

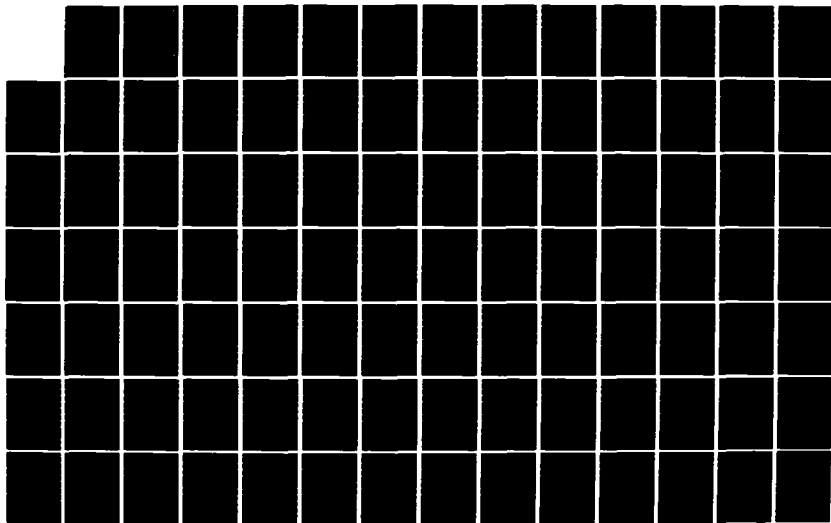
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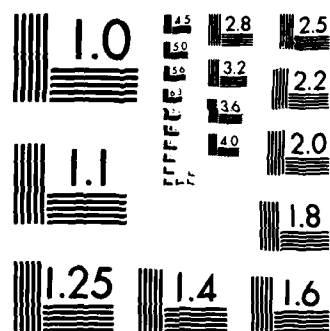
SCIENCE AND TECHNOLOGY IN THE SOVIET UNION: PROCEEDINGS 1/3
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SCIENCE AND TECHNOLOGY IN THE SOVIET UNION:
PROCEEDINGS OF A CONFERENCE, JULY 26-27, 1984

PREPARED UNDER CONTRACT
N00014-76-C-0475 (NR-042-267)
FOR THE OFFICE OF NAVAL RESEARCH

JANUARY 31, 1985

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER ---	2. GOVT ACCESSION NO. ADA152 828	3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Science And Technology In The Soviet Union: Proceedings Of A Conference, July 26-27, 1984		5. TYPE OF REPORT & PERIOD COVERED TECHNICAL REPORT	
7. AUTHOR(s) Herbert Solomon and Elliot Weinberg Co-Editors		6. PERFORMING ORG. REPORT NUMBER	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Statistics Stanford University Stanford, CA 94305		8. CONTRACT OR GRANT NUMBER(s) N00014-76-C0475	
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Statistics & Probability Program Code 411SP		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR-042-267	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE January 31, 1985	
		13. NUMBER OF PAGES 215	
		15. SECURITY CLASS. (of this report) UNCLASSIFIED	
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report) APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED.			
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)			
18. SUPPLEMENTARY NOTES			
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Sociology of Soviet Research and Development, Soviet Science, Soviet Technology.			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The theme of this Conference is the sociology of science and technology in the Soviet Union. It relates to the academic, industrial, and military settings in which research and development are initiated and developed and the process which these programs follow. These papers were prepared by experts in these subjects. There are nine papers plus introductory remarks and a foreword.			

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TITLE: Science and Technology in the Soviet Union: Proceedings of a
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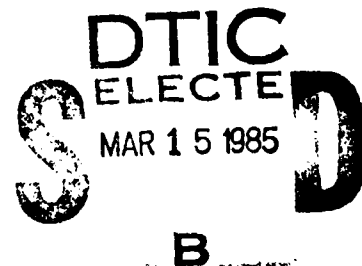
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FOREWORD

Stanford University was the site for a Conference on Science and Technology in the Soviet Union held July 26-27, 1984. Ten invited speakers gave talks on different facets of this subject. The number of scholars who devote research efforts to the sociology of Soviet science and technology is a small subset of investigators in Soviet studies. We were fortunate in securing the speakers who appeared despite their busy schedules, and who in some cases had to travel long distances. A listing of the Conference agenda including speakers and topics follows this introduction. The papers are printed in the order given at the Conference.

The Conference was sponsored jointly by Stanford University and the Navy Center for International Science and Technology (NCIST), an Office of Naval Research field office located at the Navy Postgraduate School in Monterey. Dr. Elliot Weinberg, Director of NCIST, and Professor Herbert Solomon of the Statistics Department, Stanford University, served as organizers and co-chairmen of the Conference. Financial support was provided by the Office of Naval Research. Dr. Weinberg had previously served as Director of Research at Office of Naval Research Headquarters in Washington, and Professor Solomon had served recently for two years as Chief Scientist for the Office of Naval Research Branch Office in London with responsibilities for dissemination of information on science and engineering in Europe (West and East) and the Mid-East.

To enrich the talks, a number of additional scholars were invited to participate and actively provide comments and questions for the speakers. The audience comprised the ten speakers and approximately 30 invitees from universities, government agencies, and research institutes. The papers presented in these Proceedings were in most cases completed or received final editing after the Conference so that audience input could play some role. We were pleased that Dr. David Holloway of Stanford University could participate and give a talk based on his research although other commitments precluded the preparation of a paper.

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**Conference on Science and Technology
in the Soviet Union**

SCHEDULE

Thursday, July 26

8:30	Registration and Coffee	
9:15	Introduction and Welcome	
9:30	Arthur Alexander Rand Corporation	Civilian science and military weapons systems
10:30	Refreshments	
10:45	David Holloway Stanford	"Physics is the basis of Social- ist technology": Ioffe's Insti- tute in the 1920s and 1930s
12:00	Lunch	
1:30	Seymour Goodman University of Arizona	Computers in the Soviet Union
2:30	Simon Kassel Rand Corporation -- Washington, D.C.	The outlook for Soviet advanced technologies
3:30	Refreshments	
3:50	Linda Lubrano American University	Social and political character- istics of fundamental research in the USSR Academy of Sciences

Friday, July 27

9:30	Bruce Parrott John Hopkins -- School of Advanced International Studies	Technology and political choices
10:30	Refreshments	
10:45	Steve Rosefielde University of North Carolina	Technological bias and effi- ciency
12:00	Lunch	
1:30	Condoleezza Rice Stanford	Senior military staff and science institutes
2:30	John Martens Department of Commerce	R&D contracting in the Soviet Union
3:30	Refreshments	
3:50	Egon Loebner Hewlett Packard	Close encounters with S&T in the Soviet Union

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INTRODUCTORY REMARKS

Elliot Weinberg

Navy Center for International Science and Technology

U.S. Navy Postgraduate School

Monterey, California

INTRODUCTORY REMARKS

Elliot Weinberg

Navy Center for International Science and Technology

It's a great pleasure to welcome you to our conference on Soviet Science and Technology. I know the next two days will prove exciting and productive, and, I very sincerely believe, in the national interest, as well.

Of course we are deeply indebted to Stanford University and to Professor Solomon for making all this happen and in such a lovely setting. As it happens, the timing is pretty nearly right as well. One can sense, on the part of congress, at least, a growing uneasiness about our limited understanding of all aspects of life in the Soviet Union.

Uncertainties over the significance and equity of scientific exchanges, as well as with technology transfer, have served to heighten their concern. A February issue of Science deplored the "withering of the field and a lost generation of experts" in Soviet Studies, while noting a recent comeback for this subject and some new legislation designed to help a bit. In that same article, Science Magazine stated that the population of experts in such areas as the Soviet computer industry, Soviet agronomy, and even Soviet science, is minuscule. In fact, I suspect a principal fraction of that population is in this room today!

A recent meeting of the American Library Association in Dallas concluded that "Much of the important social, political, and scientific literature produced in the Soviet Union and in Soviet-dominated countries is virtually unknown to Western librarians and scholars." The

next couple of days and the resultant report will stimulate a much broader interest in the outside community.

BUT, DOES IT REALLY MAKE ANY DIFFERENCE, ANYHOW?

Yuri Sheinin says it does. As many of you know, he is a Soviet writer on science policy (see Science Policy-Progress Publishers, Moscow, 1978). He says, "The USSR is the first state which has consciously brought about a conjunction of science and organization. This it has done at every stage of its development. The system of the agencies by means of which the state directs science has worked out and implemented in a balanced manner, with the broad support of scientists and technical workers and all the other working people, a coherent system of organization and direction of scientific activity. This system is an organic part of the metasystem of economic planning, constituting one of its ever more important and leading elements."

Whether or not the USSR can really pull it off, or is really even trying that hard may be another story. Sheinin also quotes from the new USSR constitution (1977) as follows: Citizens of the USSR are "guaranteed freedom of scientific, technical, and artistic work." So, as usual, it is left to groups such as this to decide what is credible and what is not.

Admittedly somewhat belatedly, the United States is becoming increasingly aware of lacunae in our understanding of international, particularly Soviet, progress in science and technology. Representatives from other disciplines, whether political, economic or social, acknowledge this same failure to keep abreast of international developments in these fields. No matter what one's geopolitical concerns or philosophy may be, it is clear that a better understanding

of these issues and an ability to interpret the significance of scientific developments abroad in a more accurate and timely way is the sine qua non, if we are to respond rationally to the diverse challenges, opportunities -- even threats -- that our nation must face on a continuing basis. Surely ignorance is our worst enemy, as ignorance fosters fear -- and fear can produce over-reaction -- as serious a threat to world peace as any other.

Perhaps as much as anything, our own efforts can most appropriately be directed toward improving the sociology of the US scientific community as it relates to their interest in, and understanding of, Soviet endeavors. So often we find our own community telling us "not to worry -- we know we are way ahead of them in the areas that count."

Yet examples of important scientific developments to which we in the US have been hardly privy abound. Few in this room require amplification of this remark. My own interest was remarkably sharpened when I learned of some important Russian work in ceramics, beginning with open literature publications of a new and economically attractive procedure for growing high quality ceramic material -- to order. Some 200 research papers were followed by the Soviets filing a patent in our US Patent Office -- and finally, by Russian newspaper reports of the millions of rubles being saved per year by this revolutionary new process, which is highly energy conservative and which produces cheap ceramics that take the place of industrial diamonds as abrasives, for example. All this, I have to confess, turned out to be totally unknown to our US materials scientists, a principal proportion of whom have been ONR and other DoD contractors for many years.

I will pass over developments in high power electromagnetic radiation, or in applied mathematics and certain engineering fields already long known to be at the forefront of Soviet scientific endeavor. Eventually, we must examine a broad spectrum, ranging from oceanography and Arctic and Antarctic research to informatics -- a branch of science which the Soviets have evidently been working very hard at. Their VNITI, for example, is a science/technology abstracting service which dwarfs anything we are familiar with in the US. Translating regularly from 66 foreign languages, with some 130 countries and 30,000 periodicals under review, it is clear that THEY do not mind learning from US. We know they purchase at least one copy of each of the 80,000 US government documents annually made available through NTIS. Can we do any less than to try the reverse?

Their VNITI publishes annually one million abstracts, even including unsuccessful projects not cited in published reports elsewhere. Later on this fall, at the Naval Postgraduate School, we are directing our attention to this business of seeing what we can learn from such systems. We will be holding a data base workshop, in which experts from the artificial intelligence community and others will discuss ways of looking at data bases more productively and economically. For example, one can look for research hiatuses. It has been observed, for example, that when our Japanese colleagues feel that their level of understanding in a particular field equals or surpasses the Western effort, they cease to publish in English language journals and further research can only be followed by looking in Japanese language journals. Other kinds of hiatuses may be equally revealing. As one of our distinguished speakers today, Dave Holloway, noted in his recent book, Stalin received a strong

signal to get going on nuclear weaponry from a young Air Force lieutenant who had been following the US pubs in nuclear physics and who observed a sudden lack of any reports, following initial articles on observed nuclear fission. So already in 1942, the Soviets had an early alert, and by 1943 a program was underway. Interestingly enough, if we express occasional frustration with our own US community who seem not to be as interested in Soviet work as we would like, Stalin, according to Holloway, was mighty upset that he had to hear about all this from an Air Force pilot rather than from some of his academicians! In addition to trying to get smarter about how we use these data bases, at our November workshop members of the user communities will also suggest ways to improve current procedures for inputting to these systems.

Recognizing that there are a number of dimensions to this problem of keeping abreast of new science and its implications, we have, quite deliberately, not begun by focussing on specific disciplines. This first effort is directed as much at improving our understanding of the sociology of the Soviet scientific community as at any other target. How they look at science, how it feeds into their industry, military, or economic world are as fundamental issues as determining which technical areas are most likely to warrant further scientific attention.

In all honesty, we are not even sure this whole matter is important. In March of this year, Science Magazine reported a seeming consensus that Russian influence in science is waning. Primarily based on analysis of Science Citations Index, researchers at Lawrence Berkeley found that, even in mathematics, Soviet contributions have markedly ebbed. In many areas where their publications are still adequate in quantity analysis shows the technical impact to be slight. Many reasons

for this seeming reduction in scientific quality have been offered. While we certainly do not hope to resolve these questions today, it is our purpose to at least delineate the kinds of puzzles and enigmas that we are facing in attempting to understand Soviet science and scientists.

If at the close of this session the speakers' remarks and the audience's sharp questioning and commentary can serve to help us focus on what our deficiencies are — and what we might try to do to resolve some of them, I will consider the meeting a success. If, following this endeavor, there develops additional interest on the part of the US scientific community in what the Soviets may really be doing, the Navy will be more than pleased.

So I wish us all good progress and look forward to learning and sharing with you these next several days, and, certainly, to getting a better start on this fascinating and, evidently, rather arcane, field of study.

As much as anything, it is the uncertainty of it all that is disturbing. Indeed, a remark by Will Rogers still comes back to haunt me from time to time. It went like this: "It ain't what you don't know that gets you into trouble. It's what you do know that isn't so!" Maybe, if we can sort out a little of "what we know" along Will's lines we will have done our duty for this meeting.

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SOVIET WEAPONS DEVELOPMENT AND THE SCIENTIFIC COMMUNITY

Arthur J. Alexander

The Rand Corporation

Santa Monica, California

SOVIET WEAPONS DEVELOPMENT AND THE SCIENTIFIC COMMUNITY

Arthur J. Alexander

The Rand Corporation

I. Introduction to Soviet Military R&D: The T-34 Tank

The incorporation of scientific findings and new technologies into weapons designs is accomplished by the movement of resources (including scientific knowledge and available technology) through processes that are conditioned by institutional structures, incentives and constraints, and R&D strategies. This process produces military outputs characterized by technical performance, mission capabilities, and -- ultimately -- military value. The link between Soviet science and technology and Soviet weapons is the subject of this paper.

Most weapons development processes make use of a strategy that includes three main components:

1. New designs with extended periods of product improvements;
2. Parallel development of technologies and subsystems; and
3. Construction and test of experimental prototypes of integrated designs.

The emphases and mixes among these three components depends on factors such as the speed of technological change, the flexibility on the military-production sector, and the organization and incentives on the weapons development system. The Soviet Union's approach to weapons development has evolved over a 50-year period of adaptive change. We begin this story at the time of the creation of the Soviet military economy with Stalin's first Five Year Plan in the early 1930s and the development of the T-34 tank.

In the early 1930s, great uncertainty surrounded tank technology. The machines developed during World War I were becoming obsolete and new technologies in all areas of tank design were emerging, but visions of how new vehicles should look, what they should be able to do, and how they should be used were confounded by the multitudinous possibilities enticing designers and commanders. The Soviet Union solved the design dilemmas by taking one step at a time--sometimes on parallel paths, but always incrementally. The development of the T-34 illustrates some general rules about technology development in a state of open possibilities and great flux. Since it also set a pattern for Soviet military R&D that continues to the present, the story of the T-34 has double significance.

Development of the Soviet T-34 Tank. The Soviet Union was able to develop its armored technology from the relatively primitive state that existed at the end of the 1920s to a position of world leadership in tank design by the eve of World War II. This period was a time of major uncertainties and changes in technology, components, configurations, doctrine, tactics, and threat.

Soviet armor activity can be traced back to the Czarist regime of World War I. This experience was dissipated after the revolution and it was not until the mid-1920s that the first steps were taken to reestablish tank design cadres. Some modest design work, experimental construction, and limited production was undertaken, but no really acceptable vehicle emerged from that period. It was becoming clear by the late 1920s that there were many impediments to military technology and production.

The Party and Government then gave high priority to the building of military capability in general, and to tanks in particular. Education, research, and design institutions were established or enlarged. Manufacturing technology and enormous quantities of plant and equipment were imported in large volume from the West. Experimental armored brigades and staff colleges were established. Thus, by the early 1930s, institutions were in place that would put the Soviet Union at the forefront of armor technology and production by the time of the German invasion less than a decade away.

As part of this process, a commission visited the United Kingdom and the United States in 1930 to purchase tank designs, prototypes, and manufacturing licenses. One of the Soviet's foreign purchases was from an American designer -- J. Walter Christie. From out of Christie's M1931 tank came the T-34 -- an evolutionary process that took only eight years.

The features that made the T-34 so effective were its low cost and producibility; well-shaped, heavy armor; an efficient diesel engine; well-protected and rugged independent suspension; low silhouette; and high-velocity 76 mm. gun. All of these features had been seen individually on other Soviet tanks. Their combined use on the T-34 was an example of design creativity that depended on the emerging experience gained from previous development and proof of components, subsystems, and alternative configurations.

Producibility was emphasized from the beginning. Christie's M1931 was redesigned for simplicity and was first produced as the BT-2 in 1932. Several variations followed and production rates were increased. Soviet tank production of all types during the 1930s averaged 3000 per

year. During this period, production techniques for welding, riveting, and casting armor plate were learned. For example, electrically-welded plates, which greatly speeded production, appeared on a light tank -- The T-26S -- in 1938.

