The work leading to this report was supported by funds provided by the National Council for Soviet and East European Research. The analysis and interpretations contained in the report are those of the author.
NOTE

This Report is an interim product of the Council research contract identified on the face page, the Final Report from which will be delivered at a later date.
DISCUSSION PAPER

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by

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HI-3979-DP  April 22, 1988

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TECHNOLOGY AND SOVIET NATIONAL SECURITY*

by

Richard W. Judy

The symbiosis between technology and military affairs is ancient. Russian history, perhaps more than that of any other major power, provides palpable and repeated evidence of the mutual dependency between the state's technological and economic policy on the one hand, and its military and national security policy on the other.

Military considerations have long been recognized as "change agents" carrying profound consequences for Russian economic policy and life. In the Soviet period, just as in the time of Peter the Great, the impact of military considerations on economic policy and society has been manifest. Alexander Gerschenkron described the Stalinist variation on this ancient theme in these classic words:

There is very little doubt that, as so often before, Russian industrialization in the Soviet period was a function of the country's foreign and military policies. ...the combination of ancient measures of oppression with modern technology and organization proved immensely effective. All the advantages of industrialization in conditions of backwardness were utilized to the hilt: adoption of the fruits of Western technological progress and concentration on those branches of industrial activity where foreign technology had the most to offer; huge size of plant and the simultaneity of industrialization along a broad front assuring large flows of external economies.

The purpose of this paper is to explore some implications of technological advancement for Soviet national security policy in the years ahead. An important underlying proposition is that the reverse impact of technical and economic factors on Soviet military doctrine, national security policy (taken in its broadest meaning) is no less real and significant than the "direct" impact illuminated in the quoted passage by Gerschenkron. The relationship between technology and policy is fully symbiotic and the arrows of causality run in both directions. The two sets of variables, technological and political, appear as both causes and effects, as change agents and agents changed.

*This paper is a product of Hudson's research program on the Implications of the Information Revolution on Soviet Society. That program is funded, in part, by the National Council for Soviet and East European Studies.
This relationship between technology and national security policy is anything but simple; rather, it is a dynamic, multi-dimensional and multi-staged process wherein reverberations of cause and effect are echoed and amplified through the passage of time. When that process is observed within a single dimension (e.g., strategic weapons) over a short time interval, the casual linkage may appear straightforward; a particular technological development precedes and appears to "cause" an alteration of policy. In other cases, the reverse linkage appears to hold; a particular policy necessitates development of a certain technology for its success. Over a somewhat longer time frame, we observe a classic "chicken and egg" relationship in which new technologies, sought to implement existing policy, so alter military thinking and practice that pressures mount for modifications in policy whose optimal implementation requires new technology, etc.

When thinking about militarily relevant technology, it is essential to distinguish between military technology per se, and military industrial technology that girds the loins of a nation's economy to produce weapon systems and otherwise support the forces. Furthermore, "technology" is hardly some inexorable, stateless force. Militarily relevant technology in the modern era is a quarry caught only after organized and purposeful pursuit. Without doing great violence to reality, we may resolve that pursuit into two principal phases: In the first phase, research and development (and sometimes espionage) attacks and, when successful, solves the basic scientific and engineering problems. Then comes the second or implementation phase in which newly developed technology must be "debugged" and incorporated into the military force structure or, in cases of industrial technology, into the fabric of the economy. National security policy as well as broader policy consequences may arise in either of these two phases.

Research and development to produce new weapons or to refine old ones is done by the organized science and technology establishments of nation states. For the purposes of this paper, we concentrate on two of those, the United States and the USSR. For the Soviets, the national origin of new or improved military technology, i.e., whether it is nasha ("ours") or chuzhaia ("theirs"), often has much to do with the manner in which it is incorporated into the force structure as well as its implications on military doctrine and national security policy. A discontinuous and potentially threatening leap forward in military technology by the United States historically has brought about the following Soviet response: (1) Intense pressure on Soviet military R&D to match or counter the U.S. move; and (2) diplomatic moves either or both to stonewall and obfuscate until Soviet military R&D can redress the "position of weakness," or to forestall or delay deployment of the new technology by the U.S. The point to note is that the anxious Soviet response to the adversary's (chuzhaia) technological advance is qualitatively different from the measured response to their own (nasha) gains. For example, the Soviet's crash program to match the United States in nuclear weapons contrasts with the step-by-step march of their space program.2

This paper is concerned with Soviet policy responses to technology of foreign origin. A major point of the paper is that the policy responses to
discontinuous change in foreign technology with obvious military applications have been more pronounced than their responses to more continuous changes in technology with broad civilian as well as military applications, even when the pace of that change has been rapid. This is probably only natural. A sudden leap forward of in the military technology of a foreign power seems far more likely to concentrate Politburo attention than the rapid but smooth development a new technology even if it has profound military implications.

