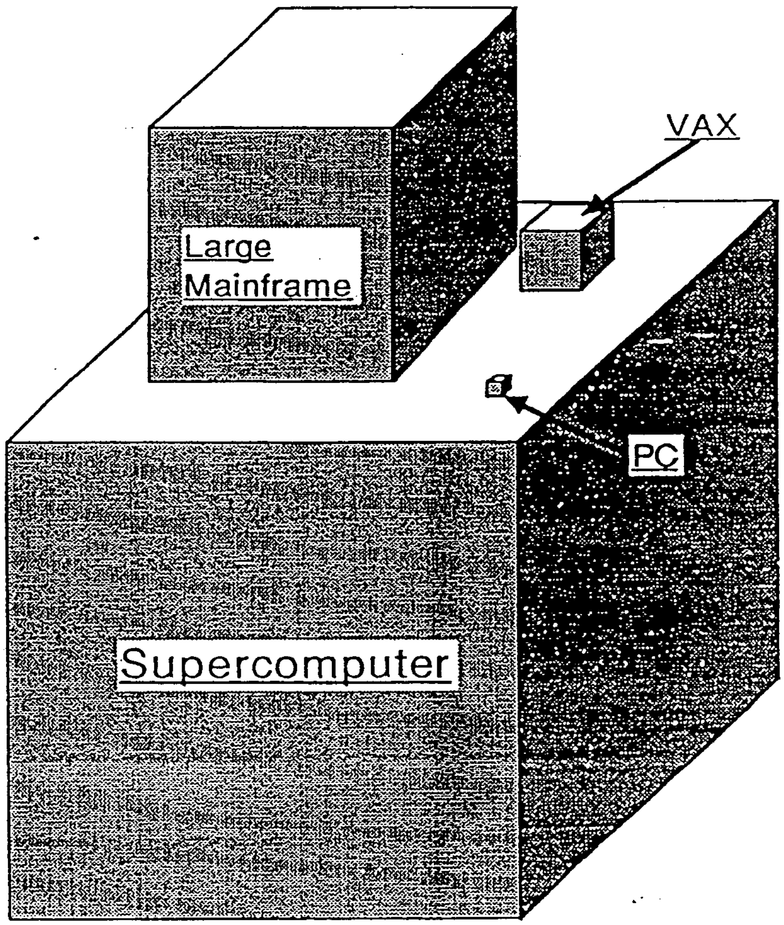

Figure 2: Relative computational capabilities of various classes of computers. Volume of each cube represents computing power. Each class of computer is roughly a factor of 10 more powerful than the next smaller class.

For general-purpose computing, a good measure of total computer power is simply the sum of the individual computer powers in a nation: just add up the hardware. For scientific computing, however, that is a bad measure. The smaller and less-powerful computers do not contribute nearly as much as their apparent individual powers might seem to imply.

A good way to estimate the scientific computing power of a nation is to use a "quadratic measure" when adding up processors. Each computer is credited with a utility equal to the square of its "raw" computing power. (This is equivalent to assuming that, when N small processors are applied to a supercomputer problem, only the square root of N processors are effectively used at one time.) Thus a large western mainframe computer that has a tenth of the general-purpose power of a Cray-1 would only have a hundredth the power for scientific computing. This penalty function agrees qualitatively with the actual experience of scientific supercomputer users. There are also empirical justifications for choosing to square the raw power of a machine, based on experience with actual multiprocessor systems.

Methods to Estimate Computer Power

There are three reasonable approaches to estimating total national computer power: inventory, personnel, and budget. The ***inventory*** approach involves adding up the actual current stockpile of computing resources of a country. It is the most direct approach, but is hampered by the difficulty of getting good inventory figures for the USSR. The ***personnel*** approach takes a representative sample of well known computing facilities, and calculates from that the computer power per technical worker. Then, knowledge of the total number of technical workers in the nation can be used to estimate the total national computing power. The main risk with this personnel approach is that of taking a non-representative sample of computing centers for the base. The ***budget*** approach is simplest but also crudest. One takes the total figures for investment in data processing equipment for each nation, and calculates how much computing power that can buy.

Inventory Approach

Tables 1 and 2 attempt to add up the processing powers of Soviet and US computers, using figures for production rates and for the stockpile of systems in use. Data for the first (Soviet) table are extrapolated from [redacted] The information in the table should be considered SECRET, though many parts of the table are confirmed by unclassified publications. The second table, showing US computer power, is unclassified and is based on data extrapolated from the IDC Processor Data Book for 1984.