Sloping armor first appeared on an experimental outgrowth of the BT series in 1936 -- the BT-IS. This armor, however, was only effective against low caliber bullets and fragments. Experiments with armor shapes showed that a conical turret had good antiballistic properties. The T-111 (T-46-5) -- an experimental prototype outgrowth of the BT-IS -- carried 60mm armor on both the turret and the hull, but its 45mm gun was too small for the heavily armored vehicle.

With the heavier armor, a more powerful tank engine was desirable. A government directive in 1932 had authorized development of a diesel tank engine.¹ This V-12 engine with an output of 500-600 horsepower became available for production installation in the BT-7M in 1938. The range of the diesel-powered tank compared to the gasoline-powered BT-7 increased from 275 miles to 400 miles, even though the weight also increased by a ton.

The increased mobility that was potentially available from the new engine forced reconsideration of the suspension system. All of the BT series tanks were designed for moving on either road wheels or tracks -- a feature inherited from the original Christie model. However, this system required complex suspension, steering, and drive mechanisms. The most important element of Christie's M1931 suspension, however, was its independent suspension and great vertical movement of the road wheels, which permitted high speed on both roads and cross-country. By 1939, eight suspension types had appeared in production tanks, and more had

been tested on experimental vehicles. On the basis of this experience, a tank design group in 1938 suggested dropping the wheel-track system in favor of a pure track tank. On their own initiative, they began design of a new tank -- the T-32 -- closely patterned after a wheel-track experimental prototype -- the A-20 -- which they had just completed. The A-20 had incorporated the new diesel engine, and heavy, well-shaped armor, but only a 45mm gun. A sister tank, the A-30, carried a larger 76mm gun. Thus, several elements were converging by 1938 -- the armor shape and thickness, suspension, and engine. The gun though was still a problem.

With the heavier armor that was undergoing development, the acquisition of a long-range, high-velocity gun would allow Soviet tank forces to face either opposing tanks or antitank artillery with relative immunity. Some of the medium tanks and all of the heavy tanks had carried short-barrelled, low-velocity 76mm guns since 1932. The early BT series models carried an effective high-velocity 45mm antitank gun with a muzzle velocity of 2,350 feet per second, but by the late 1930s this caliber was ineffective. The length of the 76mm gun increased gradually from 16 calibers in 1932 to 24 calibers in 1938, but muzzle velocity was still less than 1,200 feet per second, which -- as demonstrated by the results coming from Russian fighting in Finland -- provided firepower of little effect.² A new requirement for a high-velocity gun was then issued and a 76mm design of 30.5 calibers in length and 2,200 feet per second muzzle velocity was the outcome. (In comparison, the 76mm gun on the German PzKw IV tank was only 1,240 feet per second at that time.) This is the gun that was mounted on the A-30 prototype in 1938, but the

turret was too small to accommodate the longer weapon. The T-32 turret was specifically designed to carry this longer piece.

The low silhouette of the T-34 came about partly from the reduced height of the turret. Stalin's influence enters here as he continually urged a reduction in tank height through redesigning the turret. In 1938, he called in the two leading tank designers and emphasized the requirement for increased armor, new tracks, and a smaller turret. The results of these imperatives were seen in the squat turrets of the experimental prototypes of the late 1930s and in the subsequent T-32 and T-34. This was not achieved without cost, however, as it severely cramped the interior space of the turret and restricted the depression of the main gun to 3 degrees below the horizontal.

The T-32 was accepted for final development in 1939, and a refined version — the T-34 — appeared within a few months. Almost all subsystems and design features had appeared in previous tanks. The exception to this provides a telling argument for the utility of an evolutionary approach combined with independent subsystem development. When instructions were received to refine the T-32 design, the design bureau began work on a new transmission. The first production units were so unreliable that tanks were sent into combat with spare transmissions cabled to the rear deck. The transmission problems were not solved until late in the war.

More than 40,000 T-34 tanks were produced. Liddell-Hart characterized the T-34 in terms that can be used to describe Soviet weapons today:³

The machines were rough inside and out Their design showed little regard for the comfort of the crew. They lacked the refinements and instruments that Western tank experts

considered necessary as aids to driving, shooting, and control
. . . .

On the other hand, they had good thickness and shape of armor, a powerful gun, high speed, and reliability -- the four essential elements Regard for comfort and the desire for more instrumental aids involve added weight and complications of manufacture. Such desires have repeatedly delayed the development and spoiled the performance of British and American tanks. So they did with the Germans, whose production suffered from the search for technical perfection.

General Heinz Guderian, the German armor theoretician and commander reported on his first meetings with the T-34: "Up to this point we had enjoyed tank superiority. But from now on the situation was reversed."⁴

II. Organizations in Soviet Weapons R&D and Science

The principal actors in Soviet science and weapons acquisition include: the producers -- the nine military-production ministries; the buyers and users of the products -- the Ministry of Defense; the military and civilian science sectors; and two coordinating agencies -- the powerful Military-Industrial Commission (VPK: Voenno-promyshlennaia kommissiia), and the State Committee for Science and Technology (GKNT: Gosudarstvennyi komitet po nauke i tekhnike). The "military science" sector is defined as comprising the research institutes of the military production ministries, as well as institutes directly subordinated to the Ministry of Defense and the military services. "Civilian science" consists of the USSR Academy of Sciences, its Siberian Division, and the regional academies of sciences; the research component of the higher educational institutes; and the research establishments of the civilian production ministries.

Defense Industry. Each of the nine military-production ministries is responsible for the research, design, development, and production of

weapons or their components. (See Table 1.) Some civilian production ministries also contribute to military R&D in a minor way; and several of the military-production ministries make substantial contributions to nondefense products, especially the Aviation, Shipbuilding, Radio, Electronics, and Communications Ministries.

The bulk of applied military research and development is performed in the research institutes and design bureau of the military-production sector. More than 90 percent of applied R&D in the Soviet Union is performed in the industrial sector, including the military-production ministries. But the industrial sector also performs a significant share of basic research, varying over the years roughly from 8 to 23 percent of the national total.⁵ However, because of the far-ranging scope of scientific and industrial activity engaged in by defense industry, it is often necessary for them to go beyond their organizational boundaries for scientific support, particularly in basic research. They require some aid in weapons development itself, but generally their own research institutes adequately support the design bureaus that develop the systems and the plants that produce them. The highly directed nature of the industrial ministries' tasks renders them less able to conduct the required research on new technologies or on systems based on new or unfamiliar principles. It is in these areas that civilian science makes its greatest contribution to the military and provides flexibility to the tightly organized system.

Table 1

MILITARY-PRODUCTION MINISTRIES AND REPRESENTATIVE PRODUCTS

Ministry of Aviation Industry: Aircraft, aerodynamic missiles
Ministry of General Machine Building: Ballistic missiles,
space-launch vehicles, spacecraft
Ministry of Defense Industry: Conventional ground forces
weapons, small arms, antitank guided missiles
Ministry of Shipbuilding Industry: Naval vessels, submarines,
merchant vessels
Ministry of Medium Machine Building: Nuclear weapons
Ministry of Radio Industry: Computers, avionics, guidance
equipment electronics components
Ministry of Machine Industry: Ammunition, ordnance
Ministry of Communications Equipment Industry: Radio, tele-
phone, television, other communications equipment

An important feature of Soviet industrial structure is the organizational separation of functions and of products. Research is performed in research institutes to support their ministries' product lines; design and development takes place in design bureaus; and production in factories. Ordinarily, each type of organization is administratively separate from the others and operates under different procedures and incentives. The ministries, too, are highly independent of one another; Russians often say that dealings between ministries are more difficult than negotiations between hostile countries. The military production ministries operate, to a large extent, under the same system of incentives and constraints as the centrally planned civilian sector.

Ministry of Defense. Each of the military services has one or more directorates charged with managing its weapon developments. To support this function, these armament directorates maintain research institutes to provide technical expertise to the buyer and to manage contracts. Central agencies of the Defense Ministry also have their own institutes. Staffed with experienced civilian and military personnel, these

institutes often act as the link between the military requirement and the weapon developer. They maintain close contacts with the industrial institutes and design bureaus, keeping abreast of technical advances and possibilities as they develop. These military institutes may perform preliminary design studies and engage in research on special military needs, such as reliability of maintainability problems, but they do not appear to do detail design work or basic research.

Civilian Science. The premier establishments for fundamental research are the 200 research institutes associated with the USSR Academy of Sciences. The Siberian Division (a mini-academy of 50 institutes that is largely independent of the parent Soviet Academy) is strongly oriented toward cooperation with industry in the transfer of science and technology from laboratory to application. The regional academies, especially the Ukrainian Academy of Sciences (with its pilot production facilities and joint industrial laboratories), also tend to be better organized for industrial support and to pay greater attention to the application of research than the main division of the USSR Academy.

The universities and other institutes of higher education (VUZy) comprise the second part of what is defined here as civilian science. Research performed in this sector appears to be less coordinated and more fragmented than that performed in the academy system. One reason is that the great bulk of VUZy research is financed by contracts rather than by the State budget, leading to a diverse set of relationships and patterns of scientific involvement with an array of clients. Many of the researchers in the higher education sector participate on a part-time basis. Much of this research is concentrated in a few eminent

universities and polytechnical institutes, with the rest scattered in small projects across the universe of educational institutes. Since the late 1950s, the Soviet leadership has taken several steps to bring the VUZy closer to both the Academy institutes and to industrial R&D, particularly through the incentives of contract research.

The research establishments of the civilian production ministries comprise the third component of civilian science. Organized in similar fashion to the military production sector, these institutes participate in military R&D to the extent that their ministries contribute to military systems.

Coordinating Agencies. The Council of Ministers has created several specialist commissions concerned with important sectors of the economy. One of the most powerful of these commissions is the VPK, with representation from the military-production ministries, the Ministry of Defense, the State Planning Commission (Gosplan), and probably the Central Committee Secretariat.

As monitor and coordinator of military R&D and production throughout the economy, the VPK reviews proposals for new weapons with respect to their technical feasibility and production requirements. Draft decrees submitted by lead design organizations to the VPK specify participants, tasks, financing, and timetables for a project. When approved, the draft becomes a "VPK decision" -- legally binding on all parties concerned.

The VPK is instrumental in planning and supervising major technological programs with military uses, such as the development of integrated electronic circuit design and production. It also appears to be

involved in the planning and coordination of military-related activities in the Academy of Sciences.

The VPK is primarily an implementing organization rather than one that originates policy. Nevertheless, because the VPK originates information, sponsors technical analyses, screens recommendations, approves them, and monitors results, it has a more than marginal influence on science, technology, and weapons.

The State Committee for Science and Technology (GKNT), another agency of the Council of Ministers, was established in 1965 (as a successor to a series of earlier agencies) to plan and monitor scientific research and development, and to recommend the introduction of technological innovations throughout the economy. Evidence on the importance of the GKNT in military affairs is mixed; it has formal authority over all scientific organizations "regardless of jurisdiction," but (according to one expert) probably not over the defense sector.⁶

The Committee has no direct authority over the ministries or the Academy of Sciences system; it attempts to shape events largely through moral suasion (working through a network of subcommittees and scientific councils) or through leverage applied through its influence over foreign contracts, technology, and cooperation. Indeed, the GKNT departments dealing with foreign activities were said to be larger and more influence than its other departments.⁷

The GKNT may have some effect on military science through its formulation of the "basic scientific and technical problems" of the country and its working out of some 200 programs to deal with these problems; this is the section of the science and technology plan on which the GKNT concentrates. In particular, for the so-called "inter-branch problems,"

the GKNT controls an important share of the financing and tries to settle disputes among participating organizations.⁸ It seems likely that the military would want to participate in the identification and inclusion of such problems in the science plan so as to better influence the course of the nation's scientific effort.

Separation of Science Performers. The performers of science in the Soviet Union are marked by their separation — by administrative subordination, stage of R&D, and scientific field. As a project progresses along the successive phases of R&D, it is relayed from one institution under one system of authority to another institution in another organizational structure. Thus, a new technology may begin in a research institute of the Academy of Sciences, transfer to a research institute of an industrial ministry, enter into detailed design and development in a design bureau of the ministry, and finally be produced in one or more ministry factories.

In a complex project, since each of these organizations tends to specialize according to scientific field or class of products, several institutes, ministries, and VUZy could become involved; management and oversight would be the responsibility of a research institute or other agency in an armaments directorate of the military service customer. The VPK, through its project decrees and supra-ministerial status, exercises a necessary coordination over this organization-hopping activity.

Despite organizational separation and field specialization, there is considerable functional overlap among the various R&D performers; some Academy institutes may develop and produce products, whereas a number of ministry institutes are leaders in basic research. Moreover, this overlap is growing as several policies (discussed below) act to

break down the barriers originating in organizational separation and make the institutions on each side of the boundaries more alike.

III. Soviet Weapons Acquisition Process

Soviet weapons acquisition is highly constrained in a number of ways. One of its salient characteristics is the control and minimization of risk. An important technique used to control risk is the formal process outlining the steps to be taken in any development project.⁹ These procedures (the "formal" acquisition process) establish standardized projects steps from the statement of requirements to delivery of the product. Each project progresses according to a stipulated sequence that specifies the tasks to be carried out in each phase, the review procedures by the user, and acceptance routines. With each succeeding step, the technical possibilities become less uncertain, less research-oriented, and more narrow and applied. Science input, therefore, if it is to occur at all in the formal process, is most likely to enter at the very early stages.

The general inflexibility of the centrally planned economy is an additional constraint on weapons R&D. Because of unreliability of supply and inability to rely on contracts or plans to guarantee deliveries, designers are reluctant to ask for new products from suppliers they have not dealt with in the past. They face strong incentives to use off-the-shelf components that can be counted on to perform to acceptable (though perhaps not optimal) standards.

Over the past 50 years, since the present economic system was put into place by Stalin, military R&D managers have taken many steps to cope with the system. Design handbooks closely control the choice of

technologies, components, and manufacturing techniques. Standards organizations at the national level, in the military-production ministries, and in plants and design bureaus ensure that standardized parts and techniques are used to the greatest possible extent. But perhaps most important in the Soviet environment, the buyer (i.e., the Ministry of Defense) has real authority over the product. The military can demand that an agreed-upon product be delivered as promised. Although vigorous negotiations may precede a design bureau's acceptance of a project, the responsible organization is expected to deliver, once the project is defined and accepted.

For all of these reasons, especially the last, designers are reluctant to venture into new realms. They face powerful disincentives to use advanced technology or to look toward science for solutions to their problems. Given these constraints, the art of design is promoted where the designer works with available materials — often creatively, sometimes with genius.

The number of conservative forces acting on the system, together with the necessity of coordinating complex development projects across many organizational boundaries--military, civil, ministerial, Academy — would normally hinder military R&D, as it hinders the civilian sector. However, the Communist Party and the government have given military R&D the highest priority over materials, manpower, and production capacity. These priorities are enforced by the VPK, which also coordinates activities that cross organizational lines. The VPK and Party can intervene to ease bottlenecks or loosen bureaucratic snags. But they are still acting within the Russian system. With the increasing complexity of modern weapon systems that incorporate a broader range of technologies

and inputs than in the past, the military is likely to become increasingly dependent on the rest of the economy and could find it more difficult in the future to avoid the consequences of the civilian sector's patterns of behavior.

IV. Characteristics of Soviet Weapon Design

Constrained Use of Technology. Given the bounds on technical exuberance imposed by the process described above, it should not be surprising that the general tendency in Soviet weapons is for relatively simple designs that make much use of common subsystems, components, parts, and materials, that are evolutionary in their improvements, and that are comparatively limited in performance. Of course, exceptions to this pattern exist. The evidence is best viewed as a statistical distribution, especially revealing when compared with another country's experience. The bulk of the evidence suggests that the central tendencies in the distribution of characteristics of Soviet and US weapons are distinctly separate, although there is considerable overlap between them.

One concrete example illustrates the general tendencies described above. The Soviet SA-6 surface-to-air missile was analyzed by US defense industry specialists, who took note of its solid-fuel, integral rocket/ramjet engine. The design, considered "unbelievably simple but effective," permitted such simplifications as the elimination of a fuel control system, sensors, and pumps to control fuel flow.¹⁰ However, because the system cannot be modulated for maximum performance as a function of speed and altitude, it suffers performance degradation off its design point when it loses oxidative efficiency. The analysts also

found that the SA-6 employed identical components to those found in several other Soviet surface-to-air and air-to-air missiles whose deployment dates spanned more than a 10-year period.

An exception to this pattern -- an outlier in the distribution -- is the T-64 tank. For 35 years, Soviet tank deployment was the epitome of the standard design pattern. But in the later 1960s, the T-64 appeared with almost all subsystems of new design, but only a few with advanced performance and technology. The tank carried a new engine and transmission, new suspension, and completely new and modern fire-control system, advanced armor, and a larger gun scaled up from its predecessor, the T-62; for the first time, a deployed tank had an automatic loader, which reduced crew size from 4 to 3, and permitted the T-64 to be even smaller than the compact T-62.

However, a parallel tank project -- the T-72 -- fell within traditional weapons acquisitions patterns. The T-72, apparently, was planned as a conservative back-up to the aggressively new T-64. As a major product improvement to the T-62, the T-72 shared many of T-64's components as well as some of the older T-62's --including the diesel engine that had been improved over the years from the T-34 engine of 1938. A product-improved model of the T-72 appears to be the tank bearing the T-80 designation. In the meantime, the T-64 had severe problems after initial development and was withdrawn for a period of time. Whether it becomes the progenitor of an improved line of vehicles (perhaps one incorporating a turbine engine) or is a dead-end -- victim of the risks facing all-new designs -- remains to be seen.

Growing Complexity. The T-64 example illustrates an important point. Although strong conservative forces act on the design process,

there is some movement. Science and technology advance, as do military requirements. Weapons performance is constantly enhanced; missions grow more complex, difficult, and numerous. Some T-64 tanks reportedly carry a laser rangefinder, digital fire-control computer, electro-optical tracking system with image processors, and armor arrays of several materials.

Not only do weapon systems perform more things, but each thing also calls on more technology and science than in the past. A gun barrel firing a projectile at 6,000 ft./sec. instead of the 2,200 ft./sec. speed of the T-34 gun requires more advanced metallurgical understanding, materials, and production, measurement, and test techniques than the older guns. Today's tanks call for a greater diversity and a broader source of scientific and technical expertise in their subsystem technologies, materials, and components. And tanks are among the more mature and technically stable systems in modern armories.