To explore these points, two case studies of symbiotic interaction between technology of foreign origin and Soviet national security policy are offered. One is historical, the case of nuclear weapons, and the other is contemporary, the development of computer-based technologies.

I. Soviet Reaction to American Technological Innovation in the Early Post War Period

The pattern of "foreign technological action - Russian reaction" is a familiar paradigm. The period since World War II illustrates it well. Given that the United States, since the beginning of the cold war, has been largely successful in pursuing a strategy of compensating for numerical inferiority by maintaining technological superiority in weapons, the Soviets have frequently found themselves playing catch-up. The case of the atom bomb is classic example.

Nuclear weapons were first deployed by the United States in 1945. Swiftly, via the doctrine of massive retaliation, they became a centerpiece of American national security policy. The Soviet superiority in numbers and location in Europe was countered by the American threat to deal a devastating blow at Russia should she dare to move against war-weary Western Europe. The import of this nuclear threat was apparent to everyone and most grievously to the Soviets.

What were the consequences for Soviet national security policy of the American monopoly of nuclear technology? On the question of building their own bomb, the Soviets had two basic options: to do it or not do it. Since the idea of ceding global dominance to the Americans was abhorrent to Stalin, it was natural that the Soviets should have spared no effort to master the technology and to develop their own nuclear capability. David Holloway described the situation as follows:

But it is clear that the existence of the U.S. programme [to build the atom bomb] was an important factor in the evolution of the Soviet effort. The decision to embark on building the bomb was taken in 1942 only after reports had been received that the United States and Germany were already pursuing this goal. The dropping of the bombs on Hiroshima and Nagasaki demonstrated that the bomb could be built and that it was extremely powerful. Before 1945 many Soviet physicists had doubted that the bomb could be build; now the Soviet effort was intensified. Work on the fusion bomb was stepped up after the US explosion of November 1952.
As the Soviet nuclear capability evolved from zero toward parity with that of the United States, military doctrine and national security policy evolved as well. That an acrimonious atmosphere of cold war should have accompanied the frantic Soviet effort to produce the bomb may not have been inevitable, but Stalin's determination to hold and subjugate the territory overrun by the Red Army made it virtually so. Lacking real power to resist Western insistence that he abide by the Yalta and Potsdam agreements, Stalin sent the obdurate Molotov to bluster and stonewall, to substitute bellicosity for power.

Breaking the American nuclear monopoly and even development of thermonuclear technology did not negate the American doctrine of massive retaliation. The Americans had, in the form of the Strategic Air Command and forward bases, a credible means and a doctrine of delivering a nuclear strike to the Soviet homeland. The Soviets, with nothing comparable, had no nuclear delivery system without which the bomb was a mostly psychological weapon. So the Soviet feeling of vulnerability and the policy of glower persisted well after they mastered nuclear technology. But the other part of the policy, that of neutering the American nuclear threat, dictated creation of a delivery system. This policy imperative came together with existing Soviet momentum in missile technology and German technology captured at Peenemunde in 1953 to produce the decision to develop the SS-6, the first ICBM and the launcher of Sputnik. The SS-6 first flew in August, 1957 although it was not militarily operational before 1960 and was elbowed aside in deployment by the newer SS-7 and SS-8. Nonetheless, by the early 1960s, the Soviets had broken the American monopoly on technologies enabling the attacker to strike the enemy homeland. With the publication of Marshall Sokolovakii's Voennaia strategiia, the early 1960s also saw the articulation of a new Soviet military doctrine, what Odum called the "Second Revolution" of that doctrine, that took account of nuclear and ICBM technologies.

Soviet policy on the home front during those atomic catch up years is properly considered a part of national security policy since the USSR was truly a garrison state in those years. The fundamental features of Stalinist economic and social policies are well known: Forced draft industrialization; sacrifice of consumer sectors of the economy for heavy industry and military production; centralization of economic decision-making; suppression of all forms of dissent; isolation of the Soviet citizenry from the world community; state coercion raised to an art form. In Gerschenkron's words, "...the combination of ancient measures of oppression with modern technology and organization proved immensely effective."

What does this case show us? Does it show technology to be an exogenous factor determining the development of Soviet national security policy? Of course it does not. Absent the unyielding Soviet doctrinal tenant that no adversary should be permitted to wield strategic superiority over the USSR, the post-war American technological superiority need not have been resisted. Absent the legacy of Russian absolutism, the Stalinist state could not have persisted. Rather, the case demonstrates the interaction of technology, historical tradition, and national security policy as the Soviet Union grappled with the problem of military and economic backwardness. In this particular equation, only historical tradition and the foreign technological lead were exogenous; both Soviet technological response and national security policy turned out to be endogenous to the system.
II. Contemporary Interplay Between Technology and National Security Policy: The Case of Informatics

With many of the same variables present, we again set up the equation; this time for the case of computer- and communications-based technologies or "informatics" as the Soviets now call them. Again we have an American technological innovation and early lead. Again the technology carries profound implications not only for military power but for economic power as well. But for various reasons to be explored, the Soviet policy response and the probable implications thereof have been very different from those of the previous case.

