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Soviet S&T Policies and Strategies Under Gorbachev (U)

National Intelligence Estimate

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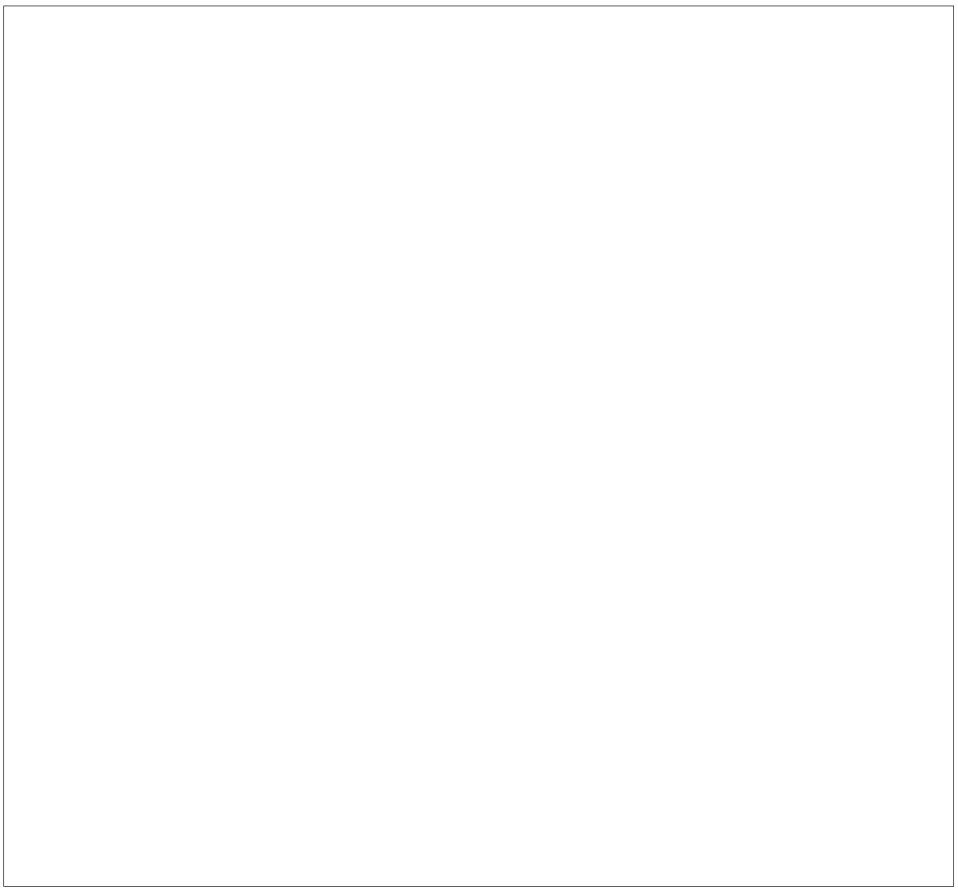

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NIE 11-7-87

SOVIET S&T POLICIES AND STRATEGIES UNDER GORBACHEV (U)

Information available as of 1 August 1987 was used in the preparation of this Estimate, which was approved by the National Foreign Intelligence Board on 6 August 1987.

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SCOPE NOTE

This Estimate assesses the formulation, implementation, and implications of Soviet science and technology (S&T) policy through the 1980s that will impact on Soviet performance in the 1990s. The key issues are (a) Soviet policies, or goals, for S&T, (b) Soviet strategies for implementing these policies, (c) the effects of these policies and strategies on Soviet domestic and foreign policy, and (d) the likelihood of the success of the S&T policy program. The Estimate covers S&T policy and strategies affecting both the military and civilian sectors, but does not address explicitly technologies or programs unique to the military. The Estimate also addresses policy affecting research, development, testing, and evaluation (RDT&E) and the assimilation of RDT&E results into production.

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In 85, we assessed the raw potential of the massive Soviet research establishment, which appears to dwarf those of other nations. The Estimate provided an understanding of the environment within which Soviet science is conducted, in addition to an assessment of the relative strength of scientific research in various fields of science in the USSR as compared with that in the United States.

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In 87, we assessed the status of the Soviets' key military *technologies*, possible future *systems* they *could* choose to develop, and how they *manage* military research.

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In this NIE we are assessing the S&T policies and strategies that Soviet leader Gorbachev intends to use to harness the potential of the S&T sector and whether he will succeed. The NIE forms the third in a triad of complementary Estimates, one on science, one on technology, and now this one on S&T policies and strategies.

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KEY JUDGMENTS

Both international and domestic pressures have forced Mikhail Gorbachev to launch his ambitious program to revitalize and modernize the Soviet economy with scientific and technological (S&T) progress as an avowed key. The Soviets fear that a permanent technology gap with the West in many key areas will have grave implications for their status in the world community and particularly for their defense posture, which requires new technologies of unprecedented scope and complexity. Many of these technologies must also be developed rapidly to keep pace with the West. Also, Gorbachev needs to shed the economic lethargy of the Brezhnev years and tap the energies and skills of a new generation of Soviet leaders at the national and local levels to develop new strategies that ensure adequate future growth.

We expect that the gains made from Gorbachev's efforts to accelerate S&T progress will not be enough to yield the growth in productivity, efficiency, or innovation called for in his civilian modernization program, without success in broader economic reform:

— The initiatives to revitalize the Soviet base for research, development, testing, and evaluation (RDT&E) should meet with moderate success.

— But the major sticking point is the lack of a coherent and incentive-driven system to diffuse these new technologies throughout the economy.

The initiatives to *revitalize the RDT&E base* are targeted at selected technology areas—microelectronics, computers, automated manufacturing systems, advanced and new materials, biotechnology, and nuclear energy—and include larger investment resources, wage and bonus reforms, increased information flow, and continued acquisition of foreign technology. Of these initiatives, we believe that Soviet plans to strengthen the resource base for RDT&E have the best chance for success, if sustained over at least the next decade and backed by successful implementation of Gorbachev's commitment to modernize the machine-building sector. Major constraints reduce the potential of the others:

— The new pay hikes for scientific workers depend on the ability of the S&T organizations and enterprises to finance them out of their own funds, a requirement that is sure to create inequities.

Moreover, the value of monetary incentives is questionable, given continued shortages of consumer goods.

— Plans to improve the information flow so as to increase domestic ties between researchers and producers and to gain access to international data pools run up against the regime's desire to retain a monopoly over this vital instrument of political control.

— Western technology will continue to fill selected gaps, but broad acquisition will be inhibited by factors such as hard currency limitations and Western export controls.

Soviet strategies to *improve technology diffusion* aim at eliminating departmental barriers, creating a new cadre of workers, improving long-range S&T planning, and revising the incentives to innovate. In many cases the defense sector will be used as a model for change. Up to now, these strategies represent conventional Soviet remedies—innovation by decree and change "from above"—that have not worked in the past and are unlikely to work in the future unless accompanied by broad economic reforms:

— Many of the organizational changes simply realign the old structure, but sectoral and bureaucratic interests remain. The attempt to redefine the roles of the major S&T policymakers so far has produced only confusion.

— A substantial turnover in the scientific cadre has provided new energy, but without a revision in incentives it will fall quickly into the old ways. Some defense managers reassigned to the civilian RDT&E sector have been unable to produce the expected miracles because they lack proper equipment, political priority, and a skilled work force.

— Long-term planning for S&T continues to be hampered by the same problems that plague Soviet economic planning in general—the lack of rational indicators such as prices and a competitive environment to provide guides to decisionmaking.

— The bias toward gross production as a measure of success will continue to provide a disincentive for enterprise managers to innovate; sanctions for not fulfilling production plans remain greater than the gains to be achieved from innovating.

— The defense-industrial sector probably is not a viable model for the entire economy because of its priority claim on resources, specific requirements, and often inefficient and wasteful practices. The problems currently encountered in the implementation of the new industrial quality control system borrowed from defense is a case in point.

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The inability of the Soviets to develop and implement an effective S&T strategy will limit their technological development. Innovative research and state-of-the-art technologies will most likely occur only in special-emphasis areas where the leadership, as in the past, focuses its attention, hard currency, and resources. Moreover, certain characteristics of the new technologies will clash with the Soviets' failure to change the modus operandi: they become outdated quickly, requiring flexibility in planning and management; they demand higher levels of quality and testing; and they depend on developments that went before, thus limiting the benefits of Western technology acquisition. Moreover, the existing Soviet system has not produced the regenerative dynamic characteristic evident in the West that would allow the USSR to catch up and keep up with "world standards" as planned.

A broad range of the Soviets' other policy objectives will also be affected by the limited fulfillment of their S&T goals:

— They will continue to view the West as a technology source and will therefore pursue S&T contacts, trade, and information exchange. Reliance on Western technology may in fact increase in areas critical to the modernization of civilian and defense industries. They are likely to expand their interest in joint ventures and licensing agreements, increase borrowing from the West, and pursue illegal methods of technology acquisition. They will also increase their use of East European S&T capabilities.

— The pressure to accelerate S&T progress and compete militarily probably will encourage the regime to improve East-West relations. An arms-control agreement, in the Soviet view, would slow US military growth and provide more time for S&T and economic strategies to succeed. Reduced tensions could also make it easier for the Soviets to acquire the types and quantities of Western technologies they have identified as critical, possibly on favorable credit terms.

— In any case, we believe that the continued priority for defense will enable this sector, at least in the short term, to compensate for the failings in S&T strategies. Even if civilian programs are given a higher priority, the dual-use nature of the target technologies will allow the defense sector to reap continued benefits.

We expect that, as the limited success from these strategies converges over the next few years with other economic pressures, societal tensions, and the defense burden, Gorbachev will face a choice

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of settling for half measures that fall well short of his needs or making harder and potentially divisive decisions that could bring more dramatic results:

— Gorbachev has decided to initiate more radical economic reforms that are aimed at tapping the strengths of market forces such as decentralized decisionmaking, increased competition, and liberalized price formation. The RDT&E sector should benefit from these changes, if effected, through increased opportunities to contract directly with production enterprises and greater flexibility over research plans and projects. Production managers, judged less on volume of output, would be more likely to innovate. There are major political obstacles to the successful implementation of such a program, however. The military, for one, might be strongly opposed to reforms that threaten their priorities. If successfully implemented, such changes would probably be disruptive in the near term. Over time, however—almost certainly well beyond the time frame of this Estimate—we believe that they could have a significant impact on the performance of the S&T sector.

— If the proposed radical reforms falter, the leadership's approach might be reduced to the more traditional characteristics of Soviet S&T strategy—increasing central control and discipline as a way to foster S&T progress. There is some support for this approach in the Soviet elite, and it might placate the military, at least in the short term. The administrative approach of "innovation by decree," however, has already proved ineffective. Its inadequacies in achieving S&T progress are likely to set back Soviet S&T and eventually military RDT&E. To avoid such consequences, the defense sector would need to increase its resources and broaden its coverage to assure development of many dual-use technologies now covered by civilian S&T. Moreover, such a retreat on Gorbachev's "openness" and "democratization" efforts would have negative domestic and international effects.