Where once a Soviet production ministry could be close to self-sufficient with its own stable of institutes and design bureaus, today an array of talents is necessary that crosses organizational and sectoral boundaries. This is true for production and testing, as well as for component development. Therefore, despite the conservatism of the process, the changing character of the systems is placing greater demands on science.

V. Science Ties to the Soviet Military

Increasingly complex systems are only one of the forces bringing science and the Soviet military closer together. The military leadership now is more experienced in technical and scientific affairs than in

the past, when operational experience rather than technical expertise was the key to the top posts. The careers of the former Minister of Defense and the Chief of the General Staff (Marshals Ustinov and Ogarkov), and several deputy defense ministers have included stints as weapon developers and scientific managers of advanced technology programs. Brezhnev himself spent several years as a Party Secretary with responsibility for coordination of military industry and especially ICBM development.

The political leadership has stated a belief in the importance of science to national economic growth and productivity. In recent Five-Year Plans, Brezhnev proclaimed a shift in emphasis from the Stalinist focus on quantitative goals to quality and efficiency — a shift that he figured could take at least a generation to accomplish. Though such proclamations are often empty, several concrete policies have been adopted that are intended to bring science closer to application.

One of the more important of these policies has been the emphasis, since the late 1960s, on contract research on a cost-accounting (khozraschet) basis. This has been part of a broader development in which new ties are being formed between civilian science and industry; the Academies of Sciences see themselves now as having an important role to play in innovation. Because of officially promoted contracting policy, combined with stable or reduced financing of science enterprises from the State budget, research institutes have actively sought potential customers. The military, with its seemingly limitless budgets, has become a choice target.

Civilian science contract work for the defense sector could be a significant proportion of all (defense and civilian) contract research. In 1975, about 12 percent of the total work of the USSR Academy of

Sciences was financed by contracts; for the Siberian Division and the Ukrainian Academy, contract research was a considerably larger proportion of the total at roughly 20 percent and 38 percent, respectively.¹¹ Individual academic institutes report up to 80 percent contract financing. From 1962 to 1975, contract funding in the Ukrainian Academy increased at a rate of 18.5 percent per year, whereas noncontract funding from all other sources grew at less than half that rate.¹² In higher education institutes, contract research accounts for more than 80 percent of all R&D, although these institutions are responsible for only a small share (about 5 to 6 percent) of the national R&D effort. Although information is scarce on military R&D in the VUZy, it should be noted that an increasingly important role is being played by production ministry laboratories created within the educational institutes, at the expense of the client ministry.¹³

The Institute of Nuclear Physics at Moscow State University is an interesting example of the growth of contract research. According to a former staff member, the Institute is formally attached to and managed by the Physics Department, which supports some 500 faculty from the State budget. The self-supporting institute, however, employs more than 3,000 people, who are engaged in a wide variety of defense, industrial, and scientific tasks.¹⁴

VI. Types of Linkages between Science and the Military

Contracts. Scientists participate in military affairs through a variety of mechanisms. Contracting is one of the most important. Not only did the directives encouraging contract research legitimize the activities of those research managers and institute directors with a

desire to do more applied work, but it also provided the incentives to do so for the scientific entrepreneur as well as for the ordinary scientist who was simply responding to opportunities.

The chief incentive has been the provision of laboratory facilities, instrumentation, expensive equipment, experimental designs and models, and capital construction that flows from contract research generally, and from military research in particular. With the priorities of military sponsorship, a laboratory can obtain scarce materials and supplies, and develop new areas of research.

Not all of the incentives to do military contract research, though, are positive. On a personal level, several disadvantages accrue to military research, especially if it is classified, and most especially if it takes place in closed, secret laboratories. Apart from the rigidity of security controls, the most frequently mentioned disadvantages are the constraints on foreign travel and on open publication of research findings. Foreign travel, always problematic for Soviet scientists, is made almost impossible by close ties to military research.

It is difficult to clear for publication a paper that originated in military-sponsored research. Sometimes a scientist can disguise the source of the research funding, or perhaps submit his papers to a journal unfamiliar with the technical publishing rules in his specialized field; but in general, military secrecy imposes a major barrier to publication, and hence affects the reputation and career of a scientist. Some Soviet scientists suggest, in fact, that it is easier to hide inferior work and less capable people under a military umbrella because the research is less likely to come under critical scrutiny. The better scientists are consequently deterred from participating in such work.

If first-rate scientists are put off by the quality and environment of military research, second-raters perhaps find this a useful channel for career advancement. Although the lower quality of military scientists has not been universally accepted or described by all sources, the evidence contains enough instances to indicate that it is a serious issue that cannot be disregarded.

Another disincentive to working on military research is that cost and schedule overruns, which are tolerated on civilian projects, are considered serious infractions in some high-priority military contracts. Although the military client might accept fuzzy excuses for failure to reach objectives in basic research, his insistence on contract provisions increases as the work moves closer to production.¹⁵

The positive incentives to perform military research act primarily on the institution, whereas the negative incentives are felt mainly by the individual; for that reason, tension between the two often occurs. Civilian laboratories and individual scientists may be expected to do military work occasionally in order to build up their equipment and facilities, which they can then use to advantage in their main line of civilian research. Refusal to do military research could possibly hinder one's career possibilities.

In summary, the political leadership's goal of bringing science closer to application, and subsequent policies emphasizing contract research, have significantly strengthened the civilian science sector's ties to application in both the military and civil spheres. Indeed, several prominent proponents of the policy are now viewing the results with alarm, fearing that the moves may have gone too far. The late M. Keldysh, then President of the Academy of Sciences and a famous leader

of applied military research in the aviation industry, declared in 1976 that an excessive orientation to production and involvement in the innovation process could impair the country's fundamental research potential. He observed that "an obvious tendency has emerged by Academy institutes not to cooperate with industry, but themselves to take the matter to its conclusion. In my view, this tendency is very dangerous."¹⁶ Even B.Ye. Paton, President of the Ukrainian Academy and a vigorous proponent of science-industry cooperation, thought that an "inordinate enthusiasm" for short-term problems would act to the detriment of fundamental research.¹⁷

Science Consultants. Consulting by civilian scientists is a frequent, but small-scale phenomenon. It seems to be largely a personal matter involving the noninstitutional effort of a scientific expert. The activity does not seem much different from US practices.

Academy personnel are sometimes included on technical committees convened by a military-industry ministry to consider the preliminary requirement for a new system. Such committees review the feasibility of the requirement and may suggest research prior to further decisions in order to address technical problems and uncertainties.

It is not always necessary for a civilian scientist to have security clearances to consult on military projects. The problems can often be described in a compartmentalized manner without a contextual framework. In some cases, results are simply sent to a postbox number so that even the institutional affiliation of the sponsor is hidden. In fact, it is through such signs that scientists often recognize a military connection to sponsored work.

Because of the absence of specific project, facility, or client identification in some of this work, it is often difficult for both participants and outside analysts to be clear about ultimate uses and users. It is perhaps for this reason that many Soviet scientists refer in a vague fashion to military research carried on in the civilian sector, without being able to delineate more clearly just what the work is about or who the ultimate client might be.

Commissions, panels, and other formally established boards are another means for bringing science information to bear on important questions. Some of the tasks of the various consultative groups include the selection of basic science directions. Such councils exist in the academy system, in the industrial ministries, and in joint groups that bring together individuals from different organizations. Assessing the importance of these groups, though, is difficult. The scientific problem councils of the Academy are consultative and have no formal administrative authority, yet they are said to "exact considerable influence over the course of research."¹⁸ They suggest topics for inclusion among the "basic directions" and recommend assignments among institutes. Furthermore, inclusion of a subject on the lists of basic problems or basic directions provides a set of highly visible priorities that can influence the choice among alternatives when research managers must make decisions between programs. Other views, however, give the Academy of Sciences councils less weight. Their powers are undefined and their administrative support is often inadequate. Moreover, some of the participants in the council activities dismiss them as of no observable value. Even the chief academic secretary of the USSR Academy complained

of the bureaucratic nature of the councils and of their inability to influence the choice of research projects.¹⁹

Coordinating groups in industry seem to fare little better. When, for example, a leading Soviet computer scientist was questioned by the author about the results to be expected from a newly appointed top-level, high-status committee, formed to iron out problems in the computer industry, he dismissed the committee with a shrug and a laugh, indicating that it met once a year, had no formal authority, and was too large and unwieldy to come up with a coherent set of recommendations.

On the basis of this evidence, it is not possible to ignore such committees, commissions, and councils, nor is it appropriate to regard them in the same light as they may be described in their charters. At the least, these bodies serve as indicators of the direction of government policy, of the research trends that are favored, and of the institutions that have been given the leading roles. They also draw scientists into contact with decisionmakers as well as allow them to communicate among themselves.²⁰ Beyond this, especially in military affairs, the various committees and commissions may at times actually recommend, coordinate, and direct the course of scientific research in an effective way.

Science Entrepreneurs. Key actors in the links between science and the military (and in the larger science transfer process) are the science-promoters. This handful of individuals participates in numerous committees and are always in demand as consultants. They help break the bonds of rigidity, allowing the system to act more effectively. They usually head their own institutes, possess solid reputations as producers or managers of science, and sit on academic and government boards.

Their institutes work on both military and civilian research; they chair problem councils and coordinating committees. Although their committees may not achieve all that is expected of them, these entrepreneurs of science have the opportunities to promote their own ideas and those of their colleagues before decisionmaking bodies and political leaders. Therefore, even if no formal ties exist, leading scientists may be connected to the military in a variety of ways.

VII. Nature of Scientific Support

Rapid Growth. Many Russian emigre scientists have described periods of rapid growth of civilian scientific support of the military, especially since the late 1960s. Some estimates have suggested that the aggregate effort has grown by many times in the past 20 years. According to counts based on the first-hand evidence of former Soviet scientists, almost half of the research institutes in the Academy seem to have participated in military research.

The resurgence of Academy support of the military in the past 20 years is not a totally new phenomenon in Soviet military-science relationships. Before war broke out in 1941, Academy institutes were working on about 200 research topics ordered by the Defense and Navy commissariats (the predecessors to today's ministries). Some leading institutes -- for example, the Ioffe Physico-Technical Institute in Leningrad -- were heavily engaged in military research.²¹ Within days of the German attack on the USSR, institutes of the Academy of Sciences were ordered to review their research programs and to redirect their efforts to defense-related work. Coordinated by a science plenipotentiary

of the State Defense Committee, scientists performed a great deal of valuable applied research during the war.

Following the war, civilian science made important contributions to nuclear weapons developments, ballistic missiles, radar, and jet propulsion. Many of the fields, stimulated by wartime science contributions, matured and stabilized sufficiently to form industrial ministries around the new technologies and products; electronics, missiles, and nuclear weapons gained ministerial status in the 1960s.

Administrative reforms in the early 1960s, however, removed from the Academy applied research institutes and those that were most oriented toward engineering. The remaining organizations were directed to concentrate on basic research. The more recent trend appears to be an attempt to find a balance between basic and applied research in the leading institutes of Soviet science.

Despite the vigorous growth of military R&D in civilian institutes, R&D contributions by the military production ministries and the Defense Ministry dominate civilian efforts by an order of magnitude. Civilian science is not a central actor in the formal weapons acquisition process. Such efforts as occur seem to be ad hoc, short-term, and associated with specific problems arising during development. The further a weapon proceeds in the development process, the more likely that civilian science support will be limited to solving unexpected and narrowly delineated problems that arise in design, test, production, or use. At the institute of Nuclear Physics associated with Moscow State University, with 3,000 employees, the ad hoc nature of much of the type of work is demonstrated by the fact that few military contracts are for more than 12 months, and most are for around 6 months.²²

Main Contributions Occur Before Formal Weapons Acquisition. The military seems to sponsor research in the civilian science community for several reasons: to ascertain the feasibility of a requirement; to investigate potentially useful concepts and technologies; or to reduce the risks inherent in new things by research and experimentation. This kind of research appears to precede the actual incorporation of a new concept, technology, or device in a development program.

The military science sector has been unable to meet all of its R&D requirements, particularly in highly advanced technologies. The technology requirements of new systems are likely to be beyond the capabilities of the military-science sector, especially in the short run, when they have not yet adapted to the new demands. A lagged response of the military scientific base, therefore, requires more extensive support from civilian science. Much of the civilian science effort appears to be directed toward developing and maturing the science base and the technologies that will later flow into the risk-avoiding weapons development process.

Civilian science's main contribution to the military is to what can be described as an enlarged "front end" of the standard acquisition process. Despite this greater attention to science and technology in the early phases, we have no evidence that the style of design has changed. Designers and military customers alike still seem to shun risky solutions, untried technologies, and immature components. It is the new task of the science community to reduce the risk through research and experiment, to prove the technologies, and to demonstrate the technical

feasibility of new kinds of components -- before they enter into weapons development.

"Big Science" and the Military. In recent years, many Soviet science leaders have advocated program planning for large science projects. The program approach emphasizes the achievement of specific goals and the drawing up of a comprehensive set of measures for that purpose. In the postwar period, this approach has been customary for priority projects in the economic, social, and military spheres. In the development of both nuclear weapons and ballistic missiles, special systems of management were headed by councils subordinated to the highest levels of government and Party to assure the adequacy of priority and resources, backed by political authority. Nuclear weapons and ballistic missiles were later institutionalized within the standard ministerial structure, but the management pattern used in the early phases of those programs has now become the norm for new special projects. "For the most important problems, a lead ministry or lead organization will be designated and granted certain rights in relation to other participants and the allocation of resources," with a government decision fully specifying schedules, resources, and executors.²³ It is not accidental that this description applied to weapon system development generally, and to the management of large, military-related, "big science" programs specifically.²⁴ It has been the chief means by which the Soviet leadership has attempted to achieve major advances in science and technology. In some instances, as in the development of nuclear weaponry, it has been highly successful. In other areas -- the supersonic transport Tu-144 being a conspicuous example -- special management techniques, abundant resources, priority, and political backing have not

overcome recalcitrant technologies and an economy that is generally inhospitable to innovation.

Current examples of the project-planning technique may include the work on high-energy devices, including so-called "particle beam weapons" and high energy lasers. Of the 20 to 30 research organizations participating in these efforts in a major way, approximately half are members of the Academy of Sciences (national and regional), one-quarter are higher education institutions, and the remaining quarter are affiliated with the military-production ministries.²⁵

Such "big science" military research activities is the new "front end" to systems that have never been built before. The differences between these activities and the science contributions during the preweapons-acquisition phase lie in the scale of the undertakings and in the breadth of the technological development that a system — new in all its parts — will require if it is to prove feasible. It is one thing, for example, to work on holographic signal processing for a conventional radar system. It is substantially more complex to devise a high-energy laser defense for ballistic missiles. All of the subsystems and components in the latter case must be researched, demonstrated, and integrated into a system. No existing organization has the capabilities to carry out the whole task for such systems. Specially designated lead institutes and loose, informal coordination seem to define the chosen approach. Once again, though, these activities appear not to have affected the standard approach to weapons acquisition. The big-science efforts are clearly distinct from weapons development, although many of the same defense industry organizations may participate in big-science projects as in conventional developments.

VIII. The Three Components of Soviet Military R&D

The Soviet Union has developed a weapons acquisition system tied to the science and production sectors that, by fostering technical change while reducing risks, is well-tailored to the Soviet set of incentives and constraints. This approach to weapons development is based on three components: evolutionary improvements; technology development; and experimental prototypes.

Evolutionary improvements limit risks and constrain uncertainty. It is the Soviet designers' first choice for advancing performance in a large proportion of successful weapons. The development of new technologies and the transfer of science to application is accomplished in a broad-based effort by both the civilian and military science communities. The funding for the effort is largely independent of weapons programs; however, the closer a scientific project is to a specific weapon, the more likely that science financing is tied to the final system. The output of technology development and subsystem maturation feeds into the product-improvement development stream as well as into the construction of experimental or trial prototypes.

Both Soviet military planners and their weapons designers have used prototypes in many weapons types as a regular means of assessing new concepts, technologies, components, and wholly new configurations. It has been a tool for determining whether an older product is no longer worth improving and whether a new design yields the desired capability. In the development of the T-64 and T-80 tanks, numerous variants of new models were observed -- obviously tests of alternative designs. Models have been reported with a turbine engine, missile launchers, and

"kneeling" suspension. Some models have apparently been produced in numbers large enough for troop tests in large-scale maneuvers.

Where technology is changing rapidly, emphasis is on developing the technology; for more stable areas, product improvement is the chief means for enhancing performance. Programs that have been conducted outside this strategy have often failed or encountered great difficulty.

Over the past 50 years, the Soviet Union has established an approach to military R&D that fits the Soviet environment. Few forces can now be discerned that are likely to cause it to abandon such an effective style.

NOTES

1. This engine may have been a Soviet copy of a Hispano-Suiza aircraft engine. The Soviet Union was importing a great deal of Western technology at that time, and some features of the imported designs could be expected to turn up in almost any new Soviet equipment.
2. The length of a gun in calibers is defined as the barrel length divided by the diameter (caliber) of the bore. Longer barrel length is a means for attaining higher muzzle velocity of the round by allowing more complete combustion of the propellant within the barrel.
3. Liddell Hart, Basil H., The Red Army, Harcourt, Brace & Company, 1956, p. 181.
4. Guderian, H., Panzer Leader, Ballantine Books, New York, 1957, pp. 182-183.