The first difference arises in the fact that informatics technology at first disguised itself as "mere" scientific computing machines and hid its wider applications from everyone. The earliest applications of computers were to compute ballistic trajectories for artillerymen. Indeed, it was for that purpose that the ENIAC, the first electronic computer, was built in the United States. The motivation for the MESM, the first Soviet computer, was similar. The second class of applications were scientific calculations in nuclear physics and a third again concerned ballistics, this time for missiles. In all of these cases, computers played the role of scientific equipment operated by scientists in a few laboratories. Few (if any) of the early computer scientists in any nation had a vision of the widespread diffusion of computer technology into the general economy that has occurred since mid-century. Should it surprise anyone that no nation's political leaders were more clairvoyant than their scientists?

A second difference stems from the circumstance that the military impact of informatics technologies has come gradually and more insidiously than that of nuclear weaponry. The explosions at Hiroshima and Nagasaki so alarmed Stalin that he gave carte blanche to Igor Kurchatov as well as the NKVD to create Soviet atomic bomb. The need for a delivery system was equally obvious to the Soviet political and military leadership. The spread of computer technology throughout the American economy and the development of a user-oriented computer market was driven not by military requirements but by the aggressive and unrelenting marketing efforts of companies like IBM, NCR, Burroughs, etc. Those efforts converted latent demand for information processing systems into orders for equipment and software. Without those marketing efforts, many computer users would never have realized that they had a need for computers nor could they have learned to use them productively. The sellers' market that has prevailed in the Soviet economy combined with the very structure of the Soviet economic system to preclude the emergence of a marketing-driven push toward informatics.

Finally, development of modern information technologies require support from an industrial base in other manufacturing and service sectors that is much broader than that which proved necessary to develop the nuclear weapons and their delivery systems. In the early post-war period, the interaction of technology and Soviet national security policy was one that could be worked out in the sector of society specializing in such matters, viz, certain institutes of the Academy of Sciences as well as the ministries responsible for defense, foreign affairs, security, and the various defense industrial ministries. Indeed, Soviet society frequently has been regarded as a
two-sector society, the first consisting of the defense sector ("Sector D") and the second consisting of everything else ("Sector E"). The problems of achieving nuclear parity with the United States were solved in Sector D.

The early, narrowly military, applications of computers in the USSR (e.g., ballistic calculations, scientific number crunching) could be and were done on a few machines (e.g., MESM, BESM) designed and largely built in institutes of the Academy of Sciences. But solving the problems posed by the subsequent explosion of informatics technologies and the information revolution could not be solved solely within the walls of Sector D. A broader infrastructure became necessary. However distinct the walls between Soviet sectors D and E may once have been, they have become increasingly anachronistic. The logic that dictates their dismantling becomes increasingly apparent as the century wanes. In fact, one result of Gorbachev's perestroika may be to erode those walls asymptotically to the point of disappearance. Nowhere is this more evident than in the area of informatics.

As in the case of nuclear weapons, the informatics technology originated in the West, largely in the United States. Soviet computer technology, beyond doubt, is more derivative than Soviet nuclear technology. American nuclear technology was protected by tight secrecy and the contribution of espionage to eventual Soviet successes in the field remains debatable. But in the case of computer technology, the Soviet indebtedness to U.S. forerunners is openly, albeit infrequently, acknowledged. The technological borrowing is so widespread as to be called ubiquitous.

The Soviet ES family of mainframe computers derive directly from IBM 360/370 predecessors that appeared between 1965 and 1975. The Soviet SM family of mini-computers derive directly from DEC's PDP-11 that first appeared in 1970. The Elektronika series of micro-computers, which have been widely used in Soviet military applications, also derive from the PDP-11. The most widely used Soviet micro-processor, the KR580 series, is a functional copy of the Intel 8080 first marketed in the early 1970s. The Agat, BK-0010, PK-1, PK-20, and other Soviet "personal computers" trace their ancestry directly the Apple II, PDP-11, Intel, and IBM predecessors. And so it goes.

To be fair, the existence of indigenous Soviet computer designs must be acknowledged. During the 1950s and 1960s, various Soviet research institutes, mainly within the Academy of Sciences, designed a variety of computers. The technology that they embodied was derivative even if the specific designs were Soviet originals. But the results were highly unsatisfactory except to those with a stake in their design. After the formation of the State Committee for Science and Technology in 1965, responsibility for computer design was removed from the Academy of Sciences and transferred to industry. Eventually, three ministries became computer producers; the Ministry of Radio Technology (Minradioprom), the Ministry of Electronics (Minelektronprom), and the Ministry of Instrument Building, Automation, and Automation (Minpribor). Of the three, Minradioprom and Minelektronprom are classified as defense ("VPK") ministries.