Gorbachev's approach will contain both decentralizing and centralizing elements. His successful balance of the two will be key to the Soviet Union's S&T future.

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DISCUSSION

1. When General Secretary Gorbachev came to power in March 1985 he outlined an ambitious agenda to revitalize and modernize the economy, proclaiming scientific and technological (S&T) progress to be key. Gorbachev stated:

> The party views the acceleration of scientific and technical progress as the main direction of its economic strategy, as the main lever for the intensification of the national economy and for raising its efficiency; and hence, for the solution of all other economic and social issues. These tasks are so pressing that action has to be taken without losing any time.

Relying on S&T progress and on other approaches to economic revitalization—most important, changes in investment policy and reforms in the economic system—Gorbachev hopes to ensure the necessary increase in the quantity and quality of industrial output and better use of limited resources. Without such revitalization, the Soviet leadership realizes that it will be increasingly difficult to meet the full range of national goals—higher living standards, better economic performance, and stronger defense during the 1990s and beyond. (See figure 1.)

2. Furthermore, Gorbachev must bring about this crucial resurgence of economic growth and modernization while sustaining the formidable military gains of the past 20 years. Generally, Soviet military and political leaders acknowledge the role of a strong economy in supporting military power. Nevertheless, they also recognize that their powerful military establishment was built up during the past two decades through massive commitment of the nation's best resources, and with growth in military spending exceeding that of the overall economy. As a result, they are seriously concerned that Gorbachev's economic revitalization plan—requiring massive investment in machinery and equipment—will increase the competition for many of the resources used in the development and production of weapons. Given resource limitations, the Soviets know that the economy must be revitalized by making the work of both the civilian and defense sectors more efficient and productive.

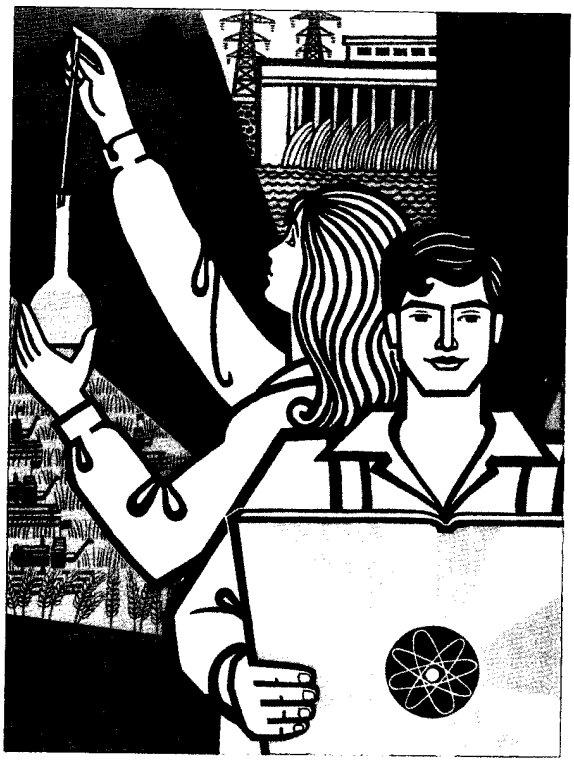

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Figure 1. S&T Progress. This recent Soviet placard sings the virtues of S&T progress: "The achievements of science and technology ensure renewal of all branches of the national economy."

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3. The rapid rate of technological change in the West is forcing the Soviet Union to concentrate on S&T improvement. Soviet officials—especially Gorbachev—have been blunt in depicting the threat posed by S&T progress in the West. They have criticized the lethargy of the 1970s, implicitly charging that the Brezhnev leadership failed to act on its promises and to appreciate the pace and consequences of Western advances. The Soviets express concern over the prospect of being condemned to a permanent lag and to technological dependence on the West. They argue that such dependence, often tied to the long-established practice of imitating foreign technology and design, not only makes the USSR and the Soviet Bloc as a whole susceptible to Western political pressures and economic sanctions but also retards the develop-

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ment of indigenous capabilities in science and innovation.[1]

4. Serious military concerns over Soviet indigenous S&T development and technological dependence on the West have surfaced. The possibility of a US technological breakthrough that upsets the strategic military balance is a continuous Soviet fear. US military programs, like the Strategic Defense Initiative and "smart" conventional weapons, require the successful integration of computing and communications activities of unprecedented scope and complexity. Soviet weapons to be introduced in the future will use more sophisticated guidance, sensor, computer, and communications subsystems, which will in turn require advanced microelectronics and advanced design, fabrication, and testing capabilities.

5. Domestic considerations also played an important role in Gorbachev's decision to concentrate on the acceleration of technological progress. (See inset.) As the inheritor of a technologically backward economy that had experienced a decade of slowing growth, he knew that his political success would be determined largely by his ability to revitalize that economy and that to do so would require a modernized industrial base. His strategy also was influenced by a changing political climate, in which a new generation of officials and administrators seem increasingly unwilling to tolerate the technological inferiority spawned by years of leadership inertia and managerial inefficiency.

POLICY GOALS

6. While the Soviet leadership often defines "S&T progress" vaguely, its aim is to harness the achievements and the momentum of the "new industrial revolution" based on advanced technologies such as computers, robotics, and new materials, and to put them to work in key economic sectors such as machine building, construction, fuels and power, and agriculture. According to Gorbachev and others, the Soviet Union by the year 2000 is to reach world standards in the following areas: biotechnology, nuclear energy, advanced and new materials, automated manufacturing systems, microelectronics, computers, and telecommunications. Consensus among the leadership is that these dual-use technologies are critical for Soviet advancement in both the military and civilian sectors (see appendix A)

[1] Notwithstanding these statements of concern, the Soviets continue to engage in a concerted and pragmatic effort to acquire Western technology in order to overcome their indigenous S&T weaknesses and close the gap as much as possible. See paragraphs 14-19, 36, and 49.

Underlying Themes of Gorbachev's Program

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The Gorbachev leadership has made it clear that the challenge of S&T progress requires major policy and institutional change. In a televised speech in April 1986 the General Secretary stressed, "To continue making mistakes in technology policy means driving the economy further into an impasse." In June he told the Central Committee plenum, "We must counter all attempts at multiplying the former approaches and errors—above all in the sphere of S&T progress." Since the 27th Congress officially endorsed his modernization goals, Gorbachev has shifted the emphasis from strategy design to problems of implementation. As he puts it, "The main task now is to transform the energy of intentions into the energy of actions." Gorbachev is pressing his S&T program with four central themes:

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- The USSR is at a crucial turning point in its history—the reindustrialization of the country ranks in historical significance with and should be given the "same political ring" as the industrialization campaign of the 1930s.
- The envisaged transformations are sweeping and unprecedented in their scale—Gorbachev explicitly equated restructuring with the word "revolution."
- There is no alternative to S&T modernization—"Any other path means a relinquishment of positions, an orientation toward lag."
- There is an urgency to take action—to recognize problems and to carry out fundamental change—"If not us, who? If not now, when?"

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7. There is also consensus (see inset on page 10) that two overall goals exist:

- A revitalized base for Soviet research, development, testing, and evaluation (RDT&E). Though, by world standards, the Soviet Union maintains the largest RDT&E base—employing about 5 million people and including over 900,000 full-time scientists and engineers—growth in the quantity of resources (human and financial) going to the Soviet RDT&E sector has been on the decline since the early 1970s (see table). The historical lack of incentives for S&T workers has resulted in poor worker morale, low productivity, and difficulty in attracting bright youth to science and engineering. Furthermore, the inadequacy of the amount and quality of equipment and testing facilities for RDT&E has been a continuous and growing problem for S&T organizations as well as for the instrument-making and

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Soviet RDT&E: Average Annual Growth in Resource Inputs [a] *Percent*

	1971-75	1976-80	1981-85	1986-90 (planned)
Number of workers in science and science services	5	3	0.2	NA
Number of scientists and engineers	6	2	2	NA
Expenditures for capital investment in science	8 [b]		NA	11
Expenditures for science (current prices)	8	6	4	6
Expenditures for introducing new technologies into industry	10	6	5	NA

[a] These figures, calculated directly from official published Soviet statistics, are subject to considerable uncertainty because the definitions of the coverage of Soviet statistics are vague and often undefined.

[b] Average for 1971-80.

machine-building ministries, which are unable to satisfy present demand.

— Improved technology diffusion. Soviet leaders and S&T specialists are calling for the removal of administrative and organizational barriers that impede the diffusion of new discoveries and technologies throughout the economy (innovation and assimilation in Soviet parlance).

"Every year only one-third of completed developments are introduced and far from all completed work is fulfilled." as emphasized by Gorbachev in the June 1987 Central Committee plenum, the Soviets recognize that enterprise incentives must be redesigned to reward innovations. These problems affect both the civilian and defense sectors to varying degrees, but in the defense area they are mitigated somewhat by its priority access to resources, better supervision and quality control, and the need to compete with the West.

8. A number of ambitious but perhaps unrealistic production goals involving key targeted technologies highlight the strong Soviet interest in seeing these technologies applied in the Soviet research and industrial process:

— The production of computer equipment is to grow by 18 percent annually through 1990. In addition, by that time the Soviets plan to produce 1.1 million personal computers, after producing virtually no PCs until the mid-1980s.

— During the years 1986-90, the target for the average annual growth in output by the main producer of instrumentation equipment is 19 percent, as compared with only 6 percent during 1981-85.

— The retirement rate for obsolete machinery in the machine-building sector is to grow from 2.2 percent in 1984 to 9.7 percent in 1990.

— During 1986-90, automation in the engineering industries is to increase labor productivity to twice or two and a half times the present level, while automation of continuous processing is to free up to half the workers.

— Installation of computer-aided design (CAD) is to increase dramatically and shorten product development times by 50 to 80 percent.

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STRATEGIES

9. Gorbachev is acting along a broad front to achieve these goals, building upon measures begun by his predecessors while adding some new initiatives of his own. In the past, Soviet leaders did not view these measures as a coherent program or strategy, nor did they—until Gorbachev—generally label them as such. Moreover, the leadership's S&T policies and strategies are aimed at all parts of the economy—the production and science sectors, the Academy of Sciences, and higher educational institutions. They are often interrelated with other domestic programs, such as economic reform and the campaigns for work discipline and against corruption.

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Revitalizing the RDT&E Base

10. The Soviet strategies aimed at revitalizing the RDT&E base include increased investment for equipment manufacture, higher worker pay and bonus schemes, better training and information flow, and increased efforts to acquire Western equipment and know-how. There seems to be a general leadership consensus that such measures have been needed.