~~SECRET~~

Table 1: Soviet Computer Power

(by Inventory method, in Cray-1 Units)

machine	number	individual power	gen'l. purpose power	scientific comp. power
mainframes				
YeS -1020	5000	.0004	2	.0008
-1030	1500	.002	3	.006
-1035	1000	.004	4	.02
-1040	700	.007	5	.04
-1045	500	.02	10	.2
-1050,52	100	.01	1	.01
-1055	500	.01	5	.05
-1060	500	.04	20	.8
-1065,66	20	.1	2	.2
total mainframes			**50**	**1**
scientific computers				
BESM-6	250	.02	5	.1
M-102	.05	.1	.005	
El'brus	50	.05	2	.1
total scientific computers			**7**	**.2**
minicomputers				
SM-3	5000	.001	5	.005
SM-4	5000	.004	20	.08
illegal VAXes, etc.	<1000	.01	<10	<.1
total minicomputers			**30**	**.2**
Total Soviet Computing Power			90	1

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Table 2: US Computer Power

(by Inventory method, in Cray-1 Units)

machine	number	individual power	gen'l. purpose power	scientific comp. power
mainframes				
IBM 308x, etc.	20,000	.1	2,000	200
supercomputers				
CDC Cyber-205	30	1	30	30
Cray-1	100	1	100	100
Cray-XM/P, -2	25	4	100	400
total supercomputers			200	500
minicomputers				
DEC VAX, etc.	100,000	.01	1,000	10
microcomputers				
IBM-PC, etc.	20,000,000	.0001	2,000	0.2

Total US Computing Power	**5,000**	**700**

Conclusions from the Inventory Approach: Depending on how one counts, the US leads by about two orders of magnitude in total computer power. The lead is greater in scientific computing than in general-purpose computing. In supercomputers, the Soviets have essentially no systems -- the "scientific" Soviet machines are the closest thing. The US lead is relatively consistent across the whole range of computer types. Tables 1 and 2 include the most significant computers for general-purpose and scientific applications in the US and the USSR. The broad distribution of systems which contribute to the bottom-line total computing power makes the results insensitive to errors in individual numbers.

Personnel Approach

An alternative way to estimate the total computer power of a nation is to take a representative sample of the computational resources at several scientific institutes, and scale that figure up to the whole country. [ ] were the places chosen as indicators for the Soviet Union. We have good information about the probable computer resources installed at each of these two centers. Although they may be better-equipped than the typical scientific or industrial computer center, they probably are less well-equipped than a typical military center.

Table 3: Soviet Computer Power

(by Personnel method, in Cray-1 Units)

INPUT DATA FOR CALCULATION:

	[ ]	[ ]
Professional Staff	100	200
Total Number of Users	200-500	1,000-2,000
Computer Facilities	3 BESM-6 1 YeS-1060 1 DEC VAX 4 IBM-PC	3 BESM-6 1 YeS-1060 2 YeS-105x (several?) PCs

RESULTS OF ANALYSIS BY PERSONNEL METHOD:

Institutional computing power		
• General-purpose	0.1	0.2
• Scientific	0.003	0.006
Computing power per user		
• General-purpose	0.000 3	0.000 1
• Scientific	0.000 009	0.000 004
Estimated computing power for the USSR (500,000 users)		
• General-purpose	200	70
• Scientific	5	2

The institute figures in Table 1 were scaled up to the USSR as a whole based on the assumption that there are about 500,000 potential professional computer users in the USSR. This number includes scientists and engineers with "Kandidat" and higher degrees. It does not include low-level programmers, keypunch operators, etc.

Conclusions from the Personnel Approach: The ***Personnel*** method of estimation gives reasonable measures of the total Soviet computing power, consistent with the ***Inventory*** method. The Soviet have roughly 1-10 Cray-1 Units of scientific computing power, and 50-500 Cray-1 Units of general-purpose power.

Budget Approach

The ***Budgetary*** method of estimation relies on published figures for the total Soviet investment in data processing equipment, along with the published costs for the Soviets to produce a Cray-1 Unit of computer power. **The Statistical Abstract of the USSR** (translated as **The USSR in Figures**) gives numbers for "Data Processing Equipment and Spare Parts" for the 1981-1983 time period. The **IDC Processor Data Book** gives similar figures for the US. (See Table 4)

Table 4: Spending on Computers

	USSR total GRuble	US total G$	US Spending by Computer Type: large G$	medium G$	small G$	personal G$
1981	2.7	17	3.9	6.3	5.0	2.1
1982	3.0	22	6.8	6.1	5.5	3.8
1983	3.3	28	8.2	5.9	5.1	8.4
1984	3.6	34	8.8	6.5	6.1	12.2

(1 Ruble = $1.25 at official exchange rates; G = "giga" = billion)

Unclassified pricing information on Soviet computers implies a rough cost of 40-200 million Rubles per Cray-1 Unit of general-purpose power, or 1-5 billion Rubles per Cray-1 Unit of scientific computing power. This applies to Soviet mainframes (like the YeS-1060) as well as to the scientific machines (like the El'brus). The comparable US figures for mainframes are roughly 10-50 million dollars per Cray-1 Unit of general-purpose power, and 100-500 million dollars per Cray-1 Unit of scientific computing power. (Western supercomputers are far more cost-effective, but they do not account for a significant fraction of the gross sales figures in Table 4 above. A supercomputer comparable to a Cray-1 costs 1-5 million dollars currently.