The entire history of the computer era in the Soviet Union has been one of playing "catch up" to American technology in both quality and quantity. The
technological time lag between the appearance of machines of comparable
capacity in the two countries hovers in the range of five to twelve years. The
difference in performance capacity between "state of the art" computers in the
two countries must be reckoned by factors of five to ten or more, and the
differences have yet to show signs of narrowing. These qualitative differences
are combined with vast quantitative differences: The magnitude of installed
computer capacity in the United States is on the order of 16 times greater than
in the Soviet Union while the annual output of computers here is roughly ten
times greater than there.\(^\text{12}\)

A critical difference between nuclear technology and informatics
technology in its consequences for Soviet policy making is the qualitatively
different impact that the two made on the minds of the men in the Kremlin. The
implications of the atom bomb struck Stalin with great force. In contrast, an
awareness of the importance of the informatics technologies dawned but slowly
in the minds of the top Soviet leadership over the course of four decades.
Little more than occasional and perfunctory exhortation is available to
indicate that the top leadership had the remotest clue of the importance of
these technologies until the 1970s. By the end of that decade, the senior
technical intelligentsia was completely aware of the informatics gap although
the message seems not to have been grasped fully by the Brezhnev
Politburo.\(^\text{13}\) Then, in quick order, the torch was passed from Brezhnev to
Andropov to Chernenko to Gorbachev.

On January 4, 1985, \textit{Pravda} announced that the Politburo had
"considered and basically approved a state-wide program to establish and
develop the production and effective utilization of computer technology and
automated systems up to the year 2000." Raising economic productivity and
efficiency by accelerating scientific and technical progress, particularly in
machine building and electronics was said to be over-arching objective of this
new program.

Gorbachev, reporting to the Central Committee in June, 1985, put the
matter in the following words:

\begin{quote}
Machine building plays the dominant, key role in carrying
out the scientific and technological revolution....
Microelectronics, computer technology, instrument making and
the entire informatics industry are the catalyst of
progress. They require accelerated development.\(^\text{14}\)
\end{quote}

The new informatics program, which has not been publicly disseminated, is
said to call for acceleration of production, improved quality, and the
introduction of new models of computer equipment.\(^\text{15}\) Applications of
informatics technology, especially computers and microprocessors, and
automation are to lead to a "comprehensive intensification of the national
economy." The program specifies scientific research, machine building,
metallurgy, power engineering, natural resource exploration, and "a series of
other sectors" as the main foci for the new the technology.

Although they remain implicit among the "series of other sectors,"
\textbf{military} applications clearly have top or near-top priority. Systems
employing sophisticated microprocessors as well as other computer and communications technologies are the technological fountainhead of the "third revolution" in Soviet national security policy. Soviet political leaders and civilian spokesmen in the computer field have made no secret of the critical importance that they attach to the military application of high-tech information systems.16

Research and development applications of information technologies occupy an extraordinarily high position in the current list of priorities. This is apparent not only from official rhetoric but from the backgrounds of the men recently appointed to senior positions in the Soviet scientific establishment. One of Gorbachev's most senior advisors on scientific matters, Academician Evgenii Velikhov, heads the Department of Informatics, Computer Technology and Automation of the Academy of Sciences.17 The newly appointed President of the Academy is Gurii Marchuk, a computer scientist, who was the founder of the Computer Center of the Academy's Siberian Section in Novosibirsk.

The application of computers to all aspects of production automation stands with military and R&D applications at the top of the Soviet priority pyramid. The Soviet drive for production automation has numerous objectives. One derives from present and anticipated future labor shortages. Another stems from a conventional concern to lower costs by harnessing technology to the production process. An important subset of those objectives, however, flow directly from considerations that have national security implications. It is these latter that we shall address here.

Computer aided design (CAD) enjoys one of the highest priorities among civilian applications of high technology. It is an application that spans the informatics and the production automation objectives of Soviet S&T policy. It also spans a broad domain of military and civilian applications. CAD's high priority dates to the 11th Five Year Plan (1981-1985) although it has risen further during the early Gorbachev years.