5. Louvan E. Nolting, "The Financing of Research, Development, and Innovation in the U.S.S.R., By Type of Performer," U.S. Department of Commerce, Foreign Economic Reports FER-No. 9, April 1976, p. 45.
6. Louvan E. Nolting, "The Structure and Functions of the USSR State Committee for Science and Technology," Foreign Economic Report, No. 16, U.S. Department of Commerce, 1976, p. 2.
7. Morris Bernstein, et al., "The Planning and Management of Industrial Research and Development in the U.S.S.R.," Science Policy Working Group, Joint US-USSR Science and Technology Exchange Program, SRI International, June 1980, p. 47.
8. Paul M. Cocks, "Science Policy: USA/USSR: Vol. II," Science Policy in the USSR, National Science Foundation, 1980, p. 40.
9. These steps have been standardized throughout civilian and military industry and are known as the "Unified System of Design Documentation" (YeSKD).
10. "U.S. Finds SA-6 to be Simple, Effective," Aviation Week and Space Technology, December 5, 1973, p. 22.
11. Cocks, op. cit., pp. 99-100.
12. Thane Gustafson, "Selling the Russians the Rope?" Soviet Technology Policy and U.S. Export Controls, The Rand Corporation, R-2649-ARPA, 1981, pp. 61, 65.
13. Julian Cooper, "Innovation for Innovation in Soviet Industry," Center for Russian and East European Studies, University of Birmingham, England, 1979, p. 36.
14. Lawrence L. Whetten, "Management of Soviet Scientific Research and Technological Development--Some Military Aspects," School of

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15. Whetten, op. cit., p. 53.
16. Vestnik Akademii nauk SSSR, 1976, No. 9, p. 41; J. Cooper, op. cit., p. 37.
17. Nauka i zhizn, 1977, No. 4, p. 19; quoted in Cooper, op. cit., p. 35.
18. Cocks, op. cit., p. 131.
19. V.M. Sisakyan, quoted by Helgard Weinert, "The Organization and Planning of Research in the Academy System," in E. Zaleski, et al., Science Policy in the USSR, OECD, Paris, 1969, p. 230.
20. These points are made by Weinert, op. cit., p. 231.
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COMPUTING IN THE SOVIET GENERAL ECONOMY:

AN INTRODUCTORY OVERVIEW

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I. General Purpose Computing in the USSR

History

By world standards, the Soviet computer industry got off to a good start in the early 1950s. Accomplishments included one of the first electronic digital computers with internal program storage, a large scale scientific computer, and the serial production of a small general purpose machine. By 1953, the year Stalin died, the Soviets were a respectable third, after the US and UK, on the world computing scene.

The so-called "computer gap" between the US and USSR really began to open up in the mid-1950s, and it became very substantial by the late 1960s. Soviet progress was not insignificant: a number of new models (not terribly innovative, but not close, compatible, copies of Western machines) appeared during this period, and there was something of a "love affair" with cybernetics. The US industry left the Soviets far behind when it was discovered that there was a vast market for computer products across a broad spectrum of US businesses and industries. Several US vendors had considerable experience with the production, servicing and marketing of a range of electromechanical products intended for large communities of consumers. The corresponding Soviet ministries were much more limited in their perceptions, effective customer base, and capabilities.

During the 1960s, serious problems began to force the Soviets to reevaluate their perceptions and practical efforts. These included lower productivity and growth rates, difficulties with the management of increasingly complex systems (e.g., the national railroad network), and problems keeping up with the US in space and military technologies.

By 1969, the Soviets had decided to significantly upgrade their computer industry so as to get some respectable hardware and software into both the high priority and general sectors of the economy. In order to accomplish this objective as expeditiously as possible, a strategy of risk avoidance was followed. Part of the foundation of this strategy was the use of proven Western systems.

Hardware

Since the early 1970s, there has been a dramatic change in the character of Soviet hardware. Before then, there had been Western influence in the designs of Soviet computer equipment, but not much close functional duplication, that is, the use of the same architecture, instruction sets, and data interfaces. In the last 12-15 years, functional duplication of well established US systems has become the rule.

At this time several US mainframe, minicomputer, and microprocessor designs have been duplicated. Several of these efforts have been fairly successful in that the equipment is produced in quantity and can run a respectable amount of the software developed for the US originals. However, the Soviets have been less successful in closely duplicating the manufacturing processes and production capacities of the US vendors. It is also worth noting that most of these efforts have been part of a partial integration of the Soviet and East European industries.

The least detailed duplication has been in high speed, large scale, scientific computing, although US influence exists here as well. However, Soviet progress in this area has not been especially impressive.

In summary, over the last 12-15 years, the Soviets have been able to significantly improve the quality and availability of computer hardware. Rates of expansion and technical upgrading have been substantial compared with the pre-1970 era. Certain important milestone achievements have also been attained. These include the creation of viable families of mainframes, minis, and micros, and a minimally respectable assortment of peripherals. Some hardware "gaps" with the US have been narrowed, usually in older technologies, but others have widened.

Software

By the late 1960s, the Soviet software situation bordered on pitiful. The host hardware left much to be desired (for example, disk stores were not widely available until the mid-1970s), and there was no effective equivalent of or substitute for a US-style, customer-oriented software industry. Vendor software support and other forms of service for the "ordinary" user was poor. All of this was severely compounded by the poor intra- and inter-ministry communications that plague Soviet civilian industry. Many computer installations used their miserable machines in quiet and desperate isolation.

An important reason for the functional duplication of US hardware systems was to expedite the acquisition of a much improved software inventory. For example, the duplication of the IBM 360/370 and DEC PDP-11 series enabled the Soviets to use large quantities of Western operating systems and other forms of systems software. These programs

had been user tested to an extent that would have been inconceivable in the USSR, given the very poor nature of Soviet user-vendor relations and the software distribution system. Furthermore, the greater availability of respectable hardware has made it both necessary and possible for the Soviets themselves to progress with their indigenous systems software efforts.

Not surprisingly, there has been less improvement in the areas of applications software and services. It is much more difficult to effectively "borrow" such things from the West. This is not to say there has not been any improvement, but these areas have a much broader interface with the Soviet economic system, and problems are harder to correct without a wider set of systemic changes.

As far as we can tell, Soviet commercial and academic (with the partial exception of mathematical algorithms) software has been remarkably free of innovative features.

Networks

In spite of much rhetoric on the potential for using computer networks to do great things in the centrally planned economies, the past and present states of practical networks in the USSR leave much to be desired. Those that do exist tend to be small, hierarchical, based on dedicated lines, and lack many capabilities that are taken for granted in the US

Some of the reasons for this are technical. The Soviet telephone system is, for the most part, incapable of supporting large volume, long connection time, rapidly switched, and reliable data communications. Satellite communications (other than for broadcast purposes) are rarely

available to "ordinary" users. Data communications activity has picked up perceptibly in the last few years, but is still very poor by US standards, and remains relatively unimpressive compared with Soviet improvements in other areas. Progress that has been made seems to be based on earlier Western achievements (e.g., a partial adoption of IBM SNA).

Much of the poor showing in this area is clearly due to fundamental systemic deficiencies. Some of these will be considered more explicitly in the following section.

II. Computing in the Soviet Economy

History

Although the widespread use of computers in economic planning and management applications was proposed in the late 1950s, the introduction of computing into the general economy did not begin in earnest until the 8th Five-Year Plan (1966-70). In this period 400 systems were installed at all levels of the Soviet economy. During 1971-75, five times this number were introduced. The vast majority of these were based on small second-generation computers. It was not until the 1976-80 plan period that a substantial number of third-generation computers began to be incorporated into enterprise management systems. By then, reasonably modern minicomputers and microprocessors were beginning to be available in substantial numbers for use in process control applications. As of the early 1980s, over 5,000 systems were claimed to be in use at all levels of the Soviet economy.

Until the mid-1970s, many management applications were little more than accounting programs for updating simple master files. Grandiose

plans for comprehensive computer use remained far from realization. These included a national data transmission system, a national network of computer centers, and OGAS, a national system that would link lower-level centers together and monitor the entire economy.

By the late 1970s, applications included unsophisticated short-term planning, accounting of plan indicators, engineering calculations, inventory control, sales, and other similar systems. At the end of the decade, most data processing departments resembled those of the mid-to-late 1960s in the US. Programs were often run in a single-job, batch mode. Terminals were slowly being introduced, but remote dial-up was essentially nonexistent.

The Current State of Computing in the Economy

Soviet computing applications fall under the general designation of ASU, or automated management systems. Some of the most important sub-categories are: ASUTP for process control, ASUP for enterprise (company/corporation) management systems, OASU for branch (ministry) management systems, and assorted systems at the regional and State Committee levels.

ASUP correspond loosely to corporate MIS in the US, but tend to be more limited in functionality and scope. Through the mid-70s, many systems existed mostly on paper, serving only to impress superiors. Many systems now do useful work, but the current state of ASUP is still characterized by relatively low levels of computer use (most installations underutilize the capabilities of modest machines) and low levels of inter- and intra-organizational data sharing. Although technical deficiencies in hardware and software are no longer the crippling

factors they once were, computing has yet to be deeply integrated into the working fiber of Soviet enterprises.

Computer-aided manufacturing (CAM) is being pushed with high priority over the next decade. In 1981-85, the Soviets plan to build nine times as many industrial robots as in 1976-80, to introduce 7,300 computer and control complexes based on mini-computers, and to install 2,700 new ASUTPs. At least 22 ministries are involved in the manufacture of programmable manipulators which will be introduced into 34 ministries. However, the level of existing systems is not up to modern US systems, and we expect most of the planned developments to continue to be relatively weak.

Virtually every important ministry now has an OASU, but these vary widely in quality, and we have not identified any that would be considered impressive by contemporary US standards. The two systems which seem to be most advanced are ASU-Pribor (of the Ministry of Instrument-Building, Means of Automation, and Control Systems) and ASPR (State Planning Committee). The former is set up along the same functional lines as ASUP, while the latter automates some of the routine calculations associated with formulating the plan. However, little appears to have changed in the methodology for plan construction.

The Economic Context of Soviet Computing

In order to broadly benefit the Soviet economy, computing must be effectively and fairly pervasively utilized at the enterprise level. The efficacy of higher-level systems depends on the data produced at the bottom. There are substantial, well-known barriers to innovation in Soviet enterprises. These include high risk due to penalties for

failure, lack of autonomy, especially in procuring supplies and services, the absence of competition as an incentive for innovation, and problems with the entry of new firms and the exit of ineffective or inefficient ones. In the case of introducing computer applications, the severity of these barriers is increased in some ways and decreased in others.

The hierarchical organization of Soviet industry, with a fairly small number of large units, seems at least superficially well-suited for the introduction of computers. A relatively small number of well-positioned ASUs can, in theory, have an impact on a large percentage of production. The centralized economy is amenable to rationalization of information flows, uniform accounting standards, uniform management structures, etc. One would expect that standardization could dramatically reduce the number and diversity of software systems.

In practice, however, standardization has reached only the level of systems software, and even here the actual performance of the centralized Soviet software houses and their customers have resulted in considerable chaos in the systems software arena. Furthermore, much of the systems software standardization that does exist in the USSR is based on the de facto standards of major US vendors. Most applications software has been developed in-house, and a "not invented here" attitude is more prevalent than in the US. Overlapping, inconsistent, or incompetent authority prevents the kind of unified policy that would be necessary for standardization on this scale.

The introduction of computing carries substantial risk for the Soviet manager. Computerized management information systems raise the specter of large investments with highly uncertain returns, major

changes in management and the flow of information, and dependence on unreliable suppliers of services and spare parts for sophisticated equipment. CAM/ASUTP systems may be easier to implement organizationally and politically, and their value may be more readily apparent in the Soviet industrial context, but they are still part of the general economic structure in which new suppliers must be obtained for materials for new production processes, new consumers of new products must be dealt with, and new prices must be set for new goods. Soviet managers are much more limited than their American counterparts with regard to the positive incentives available to balance the risks associated with moving to MIS and CAM.

It is not clear where a big payoff for Soviet MIS can come from. The relationship between MIS and practical aspects of overfulfilling plans is by no means clear. Computer applications cannot replace the extensive network of informal communication necessary in the Soviet industrial bureaucracy, including the use of influence, intermediaries, and bribes. Much of the profit from innovation in the US comes from increased market share; an incentive that is incomparably weaker in the USSR. The incentives for cost cutting are more comparable, but still weaker in the USSR than in the US. Managers try to incrementally overfulfill their plan targets in ways that encourage them to underutilize true capabilities. If the systems provide large gains, enterprises that sustain them may find themselves at the forefront of industry, only to flounder because the "ratchet effect" will mandate unsustainable growth rates.

A further disincentive is that computerized systems can open enterprises to more detailed scrutiny by higher-level authorities, making it

riskier to use the quasi-legal or illegal activities needed to survive the vagaries of the Soviet industrial way of life. The Soviet manager is faced with the choice of going to the effort of maintaining a "phoney" computerized system that has nothing to do with how he actually manages his operations; or of using a system to really help him with his operations, but which leaves a dangerous audit trail. Effective computerization may require patterns of use that are politically unacceptable to Soviet authorities: for example, giving many levels of management direct access to data, word processing, electronic mail, etc.

To some extent, computing has become an important and prestigious technology in the USSR simply because of the attention it has been getting in the US. While some of the "real" uses of computing may threaten a Soviet manager, showing it off to high-level visitors as a sign of progressive management is something he can heartily embrace. Such exposure may help his career in several ways: for example, in the competition with other enterprises for recognition at the ministry. For those sectors of the economy that are in competition with the rest of the world (in particular, defense), keeping up with the West can be sufficient reason for the allocation of additional resources.

The widespread introduction of computing has been mandated at the highest levels of the Soviet Party and Government, and billions of rubles have been allocated to this end. But performance at the crucially important enterprise level suggest that the Soviet leadership is not yet willing to make the sweeping changes necessary to fully exploit this technology. On the basis of past evidence, it is not likely that they will. But current and potential applications of computing are such that the Soviets may be forced to make adjustments well beyond what they

have done to accommodate pressures and opportunities arising from other technological advances.

III. Technology Transfer

On the surface, the Soviet computer industry and Soviet computer science seems to be pervaded by technology transfer from the West in general, and from the US in particular. The ideas, know-how, and products transferred run the full range from ways of solving very specific technical problems to broad impressions of the roles of computing on a national scale. The amount of world class innovation coming out of the USSR in general purpose computer technology and its applications is remarkably low.

However, the Soviets deserve credit for building a respectable computer industry, the second or third largest in the world (especially if the East European industries are considered part of the same "multinational corporation"). It is a substantial achievement, requiring a great deal of low profile innovation, to be able to produce and distribute machines like the IBM 360/370, DEC PDP-11, and INTEL 8080, and a half-decent collection of peripherals. The Soviets have progressed well beyond what existed around 1970, and their earlier history is such that it is unlikely they would have come as far since then without the intensive pursuit of technology transfer.

The most conspicuous failure of Soviet policies to transfer computer technology from the West is the inability to bring about a deep penetration of this technology into the working fiber of the general economy of the USSR.

A SHORT REFERENCE LIST

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THE OUTLOOK FOR SOVIET ADVANCED TECHNOLOGIES

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THE OUTLOOK FOR SOVIET ADVANCED TECHNOLOGIES

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There are two common notions about Soviet technology: one is that the Soviet Union appears, or at least claims, to be able to counter every US weapons technology development. The other is that the technological level of the USSR is considerably below the corresponding level of the West. It is difficult to imagine how, in the long run, both notions could be true at the same time. This dilemma was less acute in the age when weapons systems depended more on what is now known as traditional technologies. But, if the Soviets continue to lag behind the West in the level of technological development, will they be able to continue matching new US weapons given the fact that future weapons will rely ever more heavily on advanced technology? The issue of Soviet weapons technology thus becomes part of a broader issue of Soviet advanced technology and its progress relative to Western experience. The constraints affecting this progress in the near future are the subject of this talk.

It is my view that the future performance of Soviet advanced technologies depends to a large extent on a single organization, the Soviet Academy of Sciences, an R&D performer in the majority of areas significant to advanced technologies. I will therefore start with a focus on the Academy and the reasons why I consider it pivotal to Soviet technological development. This leads directly to the much discussed topic of industrial innovation and the impediments that characterize the Soviet R&D system. However, these problems will be treated here in the context

of the specialized technologies that are being developed today, aimed toward new civilian and military applications, and particularly those relevant to what is not commonly addressed as the Star Wars weaponry. What I want to show here is that the factors governing the Soviet development and application of these technologies are quite different from those affecting the more traditional Soviet technologies.

There is no convenient definition of what is known as advanced technology, often referred to as high, or even exotic technology. The best that one can do is to refer to it as the aggregate of methods and materials at the cutting edge of current scientific and industrial development that play a significant role in transforming society. The leading examples of advanced technologies are the microelectronics technology driving computer development, materials technology comprising composite materials and metallurgy, biotechnology including genetic engineering, etc. Less well known, but significant is pulsed power, or high energy density technology that drives the development of lasers, and microwave and particle beams, and is essential to the realization of controlled fusion reactors and directed energy weapons.

All of the above examples, as well as many other research areas leading to the development of advanced technologies, have been the responsibility of the Soviet Academy of Sciences. The Academy has been the planner, and coordinator, as well as performer of this R&D. It has concentrated in its research institutes the top scientific and engineering talent of the Soviet Union, and has accumulated a comprehensive body of expertise in the areas directly relevant to advanced technologies. In consequence, the fate of advanced technologies in the USSR has become tightly bound with the fortunes of the Academy of Sciences, and any

assessment of Soviet advanced technologies must take stock of the role played by the Academy.

The assessment offered here omits some of the important dimensions of the problem, such as the economic forces shaping technology development, and concentrates on just three issues that confront the Academy in its R&D operations: The perception of its mission, the relations with the industry, and the technological support of research.

To define the real nature of its mission, the Academy faces the choice between performing only basic research on the one hand, or including other stages of the R&D cycle and becoming involved in industrial innovation, on the other. The issue is significant, since it deals with questions of political and economic power. Basic research is performed under conditions of relation autonomy and independence of the researcher. These advantages, however, are offset by the implied retreat to an ivory tower and a relatively low level of national influence that a purely academic institution could command. The alternative of heavier involvement in industrial problems promises a higher degree of influence on vital national affairs, but is incompatible with the ideal of academic independence. The Academy has been walking a tight-rope between the two choices ever since World War II. During the war, the Academy was dedicated to the war effort and pioneered the development of nuclear weapons. After the war, it has undergone a swing towards basic research that culminated in 1961 with the loss of some of its research institutes to the industry. Since that time, the pendulum has been swinging in the opposite direction, marking an increasing involvement of the Academy in R&D that is directly relevant to technological development.