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Increased Resources

11. As part of his broader economic modernization program, Gorbachev (see figure 2) has pledged more resources to the experimental-production base and to the instrument-making capabilities of the USSR:

— The Soviets plan to increase national-level capital investments to support research and development by 70 percent during 1986-90—an average

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Soviet Assessment of S&T Problems

In their S&T policy goals to revitalize the existing RDT&E base and to improve technology diffusion, Soviet leaders recognize the longstanding problems that must be addressed:

— ***Problems Inhibiting Revitalization of the RDT&E Base:***

- *Lack of Incentives for S&T Workers.* The Soviets acknowledge the comparative decline in scientists' salaries since the mid-1960s, the increasing difficulty of attracting bright youth to science, falling enrollment rates in engineering schools, and a shortage of designers. Poor morale, low productivity, low-quality goods, and inertia in favor of the status quo are common. As Gorbachev recently stated, for "too long engineering and technical cadres and other workers in industry have become inured to the mediocre and have set their sights on lowered criteria. All this has to be put right." Such a decline in the desirability of S&T work is especially striking in Soviet society, where scientists have typically enjoyed prestige and high status.

- *Inadequate Equipment for Experimentation and Testing.* Soviet scientists and engineers often complain about insufficient quantities and the poor quality of the equipment available to them. These inadequacies, along with the lack of standardization, are especially significant in Gorbachev's targeted technology areas such as biotechnology and microelectronics. The Soviet resource problem is threefold: (1) researchers and scientists lack materials and technical equipment, such as precision measuring instruments and computers, used to carry out RDT&E; (2) RDT&E organizations lack adequate facilities to develop prototypes and to test new products, materials, and processes; and (3) the instrument-making and machine-building industries—the suppliers of much needed equipment—also have inadequate equipment and test facilities and are unable to develop and to produce the equipment necessary to satisfy present demand.

— ***Impediments to Technological Diffusion:***

- *Administrative and Organizational Barriers.* Departmental barriers, permeating the entire Soviet economic system, impede cooperation between different ministries and isolate scientific activity from manufacturing. Soviet policymakers have also long recognized that the physical separation of organizations performing different RDT&E stages (for example, research institutes, design bureaus, and test facilities) and of RDT&E and production facilities has severe negative consequences on the speed and flow of innovation. Soviet leaders have relied on long-term S&T and economic planning to compensate for the lack of information flow. However, the large and complex network of special government agencies involved in the formulation and conduct of Soviet S&T policy is often unable to develop and implement a comprehensive S&T policy because of the special interests and often overlapping responsibilities. Though these barriers exist in both the civilian and defense sectors, the problem is intensified for civilian RDT&E and production, which lack the defined requirements and supervision more prominent in the Soviet weapons development process.

- *Lack of Incentives for Enterprise Management To Innovate.* The lack of incentives for industrial managers to innovate has kept the economy from quickly absorbing new products and processes and putting them into widespread use. Soviet industrial managers, often with inappropriate machinery and limited authority, are given inflexible production targets to meet. The Soviet system continues to judge, reward, and sanction these managers by standards that place more importance on plan fulfillment than on incorporating new technologies or innovations and consequently has actually created a disincentive to innovate.

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annual rate of 11.2 percent, as compared with 7.5 percent during the 1970s. These increases are slated both for capital improvements at research and design organizations—new and better equipment and facilities—and for the development of new and better equipment (scientific instrument manufacture and industrial automation).

— Budgeted expenditures in the science sector (excluding capital investment) are to rise to 33 billion rubles in 1990, as compared with 24.8 billion in 1985. This would bring the average annual growth during 1986-90 to 5.9 percent, as compared with 4.3 percent during 1981-85 (see table on page 9).

— Industry is being encouraged to allocate an increased share of its budget to supporting S&T progress. The Supreme Soviet's Commission for Machine Building recently recommended that

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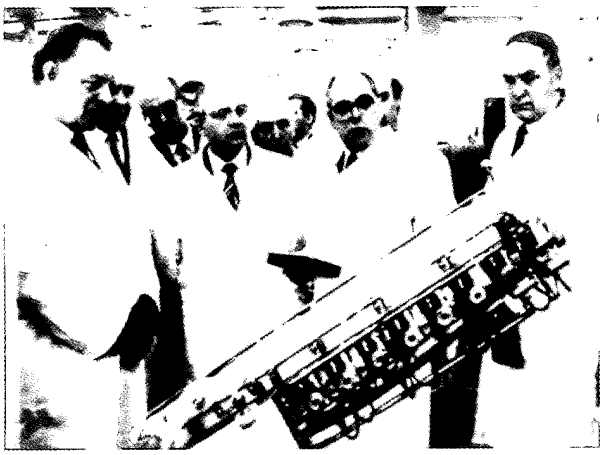

Figure 2. Gorbachev at Svetlana Electronic Instrument Plant in Leningrad. The USSR's shortage of equipment and instrumentation for RDT&E has been a continuing problem and is the basis for General Secretary Gorbachev's new goals to increase the output and quality of the Soviet machine- and instrument-making industries.

each machine-building ministry should spend up to 12 percent of its capital investment on science in 1987.

Higher Wages and Bonuses

12. Soviet legislation passed in 1985 and 1986 permits increases in wages and bonuses for scientific workers, designers, engineers, and technologists in industry as well as in the USSR and republic Academies of Sciences beginning in 1987. Wages and salary rates could rise by an average of 25 to 30 percent as a result of replacing fixed salary rates with a more flexible sliding scale of pay rates designed to reward hard work and innovative results. Following cautious bonus reforms introduced by Yuriy Andropov in 1983 and based on experiments that have been taking place in a number of cities, these new reforms will:

— Increase the number of job categories for workers in S&T.

— Provide greater pay differentials between variants of qualification.

— Increase wages in key sectors for S&T progress such as machine building.

— Provide managerial authority to increase or decrease wages on the basis of productivity and to fire unproductive workers.

The source of funds for the resulting wage increases will be largely individual enterprises and associations—using monies saved from increased productivity and worker layoffs.

Better Training and Information Flow

13. The Soviets are also attempting to raise the technological level of the S&T establishment through increased training and access to more and better information:

— They are launching a computer literacy program intended to provide up to 10 million PCs to secondary and vocational schools over the next decade.

— Educational reforms are aimed at easing the shortage of skilled technical labor by increasing both vocational training and early entry into the work force. A recently adopted reform promises closer cooperation between industry and higher education, tougher admissions, performance standards, and special training for top students.

— Domestic and international computer networks and information systems for R&D are being developed, including "Akademset"—a computer network that reportedly links several Academy of Sciences organizations in Moscow, Leningrad, Kiev, Riga, and Novosibirsk to each other and to Western S&T data bases.

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— Organizations are being created to hasten the development of information sciences and data processing. The Academy's new computer technology department, for example, will take a leading role in this area.

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Continued Acquisition of Foreign Technology

14. Despite its policy to develop indigenous S&T capabilities, the Soviet leadership under Gorbachev has maintained a strong interest in Western technology and is likely to continue attempts to acquire it—legally and illegally. Such activities will include trade and commercial ventures, S&T cooperation and exchanges, illegal trade diversion, and covert collection activities.

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15. ***Legal Technology Acquisition***. We believe that the Soviets will continue to carefully select and import Western machinery and equipment to enhance priority technologies and to help build the country's much needed experimental production base. Imported machinery is a substantial part of the equipment component of total Soviet machinery investment—roughly one-third, mostly from Eastern Europe (see figure 3). Since 1981, Soviet hard currency purchases have been primarily for the chemical, energy, and metallurgical industries—key to Gorbachev's modernization program. We believe that machinery and equipment purchases for Gorbachev's modernization

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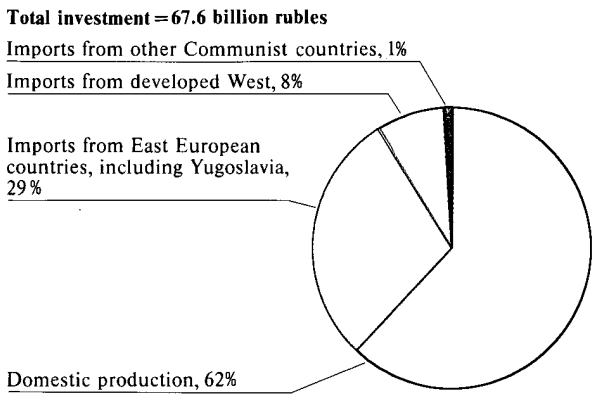
Figure 3
Share of Imports in the USSR's Total Machinery and Equipment Investment, 1985[a]



[a] Estimate assuming a coefficient of 1 for converting machinery prices from foreign trade rubles to domestic rubles.

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Figure 4. Gorbachev During 1986 Visit of Soviet Party Delegation to West German Tool Mill. West Germany is the largest Western exporter of machinery and equipment to the USSR.

program will have priority, even though hard currency constraints might force the Soviets to cut back on total imports from the West (see figure 4).

16. Meanwhile, the Soviets are attempting to find ways to enhance their access to foreign technology and to use imports more effectively, while at the same time limiting hard currency expenditures. Their goals are to raise the quality and efficiency of industry enough to meet more of their own needs and to expand their exports of manufactured goods. These initiatives include:

— Increasing imports of machinery and equipment from Eastern Europe. East European goods now make up about 70 percent of Soviet equipment imports. The Soviet leadership is continuing to pressure the East European countries to boost technological modernization through RDT&E projects and S&T exchanges bilaterally or among the countries of the Council for Mutual Economic Assistance (CEMA) (see inset on page 13). Although getting a mix of Western-level technologies and lower quality goods, the Soviets are developing a potential long-term source of additional resources and at the same time saving hard currency.

— Allowing selected Soviet organizations to trade directly with foreign partners through their own foreign trade units—instead of through the Ministry of Foreign Trade apparatus. This is designed to encourage Soviet exports and to produce a more efficient and productive system of selecting imports. Reorganizations in several trade and financial organizations—still in progress—are purportedly causing confusion, high-level infighting, and morale problems at lower levels. Nevertheless, the trade reforms provide the enterprise with incentives—they can keep part of the hard currency earnings—to produce goods for export.

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— Promoting joint ventures and other commercial relations with Western firms. In January 1987 the Soviet leadership passed a new law that allowed minority foreign ownership of Soviet enterprises—the first time since the late 1920s. The foreign partner contributes capital in the form of equipment, technology, or financing, and takes part of its return in finished or semifinished goods. Among the countries where Moscow is actively promoting joint ventures are the United States, Japan, and West European states. Soviet proposals have been weighted heavily on the chemical, light, and food industries. Proposals for Soviet-US ventures that have reached the negotiation stage include some involving oil and gas, nuclear, and agro-industrial technologies. The Soviets have also expanded their use of international financial instruments and applied to participate in the General Agreement on Tariffs and Trade (GATT). This reflects their interest in expanding their presence in international organizations and markets.