Soviet CAD technology lags seriously behind the American but it nevertheless has reached the stage of being very valuable for electronics and mechanical design work. Various problems attend the introduction of CAD in Soviet design organizations that are endemic to the Stalinist system of centralized economic management. The core problem is that system's perverse incentive structure. Not only do organizations lack incentive to improve designs but the system actually gives designers greater rewards when they create more expensive designs. High barriers between Soviet design bureaus and production organizations also impede the fullest implementation of CAD.18

Rapid progress in CAD is a critical Soviet necessity from the standpoint of national security. The complexity of modern weapon systems are beyond what conventional methods of manual design can achieve within acceptable constraints of performance, time, and cost. The same generalization holds with only slightly reduced force to the entire technological base upon which high technology defense systems rest. As Marx or Lenin might have said, CAD is an objective necessity for a sustainable third revolution in Soviet national security policy.
Industrial applications of informatics long have been among the top Soviet priorities. The pace of implementing automated process control systems surpassed that of management information systems in as long ago as the 10th Five Year Plan (FYP). The new emphasis being given to microprocessors, computerized numerical controlled machine tools (CNC), robotics, and other "smart" machinery represents a stepping up of the already high priority accorded industrial applications. The marriage of these various technologies makes possible flexible manufacturing systems (FMS), computer integrated manufacturing (CIM) and other kinds of computer aided manufacturing (CAM).

Soviet robots and machine tools are generally less sophisticated than their American counterparts but two points should be stressed: (1) The Soviets are making a determined effort to close the qualitative gap. (2) If Soviet statistics are to be believed, new computer aided manufacturing technology is being produced at a rapid clip. Gorbachev & Co. are betting that, sooner or later, these efforts will pay off.

Just as CAD is a prerequisite for the design of high-tech military systems and their electronic and mechanical components, so CAM is a prerequisite for their production. High precision, very specialized manufacturing regimes with rigorous quality standards, more characteristic of specialty job shops than mass assembly lines, are the rule in the high-tech production environment. The rub comes from the fact that the unit cost of production in specialty job shops is exceedingly high. Flexible manufacturing systems, with their ability to reconfigure and retool under computer control, are a virtual necessity if precision job-shop results are to be achieved at something beneath astronomical costs of production.

A major difference between the case of the atomic bomb and the case of informatics technology is that the Soviet policy response was clear-cut in the first case and highly complex and even confused in the second. When Stalin learned in 1942 that the Americans and Germans were working on the atom bomb, he pulled a top Soviet nuclear physicist, I. V. Kurchatov away from work on tank armour and set him at the head of a crash program not unlike the American Manhattan Project. In short, it was possible and highly effective to focus the effort narrowly within Sector D.

In contrast to the case of nuclear technology policy, an official Soviet policy for informatics technology can hardly be said to have existed until 1985. Even then, the technology and its multiple applications were so disparate and pervasive that the conventional Soviet method of centralized control has proven to be extraordinarily difficult to implement. In an attempt to bring this unwieldy sector under a single roof, the Soviets have established one after another "coordinating" entity. The State Committee for Science and Technology has traditionally held senior responsibility for technical leadership in the Informatics field. In 1983 came Velikhov's Informatics Department (otdel') of the Academy of Sciences whose charter gives it wide coordination responsibilities within and outside the Academy. In late 1985 the Soviets created the Intersectoral Scientific and Technological Complex ("MNTK") for Personal Computers with wide-ranging duties in its given area. Then, in early 1986, a new State Committee for Computer Technology and Informatics was established, apparently with broad powers to direct the
industry. Beneath all these "coordinating" bodies are the computer producing ministries, Minradioprom, Minelektronprom, and Minpribor. At the lowest level of the Soviet informatics industry, are a myriad hardware and software research institutes and production enterprises of the ministries. Under condition of perestroika wherein enterprises are supposed to have much greater power to determine their own destiny, the confusion is considerable.

The Pravda report of the 1985 Politburo discussion of fifteen year plan for informatics technology stated that the plan was "basically approved." The clear implication here that not all of the plan was approved is reinforced by the plan's non-appearance in print. It is reasonable to infer that one locus of disagreement was the manner in which the industry was to be organized. The persisting organizational confusion since January, 1985 suggests that the bureaucratic battles over who controls the informatics industry remain unresolved.

Two additional informatics topics of great controversy that appear to have been addressed but only partially resolved by the January, 1985 Politburo meeting are those of personal computing and computers in the schools. Both of these areas of computer application carry potentially profound implications because they involve the wide diffusion of computer technology to the population at large.

Until 1985, the existence of personal computers was hardly recognized. The topic was almost totally ignored in the Soviet press despite the fact that PC technology was burgeoning in the United States, elsewhere in the West, and Japan. Soviet efforts to design and produce PCs had been little, late, and lamentable. The question is: Why did the Soviets dither so? Theories abound: In early 1984, Professor Loren Graham of MIT speculated that "...it is becoming increasingly clear that these machines and their associated culture are challenging some of the basic principles of the Soviet state - state control over information and secrecy about vital data."23 Dr. Olin Robison of Middlebury College opined, "The Russians can't easily accommodate computer technology because it gives too many people too much information."24

Although the PC issue may have been one of the topics upon which there was incomplete agreement, the January, 1985 Politburo meeting appears to have adopted a major decision to proceed vigorously (by Soviet standards) with personal computers. The decision was foreshadowed in August, 1984 in a key article by Academician Velikhov.25 Since then, glasnost' has come to personal computing. No topic in the whole field of informatics has been hotter since January, 1985.