This dilemma has never been resolved and had directly affected the second major issue, that of industrial relations. The Academy of Sciences insists on its independence even in the face of the increasing need to cooperate with the industry. The latter appears reluctant to pick up the output of the Academy's research institutes and carry it to the production stage. Thus, the bureaucratic barriers between the mutually independent Academy and industrial organizations have been detrimental to the implementation of the innovation process.

Every research-development-innovation-production cycle that includes the Academy of Sciences, and therefore involves advanced technologies, is in effect fragmented among different, independent jurisdictions. It is ironic that the society characterized by pervasive political and economic centralization has produced a decentralized R&D system just where centralization would have been advantageous. According to the Soviets' own assessment, the main condition for improving the effectiveness of science is a better interaction between fundamental science and technology which should be combined into a unified scientific-technological complex.

The third major issue, concerning technological support of research, further compounds the second. The transfer of the Academy's research results to the industry generally requires intermediate facilities necessary for effective innovation. These facilities are an experimental production base on the Academy side, and technical capability to assimilate the new technology on the industrial side. Neither is available in many Academic institutes and industrial sectors.

Examples, complaints, and criticism of the impact of these problems on technological innovation have been a familiar feature in Soviet

publications throughout the past three decades, and are continuing unabated. The impression remains that little has changed: In 1983, Soviet writers repeat that "a system of transferring science's results into practice has yet to be worked out."

Soviet attempts to remedy this situation have been intensifying throughout the seventies, mainly through the establishment of joint industrial innovation programs and scientific-technical complexes involving the Academy and industrial ministry organizations, and by means of individual contractual relations between Academy institutes and outside sources. While in some cases this policy has been successful, notable in the Ukraine and Siberia, it has failed so far to solve the basic problem.

Microelectronics represents a most important advanced technology area affected by these issues. Recent Soviet discussion emphasizes the fragmentation of the R&D cycle, its bureaucratic and psychological barriers, and the scarcity of intermediate facilities in this area. The Soviets note that the overwhelming majority of discoveries and inventions in microelectronics have been made in the US, where the organization of scientific research in large companies has avoided the gap between fundamental science and technology.

Academy's contract work in microelectronics is said to be routinely duplicated by industrial institutes because of the technological disparity between the industry and Academy due to the lack of experimental production facilities. The cases in which design development is performed directly from Academy's results are a rare exception.

The cause of microelectronics and computer technology in the USSR has been vigorously promoted by the Ye. P. Velikhov, vice-president of

the Academy of Sciences, who recognizes the fragmented R&D cycle and inter-agency barriers as the primary factors responsible for the poor performance of Soviet computer industry. Velikhov attributes the success of the BESM-6, one of the early Soviet computers, to the fact that it was developed in an Academy institute equipped with pilot production facilities. Velikhov has succeeded this year in achieving what probably is the largest one-time expansion of computer technology R&D: the establishment of a new department of the Academy of Sciences, called Informatics, Computer Technology, and Automation, and of three new research institutes under this department dedicated to the development of super-computers (over 1 billion operations per second) and new types of smaller computers. Particular attention has been paid to ensure the availability of pilot production facilities for the new institutes.

However, the possession of a substantial pilot production facility is no guarantee that the Academy's work will be accepted by the industry. A case in point concerns the Institute of Atmospheric Optics in Tomsk, one of the more innovative and successful institutes of the Academy of Sciences. For the past decade, the institute has been developing a new all-weather navigational guidance system for aircraft and shipping based on the laser principle. The system has been successfully tested in prototype form under actual operational conditions. However, the industry has refused to accept it from the Academy in the prototype stage, and has insisted on fully operational systems. This, however, calls for the kind of production facilities that fall beyond the stated mission of Academy's institutes.

There are recent indications that the Academy would like to use even stronger measures than the acquisition of pilot plant capability or

the formation of science-production associations. A new organizational structure was proposed for microelectronics R&D that would involve the transfer of some industrial R&D institutes to the Academy. Since the majority of highly qualified Soviet specialists in mathematics, physics, and chemistry, that define the quality of microelectronics research, is concentrated in the Academy of Sciences system, it was claimed that the leading Academy institutes should be in total charge of such organizational structures. A few institutes should form the basis of sufficiently large and well equipped associations that include a leading institute in basic research, special design bureaus, and pilot production plants. The technological equipment of the association should provide the capability for an entire R&D cycle down to prototype construction. Such equipment should be above the technological level prevailing in the corresponding industrial branch.

At this time, there are very few scientific production associations based on the participation of the Academy of Sciences. It is doubtful if a large-scale expansion of this system could ever be realized. For one thing, the necessary transfer of some existing industrial research institutes and pilot plants to the jurisdiction of the Academy would be strongly resisted by the industrial ministries. For another, scientific leadership of production is generally not considered desirable from the viewpoint of industrial management. Finally, the bureaucratic patchwork that such associations essentially represent fails to resolve the conflicting interests and incentives of the participants by merely bringing them together into an association.

The less than adequate technological base of the Academy research institutes, and the equally insufficient support received from the

industrial facilities, tend to limit the developmental capabilities of the Academy in areas requiring interaction with the civilian industry. It would be of interest to determine if these limitations are lessened in the interaction between the Academy and the military. Such an interaction must have been expanding steadily at least in the past decade. While in the past, advanced or exotic technologies played a relatively minor role in the development of traditional weapons systems, it is obvious that military interest in the technologies considered here, and especially in microelectronics, composites, and pulsed power, has been rapidly increasing. In order to exploit the potential inherent in these technologies, the Soviet military must turn to the Academy of Sciences as the performer of the early stages of R&D and as the national planner and coordinator of R&D in these areas.

Since the military sector has a more efficient procurement system and a greater capability to cut across bureaucratic obstacles than does the civilian sector, we should expect the former to be more effective in transforming the Academy's research into advanced technologies.

Soviet open-source technical literature tells us in considerable detail about the nature, direction, and progress of research performed by the Academy of Sciences and the universities in basic and applied sciences and engineering, as well as in the later stages of the R&D cycle of many subject areas. The literature dealing with the assessment of R&D organization tell us much about the innovation problems discussed so far. This literature, however, is less informative about industrial production details and much less about the later stages of military R&D cycle. While we know a good deal about the organization of the Soviet military-industrial procurement system, we know less of the interface

between the military procurement and the Academy of Sciences which must include the State Committee for Science and Technology, the Military Procurement Commission (VPK), and other Soviet military agencies.

Consequently, we know very little about the actual capability of the Academy of Sciences to generate advanced technologies in service to the military. While it is clear that this capability must be higher than its civilian counterpart, there are several reasons to believe that it may be, nevertheless, far from satisfactory, and that the problems impeding the practical realization of the Academy's research affect the military as well as the civilian sector.

First, the participation of the Academy implies a fragmented research-development-production cycle. It is unlikely that, even in a military setting, the Academy's institute, or any part of it, can be effectively subordinated to another organization, or, conversely, that a military institution can become a part of the Academy. The single organizational structures encompassing all the stages of the R&D and production cycle exist in the Soviet military establishment and have demonstrated their efficacy. The design bureaus of the military aviation industry are an example of such structures. However, the Soviet aviation R&D has so far made a limited use of Academy's institutes and of the advanced technologies fostered by the Academy. It is possible, therefore, that the success of the aviation design bureaus has been due, at least in part, to the continuity of their R&D cycle and the absence of the problem of integrating the Academy's activity.

Second, progress in the development of any given advanced technology depends on the state of the art in a wide range of supporting technologies. Many of Soviet technologies that have reached a high state of

the art owe their eminence to the forced development of a narrow technical area, rather than to a general "grass-roots" progress of broad areas that, in the West, has been stimulated by vigorous mercantilism. Narrow development misses many technologies, leaving a thin infrastructure of support which advanced technologies can draw upon. In the example of microelectronics, such infrastructure consists of chemical technology, materials processing, circuit design, lithography, etc., which are not all sufficiently mature in the USSR. In the words of the Soviet analyst, "If to solve narrow individual problems one needs to have only some technologies available, a broad goal-oriented proof-of-principle research requires the entire technological complex of electronics." Since the scarcity of a technological infrastructure is a problem of national dimensions, it should be expected to affect the Soviet military sector as well.

Third, the shortage of experimental technology and especially, computer technology, generates secondary effects that are also likely to reach the military sector. Thus, the tradition and style of R&D that have evolved in an environment of equipment and computer scarcity can be expected to be pervasive. The Soviet predilection for analytic approaches in the place of numerical solutions and computer simulation in general is a case in point. While the military sector may have more and better computer equipment than the civilian sector, the R&D style of the Soviet researchers and, particularly, of those coming from the Academy of Sciences, may well preclude the full realization of the available computer capability.

Fourth, a psychological factor affecting the interaction between fundamental science and industry has been noted by Soviet analysts.

They stress the importance of creative enthusiasm, defined as a high degree of involvement of individual scientists and research teams in new ideas, discoveries, and proposals. Equally important is the continuity of creative enthusiasm in the transition from the early to the late stages of the R&D cycle. The Soviets point to the Western practice of gradually integrating technologists, designers, and production men into the initial team of researchers without affecting morale, made possible by the unified R&D cycle. In the fragmented cycle characteristic of many Soviet R&D projects, the inter-agency, and even inter-office organizational barriers impede the transmission of creative enthusiasm from one team to another. Not only the leaders of Soviet research teams, but also the majority of the active members of the teams tend to display a negative attitude to suggestions for joint development of a project

The first of these impediments to successful innovation — a fragmented R&D cycle — is by far the most important, to some extent determining the effect of the others, since a well-integrated R&D cycle would tend to secure a better industrial support of research and better morale. However, it is important to note that this problem does not affect all technologies in the same way. It clearly is most telling in those R&D cycles that start with basic and applied research performed by the Academy of Sciences and are expected to lead to mass-production with the participation of the industry. It is obviously less acute in those technological areas in which the entire R&D process terminates in prototypes, or involves operational systems that do not require extensive participation of industrial production facilities. Some of these areas represent large-scale scientific research projects that may have pronounced military significance, or that involve a degree of

technological risk too high to be assumed by industrial R&D. The Academy institutes active in such areas perform work similar to that of the US national laboratories, such as Livermore and LANL.

A most important such area is the pulsed-power technology, the foundation of many, if not all, future high-power laser, microwave, and particle-beam devices, controlled fusion reactors, and advanced industrial applications to metal forming, welding, and conditioning of materials. In many of these applications, the energies involved are so high that they must be produced and delivered in pulses, rather than continuously; hence the term, pulsed power.

A potential major military application of pulsed power is represented by what is now called directed energy weapons. These weapons would utilize beams of laser light, microwaves, or subatomic particles in the role of projectiles. Since the principal advantage of these beams over conventional material projectiles is the speed of aiming and delivery, their natural role would be in defense against fast missiles attacking in large numbers. These are the basic elements of Star Wars scenarios which, in practically all cases, require the development of one form or another of high energy density technology. Star Wars also probably represent the first large-scale military concept that is totally dependent on advanced technologies.

The Soviet Academy of Sciences has been developing pulsed-power technology at a relatively high level of effort for the past three decades. This does not by itself mean that the Soviet Union has been engaged in the development of directed energy weapons, or that it even considers such weapons feasible. The Soviet open-source technical literature carries no references to such applications of Soviet R&D.

Instead, major parts of the Soviet pulsed-power R&D are stated by their performers to be dedicated to controlled fusion reactions and relativistic microwave devices. It is, of course, likely that various military applications also play a part in this effort. However, the important point in this discussion is that pulsed power represents precisely the kind of advanced technology, marked by a high degree of risk and relatively free of industrial involvement, that the Academy of Sciences would be in the best position to pursue.

In the hands of the Academy of Sciences, pulsed power R&D has been performed under a single administrative roof from basic research to the construction of prototypes and even operational systems. It had therefore avoided the major organizational impediment to successful innovation. The Academy has been able to focus its resources and its wide range of scientific and engineering talent on the task of bringing pulsed-power projects through all the stages of the R&D cycles. One would expect, therefore, the pulsed power area to be an outstanding Soviet example of successful R&D applications. Nevertheless, that is not the case. The development of pulsed power appears to reflect the same military versus civilian differences that are evident in much of Soviet technological development.

There are several examples of major experimental pulsed-power projects and facilities of a civilian nature that have been developed and built and are operated by the institutes of the Soviet Academy of Sciences. Foremost among them are the laser-driven fusion reactors at the Lebedev Physics Institute, the electron beam fusion reactor at the Kurchatov Institute of Atomic Energy, the pulsed magnetohydrodynamic (MHD) generators at Kurchatov, and the continuous MHD power plant by the

Institute of High Temperatures. While the development of these facilities would probably not be possible if it involved an R&D cycle split between the Academy and industrial organizations, their performance has, so far, not been satisfactory, mainly because of the limited infrastructure of supporting technologies. Thus, the Lebedev laser fusion project has been forced to choose neodymium glass configurations that are wasteful of energy, because a more efficient design requires advanced surface coatings that have not been available. The Kurchatov project still is based on the electron beams, even though they have been long ago abandoned in the corresponding US project in favor of proton beams. The persistence of the scientifically discredited technique is probably due to the scarcity of computer simulation capability. Further development of the MHD plant depended, among other factors, on the experimental availability of an efficient superconducting magnet system which had to be imported from the US for the Soviet facility.

A much more successful outcome is evident in pulsed-power projects of the Academy that have an obvious military significance. In fact, these projects, taken together, represent a single area with the largest number of scientific and technical developments that have been adopted and further refined in the West, in a kind of reverse technology transfer. The following are examples of devices invented or developed at institutes of the Academy of Sciences, or associated with the Academy, and later utilized in major US experimental projects:

<u>Device</u>	<u>Description</u>	<u>Inventor</u>	<u>Institute</u>
Gyrotron	microwave cyclotron maser	Gaponov	Applied Physics Institute
Ion source	high-brightness ion beam generator	Dudnikov	Nuclear Physics Institute
Explosive opening switch	fast high-current circuit breaker	Mesyats	Institute of Atmospheric Optics
Gyrocon	RF accelerator energy converter	Budker	Nuclear Physics Institute

The examples of the two types of pulsed power, one of a predominantly civilian nature and the other of a possible military purpose, suggest that the latter is a more effective stimulus even in an independent organization, such as the Academy with full control of the entire R&D cycle. These examples also suggest another important point. In all of them we see the decisive effort of one individual who developed the concept and saw the project to its successful conclusion. This pattern is evident in many Soviet technological success stories, such as the outstanding performance of the Ukrainian Academy of Sciences in industrial innovation due solely to the efforts of B.Ye. Paton, its vice-president and director of the Electro-welding Institute. A similarly effective organization of technology development in Tomsk, has been due to G.A. Mesyats, director of one of the local Institutes dedicated to pulsed power. A large measure of credit for the development of Soviet pulsed-power technology as a whole, and probably for its military significance, should go to Ye.P. Velikhov, vice-president of the Academy of Sciences, USSR, who has also been the driving force behind most of the exotic high-energy concepts based on pulsed power.

If the first paradox of Soviet R&D was the decentralized cycle in a centralized organization, the second paradox is the decisive role of the

individual in an otherwise wholly collectivist society. These individuals achieved their results in spite of the system and its impediments. Progress in Soviet technology thus depends on individual initiative, just as in any capitalistic system. The difference is that in the Soviet Union the difficulties in the path of these individuals are much greater.

To sum up this argument, the following points can be made:
The development of advanced technologies in the Soviet Union may be successful in situations where their application

- ° represents one-of-a-kind system, rather than mass-produced systems;
- ° does not require broad interdisciplinary network of supporting technologies; and
- ° is supported by the military.

The Academy of Sciences is particularly well adapted to pursue R&D projects that satisfy the first two conditions; it is also well endowed with gifted individuals whose dedication can spell the difference between success and failure. The problems of inter-institutional cooperation may probably be minimized in cases of military support of the Academy for specific military applications of advanced technologies where the Academy has maintained a strong position. Here, pulsed power would be an outstanding example. Many aspects of space defense technologies, and especially pulsed power, are compatible with this configuration of R&D. It is possible, therefore, that within the above limitations the Soviet Union could mount a significant space defense effort in which the Academy of Sciences would repeat the role it played in the initial development of nuclear weapons.

The future is less promising for the development of advanced technologies that calls for close participation of industrial production organizations and a mature and extensive technological infrastructure. In the long run, the Soviets might probably do better if they restricted the Academy of Sciences, as a performer of R&D, to basic research and transferred its applied research and development institutes to the industry. On the other hand, the authority and expertise of the Academy, the R&D problems affecting Soviet industry, and, above all, the role of the Academy as a scientific planner of scientific progress tend to preclude such a solution. Thus we are led to the third paradox of Soviet R&D: scientific planning is not necessarily compatible with the development of science. The rigidities and controls implied in a planned program clash with the random initiatives and uninhibited interaction of men and ideas which our experience shows to mark the indispensable environment of science and technology.

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SOCIAL AND POLITICAL PROBLEMS IN SOVIET BASIC RESEARCH

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Science is viewed as an international body of knowledge that transcends the traditional borders of nation-states. The intellectual content of the natural sciences is basically the same in different countries, and the processes of scientific research are thought to have certain universal characteristics, with high values placed on organized skepticism, rationality, new information, and the search for truth. Yet science is just as much a national product. Variations in philosophies of science and in modes of analysis often are rooted in different cultures, and they affect science's intellectual structure. Most obvious is the diversity of social and economic support systems that enable science to develop in different directions and for different purposes.

The universal and culturally specific characteristics of science are difficult to delineate, since science exists simultaneously in both a national and an international context. The same is true of politics. The boundary line traditionally set between domestic and foreign politics also has been eroded by the growing interdependence of political and economic communities, and by the realization that the politician acts in both national and international arenas. Domestic programs frequently have external consequences, and foreign policies are often the outgrowth of domestic needs. The national and international characteristics of science merge with the vicissitudes of national and international politics when countries exchange scientific information

and personnel. Nowhere is this more evident than in the area of scientific cooperation between the USA and USSR.¹

Much of the professional behavior of Soviet scientists resembles the behavior of scientists in other countries. But the institutional setting differs sufficiently to give the Soviet scientific enterprise social and political characteristics peculiar to the USSR. In order to survive and to prosper in the institutional networks of fundamental research, the scientist must know "how to work the system." Soviet scientists do this well. They are aware of their opportunities and constraints. They are not passive victims of a totally closed system. On the contrary, they are active participants in shaping the research traditions and policies that affect their work.