Being generous to the USSR, one could allocate one quarter of their "Data Processing Equipment" budget to big mainframes, which contribute maximally to Soviet computer power. (Actually, the figure might be somewhat lower, since much of the computing budget has to be devoted to peripherals, mini- and microcomputers, and maintenance.) For the US systems, we use the "large" sales column of Table 4. Those figures produce the following results for ***annual additions*** to total computer power.

Table 5: Annual Growth in Computer Power

(by Budgetary method, in Cray-1 Units)

	USSR		US	
	genl-purpose	scientific	genl-purpose	scientific
1981	20	.8	100	10
1982	20	.9	200	20
1983	20	1	200	20
1984	30	1	300	30
totals:	90	4	800	80

Totals over these four years give an approximation to the current inventory in each country. The US figures are clearly very crude, but are given for comparability with the Soviet numbers. The Soviet figures agree quite well with the *Inventory* and *Personnel* approaches to estimating the total Soviet computing power.

Caveats and Uncertainties

Our analysis of total Soviet computing power is a broad one. We believe our conclusions are robust, but there are overall limitations and uncertainties that should be made clear

The estimates here of computational power do *not* take into account the generally inferior state of Soviet peripheral devices (tape and disk drives, printers, plotters, etc.). Poor peripherals make it much more difficult to use computers efficiently, and reduce the effective computer power of a nation. Soviet computers also tend to be less reliable than their Western counterparts, and tend to take longer to be repaired. And because many Soviet machines are produced in only very small numbers, the Soviets tend to lack the breadth of software tools (good operating systems, compilers, debuggers, etc.) that users in the West take for granted. Development of good software is a difficult undertaking, and when a user community is small or fragmented it is much harder to accumulate a "critical mass" of customers

Our *Inventory Approach* has some obvious limitations. The figures for inventory of Soviet computers are crude – they are rounded off and extrapolated from old or incomplete data. We estimate that correct inventory figures could be as much as a factor of three different from the numbers cited in Tables 1 and 2. Our estimates of individual processor power are rough, but probably come within a factor of three of the correct values. We have not included data on other classes of computers, such as special-purpose machines, array processors, or unique military systems. (*Per capita* data on other countries such as Japan and the nations of Western Europe could also be added to the tables, and might allow some useful comparisons.

The high degree of consistency among the three independent methods of computing total Soviet computing power is also evidence that our analysis is robust. We thus believe that our overall estimates of Soviet computing power are accurate to within an order of magnitude -- that is, the truth is probably between three and one-third of our numbers. Since the differences between the US and Soviet figures are much greater than that uncertainty, especially for scientific computing, our observed differences are statistically significant.

Conclusions

The Soviets are about one to two orders of magnitude behind the US in total effective computing power. Their lag is significantly worse in scientific computing than it is in general-purpose computing. For general-purpose problem-solving, the USSR has a total of 50-500 Cray-1 Units; for scientific computing, the USSR has 1-10 Cray-1 Units.

To the Soviets, the acquisition of a single supercomputer would give a 10%-100% increase in total scientific computing power. Acquisition of a single VAX-class superminicomputer would give the Soviets only a tiny increase in capability, roughly 0.01%, for either scientific or general-purpose computing. In terms of computational power per Ruble, however, the Soviets certainly will find it highly attractive to acquire Western computers of all classes.

For further commentary on Soviet large-scale scientific computing, and the consequences of it for a variety of Soviet programs, see the Scientific and Technical Intelligence Report That report concluded:

> Soviet development of supercomputers -- required for large-scale scientific computing (LSSC) -- lags that of the United States by about 10 years. Through the year 2000, Soviet LSSC is virtually certain to remain at least five and probably 10 to 15 years behind the West. At present, we believe that the Soviets have no machines in the true supercomputer class. The best Soviet scientific computers are slower by at least a factor of 20 than their Western counterparts, and Soviet claimed computer capabilities are greatly exaggerated. Rapid future Soviet progress in LSSC is likely to depend on the technology transfer of both software and hardware from the West. Accordingly, we expect substantially increased Soviet efforts at industrial espionage -- particularly efforts directed at software acquisition.