How Soviet PCs will be used is a question offering even richer possibilities for speculation than those of why it took so long to decide to build any and which PCs eventually will be built. Some early Western speculation held that PCs would be kept under lock and key like copiers. Others said the PCs will be out and available for use but the printers would be locked away. As of early 1988, the weight of evidence appears to be that glasnost' is prevailing and that the new Soviet PCs will be out and available for professional and educational use. Some Soviet informatics visionaries now anticipate a full-blown, PC-based, information society a la Americain."26
The momentum of personal computers, even in the Soviet Union, seems to be so great that they can't be locked away. On the other hand, their scarcity will for years confine PCs mainly to official desks except for those that find their way into private ownership by way of blat, luck, and the second economy. PCs bode to become valuable productivity tools in Soviet workplaces as well as coveted status symbols.

Education computing long was stuck on the bottom rung of Soviet informatics priorities. But this area also found its way into the long run plan discussed and "mainly approved" by the Politburo in January, 1985. The new crop of Soviet leaders appears to recognize that the right kind of human capital formation is no less necessary than computer hardware to the realization of their informatics dream. Considerable energy and talent recently has been infused into the world of Soviet educational computing. A multi-stage plan exists for getting computers into Soviet schools over the next fifteen years.

The plan calls for about 400 thousand PCs to be shipped to the schools during the 12th FYP. This is enough to equip about 30 thousand schools or one out of every two Soviet secondary schools. The number of computer-equipped classrooms is supposed to reach 100 thousand by 1995, and 120,000 by the year 2000. All of this implies a plan to put about 1.3 million computers into Soviet schools by 1995 and about 1.6 million by the end of the century. These numbers compare with over 1 million computers in American public schools in 1987.21

Even if Soviet plans are fulfilled completely, something that depends upon their success in spurring PC production, Soviet educational computing will for some time be much less "hands on" and much more theoretical than educational computing in American schools. But the pressures are building fast in the Soviet educational community to extend the use of educational computers to other disciplines and applications. The widespread usage of computers in Soviet schools now appears only a matter of time.

The Gorbachev leadership clearly has adopted policies intended to redress the informatics lag behind the United States. But the structure of the Soviet society continues to straightjacket development of the informatics technologies and the industries based on them. To break those bonds to the extent necessary to design and produce state-of-the art informatics hardware and software will necessitate more radical measures of economic and organizational reform than the Soviets heretofore have been willing to contemplate. Similarly, the process of applying informatics broadly across the Soviet society will carry implications that are only beginning to be foreseen.

III. Implications for Economic and Organizational Reform

The characteristic policy response of the Soviet leadership to perceived problems in science and technology has been to centralize organizational responsibility. The model, of course, is Kurchatov's task force to create the Soviet atom bomb. In Soviet theory, a high-priority, centralized effort brings the best people and other necessary resources together with the power to crack bureaucratic heads together and make things happen. This ability to focus
energy and resources on high-priority objectives has long been conceded, even by westerners, to be an advantage of the Soviet command economy.

It should hardly be surprising, therefore, that when the Gorbachev leadership finally recognized the importance of the informatics technologies, its policy response was to try to centralize responsibility for their development. The various inter-sectoral coordinating bodies previously described were created to overcome lofty ministerial and other bureaucratic barriers. But the results have been highly disappointing. Design bureaus retain stubborn pride in their local design efforts and resist cooperation with others. The "Not Invented Here" syndrome prevails. Ministries with turfs to protect and many other obligations to meet resist "coordination" and seek to produce what is easiest for them. Flexible and rapid action are frustrated by the multitude of players each of whose assent must be obtained. Gosplan and Gosnab, the state planning and supply committees, retain a firm grip on the power to allocate resources. The lock step of the five year planning process imparts great rigidity. The centralized agencies (GKNT, MNTK, etc.) entrusted with responsibility to lead the charge have proven powerless to mobilize and direct this bureaucratic rabble. Occasionally, the "lead organization" has become more a part of the problem than of the solution. A prominent Soviet computer scientist recently put it in the following terms:

One of the impediments to unleashing creative initiative and forging new knowledge is, in my view, the institutional assignment of responsibility for one or another sector of the national economy: for example, as in the designation of lead organizations that "answer for" progress in a particular area of science. The consistent pursuit of this principle at all levels of the management hierarchy breeds monopoly, the obsequiousness of so-called sectorial science, and the unwillingness or inability to understand others' ideas. Society needs a mechanism for circulating new knowledge, no matter where it may originate or who may be its messenger.