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East European Contribution to Soviet S&T [a]

Partly in response to Western sanctions and to changes in Soviet perceptions of the costs and benefits of Western technology, Moscow is trying to get more and better technology from its East European allies. The Soviet leadership is putting pressure on the East European countries to boost technological modernization. Moscow particularly wants intra-Bloc structures that will increase the level of collaboration and hasten technological development in priority areas—laid out in the CEMA Comprehensive Program for S&T Progress Through the Year 2000 and also identical to Soviet domestic target areas—of electronics, automation, nuclear energy, new materials and technologies, and biotechnology (see appendix C). The Soviets have also called for S&T organizational changes among CEMA members, such as the creation of "international production and technological complexes" in CEMA countries and participation by other CEMA countries in the USSR's newly formed interbranch S&T complexes (MNTKs). Two new CEMA Standing Commissions have been created—the first new organs at that level since 1975—for the materials and biotechnology areas.

The CEMA 2000 program, just beginning to get under way, provides a potential long-term source of additional resources and technology to aid the Soviets in their quest for S&T progress. The program provides an extensive list of general intentions and projects, although it lacks concrete suggestions for action in the near future to initiate, guide, and control the stated tasks. The plan does serve as an important guide to inspire the directions of regional economic development beneficial to Soviet long-term goals. While past joint projects have tended to be of limited success, the integration of the CEMA computer industries—developed over the past 15 years—has used massive transfers of Western technology to accelerate progress in the area. While still lagging behind Western achievements, the Soviets and other CEMA countries have embarked on a long-term comprehensive program, hoping to build on the success of their joint computer effort. Nevertheless, longstanding and major political, economic, and technological impediments will constrain the pace and scope of these Bloc-wide efforts

17. Gorbachev has placed importance on continuing and increasing international scientific contacts. These contacts, in the form of scientific conferences, formal government-to-government S&T exchanges, academic study, and private business relations with US firms, are an important means by which the Soviets acquire Western knowledge and technology. Approximately 2,000 Soviet Bloc citizens come to the United States each year in nontourist status. Despite fluctuations in the number of requests for US visas during the late 1970s and 1980s, Soviet major interest areas continued to be fairly steady (see figure 5). In addition, Soviet S&T contacts with the rest of the West are extensive. For example, the French estimate that more than 19,000 Soviet S&T personnel visited France during 1986.

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18. We believe that Moscow would like to reverse the decline in S&T visits caused by strained diplomatic relations in the early 1980s. Gorbachev has agreed to several US-Soviet S&T exchange agreements—including the general (umbrella) agreement renewed in November 1985 by him and President Reagan at the Geneva summit meeting—and cooperation agreements on oceanographic studies, standards, atomic energy, and space research. Other agreements—such as those on environmental protection, medical science and public health, artificial heart research, agriculture,

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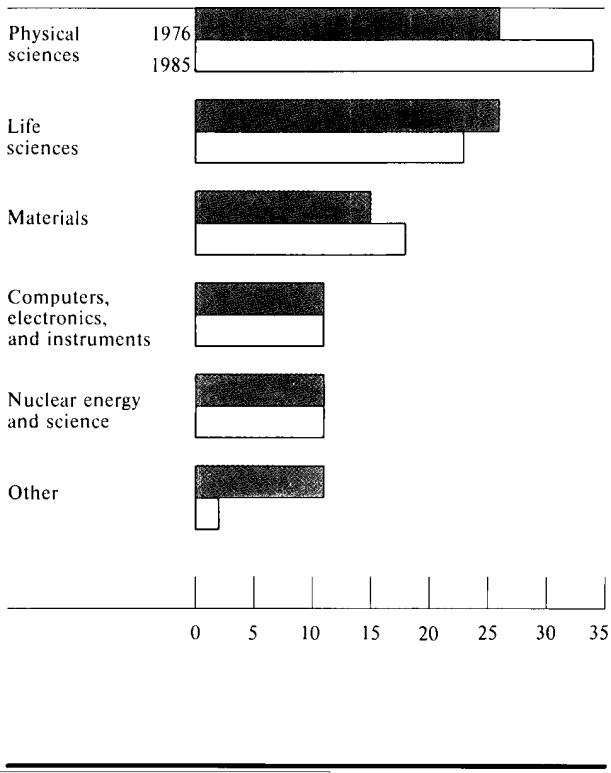
Figure 5 *Percent of total*
Trends in Soviet Requests for US Visas, by Discipline, 1976 and 1985



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and housing construction—are up for renewal over the next two years. The USSR also has S&T cooperation agreements with France, the United Kingdom, Italy, Sweden, Germany, Finland, Canada, Japan, and Australia.

19. ***Illegal Technology Acquisition.*** We believe that Soviet illegal and covert technology transfers will continue to play a significant role in supplementing Soviet military research and manufacturing capabilities and in narrowing the technology gap with the West. Two such efforts have significantly improved Soviet capabilities in both defense and civilian technologies:

- A program run by the Military Industrial Commission (VPK) seeks the latest technology to improve the technical levels and performance of Soviet weapons, military equipment, and defense manufacturing equipment. This effort uses Soviet intelligence services, their surrogates among the East European services, and Soviet trade and RDT&E organizations to collect targeted equipment and documents from Western defense contractors, manufacturers, foreign trading firms, academic institutions, and electronic data bases. Collection has focused most significantly on electronics, communications, aviation, radar and computers, and chemicals.
- A trade diversion program run by the State Committee for Science and Technology (GKNT) targets equipment items—for example, computers and machine tools—for direct use in production lines, for reverse engineering and copying, and in support of research programs to enhance productivity, boost product quality, and meet planned targets. We believe that this program is responsible for most diversions of COCOM-controlled, dual-use equipment to the USSR. Decisions are made on the use of technology and equipment, acquired by the VPK and GKNT for the design of weapon systems and associated production equipment, early on in the Soviet RDT&E process, most often at the design bureau level.[2]

Improving Technology Diffusion

20. The Soviet regime is taking a varied approach to eliminate the obstacles that have in the past impeded the successful diffusion of technology throughout the research-to-production cycle. First, the S&T institutional structure and methods of operation are being reworked and the cadre renewed. Secondly, Gorbachev is beginning to tackle the problem of supplying the proper incentives to innovate—a part of his larger program to "restructure" the economic system. Gorbachev's address to the June 1987 plenum outlines more extensive measures for radically restructuring the management of the economy, including price structure reforms, enhanced incentives, increased competition, and decentralization. The defense-industrial sector is being used to some extent as a model for change.

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21. Some of these measures have encountered foot-dragging in the bureaucracies. For example, former Academy of Sciences President Anatoliy Aleksandrov has hinted that his failure to vigorously back the introduction of interbranch S&T complexes (MNTKs) was a factor in his replacement last year by the current President, Guriy Marchuk. Economic reform is encountering stiff resistance in the party and government bureaucracies and perhaps in the Politburo itself despite the incremental nature of the process thus far.

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Changing the Roles of S&T Policymakers

22. Calling for an improved, comprehensive, and integrated S&T policy, Gorbachev, like Brezhnev, is attempting to make important personnel and organizational changes in the three national agencies that coordinate science and technology: the State Planning Committee (Gosplan), the GKNT, and the USSR Academy of Sciences. The leadership is attempting to redefine the roles and functions of these organizations, to eliminate overlapping functions, and to withdraw them from day-to-day operational planning so they are able to carry out more strategic planning. These changes also aim at improving S&T interaction between the military and civilian sectors to the mutual benefit of both. On the one hand, the defense establishment is being called upon to assist civilian industries in the application of technology. On the other hand, the scientific community (especially the Academy of Sciences) is being driven to enhance military-related RDT&E, while key civilian ministries are under pressure to help modernize the defense industries as well as their own plant and equipment to better support weapons production.

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23. ***Gosplan.*** We are uncertain about the eventual role of Gosplan in Soviet S&T policy since there is much confusion surrounding the organization's role in economic change. Gosplan, now responsible for overall

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Soviet economic planning and introducing new technology into the production process, is to become "the country's economic-scientific headquarters," according to Central Committee secretary and Politburo member L. N. Zaykov. Despite recent criticisms of Gosplan, the leadership has expressed commitment to strengthening its control over the main directions of the economy and in integrating S&T into economic policy and plans.

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24. ***GKNT.*** The GKNT, charged with maintaining a unified national S&T policy and promoting widespread use of innovations and the ministerial science it supervises, has continued to come under criticism from Gorbachev and others for the past several years. It is criticized for taking "only very timid steps toward uniting science and production and amalgamating scientific research institutes and design bureaus . . . still adhering to a wait-and-see position on these matters."

25. ***USSR and Republic Academies of Sciences.*** The Gorbachev leadership, continuing efforts begun under Leonid Brezhnev, is placing increased attention on the potential economic and military applications of the huge research effort of the USSR and republic Academies of Sciences, historically known for their work in fundamental research. The leaders (see figure 6) now running the USSR Academy, including newly elected President Guriy Marchuk, are supporting more enthusiastically the party's demands, are closely tied to the military-industrial complex, and have the experience to direct a more applications-oriented policy. Marchuk has called for strengthening the role of the Academy's substantive departments in directing and planning Academy research, imposing age limits on institute directors, concentrating the Academy's work on basic and long-term scientific research, and developing temporary intersector scientific laboratories to work on short-term targeted programs. The leadership is likely to continue to increase the Academy's role in applied research, while striving to avoid a drastic shift away from fundamental work, and to expand the Academy's role in developing and promulgating the use of computers (see inset on page 16).

Figure 6. Meeting of Soviet and Japanese Science Leaders. Kodzi Hushimi, president of the National Scientific Council of Japan, meets with Yuriy Ovchinnikov (center) and Yevgeniy Velikhov (right), vice presidents of the USSR Academy of Sciences. Velikhov heads the Academy's newly created Department of Information Science, Computer Technology, and Automation. Ovchinnikov, a specialist in biotechnology, heads the new MNTK Biogen.

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Restructuring the RDT&E Network

26. At the working levels, Gorbachev is continuing to emphasize increased managerial authority and new organizational forms, such as science and engineering centers and interbranch S&T complexes (MNTKs), which are being created to break institutional and administrative barriers between science and industry. Speaking in August 1986, Gorbachev explained:

> Our country is great . . . one cannot—it just isn't possible to—manage the whole of this huge economy from only the center;. . . a significant part of responsibility for the solution of many questions must be transferred to local organs. And that means that they must be given corresponding rights too.