The first part of this paper highlights some of the social-psychological conditions of fundamental research in the USSR Academy of Sciences. These conditions permeate the research environment and provide an understanding of how scientists behave in the traditional setting of the Academy.² Problems in the social structure of Soviet science have political implications (which are noted at the end of the first section). The second part of the paper focuses on the policymaking structure of the Academy and on some of the tensions that have developed between scientists and political leaders. The issue of national security and human rights provides a framework for exploring those tensions at both the national and international levels of analysis.

Social Factors Affecting Soviet Sciences

The social structure of Soviet science is affected (1) by the

recruitment and mobility of scientific personnel and (2) by the scientists' motivation and job satisfaction. In the first set of characteristics, recruitment means the factors affecting the entrance of young people into the scientific profession, whereas career mobility refers to the changing of research fields or institutions of employment after becoming a scientist. In the second set, the concepts motivation and satisfaction refer to the attitudes of scientists toward science as a profession and toward the specific conditions of their research environment.³

First, in the area of recruitment, Soviet sociologists have studied two sets of characteristics -- a person's initial motivation in becoming a scientist and the quality of training young scientists receive. In several studies by A.I. Shcherbakov, for example, which were conducted in Ufa, Kharkhov, and Novosibirsk in the late 1960s, it was found that many young people were attracted to science because of the glamorous attention that the mass media gave to the privileges of scientists. Shcherbakov complained that the public was generally unaware of the huge amount of effort that serious scientists must put into their work every day. He concluded that the distorted views of science's luxuries vis-a-vis its difficulties drew some people into the profession who were not prepared for the commitments that would be necessary in high quality research. To emphasize his point, he noted that approximately one-third of the scientists surveyed said that an interest in scientific work was not their primary reason for becoming scientists, and 26 percent of those in Kharkov chose science for "accidental reasons."⁴ It is not clear how widespread this was in the 1960s, but those respondents would be the scientists who are at mid-career right now.

The quality of the preparation of young scientists was examined by O.M. Nikandrov and V.F. Tarasov in 1975 and 1976. Their data came from surveys of scientists entering the institutes of the USSR Academy of Sciences in Leningrad. The poor quality of training that they had received was evident from the fact that less than 43 percent of them said they were able to perform scientific tasks. And only 33 percent said they understood the contemporary methods of scientific research. The authors of the study laid the blame squarely on the higher educational establishments, many of which were not providing any preparation in research methodology.⁵

Problems of poor training are exacerbated by difficulties in the coordination of a person's skills with job requirements. Another scholar, S.A. Kugel', has documented the discrepancy between fields of education and fields of employment among scientists who were in branch and academy institutes in the late 1960s and early to mid-1970s. He found that less than 28 percent of the scientists in Leningrad were working in the "narrow specialty" of their diploma. Although 42.8 percent were employed in the "general specialty" of their diploma.⁶ In a more recent survey, Kugel' found that there was greater correspondence between fields of training and initial employment. Thirty-seven percent of the physicists and chemists in the Leningrad institutes of the Academy, and 46.4 percent of the biologists, had started their scientific research work on a theme that coincided fully with their educational specialty. However, Kugel' still criticized the discrepancy that remained between the preparation of specialists and the newly emerging directions of science.⁷

There is some evidence, therefore, that young scientists are being recruited into new job positions for which they are poorly trained. They may subsequently change professional fields again, and they may change their institutions of employment. There is a high degree of professional mobility in Soviet science. This is not always a negative factor, since fresh perspectives in a new field might enhance a scientist's creative insight and scientific contribution. Institutional mobility is often an accompanying feature of changing fields, but not always. For example, there is more mobility of fields in the academy institutes of Leningrad than there is in the branch and educational institutes, but the Academy has the highest degree of stability in the institutional affiliations of its personnel.

The motives behind institutional mobility are not necessarily the same as the motives for changing one's area of specialization. What do scientists give as their reasons for going from one field into another, or for combining two fields of research? Soviet psychologist L.K. Kuzmina analyzed the combination of fields from a 1975 survey of academy institutes in Leningrad. She found that 40 percent of those surveyed worked in two specialties because of the way that science was developing the borderlines of traditional fields. Thirty percent worked in two fields because they were unable to find other specialists for the information they needed. Another 30 percent would periodically develop an interest in related fields of science and would combine that with their original specialty.⁸ In a separate study scientists said they had difficulties in finding work in their old specialties. They had to move into new fields because it was their first job assignment after graduation or because of the institute's research plan.⁹

What motivates a scientist to remain in his or her place of employment or to move to another one? Soviet scholars treat motivation as a psychological variable tied closely to a scientist's satisfaction with work and working conditions. Motivation and satisfaction might explain some of the patterns of recruitment and mobility. Creativity and independence are cited most frequently by Soviet scientists as the key factors stimulating their research and other professional activities. Some scientists, however, are motivated more by the prospects of material rewards and professional recognition. Scientists who place a high value on creativity tend to be satisfied with the way their work is organized and with the development of their own professional interests. By contrast, those whose motives are primarily materialistic are generally dissatisfied with the social conditions of their research. They complain, for example, about their wages, the distribution of bonuses or rewards, and the internal relationships of the collective.¹⁰

With such a high value being placed on individuality and independence in research, one would expect that collectiveness (kollektivnost') would not be very popular among Soviet scientists, and it is not. Considering all the attention given to collective research in contemporary "big" science and the official norms of Soviet culture, it is indeed remarkable that Soviet scientists have expressed such a public disdain for collectiveness, especially the young scientists. This may indicate a change of attitudes in the next generation, but it is more likely a reflection of the fact that older scientists have already acquired a greater degree of independence in their work, whereas younger scientists have not. Younger scientists are pressed to accept the research themes of their elders. Senior scholars are less likely to complain about too

much collectiveness, because much of their own productivity is dependent on a subordinate collective of junior scientists under their direction and control.

There has been some attempt to provide greater independence in research through more flexible working hours. A study published by S.B. Gurvich in 1979 found that the gifted and productive scientists tended to work better when they could organize their own schedules, although this did not work well for scientists who were less productive to begin with.¹¹ Creativity and independence are strong motivations for scientists, but these can be frustrated by rigid management, poor equipment, and inadequate support systems. In their studies of the social organization of scientific work, Soviet sociologists have found that scientists complain the most about the quality of their scientific administrators and about the availability of information.

The most frequently cited complaint is that administrators are too coarse (grubyi) and insensitive to the collegiality that ought to prevail in scientific collectives. In fact, in three studies, in Novosibirsk and Leningrad, the rudeness of science administrators were the number one reason for conflict arising in research institutes. Elaborating on the situation in Novosibirsk, Shcherbakov noted that by 1974 many scholars of the older generation had given up their leadership positions to their junior colleagues. In some places this process was painless, but in several collectives the number of conflicting situations increased. This happened mostly because the appointment of new people for certain leadership posts occurred without a prior examination of the scientists' qualities and without training them in the basics of organization and administration.¹²

Soviet scientists have expressed their deep dissatisfaction also with the dissemination of scientific information. The problem is particularly acute in the more rapidly expanding fields of science where scientists are unable to keep up with the growing volume of information, at the same time that they are unable to get all the information they want. A side effect of this is the development of personal channels of information to supplement the official ones. Here is where problems of leadership have intersected with problems of information, since scientists seem to pay deference to those individuals who are centers of the informal networks of scientific communication. These individuals become the unofficial, de facto, leaders in their fields and, apparently, they exert an influence among scientists that is distinct from the influence of the official leadership structure.¹³

The existence of informal scientific leaders takes on a special significance in view of the centrality of science to the lives of scientists and the lack of strong social leadership outside the work place. When unofficial networks of information become more dominant and useful to scientists than the official channels are, there is the possibility that informal scientific leaders will become the conduits of social and political information as well. In this sense, the professional contacts that develop in science may be viewed as potential networks of freedom and community building.

Policy Implications

While mindful of the limitations in the studies of Soviet sociologists, I would like to suggest ways in which the information they generate could be utilized to recommend changes in Soviet science policy.

First, in the area of recruitment into science, we see that some young people are entering the scientific profession primarily for the material rewards and social amenities that go with it. This may be a very realistic attitude, and it is not necessarily detrimental to science. However, if these scientists also lack a serious commitment to the intellectual processes of scientific discovery and verification, then the quality of science will surely suffer.

The seriousness of the problem may be suggested in the data analyzed by Nikandrov and Tarasov. While the authors blamed the poor performance of scientists on the low quality of training they had received in the higher educational establishments, that in itself may have been a consequence of an indifferent attitude toward learning on the part of the students. We do not have specific data on science students to confirm this. There is much that has been written, instead, about the inadequacies of educational research facilities, scientific supplies, and equipment. But studies of the Soviet educational system have shown that other university students are more interested in personal relationships and in having a good time than they are in scholarly preparations for their future careers.¹⁴ Science students may be affected by these attitudes as well. Therefore, we could look at poor training as a combination of problems in the educational institutions and in the motivations of youth.

The Soviet leadership is certainly aware of the difficulties that educational establishments have had in performing basic research. Articles on this have been written at least as far back as the early 1950s, if not earlier. The USSR Academy of Sciences is expected to coordinate and to help the universities through such programs as the

retraining of faculty members under the Academy's direction and the employment of aspirants in academy laboratories. Members of the Academy also serve as advisors in the determination of university curricula and in the selection of textbooks. Short of a major renovation of university research facilities, which is unlikely, the government will probably continue to pursue a policy of encouraging closer ties with the Academy. This has resulted in some progress in the improvement of university research conditions, but they are still relatively inferior to academy institutes.

We also saw from the above data that there is a high degree of professional mobility among Soviet scientists, especially the younger ones. A change of professional specialization or place of work later in one's career is not necessarily a negative phenomenon. It indicates a degree of flexibility in the Soviet research network, and it should probably be encouraged. What is needed, however, is a policy that would remove the discrepancy between the institutional stability and field mobility of the USSR Academy of Science, on the one hand, and the institutional mobility and field stability in the branch institutes, on the other. Right now, the advantages and disadvantages of professional mobility are skewed: the Academy benefits from the development of new fields, and the branch institutes suffer the disruption that accompanies the replacement of personnel. If the government were to improve the pay scales and working conditions of branch institutes, then there might be a more balanced exchange of scientists between them and the Academy and a better working relationship between research and production personnel.

The second area discussed was the motivation of scientists after they are professionally employed. The factors cited by scientists as

the most important were independence and creativity in their work. Younger scientists have been restrained, however, by the seniority system and limited opportunities. As a scientist gains seniority there is a better chance of choosing one's own research theme. The problem with this practice, however, is that the potentially most creative period of a scientist's career is spent under someone else's tutelage. The young scientist is not prevented completely from exercising his or her initiative at this stage; much depends on the personalities involved. But the system as a whole does not enable junior scientists to select themes that are independent of the work of their superiors. This results in the potential loss of a young scientists' creative insights and bold initiatives in any instance where they might challenge the authority of his or her mentor. It would be extremely difficult for the government to embark on a policy to change this. The seniority system is thoroughly engrained in Soviet culture, where status and position take precedence over the provocative challenges of youth. This may be good for the stability of social traditions, but it can inhibit the advancement of knowledge.

Regarding independence in the social organization of research, we saw that flexible work schedules could enhance a scientist's opportunity to work according to his or her individual mood and to blur the distinctions between workplace and leisure time. This is a form of independence that might contribute to a more creative output, although some professionals are more creative when they operate under pressure. A consequence of extending one's work into a personal environment is that the ties among colleagues and friends may become closer and multifunctional.

This takes on a special significance if the same people are connected to the informal communication networks that exist outside the official structures of Soviet science. The creation of such networks are themselves a consequence of the scientists' dissatisfaction with the formal channels of scientific information. But they are also a natural mode of professional interaction. Governmental attempts to solve the technical and administrative problems of publication, translation, and distribution cannot ever replace the continuing demand for direct and personal scientific communication.

Another area of dissatisfaction is that of scientific leadership. The implications of Soviet survey data are that scientists will resist the imposition of strict administrative controls and will gravitate, instead, to the informal scientific leaders whom they trust and respect. The personality profiles of science administrators in these surveys are sufficiently negative to suggest the need for a government policy that would dismiss, reprimand, or retrain those who receive low evaluations. A better working relationship might be established within research collectives if the informal leaders were given official administrative posts. This would not be a panacea, of course, since many other problems would still remain in the supply system and in the training of laboratory assistants. Nonetheless, a reform in the selection and training of science administrators would help improve the psychological climate of scientific research and this, in turn, might help produce better science.

The significance of survey data as an instrument of Soviet science policy depends on several factors. First is the access of social scientists to policymakers and the aggressiveness of scholars in promoting

certain policy recommendations. A second factor is the attitude of political leaders toward social science data. A third issue is the integrity of the research effort and the quality of the data that are generated. And, fourth, there is the relative impact of other specialists who might provide different information in some of the same areas of science policy. Most of the sociological research on Soviet scientific collectives has been conducted by scholars who are affiliated with the USSR and Ukrainian Academies of Sciences. The channels of communication between these scholars and Soviet policymakers are of two kinds: open publications and inside reports to the CPSU Central Committee's Department of Science and Education and to the USSR Council of Ministers' State Committee on Science and Technology.

Of course, the Central Committee and the State Committee have other sources of information to assist them in the making of science policy. The USSR Academy, where many of the decisions for scientific research are formulated and implemented, is dominated by scientists who are not necessarily aware of the social and psychological analyses of their own research behavior. Scientists continue to have a great deal of influence on Soviet science policy, and they have a long tradition of high social status and prestige. It is conceivable that their power might be eroded, in areas of management and organization, by proposals from the sociologists of science.¹⁵ At the present time, however, the political leadership still appears to be more responsive to scientists and to science administrators than it is to sociologists.

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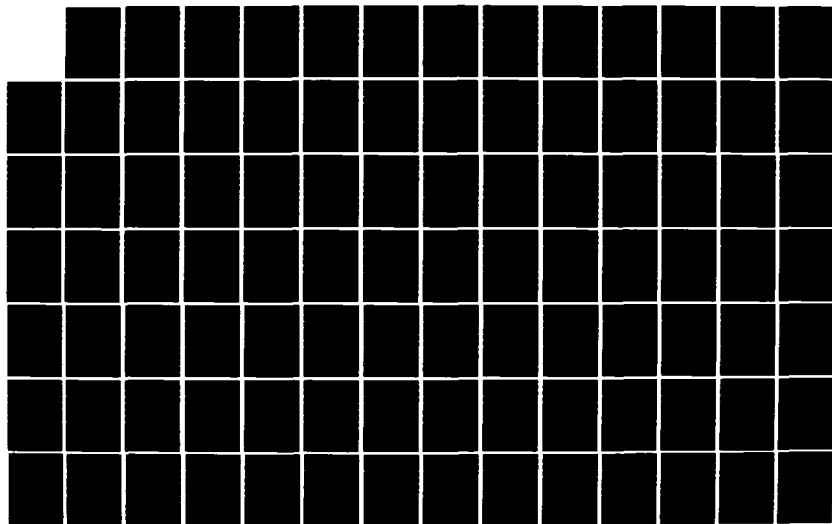
SCIENCE AND TECHNOLOGY IN THE SOVIET UNION: PROCEEDINGS
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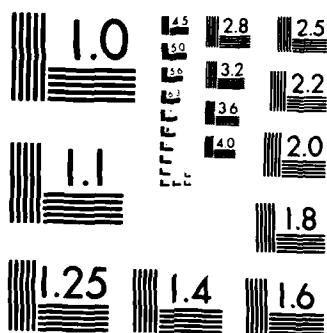
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Decisionmaking in the USSR Academy

The most prominent members of the USSR Academy of Sciences have been advisers to the government, either as individuals or collectively through the academy's presidium. The academy leadership has long been dominated by scientists in the fields of physics, chemistry, biology, and the earth sciences. These scientists used the presidium for central control of academy decisionmaking during the Stalin period. A series of reforms in the 1950s subsequently helped to decentralize the decisionmaking process. This gave academy scientists more opportunities to influence science policy at lower levels, while the presidium maintained overall coordination and control.¹⁶

Academy departments became important arenas of policymaking during this period. Since the mid-1950s scientists have participated in department general meetings to discuss such matters as the training and recruitment of scientific personnel, problems in the supply system, and the replacement of material equipment. Departments approve the annual plans of research institutes within their jurisdiction and coordinate these proposals with the five-year plans that are submitted to the academy's presidium. The influence of scientists at the department level can be felt also in the selection of institute directors and academician-secretaries, in the approval of nominations for the academy's presidency, and in the submission of nominations for the election of corresponding members and academicians.

Institute directors, who participate in department general meetings, have a great deal of influence over the conduct of research in their laboratories. The principle of one-man management within academy

institutes has been on record at least since the 1935 statutes, and it has been reinforced several times since then. On most issues the director usually seeks the advice of the institute's academic council (uchenyi sovet), which consists of corresponding members, academicians, and other leading specialists employed at the institute. Meetings of academic councils provide formal opportunities for scientists to influence the director's decisions on administrative and scientific matters, and they give the director support for policies that he can pursue at higher levels.

Since 1972 academic councils have met jointly with party bureaus to discuss the planning and fulfillment of research in academy institutes. The initiative sometimes rests with the party, which submits proposals to the council for approval. Alternatively, if the issue is important, the party group within the academic council consults in advance with the party bureau before the council reaches its decision. Party bureaus are assisted by scientists on the institute's staff, so that scientists remain closely involved in the entire process.