Centralized management of science and technology may work satisfactorily when there is but a single great objective, such as the creation of an atomic bomb, to be achieved. It cannot work well when there are many projects because not all of them can enjoy top priority. When, as now, more than 20 MNTKs claim top priority for resources and ministerial attention, the power of selecting which "top priority" to recognize reverts to the ministries, and that defeats the original intent. The Soviets now are desperately seeking new institutional forms to promote science and technology. Within the constraints of their system, however, that is anything but an easy search. Academician Velikov spoke of recent Soviet institutional experimentation in the following, rather wistful, terms:

But all of these [institutional] forms still do not accomplish the unimpeded movement of our scientific developments to industrial production. It is well known that in the rest of the world, especially in the United States, the most widespread form of innovation is through
the medium of "entrepreneurial" firms which are small firms in which the originator of one or another system or idea follows it from the beginning to the final product. The encouragement of such small groups whose work is of such great value is extraordinarily important for us. This is how the personal computer and many other innovations first appeared on the world scene. Alas, we still lack such entities. Today, if a scientist attempts to cross the border between science and industry he lands in an unfriendly and hostile environment.

In the Gorbachevian grand strategy, urskorenie (economic acceleration) and intensifikatsia (raising the technological level of production) are seen by the Soviet leaders to depend upon perestroika, i.e., the package of Gorbachev's economic reforms. It is therefore relevant to ask; How may perestroika affect the Soviet system's receptivity to technological change?

The essential core of perestroika that will effect both the supply of and demand for technological innovation is the imposition of full financial accountability and independence upon the basic decision-making unit of the Soviet economy, i.e., the enterprise. Much remains to be learned about how in actual practice this will be accomplished (i.e., Will enterprises really be on their own without petty tutelage from above?) and under what conditions (e.g., Will prices be allowed to reflect relative scarcities? Will taxes and other exactions from enterprise revenues reward or penalize technological innovation?).

For perestroika to effectively promote technological innovation in the Soviet economy, it must be radical. In concrete terms, that means ensuring the following six components:

1. Financial independence: Enterprises must become truly independent, free to prosper or fail in accordance with their own efforts, decisions, and luck.

2. Merit pay: Individual remuneration must be proportional to the value of a person's contribution to his enterprise's financial health.

3. Freedom of entry: The legal and bureaucratic obstacles to new enterprise creation must be cleared away.

4. Unfettered exchange: Produced goods and services must be bought and sold only with the mutual consent of buyer and seller and without undue societal constraints. The state must contract for goods and services like any other buyer.

5. Rational prices: Price formation must be flexible enough to respond to changing relative scarcities, and prices of goods and services must approach
market-clearing levels and/or be freely contracted between buyers and sellers.

6. **Neutral taxes**: Exactions from individuals and enterprises must not discriminate against risk-taking, hard work, or innovation.

Acceptance by the Soviets of a *perestroika* sufficiently radical to include these six provisions would merit the term "revolutionary." In the near future, however, they are likely to prefer less radical reform. Proportional to their timidity will be their failure to achieve their aspirations to make technological dynamism an inherent attribute of their system.

**IV. Implications of Applying New Technology**

Historically, the adoption of significant new technologies produces three classes of impacts. The primary impacts are simply the benefits sought by the decision to adopt the technology in the first place. Secondary impacts result from the adjustments necessary to accommodate to the new technology and are transitional in nature. Tertiary consequences are manifest in the longer term, are largely unanticipated, and diffuse in their societal impact. Both the secondary and tertiary impacts may be judged by different people to be either favorable or unfavorable. By way of illustration, we offer a few anticipated secondary and conjectured tertiary impacts of a widespread Soviet adoption of the information technologies.

The massive introduction of new, computer-based design and manufacturing technologies (CAD/CAM) will bring organizational and individual trauma. For example, the change from conventional manufacturing to CAM has serious implications for the work force. Many workers and skills are rendered redundant. Those workers remaining on the production floor must perform a wider range of duties and they normally require substantial retraining. The nature of work changes qualitatively. Workers' attributes of attentiveness, diagnostic acuity, initiative, sense of responsibility, and concern for quality assume preeminence. Narrow job classifications, which may have been suitable for traditional manufacturing, become irrelevant or a hindrance to the adjustments required for CAM.

Flexible manufacturing systems (FMS) and computer integrated manufacturing (CIM), if they are to be successful, necessitate an entirely new and integrated approach to product and manufacturing process design. If a product is to be manufacturable by robots and movable by computer-controlled materials handling equipment, its assemblies, its components, and the product itself must conform to constraints imposed by the specifications of the robots and equipment. Product designers must bring manufacturing considerations into their work at the earliest stage. Standardization of components and subassemblies for different final products becomes very important.