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These changes include:

- Expanding the number of science and production associations, centers, and complexes, within the economic branch ministries, that link institutional performers in the research-to-production process.
- Creating MNTKs—new organizations that have RDT&E and manufacturing facilities tasked to develop and produce target technologies that require the cooperation of several ministries and the academies. All the MNTKs are oriented toward practical applications, while many target

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Directions for the Academy of Sciences

In the past year, the Soviet leadership has given significant attention to the role of the Academy in directing science to serve economic reform and modernization. We have seen several directions developing, including:

Increased Emphasis on Applied Research. The Academy's changing emphasis from basic to applied research has intensified in the 1980s and may result in a reduction or leveling off of some fundamental science, although a smaller core of scientists can be expected to continue to produce world-class scientific results. The shift is evidenced in several ways:

- Increased Academy participation in national S&T priority programs and in coordinating key target programs and interbranch S&T complexes (MNTKs).
- Establishment of new Academy institutes and laboratories dedicated to applied research in "target" areas such as energy, metallurgy, and biology, and in crucial industrial and defense technologies.
- Organizational reforms that bring industry representatives into research teams of various Academy institutes to help speed up the transfer of RDT&E into production.

Concentration of Fundamental Research on Goal-Oriented Projects. Marchuk has recently reiterated not only the Academy's role in applied research, but its need to be more pragmatic in its choice of fundamental research projects—to focus on the theoretical foundations of new types of equipment, advanced processes, and new materials. The leadership is fighting a conservative "ivory tower" attitude present in many older Soviet academicians who are steeped in an academic tradition that focuses on the basic natural sciences with little or no practical application in the near term. We believe that those areas, closely coupled to applications such as condensed matter physics and semiconductors, are likely to receive greater emphasis

Active Role of Regional Science Centers. The Academy is also pressing its regional scientific centers to play a more active role in solving regional economic problems and coordinating the research of industrial and educational establishments with that of Academy institutes. For example, the Academy, backed by regional party leaders, has sought to strengthen its role in spearheading the advance of S&T in Leningrad, a major center of defense industry and high-technology development. Apparently, party leaders are trying, nationally and locally, to use the Academy to break down or circumvent ministerial barriers to technological change. The recent conversion of the USSR Academy's Far East and Urals scientific centers to departments indicates Marchuk's first move to restructure the Academy and to decentralize its day-to-day decisionmaking.

development of advanced equipment and materials for industrial modernization—especially machine tools, robots, flexible manufacturing systems, microelectronics, computers, and composite materials (see appendix B).

- Increasing access to and joint use of facilities and services across sectors on the basis of negotiated settlements and shared interests. Academy scientists, for example, are making greater use of the experimental and pilot production bases of ministries—including the defense industries (see inset on page 17)—while the latter are tapping the basic and applied research capabilities of the Academy.
- Increasing the reliance on CEMA organizations. The CEMA Comprehensive Program for S&T Progress Through the Year 2000 provides for joint work on 93 S&T "problems," entailing several thousands of subprojects and programs (see appendix C). Although it is unclear whether all 93 are clearly defined as yet, Soviet officials claim that the first concrete results—production of new high-technology equipment—will be as early as 1987. Much of the lead work will be done by Soviet organizations, such as the Academy and individual MNTKs.

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Renewing the Cadre

27. The positioning of competent and dynamic people—talented party technocrats, successful industrial managers, and defense industry specialists—in pivotal party and government jobs is crucial to the success of Gorbachev's overall S&T policy. In the past, ministry and RDT&E organization heads have been blamed for empire building and creating barriers to cooperation and information transfer. Gorbachev has removed Central Committee department chiefs who oversee machine building, construction, trade, and the service sector, has appointed new heads to all three S&T policymaking organizations, and has replaced over half the country's ministers and state committee chairmen. The Soviets also are pushing to advance younger scientists and to provide them with more opportunities in S&T. Academy of Sciences President Marchuk, for example, recently announced the enforcement of mandatory retirement for Academy institute directors and other Academy leaders—though they may accept jobs as advisers to new institute directors and to the Academy's Presidium.

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Improving Long-Range Planning

28. The Soviets believe that they must produce longer term and integrated S&T plans, given the

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Military Involvement in Civilian RDT&E

Although none of the publicly identified S&T programs are weapons development programs, many (particularly the target programs) focus on the development of new technology, materials, and manufacturing processes that can be used to help design and produce sophisticated weapons. Moreover, Soviet military RDT&E and production organizations are now participating in several civilian S&T programs as both developers and end users of new technology. These programs appear to be an important mechanism for technology transfer between military and civilian sectors; they are being used both to modernize the civil machine-building base and to retool defense industry with critical high technologies:

— Several organizations involved in the Industrial Robots Program are major RDT&E centers of defense-industrial ministries. They include the science and production associations Pozitron (defense industry), Ritm (shipbuilding), Svetlana (electronics industry), and Leningrad Optical-Mechanical Association (LOMO) (defense industry). As part of this program, industrial robots and manipulators are being introduced into production lines at several defense plants for welding, painting, and forge press operations.

— The Ministries of the Defense Industry, Aviation Industry, and Radio Industry are involved in the Powder Metallurgy Program.

— The Ministries of the Radio Industry, Communications Equipment Industry, and Electronics Industry are major participants in about a dozen programs in computer technology, microprocessors, and microelectronics. Computer-aided design (CAD) systems are being introduced in several defense industry establishments, possibly under the target program on automation of research and design engineering.

— Various elements of the Ministry of the Defense Industry are taking part in the Industrial Lasers Program. In addition, laser technology is being introduced at the Baltic Shipyard under this program.

increased magnitude and complexity of their goals. Toward this end they have formulated:

— A 20-year Comprehensive Program for S&T Progress, which aims to integrate and drive annual and five-year plans (FYPs), sets national priorities to solve key economic and social problems, directs resources and funds, and identifies large-scale economic target programs. For the 12th FYP, the leadership is emphasizing programs in heavy industry, machine building, and the chemical sector, and continuing those in food, energy, and consumer goods.

— Long-term and short-term "target" S&T programs. Modeled after weapons development programs, these are meant to support major economic programs, cut across departmental lines, and promote technology transfer between the defense and civilian sectors. The majority of these 160 S&T programs approved for the 12th FYP are probably similar to those of the 11th FYP, during which almost 60 percent of the long-term and almost 70 percent of the short-term S&T programs focused on Gorbachev's priority areas—computers, nuclear energy, biotechnology, and automation. We believe that the Soviets are also placing special emphasis on machine building (including robotics, lasers, and cryogenic machinery) and metalworking.

— The CEMA Comprehensive Program for S&T Progress Through the Year 2000. Adopted after much public Soviet prodding in December 1985, this program aims to promote "mutual cooperation, specialization, and the integration of production, consolidation of the material and technical base of the CEMA member countries, growth of prestige and attractiveness of socialism in the world." Mirroring the target areas of interest to Gorbachev, the CEMA 2000 plan delineates cooperation in bioengineering, nuclear power, advanced materials, computers and microelectronics, and machine automation (see appendix C).

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Revising the Incentives To Innovate

29. The Soviets are reforming the economic system in an effort to make it more efficient. This is an ongoing process that, according to some Soviet officials, will not be completed until the year 2000. A part of this effort is to change the system of plan targets and incentives for both enterprises and workers in order to promote the innovation and diffusion of the appropriate technologies into machine building and the rest of the economy. Reform measures already in place that could support technological change include the following:

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— Labor productivity and improvement in product quality are emphasized as success indicators for enterprises.

— The shift in measuring performance from a gross to a net concept supposedly favors the introduction of new equipment and processes that save on materials.

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— Increased enterprise autonomy to use production development funds gives factory managers greater authority to procure new machinery and equipment.

— Wages and bonuses are tied more closely to cutting costs, reducing manpower, and improving product quality.

— Prices are being made more flexible to reflect product quality. Wholesale prices on top-quality goods may be increased up to 30 percent while output not meeting such standards is subject to price discounts of 5 to 15 percent—charged partly to incentive funds.

— Material and criminal liability can be levied on designers, S&T organizations, and officials who allow "irregularities to occur or substandard goods to be produced."

30. In the spirit of Gorbachev's campaign for *glasnost* and *otkrytost* (publicity and openness), managers, institutes, and ministries have been publicly censured for lack of innovation. According to *Pravda*, at the March 1986 Moscow City Party Committee plenum, Boris Yel'tsin, first secretary of the committee, brutally criticized unproductive Moscow research institutes and design bureaus and threatened to close down 10 to 15 institutes immediately.

Using Defense as a Model

31. Many of these changes use as a model the defense sector, which emphasizes traditional methods of centralized planning, organization, and management—mechanisms that in the Soviet view compensate for inadequate information flow (see inset). Typical is the ambitious new system for quality control called State Acceptance. Introduced in 1,500 civilian enterprises beginning on 1 January 1987, it employs 25,000 inspectors and covers an estimated 15 percent of all industrial products and nearly a third of the production from the machinery sector. This system undergirds a program of incentives to industry that, according to Gorbachev, ensures that those who produce "garbage" do not get rewarded. State Acceptance, a reflection of the quality control system in the defense sector, requires the State Committee on Standards to enforce quality standards through a system of local offices and inspectors at major industrial enterprises. These local quality control offices are independent of ministries and enterprises, unlike the quality control units that have existed in Soviet factories for many years, and therefore are envisioned to provide objective and effective monitoring similar to that done in the defense-industrial sector by military representatives assigned to defense-related enterprises.

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Technology Diffusion: Emulating and Tapping the Defense Sector

Moscow's focus is on engineering a high-technology revolution and industrial revitalization from above—using its own military economy as its model. The leadership is looking to the defense industries—and their traditional methods of centralized planning, organization, and management, as well as strong party direction—to advance the Soviet technical industrial base across the board. Measures the leadership is taking to apply this model to the civilian sector include:

— Improving the effectiveness of bureaucratic levers—the party's sponsorship and oversight of new technology development, and strong centralized management—that have been generally weak in the civilian sphere but are crucial to military technology and defense modernization.

— Strengthening the role of long-range scientific forecasting and technology assessment in economic planning—important management tools used in defense for decades.

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— Creating big, goal-oriented projects to accelerate the development of key technologies (lasers, computers, robotics, biotechnology) modeled along the lines of the USSR's nuclear and missile programs.

— Organizing new superagencies under the Council of Ministers, led by deputy premiers and patterned on the Military-Industrial Commission, to oversee and coordinate the work of related ministries.

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— Introducing military-style quality control inspections at the most important industrial enterprises outside the defense sector.

— Moving top defense executives with experience in managing high technology into critical civilian jobs.

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PROSPECTS FOR SUCCESS

32. Gorbachev already has put his personal stamp on Soviet S&T strategy, predominantly by his outspokenness and vigor in pursuing change. In his short time in power, Gorbachev has gone far in raising the leadership's consciousness of the importance of S&T policy and its integration into economic policy. To marshal public support for his policies, Gorbachev is actively encouraging increased candor and publicity in dealing with problems of Soviet S&T and the possibili-

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ties of their solution. Gorbachev also is publicly censuring those within the elite who are not implementing the new standards and strategies he has set. But now he must move from plans and garnering support for his policies to implementing his S&T program. Its success will depend as much on the creation of an adequate incentive system for innovation—to spur the production of more technologically advanced machinery and equipment and guarantee its use throughout the economy—as on the sustained allocation of the necessary personnel and investment resources.