Another important type of advisory body in the academy system is the science council (nauchnyi sovet), each consisting of an interdisciplinary group of scholars working together on specific scientific problems. Set up initially as temporary task forces, science councils have emerged as a regular channel through which scientists from different institutes can exchange ideas and influence science policy. The councils organize special conferences and seminars in which scientists discuss the methodological and substantive aspects of research in progress. They provide a horizontal linkage among the institutes in

different academy departments, thereby breaking down traditional disciplinary barriers and compartmentalization.

These institutions serve as the formal channels through which Soviet scientists become involved in policymaking. Presidium members, academicians-secretaries, and institute directors play important roles as administrators of science, exercising leadership and initiative at different levels of the academy bureaucracy. But a scientist's influence depends as much on his personality and reputation as on his official position. Because of the uniquely high status of certain individual scientists, an informal process of direct contact with political leaders coexists with the more formal channels of communication. It is not uncommon for prominent scientists without administrative positions to have access to high party circles where they can present alternative views.

Individual scientists have been outspoken in a number of areas of public policy, that is, policies that affect the larger public and not just the scientific community. The most notable of these policy areas are human rights (including civil rights for all citizens and professional rights for scientists) and arms control. Both issues bridge the analytical divide between domestic and foreign policy, since their impact is felt both nationally and internationally. The rest of the paper deals mainly with the first of these two issues.

Politics and Human Rights

It is well known that Soviet scientists, especially physicists, have been in the forefront of social protest in the Soviet Union. Their activities have ranged from the founding of the Committee for the

Defense of Human Rights in 1970 by three physicists, Andrei Sakharov, Valeri Chalidze, and Andrei Tverdokhlebov, to the work of Yurii Orlov for the Helsinki Monitoring Group until his arrest in 1977. Sakharov, under house arrest in Gorkii since 1980, is the most prominent example. Actually it was the issue of atmospheric testing of nuclear weapons (and later the influence of the Medvedev brothers) that brought Sakharov into the arena of public protest. Sakharov had been unsuccessful in persuading Khrushchev to stop atmospheric weapons testing in 1958 and again in 1961 and 1962. Sakharov was joined subsequently by his colleague Chalidze in providing legal counsel and support to Soviet dissidents on trial (until Chalidze was deprived of his own citizenship in 1972).

Surely the great majority of Soviet scientists are not involved in public dissent, but many of them resist the attempts of party organizations to promote ideological controls over research institutes. The Lebedev Institute of Physics, in particular, was singled out for criticism by party officials in the early 1970s, and scientific institutes in Akademgorodok have also been criticized. There has always been tension between scientists and administrators in the Soviet Union. During the past two decades this has been most evident in the restrictions placed on Soviet scientists when they want to communicate with scientists from other countries through travel, writing, and international conferences. Soviet officials have recently intensified their controls over scientific information by passing a law that no scholar from a Soviet institution can discuss his or her work with a foreigner without first obtaining permission.¹⁷

One could say that the protection of information in the USSR is an extension of Soviet policies of secrecy and that this is typical of an

authoritarian culture, in direct conflict with the scientific ethic. But that would be an analysis out of context. The politics of science and the tradeoffs between the international freedom of scientific communication, on the one hand, and national secrecy and security, on the other, are to be found in non-authoritarian countries as well. Indeed, this is an issue presently facing the US government. The National Academy of Sciences issued a report on the subject in 1982, and the matter is still under review at the Department of Defense, the Office of Science and Technology Policy, and other government agencies.¹⁸

American scientists and government administrators are wrestling with the lesson that might be drawn from the impact of secrecy on the quality of Soviet science. For the past two years, US officials have been looking at the impact that restrictions might have on the quality of American science. At first, it appeared that the interests of national security clashed directly with the rights of scientists to exchange scientific information. Now it is being argued in Washington that national security depends on the freedom of scientific communication. But the appropriate guidelines have still not been worked out in detail.¹⁹

Despite the ideals of freedom in science, the reality is that scientific communication is restricted even in capitalist democracies by the practice of industrial secrecy and by pressures of professional competition. Conflicts arise when the scientist, after insisting upon the need for scientific freedom, confronts the equally compelling need for the protection of national security. Often the policies that serve the interests of science also satisfy the requirements of national security. At other times, they do not. Political leaders, of course, see

the relationship of science to politics from a different vantage point than that of the scientist. The politician places a higher priority on the power and security of the nation-state than he does on the advancement of knowledge. Science thus becomes instrumental in the achievement of political goals, rather than the reverse.

The issue of human rights became a focal point for discussions of scientific and technical cooperation between the USA and the USSR in the 1970s. Often, however, scientists invoked the phrase "human rights" when they were really advocating something else — namely, the prerogatives of their profession. It would be more accurate to call these "professional rights," which would include the right to study science, the right to question scientific truths, the right to publish scientific research, and the right to participate fully in scientific discourse.

When the concept of human rights is defined more broadly, however, it includes a wide range of social, economic, and political rights that extend to all citizens, regardless of profession. Human rights, in this case, would encompass the entire spectrum of civil liberties, social welfare, and economic security. American scientists often appealed to this broader conception of human rights when they rallied to the defense of their beleaguered colleagues abroad. Orlov, Shcharansky, and Sakharov were arrested not for their scientific work, but for their social activism. Of course, this prevented the normal continuation of their research. Nevertheless, American scientists were arguing not only that, as scientists, these individuals ought to be allowed to pursue professional work without restriction, but also that, as citizens, they ought to be allowed to exercise civil liberties without reprisals.

One of the unspoken assumptions underlying American protests of the 1970s was the belief that there should be a common political framework for scientific discourse. Under the guise of criticizing Soviet treatment of scientists per se, Americans were really attacking Soviet political institutions and culture. Ironically, the more dramatic political change on this issue took place in the United States as American scientists feared that their own civil liberties and professional rights were being threatened by Congressional legislation and by executive actions.²⁰ The issue of human rights has had a profound impact on the international politics of Soviet science. Soviet-American cooperation under the bilateral agreements, the inter-Academy exchanges and the IREX programs suffered substantially after the internal exile of Sakharov in January 1980. In February of that year, the National Academy of Sciences passed a resolution to suspend all inter-Academy symposia, seminars, and new projects until Sakharov was released. The resolution was reconfirmed in August 1980 and is still in effect in 1984.²¹

When the NAS Council passed its August 1980 Resolution to suspend joint scientific meetings with the USSR Academy, it also established, as an explicit exception, a Committee on International Security and Arms Control. The Committee has continued to meet with representatives from the USSR Academy twice a year to discuss the technical and scientific aspects of arms control. It is noteworthy that Soviet delegations to these meetings were chaired by Academician Ie.P. Velikhov, Vice-President of the USSR Academy of Sciences. Velikhov also led the Soviet delegation to Capitol Hill to testify on the nuclear winter before the Joint American-Soviet Scientific Forum on Nuclear War in December 1983. To underscore the Academy's concern over this issue, on May 1, 1984, NAS

President Frank Press said that "the time is ripe, as it has not been for many years, for a [US] President to propose and secure Senate ratification for deep cuts in nuclear weapons and [to] take other steps that will reduce the danger of nuclear war."²²

I think we can look at studies of the nuclear winter as an example of exploratory research set within a strongly political context. Soviet and American scientists seem to have the potential of influencing arms control policy in both countries. They have to use different channels to affect those policies -- with Carl Sagan and associates appealing to the general public and to Congress, and with Velikhov prominent in the USSR Academy of Sciences. (At least one Western observer, Stephen Fortescue, has identified Velikhov as a possible successor to Alexandrov as President of the Academy.²³) One can only hope that both Soviet and American scientists will use their expertise and their political skills effectively in this most critical issue of public policy.

NOTES

1. For an elaboration of this theme, see Linda L. Lubrano, "National and International Politics in US-USSR Scientific Cooperation," Social Studies of Science, Vol. 11, No. 4 (November 1981), pp. 451-480.
2. For a description of the R&D role of the USSR Academy of Sciences since 1961, see Stephen Fortescue, The Academy Reorganized, Occasional Paper No. 17 (Canberra: Australian National University, 1983). The structure of the Academy system is outlined briefly in Ursula Kruse-Vaucienne and John Logsdon, eds., Science and

Technology in the Soviet Union (Washington, D.C.: George Washington University, 1979).

3. This part of the paper is based on data from surveys conducted in the USSR by Soviet sociologists of science. While there are some methodological and technical problems with the surveys, they do reveal shortcomings in the social organization of Soviet science. Such negative information is a conservative estimate of the real shortcomings that exist, since there is self-censorship by the respondents during data collection and editorial censorship when the results are published. For a more detailed analysis, see Linda L. Lubrano "Survey Research as a Source of Information for Soviet Science Policy," Soviet Union/Union Sovietique, Vol. 9, Part 1 (1982), pp. 55-81. Portions are reprinted here with permission of Charles Schlacks, Jr., Publisher.
4. A.I. Shcherbakov, Sotsial'no-ekonomicheskie problemy effektivnosti nauchnogo truda (Novosibirsk: Nauka, 1975), pp. 70-72.
5. O.M. Nikandrov and V.F. Tarasov, "Nekotorye voprosy effektivnosti podgotovki i truda molodykh nauchnykh rabotnikov," in Problemy deiatel'nosti uchenogo i nauchnykh kollektivov, VI (Moskva: Akademiia nauk SSSR, 1977), pp. 162-63.
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8. L.K. Kuzmina, "O faktorakh maiatnikovoi professional'noi mobil'nosti," in Nauka i tekhnika, IX (Moskva: Akademiia nauk SSSR, 1977), p. 107.
9. S.A. Kugel', "Sotsial'no-professional'naia struktura i mobil'nost' nauchnykh kadrov v usloviakh nauchno-tekhnicheskoi revoliutsii" (Doctoral dissertation, Institut sotsiologicheskikh issledovani, 1974), p. 318.
10. D.M. Shanov and A.G. Kuznetsov, "Opyt sotsiologicheskogo analiza problem sotsial'nogo planirovaniia i upravleniia v nauchnom kollektive," in Problemy sotsial'nogo-planirovaniia v nauchnom kollektive (Moskva: Akademiia nauk SSSR, 1977), pp. 65-66 and 70.
11. S.B. Gurvich, "Kak khotiat organizovat' svoe vremia sami uchenye," Vestnik Akademii nauk SSSR, No. 6 (June 1979), pp. 55-57.
12. Shcherbakov, Sotsial'no-ekonomicheskie problemy, pp. 81-83.
13. I.V. Sergeeva, "Sotsial'nye problemy organizatsii nauchnogo tvorchestva" (Kandidat dissertation, Institut sotsiologicheskikh issledovani, 1970), pp. 86-90.
14. Love, entertainment, and sport were cited by students as more important than career preparation in M. Kh. Titma, "Formirovanie zhiznennykh orientatsii uchashcheisia molodezhi," Sotsiologicheskie issledovaniia, Vol. 4, No. 3 (July-September 1977), pp. 55-56.
15. For an elaboration of this theme, see Linda L. Lubrano, "Soviet Science Specialists: Professional Roles and Policy Involvement," in Richard Remnek, ed., Social Scientists and Policy Making in the USSR (New York: Praeger Publishers, 1977), pp. 59-85.

16. Linda Lubrano Greenberg, "Policymaking in the USSR Academy of Sciences," Journal of Contemporary History, Vol. 8, No. 4 (1973), pp. 67-80.
17. F. Stephen Larrabee, "Higher, Thicker Kremlin Walls," New York Times, May 29, 1984, p. A19.
18. Dale Corson, NAS Panel Chairman, Scientific Communication and National Security (Washington, D.C.: National Academy Press, 1982).
19. Mitchell Wallerstein, "Scientific Communication and National Security," Science, Vol. 224 (May 4, 1984), pp. 460-466.
20. I am referring to the Brown Resolution of 1980, which called for a suspension of travel by US citizens to the Soviet Union and to the subsequent efforts of executive agencies to set US restrictions on communication between American and Soviet scientists. See Lubrano, "National and International Politics in US-USSR Scientific Cooperation," op. cit.
21. To keep this in perspective, however, it should be mentioned that the inter-Academy exchanges suffered more from President Reagan's budgetary cutbacks than from human rights protests. The bilateral activities were curtailed by the Carter and Reagan administrations in response to the Soviet invasion of Afghanistan and the imposition of marshall law in Poland. For an update on US-USSR scientific exchanges, see Linda L. Lubrano, "The Political Web of Scientific Cooperation between the USA and USSR," in Sectors of Mutual Benefit in US-Soviet Relations, ed. Nish Jamgotch, Jr. (Durham: Duke University Press, 1985).

22. Frank Press, Annual Report of the President (Washington, D.C.: Academy of Sciences, 1984), p. 26.
23. Fortescue, op. cit., pp. 94-95.

22. Frank Press, Annual Report of the President (Washington, D.C.: Academy of Sciences, 1984), p. 26.
23. Fortescue, op. cit., pp. 94-95.

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TECHNOLOGY AND SOVIET POLITICAL CHOICES

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The purpose of this paper is to survey, from an historical perspective, how technological considerations have figured in Soviet political choices. Because this is an enormous subject, the paper focuses on two specific issues: (1) Soviet interpretations of the technological and military competition with the West, and (2) Soviet attitudes toward the utilization of Western technology.

The Technological and Military Competition with the West

Ever since Stalin's time the Soviet regime has regarded technological progress as both an intrinsic good and an imperative of international politics. The members of the Stalinist elite pursued this goal with great optimism. They believed that the USSR's superior dynamism would enable it to surpass the industrial West economically in a short historical period. In their view, the socialist system was free of the impediments to growth and technological change graphically illustrated by the economic disruption of the capitalist West during the Great Depression.¹ Stalinist observers regarded centralized control of society as the most rational means of harnessing research, industrial investment, and human labor to the state's technological goals. Convinced that idle resources, competitive fragmentation of industrial effort, and wasteful duplication of scientific research were inherent features of capitalism, they felt certain that the West could not mobilize its technological resources as effectively. This belief in the

superior technological dynamism of the Soviet system bolstered the elite's sense of its own political legitimacy and reinforced its determination to impose ruthless economic sacrifices on the Soviet populace.

Despite this historical optimism, a sense of impending conflict with the West tinged the Stalinist pursuit of technological advance with intense anxiety. Members of the political elite were acutely aware that they ruled a country that was technologically backward in comparison with its Western rivals. They feared that the political and economic dynamics of the Western powers would draw the USSR into a major war before the country accumulated the economic and military means to withstand such a test. This atmosphere of grave external threat, epitomized by the doctrines of capitalist encirclement and the inevitability of war, was undoubtedly inflamed by Stalin as a method of consolidating his personal tyranny, but it was also fed by real external dangers -- chief among them a resurgent and aggressive Nazi Germany.

Early Soviet thinking about the technological competition with the West thus reflected a mixture of long-term optimism and short-term fear. Under Stalin this combination of views exerted a profound influence on domestic technological priorities. The overriding goal of the regime's policy toward science and technology was to devise sophisticated military weaponry on a par with Western achievements. To this end, the regime funded and staffed military R&D projects far more generously than civilian ones. It also gradually worked out a set of special administrative arrangements that protected military R&D from many of the obstacles that inhibited native innovation in other fields. These arrangements included repeated interventions by top leaders to resolve bottlenecks in weapons-development programs, the staging of R&D

competitions among weapon designers to assure high-quality prototypes, and granting the military establishment the power to refuse unsatisfactory output from the defense industries.² These features distinguished military innovation from research and production in other sectors.

During the Khrushchev years (1953-1964) the political elite reevaluated the international political context of the Soviet drive for technological supremacy. Stalin's successors muted the theme of life-or-death urgency that had run through earlier thinking about the race with the West. Soviet apprehensions were still strong, as demonstrated by the political vulnerability of Georgii Malenkov to the charge that he had underestimated the need to promote the further advance of Soviet military technology. But the elite's anxiety was not as sharp as in the past. After much political zigzagging, Khrushchev formally proclaimed that capitalist encirclement, the inevitability of war, and the danger of capitalist restoration in the Soviet Union all belonged to the past. In this respect, he departed dramatically from the Stalinist outlook, even though some of his rivals continued to adhere to it, and he tried to translate this change in worldview into a new technological strategy and new priorities for domestic research and innovation. Khrushchev strove to exclude from the Academy of Sciences certain fields of applied research that had traditionally supported the development of conventional weapons, and he tried to slash the manufacture of conventional armaments in favor of nuclear missiles, in order to channel more resources into civilian economic pursuits.³

At the same time, neither Khrushchev nor his political rivals abandoned the Stalinist belief in the superior technological dynamism of the Soviet system. Buoyed by the USSR's continuing high growth rates and

the spectacular Soviet space feats of the late 1950s, the party authorities set a closer date for surpassing the US economically than had been set in the Stalin era. Khrushchev's political colleagues did not object to his stress on quickly overtaking and surpassing the US. Rather, they disliked the way that he proposed to go about doing so, because they distrusted his sanguine appraisal of Western intentions toward the USSR. The leaders' persisting disagreement over Western intentions was closely connected to their dispute over the importance of promoting heavy industry and military technology. In the end, the conflict over this issue contributed to Khrushchev's downfall.

Broadly speaking, the men who deposed Khrushchev agreed that the intentions of the West toward the socialist world were less benign than Khrushchev had contended. The new leaders moved part way back toward the Stalinist outlook by toning down the theme of peaceful coexistence and by rapidly building up the quality and quantity of Soviet military technology. But despite their show of public unanimity in the mid-1960s, the leaders differed over how far to carry this policy. Some, such as Brezhnev, Suslov and Shelest, underscored the hostility of the West and the pressing need to raise Soviet military weaponry to higher technological levels. Others, such as Kosygin and Podgornyi, doubted that the Western threat required so vigorous an effort to drive military technology forward, and they were more apprehensive than their Politburo colleagues about the rate of technological advance in the nonmilitary sectors of the economy.⁴ Indeed, this second group of leaders began to experience grave doubts about the USSR's ability to compete successfully with the West, particularly the US, in technological terms. Their willingness to express this doubt in a relatively open fashion was a new

phenomenon in Soviet politics. These apprehensions were a principal cause of Kosygin's early interest in negotiating curbs on the East-West race in strategic weaponry. Inspired by a more optimistic view of the economy, Kosygin's critics within the Politburo assigned high priority to expanding Soviet military might, and they opposed his attempts to alter Soviet technological priorities.