Piecemeal introduction of the more sophisticated types of CAM, such as flexible manufacturing and computer integrated manufacturing, is hardly feasible. In an existing organization, the old manufacturing line usually must
be shut down, the area gutted of old equipment, and the new equipment installed. Obviously, much careful planning must precede this step or the new system will work poorly if at all. The various components and other pieces of equipment must arrive in a timely fashion so that they may be installed by skilled workmen. Missing links in an automated line typically mean that the line cannot operate or must do so with "inserts" of manual labor at the missing links. This is usually an expensive expedient and often quite unsatisfactory.

Full realization of the potential benefits of CIM require that the control of inventories at both ends of the manufacturing processes be integrated into the system. At the input end, the computerized system should maintain stock records of all purchased and manufactured components and subassemblies. From these and from usage data captured while the computers monitor the production processes, the system should trigger orders to suppliers, preferably on a computer-to-computer basis via telecommunications linkage. At the output end, the CIM system should interface its inventory of finished products with sales and shipping information, again, on a computer-to-computer basis.

The integration, under computer control, of a broad range of functions from material input to manufacturing to product distribution creates the conditions for highly integrated data collection, storage, and processing. The experience of American firms is that a preponderance of the payoff from CIM comes at this stage where the CIM system interfaces with the management information system. Great savings of personnel costs and improvement of function become possible at middle management levels as the system takes over responsibility in functions like ordering, receiving, inventory, shipping, accounting, etc. Two important points are to be stressed:

First, profound innovation is unsettling in all societies but the specific circumstances and traits of the Stalinist soci-economic system exacerbate the difficulties.

Second, Soviet enterprise managers will consider the costs of implementing new technology prohibitive the more their concern with short term versus long term performance, the more they face conditions of a sellers' market, and the more they face inflexible labor conditions and unresponsive suppliers. Since these features characterize the traditional Stalinist form of Soviet industrial organization, the Soviets will encounter very serious difficulties so long as they retain that form. If the incentive structure that Soviet enterprise managers confront continues to reward fulfillment of an plan based on historical performance levels, those managers are likely to see few benefits to balance the risk and expense associated with the introduction of new technologies.
V. Conclusion

The conclusion that emerges from the foregoing is that radical economic reform, perestroika and more, is a condition for the successful implementation of Soviet dreams to develop and implement new technology in general and informatics in particular. Glasnost' and perestroika are logical conditions if the Soviets wish to overcome the increasing lag that separates the way in which the informatics and other technologies are developed and implemented in the USSR from the way they are in the West.

Modern high technology, especially that of informatics, interacts with Soviet history and doctrine to help forge new national security policies just as did the post-war nuclear and missile technologies. But the similarities are less impressive than the dissimilarities. Not only does the drive for informatics technology help to put glasnost' and perestroika in vogue, it dictates an opening to rather than a shutting out of the West.

Alexander Gerschenkron would be amused to see how the informatics technologies are standing Peter the Great and Stalin on their heads. No longer does it prove immensely effective for the Kremlin combine "... ancient measures of oppression with modern technology and organization." Indeed, all of the "advantages of industrialization in conditions of backwardness" seem to have been exhausted. The quest continues to adopt "the fruits of Western technological progress," but the means of doing so have become, we may dare to hope, both more civilized and more civilizing.
ENDNOTES


3. The cases discussed below illustrate how this point has worked out in the Soviet case. In fact, the United States also responds asymmetrically to Soviet and U.S. leaps ahead various heats of the military technology race. Reflect, for example, upon the American response to the surprise of Sputnik and to the various "missile gaps."


5. Ibid, p. 455.


9. Informatics, Informatika in Russian, is used by the Soviets to mean the entire panoply of computer and communications technologies and their applications. The word is used here with that same meaning.

10. The letters "ES" are from edinaia sistema or "unified system."

11. The letters "SM" are from sterna malaia or "small system."

13. See, for example, Glushkov, V., and Kanygin, Iu., "Stanovlenie otrast'i," *Ekonomicheskaia gazeta*, 52, 1980, p. 11. Academician Glushkov, now deceased, was one of the intellectual fathers of Soviet computer science and the founder of the research institute that now bears his name in the Ukrainian Academy of Sciences. In this article, the authors point up fragmented nature of the "machine informatics" industry in the USSR. They fault the State Committee for Science and Technology for failing to provide unified leadership for developing and applying computer technology.


17. This entity was established in 1983.

18. These difficulties certainly attend the civilian sectors. They are present also in the military sphere although probably to a lesser degree.

19. The word "industrial" is used generically to include manufacturing, extraction, construction, and transportation although industries like machine building, energy, and electronics are clearly in the top spot. The definition excludes trade and services.

20. "ASUTP" is the Soviet acronym for "automated process control system."


22. *Glasnost'* has produced abundant confirmation of the bureaucratic straightjacket that binds Soviet efforts to develop the informatics industries. See, for example, the sorry tale of how the Soviets have failed to produce and deploy fibre optics communications netwrks given by Tarasov, A., "Paradoksy 'Svetovoda'," *Pravda*, February 26, 1988, p. 2.