The RDT&E Base

33. Plans to strengthen the Soviet *S&T resource and experimental-test base* probably will meet with moderate success, backed by Gorbachev's program to modernize the machine-building sector. The lack of equipment permeates multiple layers of the Soviet economy and directly affects the quality, capabilities, and morale of the work force. Some of the most ambitious targets, however, will not be met. The computer literacy program, for example, assumes the creation of more than 50,000 computer labs equipped with a million PCs, but Soviet domestic capabilities are unlikely to meet this production demand—Soviet sources estimate that only about 1,000 PCs will be produced this year—much less service and supply it with the necessary peripherals and software.

34. The efforts to raise the quality and morale of the *S&T labor force* probably will meet with limited success. The new education measures may generate higher quality graduates, but are less likely to make the educational system more flexible and conducive to technological change. Benefits that do result are not expected before the 1990s. Plans to raise the pay of S&T workers depend entirely on the success of S&T organizations and enterprises in raising productivity, and they may not have enough funds to finance both a wage reform and new equipment. Moreover, monetary incentives to workers in an economy with a dearth of consumer goods and services are of limited value. The Soviets are attempting to tackle this problem also, but results are at best several years away.

35. The strategy to *increase the flow of information* runs the risk of spreading politically undesirable ideas and threatening the regime's traditional monopoly over information flow—a major instrument of political control. Therefore, the regime is likely to counter such a trend by controlling access to computers, as it has done for copying machines, and by structuring inherent limits on items such as disk storage, modems, and printers. This type of restriction on information flow would work against efforts to speed S&T progress.

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36. We believe that the Soviets will continue to have success in *acquiring Western technology* to supplement Soviet S&T, and that such acquisitions will provide a short-term fix while the Soviets attempt to build their indigenous S&T capabilities. The reliance on Western technology may in fact increase in areas critical to the modernization of civilian and defense industries. However, there are constraints on the legal and illegal acquisition of foreign technology:

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- Hard currency limitations continue, exacerbated by current world oil prices, and the Soviets are likely to place increasing emphasis on alternatives to hard currency imports, including commercial ventures with Western firms and continued reliance on the S&T capabilities of Eastern Europe.
- The Western business community, however, has received the vast majority of the Soviet joint venture proposals with little or at best mild interest, complaining that they are one-sided and still too vague to represent serious bids.
- Soviet susceptibility to Western trade sanctions and technology bans continues to make the leadership apprehensive over the cost and wisdom of technological dependence on the West, although the diffusion of technologies throughout the world makes it harder for Western governments to deny Soviet access.

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- Technology diffusion problems have limited the contribution of Western technology to the growth of industrial productivity, reducing Soviet enthusiasm for Western equipment and technology as a panacea for domestic shortcomings.

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Technology Diffusion

37. Despite some improvement in their RDT&E base, the Soviets will be limited in making S&T progress under the current strategy package because of their inability to improve technological diffusion. Gorbachev's strategies in the S&T area reflect conventional Soviet remedies that have not worked in the past. For the most part, Gorbachev is continuing the Brezhnev approach of mandating change "from above" and using the defense industry as a model for change.

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38. Soviet plans to *break down departmental barriers and to redefine the roles of Gosplan, the GKNT, and the Academy of Sciences* are likely to encounter serious problems. Many of the new organizational changes simply realign the old structure, and sectoral and bureaucratic interests remain:

— Uncertainty exists over whether Gosplan or the GKNT will have the responsibility to ensure the integration of science and economic planning since Gosplan is to become the country's "economic-scientific headquarters."

— Despite calling for an increased role for Gosplan in S&T policy, Gorbachev has singled it out as an example of opposition to change—clinging to old habits, thinking, and styles of management. We believe that Gosplan's main role will continue to focus more on the economic than on the technical side of S&T progress. We also doubt whether Gosplan will be able to shed its historical bias toward the production sector and maximizing industrial output.

— The future establishment of firm roles in S&T planning is tenuous in light of current economic reform proposals that could result in some decentralization of decisionmaking and planning.

— New commissions and organizations, such as MNTKs, cloud policymaking responsibility. Proponents of the new Bureau of Machine Building, for example, argue that the GKNT should get out of technical policy at the engineering level.

— Changes in the Soviet management of the foreign trade system that decentralize foreign equipment acquisition to some extent are likely to affect the GKNT's role as coordinator of foreign technology acquisition efforts.

— Though the leadership appears to be increasing its reliance on the Academy of Sciences, the issue remains how much these changes can affect S&T and the economy as a whole. Academy experience in innovation is localized, confined mostly to scientific centers in the Ukrainian Academy and the Siberian Department of the USSR Academy. Furthermore, the Academy system is a relatively small part of the total Soviet S&T base, occupying about 9 percent of the total reported expenditures for science, and it suffers from an aging cadre as well as an antiquated building and equipment base. The leadership risks straining the Academy's resources and pushing it into areas, such as production engineering and testing, which are further from its expertise. Emphasis on applied research in the Academy may, indeed, decrease the quality and volume of basic work needed for long-term indigeneous S&T development.

— Gorbachev's commitment to the creation of the MNTKs suggest that they could provide increased development and assimilation of technology. Obstacles are appearing already, however, as shown recently when the slow pace of creating MNTKs was criticized by Academy officials and party heads who admitted that so far they are "largely paper exercises." According to Yuriy Ovchinnikov, Academy of Sciences vice president and head of Biogen, the biotechnology MNTK, a paradox is taking place. The MNTKs are declared from above to be instruments of acceleration, but their material support so far has been based on traditional, unhurried tempos and methods. It is likely that even when fully operational they will encounter strong bureaucratic inertia and technological conservatism in both science and industry similar to the problems encountered by scientific production associations in the 1970s.

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39. Gorbachev has been able to move quickly on the *cadre* front and has promoted officials with a strong track record for innovation. This appears to be a positive step for Soviet S&T and is likely to provide some fresh blood and new energy to back Gorbachev's policy. Individual ministers and RDT&E organization heads have been blamed for empire building and helping to create the barriers to cooperation and information transfer. The lack of expertise by leaders and managers has often resulted in poor planning as well as a stagnant work environment. Nevertheless, Gorbachev's cadre changes have affected only a small portion of the S&T community and have not been a complete success. Some defense-industrial managers reassigned to the civilian RDT&E sector, for example, have not been able to perform the miracles that Gorbachev seemed to expect. These managers, with their strong military RDT&E experience in the defense sector, are finding themselves in an entirely different environment—one that lacks the proper equipment, political priority, raw materials, and skilled work force. Moreover, if incentives to innovate are not revised, the new managerial cadre will quickly fall back into the stagnant ways of its predecessors.

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40. *Long-term planning* to date has not been successful, even in the Soviet view. Despite continuing

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leadership pressure on the bureaucracy to integrate economic and S&T planning and to raise the priority of S&T programs, we believe bureaucratic resistance, continued departmental barriers, and technological conservatism will continue to hamper their effort. The transition to comprehensive S&T and economic planning puts enormous demands on Soviet planners who do not have established measures and methods for calibrating S&T progress or the "economic effectiveness" of new technology. The leadership, recognizing these problems, recently has created new organizations to improve "scientific" planning of S&T progress. While long-range S&T forecasting and planning have been important management tools in the Soviet military-industrial complex, we believe that the civilian economy lacks analogous advantages such as a well-defined customer/consumer and a framework of desired capabilities and requirements in which to evaluate the merits of alternative lines of S&T development.

41. Though too early to predict its outcome with certainty, we believe that the new *system of quality control* will have to overcome several constraints and survive a turbulent period of industrial disruption before experiencing any significant achievement of the increasingly demanding technical standards of industrial production. The system of inspectors, who are purportedly independent of the developing or producing enterprise, does show promise and has been successful in the defense-industrial sector. Nevertheless, significant constraints exist:

— The rejection of materials and equipment has significant potential to create economic reverberations such as bottlenecks and production slowdowns, as well as morale problems. During the first quarter of 1987, high rejection rates reportedly cut worker bonuses and disrupted production of goods such as computers, radios, and metal-cutting machine tools. While the leadership may have expected such disruptions, the issue remains how long the program's initial disruption will be tolerated and whether inspectors will be pressured to continue high rejection rates.

— The inspectors must be highly trained and well-qualified specialists to do their job effectively. Filling these 25,000 posts may result in a drain of talented engineers from production—the only pool of qualified people—or a glut of less qualified paper pushers. Gorbachev has already expressed dismay at some of the newly created bodies for sinking "in the mire of bureaucracy and red tape."

— High-quality, sophisticated diagnostic equipment is often needed to perform inspections for quality control. The USSR at present lacks this type of equipment and therefore is dependent on improvements in its instrument-building industry and on foreign trade. Moscow appears to recognize that the long-term solution of the quality problem requires more than punitive administrative measures like State Acceptance, but there is little evidence of a consensus on what kind of economic levers, if any, will be introduced to deal with the problem.

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42. As in the case of the new State Acceptance system, the leadership appears to recognize that carrots as well as sticks must be offered to spur technological change. However, the present *incentive system*, limited by taut planning requirements and inadequate supply arrangements, continues to place Soviet managers in a no-win situation: they are penalized for failure to meet innovation targets, but they are penalized more if they fail to meet output targets. For example, a 1983 decree stipulated a 25-percent reduction in managerial bonuses if new technology targets were not met; yet nonfulfillment of the deliveries target led to *total* loss of bonuses. This reliance on *val*, or volume of output, continues to be a major disincentive to the application of new technologies and processes. Now, under Gorbachev, enterprise managers have new worries about quality control—another potential barrier to plan fulfillment—and increased material and personal responsibility for the goods designed and produced.

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43. Reforms in economic planning and management that could be critical to improving the incentive structure and efficiency in S&T development and innovation have recently been outlined by Gorbachev. These include changes in the supply system, the expansion of authority and independence at the enterprise level, increased reliance on contracting, reduced plan output targets and other economic indexes, and reforms to the pricing system. If these reforms could be fully implemented without any fragmenting political side effects, Gorbachev should realize considerable success in relation to past Soviet performance. Although the recent plenum strengthened Gorbachev's hand to pursue his economic reform agenda, resistance to such change is strong and successful implementation is still far from assured.

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44. The Soviets have several problems with the general notion of extending leadership intervention and the *defense industry model* to the entire economy:

— Though civilian goal-oriented programs are to have priority, priorities by definition must be

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limited. Civilian programs will be second to, or at most competing with, military programs for materials, competent and experienced managers, and attentive supervision of high-level government and party officials. Similarly, while resembling defense RDT&E conglomerates at least on paper, the newly formed MNTKs cannot be successful unless they have adequate control over financing, influence on policy directions, and access to material and personnel resources. To date, they do not.

— The planning and management approaches of the defense sector, moreover, cannot be transplanted easily to the civilian sector; they will not work there with equal success. The civilian RDT&E sector lacks the defense sector's defined, closely coupled customer who has specific requirements and specifications for future products and who lends constant supervision to maintain quality.

— The Soviet defense RDT&E sector may not be the best model for improved productivity and efficiency. Military output has been high in numbers of new weapon systems, improved effectiveness, and increased capabilities, but, on balance, productivity in both civilian and military RDT&E has been notably poor. The defense sector's reputation for quantity and, more recently, quality has sometimes been achieved at a substantial resource cost.

IMPLICATIONS

45. The limited success that we expect from Gorbachev's S&T program (see inset on page 23) is unlikely to produce the large gains in productivity, efficiency, and innovation promised by Gorbachev's modernization program. Even in the unlikely event that the Soviets radically improve their RDT&E base, the basic systemic flaws will limit state-of-the-art technological development to special-emphasis areas—biotechnology, for example—where the leadership, as in the past, focuses its attention, hard currency, and resources. Significant S&T problems will remain unresolved, therefore, including contentious resource allocation issues, inadequate information flow, lack of cooperation between the RDT&E and production sectors, and a continued bias toward production. Falling short of his proposed S&T goals might open Gorbachev's administration to charges of immobilism, but he could try to reduce political repercussions by softening his rhetoric, reducing the pressure on party and government cadres, and easing up on controversial issues.

46. Furthermore, the unique qualities of the new technologies targeted by Gorbachev—materials, microelectronics, computers, biotechnology, nuclear power, and machine automation—are likely to compound the existing problems and create additional obstacles to implementing Gorbachev's technology strategies:

— The targeted technologies often have a very short "lifetime" due to the rapid pace of development. Improved long-term planning and priority S&T programs provide limited benefit and may even inhibit progress by misdirecting limited funds and resources.

— They depend on and are interrelated with older technology. Reliance on Western technology could have negative repercussions on future Soviet technology development and capabilities. For example, while the Soviet acquisition of Western technology has radically advanced the quality and quantity of microelectronics production, the United States still has a minimum technology lead of at least two to three years, and a minimum production lead of eight to nine years.[3]

— They demand new levels of quality and testing that must be built into the design capabilities, clean-room technology, and production process. For example, computer-aided design, quality controls, and nondestructive testing capabilities are critical in the materials area for efficient production of resins and fibers and to avoid costly overdesigning of composite parts. Similarly, quality testing of integrated circuits must be part of the production process to avoid discovery of defective parts only when they fail to function after being assembled onto printed circuit boards. Such quality control not only requires Western technology, but presents the equally difficult problem of disciplining and reeducating workers to follow though with time-consuming and often annoying work habits—procedures required, for example, to keep their clean rooms clean.

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— They require scientists and engineers—who play a major role in S&T development—to keep abreast of the rapid changes taking place in their own and interrelated fields. Although the Soviets have been developing their system of automated data links for S&T information transfer for many

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Indicators of Progress in S&T Strategy Implementation

- Closing of inefficient or redundant RDT&E organizations and the transfer of workers between organizations and sectors. Gorbachev is likely to recruit from party organizations in 22 cities where about 80 percent of S&T is concentrated.
- Legal enactments encompassing and outlining some of the broad administrative and organizational changes aimed at accelerating S&T progress. Specifically:
  - Regulations governing the USSR State Committee for Science and Technology (GKNT) (planned for the fourth quarter of 1986 but still not promulgated).
  - USSR law on product quality (planned for the first quarter of 1987).
  - USSR law on discoveries, inventions, and licenses (planned for the latter half of 1987).
- Improvement in Soviet economic effectiveness and efficiency indicators. Western specialists, have used such indicators to assess change as the Soviets themselves see it. However, as these scholars warn, observers must exercise caution because of differing definitions, methodologies in estimating, and potential bias of the Soviets to inflate these reported indicators:
  - Capital/labor ratios. Increased capital investment would result in increased ratios. According to Soviet sources, for every worker in Soviet "science and science services" in the early 1980s there was an average of 6,200 rubles' (constant 1973) worth of capital stock (building and equipment) and, of this total, about 3,200 rubles' worth of capital equipment.
  - Prototypes of new machines and equipment. Soviet annual statistics have shown a continuous absolute decline since the early 1960s in the creation of prototypes of new machinery and equipment, especially in areas of instrumentation, automation, and computer equipment. Statistics published in 1986 show that the number of total inventions decreased during the 1981-85 period by an average annual rate of about 1.3 percent Observers should also be aware that some restraint in these growth rates is expected because of the tendency toward higher development costs per prototype at higher levels of technological advancement.
- Further changes in economic and S&T planning and management to increase the autonomy of Soviet RDT&E and production enterprises and to decrease the importance of output or *val* indicators to measure enterprise success.
- Further economic reform consisting of administrative decentralization, greater competition, and a liberalization of the price system and foreign trade.
- Joint venture agreements completed with Western companies, especially in areas such as nuclear energy, biotechnology, machine building, materials, and automation.

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years, Gorbachev has been conspicuously silent on the issue of S&T networks and has not labeled it a priority aim in S&T policy.

47. For military RDT&E, the effect of Gorbachev's continued technocratic approach is more positive than for the general economy. Like the civilian sector, defense could profit from even limited or patchy improvements in the targeted technologies and in the research-to-production cycle. Though scientists and engineers working in military RDT&E have proved to be innovative in using available technologies to design effective weapons, they have not shown themselves to be as innovative as their Western counterparts in making technological breakthroughs. The inadequacies of the current Soviet S&T strategies are likely to be mitigated by past Soviet efforts since the 1970s to modernize the defense sector. Soviet military RDT&E has experienced continuous expansion and investment in its facilities and equipment and is likely to be in a better position to maximize the gains that are made through Soviet strategies such as the acquisition of Western technology.

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48. The Soviet military has a vested interest in the S&T strategies chosen. Priority for civilian programs increases the competition for scarce resources, potentially squeezing military RDT&E programs and defense modernization needs. We do not know how far Gorbachev will go in emphasizing the civilian RDT&E as opposed to the defense sector. Since the targeted technologies are of a dual-use nature, however, the military is not likely to be squeezed without getting a very important benefit in return. The technologies targeted by the 12th Five-Year Plan are "the leading directions of scientific-technical progress and simultaneously the basic catalysts of military-technical progress."

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Gorbachev reportedly assured defense leaders that both the military and defense industry will benefit from modernization advances.

49. Given the problems they may encounter in attempting to transform their indigenous RDT&E base, the Soviets are likely to increase their pursuit of contacts and trade with the West. Reforms in the trade area are also likely to spur increased Soviet interest in trade as individual enterprises have more autonomy to contract with foreign firms and take advantage of foreign markets. The need for Western technology might encourage the Soviets to increase borrowing from the West, to raise the cost of exports to Eastern Europe, and to sweeten the terms in foreign commercial ventures with the West—for example, by increasing the allowable share of foreign ownership in joint ventures. The Soviets are likely to continue to encourage S&T exchanges and other types of S&T cooperation with the East and West in all areas relating to their S&T goals. These contacts, while often portrayed as a sign of Soviet good will and progressiveness, also serve the foreign policy goal of integrating the Soviet Union into the community of advanced Western industrial democracies. Because of increasing hard currency constraints, the Soviets will continue to look to domestic or East European alternatives to Western technology and will clearly make greater use of technology developed in the East European countries through trade, joint ventures, and S&T exchanges. Though some of the technology is more advanced than that available in the USSR, it will still lag well behind the Western state of the art in most key areas.

50. Though they are difficult to quantify, we believe that Moscow will continue and possibly increase its illegal methods of technology acquisition—especially in the advanced technology areas, such as microelectronics and computers. High-priority end users will want state-of-the-art Western equipment, particularly for military projects and key modernization programs. The Soviets are likely to continue to use the already well-proven means, such as intelligence channels, trade diversion, and industrial espionage. However, hard currency constraints may force them to be more selective in the technology they acquire and more creative in their approach—for example, using legitimate joint ventures to help establish conduits for illegal technology acquisition. In the area of dual-use equipment, our experience has shown that, despite efforts by Western enforcement agencies, the Soviets have been able to acquire such technology.

51. Gorbachev's strategies to achieve his S&T and economic modernization policies in any event will require time. Whether he gets the time he needs could depend to a large extent on the state of the East-West relationship, and particularly on the military competition with the United States. The Soviets see themselves under considerable military pressure from Washington. Gorbachev, therefore, must reconcile a long-term industrial modernization program with an accelerating military-technological competition. Improved East-West relations, if they produce constraints on US military programs even on a modest scale, could buy Gorbachev more time. He appears to be acting, in our view, with an appreciation that an arms control agreement could—especially in tandem with mounting US budgetary pressures—dramatically slow US military expansion. Reduced tensions could also make it easier for the Soviets to acquire the types and quantities of Western technologies they have identified as critical, possibly on favorable credit terms.

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52. Soviet attempts to accelerate S&T also have implications for increased information flow between East and West. In an effort to exploit world scientific and technical literature and Western trade journals, catalogues, and advertising, Soviet citizens would gain broader access to outside news, increasing their vulnerability to foreign influence. Information access and more East-West cooperative ventures could also raise the potential for increased patent and copyright infringement, international contract disputes, and involvement by international arbitration and enforcement organizations.

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A CHANGE IN STRATEGY?

53. Future Soviet S&T policies and strategies are closely intertwined with the successes or failures of Gorbachev's broader economic and domestic policies. We believe that as problems of technology inadequacies, economic revitalization, societal pressures, and the defense burden converge over the next few years, Gorbachev will face an increasingly clear choice as to whether to settle for half measures that fall well short of his needs and expectations or to make harder and potentially divisive decisions that could bring more dramatic results.

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Systemic Reform

54. Apparently recognizing that one of the major sticking points of the current S&T strategy is the lack of incentives to innovate, Gorbachev has begun to initiate more radical economic reforms aimed at tapping market forces—increased competition, liberalized price formation, and decentralized control over supply. This

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approach—long thought necessary by many Western observers—could produce the following benefits:

- Decentralization in planning and management could help remove barriers to cooperation that have permeated Soviet S&T. Increased contacts between the science and production sectors would improve and better define the consumer-supplier relationship, increasing the likelihood of better suitability, quality, and oversight.
- Increased autonomy at the level of individual S&T organizations would add much needed flexibility to the Soviet S&T system. Because of the rapid pace of technology development, organizations require the ability to redirect funds and people quickly without waiting for permission from above.
- The switch to other indexes of economic success—such as profit, quality, or product demand and a rational price system—could decrease the bias toward gross production and reduce the disincentive to innovate that exists today. If industrial managers can profit from innovating, even with short-term decreases in production, their choices in technology and production processes are more likely to incorporate more efficient, profitable advanced technologies.
- Requiring S&T organizations to finance more of their RDT&E without state aid and to compete with others for contracts while allowing some to fail would help eliminate the most inefficient.

55. Gorbachev would have to overcome enormous political obstacles to implement such a reform program:

- The military-industrial complex, whose resource priority depends on the maintenance of central planning, is likely to feel threatened by potential administrative decentralization and changes to the price and supply systems. Defense would be on a more competitive basis with the civilian economy and would require special dispensation to assure its priority access to needed resources.
- Party and government bureaucrats, whose power and perks are tied to the present system, are likely to resist major reforms.
- The need for a free and rapid flow of information increases dramatically when the locus of decisionmaking is moved to a lower level. The potential impact of greater access to data on political power will not be lost on the leadership.
- Although competition provides important incentives for innovation and creativity, the loss of job security and stability of institutional standing could violently rock Soviet S&T. The morale of a large portion of S&T workers—who are not at the technological frontiers of their work—could decline and labor unrest increase.
- Such reforms would not obviate the need for a well-defined national S&T policy and its integration with economic goals. A support structure, for example, would be needed to encourage essential fundamental research that otherwise would not be supported by contracts.

Even if we assume that the Soviets fully implement such reforms—an assumption of great uncertainty—we believe that the ultimate improvement in S&T is well beyond the time frame of this Estimate.

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Increased Centralization and Discipline (Neo-Stalinism)

56. Though seemingly the least likely direction for the Soviet leadership to take at this point, its approach, if radical economic reforms falter, might be reduced to the more traditional characteristics of Soviet S&T strategy—increasing central control and discipline. Some support exists in the Soviet elite for a return to strong leadership and greater discipline. This approach would place increased emphasis on central control, stronger rewards and punishments at the workplace, increased administrative measures, and greater ideological orthodoxy. Gorbachev might be attracted to this approach since it contains some aspects of his existing strategies and could be viewed as providing enough resources to mollify defense.

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57. But administrative measures and "innovation by decree" have already proved ineffective means to solve the fundamental problems of Soviet S&T. Furthermore, because of the unique qualities of the new technologies involved, this top-down style of management would be likely to set Soviet S&T back even further in world standings. Moreover, this approach would significantly increase tension in society—especially after Gorbachev's promises of "democratization" and "openness"—and it would again increase the potential for abuse of political power by officials. The military might be untouched by these problems in the short term, but over the long term, because of the importance of many dual-use technologies, the military would probably need to increase their resources, continue Western technological acquisition, and broaden the military RDT&E base to prevent a decrease in the technological capabilities of future weapon systems.

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58. Gorbachev's approach will contain both decentralizing and centralizing elements. His successful balance of the two will be key to the Soviet Union's S&T future.

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APPENDIX A

TARGETED TECHNOLOGIES FOR THE 12TH FIVE-YEAR PLAN

Soviet S&T policy for the 12th Five-Year Plan (1986-90) targets five key areas for development: biotechnology, nuclear energy, advanced materials, microelectronics and computers, and machine automation. The Kremlin is calling for Soviet levels to reach world standards in these areas by the end of the century and is insisting on increased assimilation of such developments into widespread use in industry.

Biotechnology. Biotechnology includes the techniques of genetic engineering (recombinant DNA and cell fusion) and biochemical engineering (fermentation and large-scale plant and mammalian cell culture). Biotechnology has enormous potential to increase industrial productivity and create new products and processes across such diverse industries as pharmaceuticals (for both diagnostic and therapeutic uses), process and specialty chemicals, agriculture, energy, and intelligent biosensors. There are also important military applications of the technology in chemical and biological warfare and defense, battlefield detector technology, and medical protection of the soldier. In the longer term, there is potential for specialty materials such as lubricants and structural materials, and the use of biochips in large-scale computer technology.

Nuclear Energy. Nuclear energy technology, important to both military and civilian applications, includes conventional reactors, fuel-cycle technology, and fusion power. Conventional reactors, used to generate nuclear electric power, are an important part of Soviet energy resources. Nuclear-fuel-cycle technology is needed to enrich natural uranium to reactor-grade uranium, to reprocess spent-reactor-fuel elements to recover useful nuclear fuel, and to dispose of high-level radioactive waste materials from the spent-fuel elements. Fusion technology includes tokamaks, magnetic mirrors, lasers, and particle beams. This technology contributes to the development of directed-energy weapons with applications for air defense and for antisatellite and ballistic missile defense. Civilian uses include fusion research aimed at developing reactors for use in electric power plants and lasers for industrial materials processing, for medical applications, and for communications.

Advanced Materials and Technologies for Their Production. Advanced materials include metals, ceramics, and composites (including advanced plastics). Processes to produce these materials include materials preparation, metal casting and forging, filament winding, tape laying, weaving, and rapid solidification technology (for producing alloys that have unusual properties). Soviet use of advanced materials has been predominantly in military applications. Advanced metals, ranging from strong superalloys to lightweight aluminum-lithium alloys, are necessary for products such as high-performance aircraft and jet engines. Use of composite materials has improved missile design and aircraft range, payload, and maneuverability and has made practical such radical aircraft design as the forward-swept wing. Lightweight reinforced composites are replacing metals, providing benefits such as better performance, including fuel economy. Advanced structural ceramics are being developed for use in wear- and corrosion-resistant industrial applications and fuel-efficient engines and for certain armor applications.

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Microelectronics and Computers. Semiconductors (particularly integrated circuits), computers, software, and peripherals, such as terminals, printers, and magnetic and optical storage units, are used in almost all Western industrial sectors to increase the performance, capability, and reliability of a large number of products used for both manufacturing and RDT&E. The development of these products, their subcomponents, materials such as silicon and nonsilicon devices, software, and the fabrication equipment are continuing in the West and Japan at a rapid rate, with advances in computer hardware and software power, speed, efficiency, and applications. Also related is the telecommunications system which, since the advent of digital transmission and switching systems, has served to link rapidly proliferating computers and data bases in commerce, government, and industry. Military applications are numerous, but include command, control, communications, and intelligence systems, avionics, fire control, and missile guidance.

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Machine Automation. Advances in microelectronics have led to a new generation of highly automated,

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general purpose machine tools with dramatically increased capabilities for commercial and military industrial production. Machine tools include lathes, drill presses, machining centers, grinding machines, and forging presses that are numerically controlled (NC) or directed by an operator. Robotics, a newer innovation in machine tools, substitute for human labor, allowing flexibility in automating manufacturing processes that, when combined with NC machine tools, can sharply boost productivity. The Soviet military is interested in machine automation and robotics for both operational and manufacturing uses, including welding, machining, painting and coating, and assembly of a variety of weapon systems. These technologies increase productivity through increased production rates and reduced scrap losses, provide better quality control by reducing the variations in products caused by operator error, allow more flexibility in changing from production of one product to that of another, and provide greater accuracy and the ability to machine more complex shapes—qualities particularly vital in the production of missile and aircraft systems.

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APPENDIX B

SOVIET INTERBRANCH S&T COMPLEXES (MNTKs)

Gorbachev and other Soviet policymakers are putting much emphasis on the new MNTKs, through which, according to Academy of Sciences President Guriy Marchuk, "the greatest national economic benefit is to be gained." These complexes are supposed to include research, development, and manufacturing facilities from both the Academy of Sciences and the industrial ministries. Many of the technologies the MNTKs are to develop are dual-use—important for cost-effective production of more sophisticated weapon systems as well as for high-quality civilian goods. The MNTKs are named below, with their areas of focus:

- **Robot**—robotics and flexible manufacturing systems.
- **Avtomatika** [4]—computer-aided design and manufacturing systems.
- **Nadezhnost' Mashin**—diagnostic means and systems to improve machine reliability.
- **Rotor**—rotors and rotary-conveyor lines.
- **Tekhnologicheskiye Lazery**—industrial lasers.
- **Impul'snyye Mashiny** [4]—pulsed-power machines and storage devices.
- **Svetovod**—fiber optics.
- **Mikrofotoelektronika** [4]—miniaturized optoelectronic devices.
- **Institut Elektrosvarki Ye. O. Paton**—welding and electrometallurgy.
- **Poroshkovaya Metallurgiya**—powder metallurgy.
- **Antikor**—anticorrosion techniques and protective coverings.
- **Metallurgmash**—metallurgical equipment.
- **Mekhanobr**—advanced crushing and pulverizing equipment.
- **Biogen**—biotechnology.
- **Katalizator**—catalysis.
- **Termosintez**—synthesis of new inorganic compounds.
- **Radiatsiya** [4]—industrial applications of radiation.
- **Membrany**—polymers and membrane technology.
- **Nefteotdacha**—oil and gas enhanced-recovery technology.
- **Personal'nyye EVM**—personal computers.
- **Mikrokhirurgiya Glaza**—eye microsurgery.
- **Geos**—geological prospecting.
- **Nauchnyye Pribory**—scientific instruments.

[4] Proposed but not yet confirmed. (U)

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APPENDIX C

CEMA COMPREHENSIVE PROGRAM FOR S&T PROGRESS THROUGH THE YEAR 2000

Computers and Electronics

1. Supercomputers (speed over 10 billion operations per second).
2. Personal computers and software.[5]
3. Integrated circuits.
4. Fiber-optic communications.[5]
5. Microelectronic instruments (production efficiency, reliability and quality).
6. Integrated digital information communications systems.
7. New-generation satellite communications and television broadcast systems.

Machine Automation

8. Automated production systems.[5]
9. Integrated control systems.
10. Robot-equipped laser technology.[5]
11. Automated processes for producing ultraprecise equipment.
12. Industrial robots and manipulators.[5]

Nuclear Power

13. Improvement of nuclear power stations (VVER-440 and VVER-1000 water-cooled reactors).
14. Improvement of handling natural uranium and nuclear wastes.
15. Development of equipment for fast-breeder reactors.

New Materials and Technologies for Their Production

16. New high-strength corrosion- and heat-resistant compound and ceramic material.
17. Creation of ceramic internal combustion and ceramic gas turbine engines.
18. New plastics capable of replacing natural materials.
19. Wear-resistant materials (using powder metallurgy methods).[5]
20. Amorphous and microcrystalline materials combining mechanical, electrotechnical, and anticorrosion properties.
21. New semiconductor materials.
22. Continuous-casting technology.
23. Industrial lasers.[5]
24. Application of plasma, vacuum, and detonation technology for applying reinforcing, wear-resistant, and anticorrosion coatings.[5]
25. Technologies using high pressure, vacuum, impulse effect, and explosion energy for the synthesis of new superhard materials.

Bioengineering [5]

26. New biologically active agents and medicinal compounds for medicine.
27. Microbiological agents to protect plants, bacterial fertilizers, and hybrids.
28. Feed additives and biologically active agents; new bioengineering methods for the effective prevention of diseases among livestock.
29. Technologies for processing agricultural, industrial, and urban waste.

[5] Interbranch S&T complexes (MNTKs) have been created. (U)

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