The intraelite debate over these issues intensified in the late 1960s and 1970s. The debate was stimulated by international political changes such as the gradual American withdrawal from Vietnam and the formation of a more conciliatory West German government, which made it easier to argue that Western attitudes toward the USSR were becoming more temperate. Equally important were spreading internal doubts about the sufficiency of the Soviet rate of economic and technological advance vis-a-vis the West. The exponents of the Kosygin line argued that the USSR should improve relations with the US and conclude a diplomatic settlement in Europe as a way of offsetting the technological shortcomings of the economy. They also argued that the aggressiveness of the imperialist countries was abating, making it possible to conclude arms control agreements without imperiling Soviet security. This line of analysis helped persuade the party leadership, after considerable internal conflict, to reach a German settlement. It also weighed heavily in the decision to sign the SALT I accord with the United States.

By the early 1970s, Brezhnev had come to accept many of Kosygin's views, and his change of heart may have contributed to a slowdown in the growth of Soviet military spending during the mid-1970s. Brezhnev also made several attempts to increase the relative priority of civilian R&D needs by urging the military R&D establishments to help meet them.⁵ But

he appeared to be unwilling to try to force through a fundamental change in the allocation of scientific and industrial resources between military and civilian uses.

In the 1980s, the allocation issue has become more contentious. Faced with the US military buildup, many members of the Soviet leadership have concluded that Western hostility to the USSR has sharply increased and that Soviet military preparations must be accelerated. Military figures, particularly Marshal Nikolai Ogarkov, have been especially outspoken advocates of this view.⁶ Under such pressures, Brezhnev reluctantly agreed to accelerate military R&D at the expense of civilian research undertakings. But while granting the need for more rapid development of new types of weapons, he apparently refused to increase the rate of weapons production.⁷ His successors have followed the same line. The running Soviet debate over military spending has been linked to a dispute over the relative capacities of the Soviet and Western economies to sustain an expanded military effort, and Chernenko has avoided approving a faster Soviet buildup partly because he doubts the USSR's ability to win an all-out arms race. Earlier this year, for example, he warned the commission revising the 1961 party program, in which Khrushchev had predicted an early economic victory over the West, that the new version should not underestimate capitalism's reserves of political and economic development.⁸ Chernenko probably also helped engineer the recent removal of Ogarkov as chief of the General Staff, thereby neutralizing the most forceful Soviet proponent of a greatly increased military effort.

Attitudes toward the Utilization of Western Technology

During the 1930s, the Stalinist commitment to rapid technological independence from the West was reflected in a level of R&D spending that was extraordinarily high for a semideveloped country such as Soviet Russia. But Stalinist planners did not initially rely on native R&D to create the technology for the industrialization drive. Aiming to overtake the West in one all-out campaign, they inaugurated an enormous draft on Western technology and used their expanding R&D establishment primarily to copy and adapt that technology. This orientation toward copying and assimilating foreign know-how provided immediate economic benefits. It also had an enduring impact on many scientific and industrial organizations that later made the transition to indigenous technological innovation more difficult.

Technological borrowing was simpler than creating indigenous technologies, but it was not easy, especially from a political standpoint. Apart from the predictable economic and cultural impediments to effective technology transfer, a powerful political tension soon emerged between the Stalinist elite's hostile attitude toward the West and its policy of relying heavily on Western technology to speed up industrialization. At first the only institutional barrier was the exclusion of foreign investment as a channel of technology transfer. But as Stalin and his minions tightened their hold on society and fanned the hysteria that drove the purges, other channels of technology transfer were gradually closed off. To reduce its strategic vulnerability the regime scaled back imports of foreign equipment. Wary of foreign ideological influences, it shifted from technical assistance agreements and

international exchanges of specialists to the antiseptic practice of reverse engineering. Ultimately it reduced even the influx of foreign technical literature. These changes buttressed the Stalinist system politically. But they sharply reduced Soviet access to the fruits of foreign science and technology for much of Stalin's reign.⁹

Under Khrushchev Soviet policy assigned a larger place to technology acquired abroad -- not only from other Comecon countries but from the West. While Khrushchev and his supporters expanded domestic R&D at an extremely rapid pace, they were less fearful of entanglement with the outside world and more cognizant of the costs of foregoing the use of Western technology in lagging Soviet industrial sectors. Imports of Western equipment and technical literature increased, as did personal contacts between Soviet and foreign specialists and Soviet participation in international scientific organizations.

The mounting Soviet interest in Western technology raised new issues for Soviet diplomacy. Although some Western countries were willing to treat political and economic relations as separate issues, some were not. In 1963 and 1964, Khrushchev apparently began to consider making concessions to West Germany over the political status of East Germany in exchange for an infusion of West German credits and technology. This plan was frustrated by Khrushchev's colleagues and contributed to his removal.¹⁰ But it posed an issue that was bound to recur in subsequent years.

Under Brezhnev and Kosygin the regime continued to expand its utilization of Western technology. In the late 1960s there were serious disagreements within the leadership over whether to require Western acceptance of the East European status quo before expanding Soviet-

Western economic relations further.¹¹ But after the European settlement at the beginning of the 1970s, Brezhnev and his colleagues felt freer to expand East-West commerce without fear of negative political consequences.

The experience of the 1980s, however, has raised new questions about the political costs of economic relations with the West. The Western embargoes sparked by the Soviet invasion of Afghanistan and events in Poland have persuaded a few Soviet officials that these ties should be cut back; a larger number of officials have concluded that the USSR must exercise more caution in expanding such relations in the future. Given the troubled state of the Soviet domestic economy, Soviet apprehensions will probably not lead to an absolute reduction of the utilization of Western technology, but they are likely to slow the growth of the USSR's dependence on Western know-how.¹²

Apart from such diplomatic factors, there are other barriers to the widespread acquisition and application of Western technology. The Soviet regime's ongoing struggle against "ideological coexistence" reflects not simply its hesitancy to strike political bargains in exchange for Western know-how, but also its fear of spontaneous ideological contamination not wittingly fomented by Western governments. As a result, Soviet science and industry continue to be isolated from a large share of Western R&D achievements, particularly achievements in the form of unembodied technology.¹³ Moreover, thanks to the centralized administration of trade and the political barriers to easy communication with foreign specialists, the system has often failed to make efficient use of the Western technology that it does acquire.¹⁴ No doubt the benefits received have been substantial, but they have not been as large

as a regime with a different economic system and a more relaxed attitude toward foreign contacts might have obtained.

NOTES

1. Bruce Parrott, Politics and Technology in the Soviet Union (Cambridge, Mass., 1983), Chapter 2.
2. David Holloway, "Innovation in the Defense Sector," in Industrial Innovation in the Soviet Union, ed. Ronald Amann and Julian Cooper (New Haven, 1982).
3. Parrott, Politics and Technology, Chapter 4.
4. Ibid., Chapter 5.
5. XXVI s"ezd KPSS, I (Moscow, 1981), pp. 24, 62.
6. Kommunist, No. 10, 1981, pp. 85-91.
7. Pravda, 28 October 1982, p. 1.
8. Kommunist, No. 7, 1984, p. 7.
9. Parrott, Politics and Technology, Chapters 2 and 3.
10. Ibid., Chapter 4.
11. Ibid., Chapter 5.
12. Bruce Parrott, "Soviet Foreign Policy, Domestic Politics, and Trade with the West," in Trade, Technology and Soviet-American Relations, ed. Bruce Parrott (Indiana University Press, forthcoming).
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TECHNOLOGY AND TECHNICAL EFFICIENCY IN THE SOVIET UNION:

DOMINANT PATTERNS OF CONSTRAINED OPTIMIZATION

IN A NONCOMPETITIVE ECONOMIC REGIME

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TECHNOLOGY AND TECHNICAL EFFICIENCY IN THE SOVIET UNION:
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I. Introduction

Western scholars broadly agree that the Soviet economic system inhibits technological progress and impairs economic efficiency. This view is based partly on empirical studies of the sort pioneered by Abram Bergson and partly on theoretical assessments of the diverse ways non-market mechanisms distort economic calculation and technical choice.¹ These kinds of evidence are invaluable to a point, but fail to deal adequately with three issues essential for a comprehensive appraisal of Soviet technological performance. They do not consistently distinguish between the concepts of technical efficiency and productivity; phenomena affected very differently by Soviet economic arrangements. They do not sort out the relative importance of the various factors inducing technological distortion, and they conceal crucial distributional aspects of the problem that cause technological losses to vary widely across the economy.

This essay focuses on these three issues. It attempts to show that the Soviet economic system does not foster "technical inefficiency," although it does cause interfirm and intersectoral factor misallocational. Second, it will be argued that the principal cause of technological distortion in the Soviet regime is the institutionalization of noncompetitiveness, a phenomenon closely associated with the abolition

of private ownership of the means of production. And, third it will be maintained on theoretical grounds that the technological losses borne by the system fall primarily on the civilian consumer sector, leaving military technology relatively unimpaired. These findings are then utilized to evaluate Soviet performance prospects. On the basis of this analysis it is concluded that system induced technological shortcoming will not significantly impede aggregate Soviet growth or the continuous improvement of Soviet weapons capabilities in the Eighties.

II. Planning, Technology and Productive Efficiency

The case in favor of the proposition that the Soviet system causes technological distortion and promotes inefficiency is disarmingly simple. Socialist theory teaches that planning is a device designed to enable the leadership to replace private transactions with officially sanctioned exchanges that are the functional equivalent of generally competitive transactions, given socially optimal lump sum transfers.² This lofty goal, as socialists and nonsocialists alike acknowledge however is thwarted in practice by informational, computational and bureaucratic obstacles, with the result that economic outcomes in planned regimes are inferior both in a strict Paretian and in an extended Bergsonian sense after allowance is made for income transfers.³ Violation of these Paretian and Bergsonian norms implies ipso facto that factors are not allocated to their best economic use and the mix of goods and services produced, including technological goods and services is suboptimal. It thus follows directly from the practical limitations of planning that insofar as Soviet planning is imperfect, production is

economically inefficient, and technological innovation, diffusion and distribution are non ideal.

III. Sources of Technological Distortion and Inefficiency Under Planning

This deduction is the essential point of departure for any complete appraisal of Soviet technology and productive efficiency, but it tells us little about the specific characteristics that distinguish technological losses under planning generally from those observed under the Soviet central command planning system. In order to evaluate the latter issue it is necessary to recognize that technology in planned regimes may be suboptimal in three distinct senses: technologies chosen and implemented may not maximize the achievable present discounted value of future income streams, given planners' preference; the factors of production required to produce chosen, or ideal technologies may be suboptimally allocated across firms and sectors; and factors at the disposal of firms may not be put to best use, causing actual performance to shortfall technological potential. The first type of suboptimality is attributable to the violation of planners' sovereignty and arises because producers and wholesalers in planned regimes have weak incentives to take purchasers' preferences into account in designing and distributing technological goods and services. The second type of suboptimality is caused by the prohibition of competitive bidding for scarce factors of production, mandated by the State to prevent automatic market forces from superseding the plan. The third type of suboptimality arises because input utilization norms established by the central authorities may be predicated on incomplete information, and/or the incentive rules governing factor utilization may be misdesigned.

IV. Exogenous Demand and Internal Optimization

These three types of planning failure can be further simplified and expressed in the form of two fundamental optimization problems: one pertaining to exogenous demand; the other to internal resource utilization. The optimization of exogenous demand requires the systems directors to devise ways of coordinating input and output supply with purchasers' demand, without compromising the regulatory authority of the planners. This task is essentially external to both the producer and purchaser because they are theoretically prohibited from coordinating their actions through free, and unfettered negotiation. Planners therefore either must mediate the demand-supply adjustment process, or devise institutions that permit controlled direct negotiation.

The internal optimization problem poses a very different set of issues. The technical efficiency of enterprises, or any other productive activity including research and development, given prevailing factor supplies and other technical-bureaucratic constraints, depends on the rules and incentives governing managerial action rather than on the direct mediating role of the planners. If these rules and incentives systematically induce managers to produce socially dispreferred goods, and to divert factors from their best internal use, production will be technically inefficient. Output value, including the development of new technologies, will be below the technological potential embodied in the existing capital stock, labor skills and production arrangements. Improvements in technical efficiency can be achieved by fashioning incentives that encourage better economic resource use, by tying these

incentives to superior performance indicators, and by eliminating socially unjustified impediments to managerial action.

V. The Coordination of Exogeneous Demand Under Soviet Planning

The coordination of exogeneous demand in the Soviet Union departs from the pure planning and command planning models in two important activities: the coordination of interindustrial supply and the production of customized final goods. In the first instance, purchasers of intermediate inputs whose own supply activities would be jeopardized if they did not receive the external resources they required in a timely manner are permitted to directly negotiate purchase contracts with their suppliers. Although these negotiations are constrained in diverse ways, especially with regard to price, contracting enables buyers (and sellers through multilateral bartering) to more effectively achieve their objective. Insofar as these objectives are coincident with the purposes of the State, as they should be in enhancing the efficiency of interindustrial supply, it follows directly that they mitigate the losses of command planning and facilitate the diffusion of some customized intermediate goods technologies.

The same line of reasoning holds with regard to customized investment durables, particularly construction goods, and weapons. The Soviets permit purchasers of construction services, machinery for new investment complexes and military durables to participate in determining designs and supply assortments. The MOD, for example, does not passively accept weapons designed by disinterested civilian engineers, expediently modified by the dictates of incentives governing managerial choice. Military bureaus design military hardware within parameters set

by military officials, and enterprises are required to enter into binding legal contracts to assure that the right goods are produced and delivered. These direct links, along with the related phenomenon of privileged access to scarce input supplies greatly reduce the theoretical losses of exogenous demand planning, but, of course, do not eliminate them entirely due to bureaucratic rigidities and the absence of domestic and foreign interfirm competition.⁴ Only in the civilian consumer goods sector, where direct links for all intents and purposes do not exist, are the welfare costs of planning as high as command planning theory implies.

VI. Technical Efficiency Under Soviet Planning

Technical efficiency in the Soviet Union is sought primarily by tying managerial bonus rewards to performance indicators such as profit, gross revenue and gross output. Bonus rewards are both direct and indirect. Managers receive cash payments for over norm performance and enhance their career opportunities through their conspicuous success. The performance indicators stressed are all filially related and promote full capacity utilization at State established prices. Profit maximization encourages managers to equate marginal revenues across product lines and to produce up to the point where marginal cost equals marginal revenue in all activities. Revenue maximization promotes the identical outcome, with the difference that total production is constrained by input availabilities or budget restrictions rather than the rule requiring marginal cost to equal marginal revenue. Output maximization retains the input availability and budgetary constraints, but eliminates the influence of price in determining the optimal intrafirm product

mix. All three criteria encourage managers to fully employ the resources at their disposal and to allocate factors to their best use, differing only with regard to the boundary of economic input utilization and the choice of outputs. It follows therefore that the production potential embodied in the technologies of Soviet firms should be fully or overfully exploited on a technical basis, (given prevailing rules of Soviet price formation) and will conform with competitive Western practice wherever profit maximizing is in force.⁵

Technical efficiency, of course, is not equivalent to economic efficiency. Insofar as the prices governing managerial action fail to reflect purchasers' preferences and true marginal factor productivities, technical efficiency will not optimize social welfare; nonetheless, it is important to recognize that the management of Soviet firms isn't quixotic. Factors can and presumably are routinely directed to the best, nominal engineering use.

Moreover, two other aspects of Soviet intrafirm optimization deserve special appreciation. First, enterprise managers do not have to concern themselves with the effective, specific demand functions confronting them. There is no market risk. The State will either buy all goods enterprises produce, or goods will be sold according to contract. As a consequence Soviet enterprises can safely operate much closer to their production frontiers than Western firms. Second, enterprise activity can be easily maneuvered to full and overfull capacity levels by State manipulation of output prices. Increased prices raise profit margins and induce expanded production. The State thus can promote full employment and macro stability merely by keeping wages low relative to

product prices, partly offsetting the microeconomic efficiency losses entailed by administrative price fixing.⁶

VII. Technological Choice Under Soviet Planning

The merit of technological choice: the design and selection of nominally best technologies in the Soviet economic system can now clearly be seen to depend importantly on the coordination of exogenous demand and the rules and incentives governing purchasers' and sellers' optimizing behavior. With regard to the former, it has been shown that while conventional bureaucratic rigidities and the absence of interfirm competition do impede optimal technical choice, there are no persuasive system's reasons for supposing that the separation of buyers and sellers per se seriously impairs technological choice in the military sector, and segments of heavy industry, although its effect on civilian technology is probably pernicious. Military and heavy industrial technology may be inferior due to the lack of multilateral, interfirm competition and the organization of Soviet science, and may display characteristics that depart drastically from Western counterparts due to differences in tastes, but these causes cannot be primarily attributed to the inability of buyers and sellers to bilaterally negotiate engineering characteristics and supply under central planning.

The performance indicators used to select competing technologies and subtechnologies are also likely to generate surprisingly good results. The Typical Method, introduced in the late sixties, utilized by Soviet planners to make investment and technological choices, provides a sound set of criteria for computing the present discounted value of alternative investment options in the military, heavy industrial and

consumer sectors alike.⁷ As in the case of managerial profit maximizing, outcomes will not be economically ideal, but the Typical Method should guide decisionmakers in the right direction.⁸

VIII. Technological Diffusion Under Soviet Planning

Systems theory suggests however that there is one area in which Soviet planning is severely deficient: technological diffusion. Established enterprises in the Soviet Union have scant incentive to modernize their technology. The introduction of new equipment necessarily disrupts the normal work routine, jeopardizing managerial bonuses in the short run, with little prospect of compensatory reward. More important still, the long term benefits of enhanced productivity do not accrue to the managers, who are neither entrepreneurs, nor equity holders. The gains from new technology are invariably appropriated by the state either in the form of above bonus fund profits, or through reduced output prices. Managers as a consequence earn no reward for risk bearing and as rational utility optimizers avoid modernizing their equipment whenever they can.⁹ Similar considerations may also affect technological choice. Insofar as established enterprises are compelled to modernize, managers will incline towards disruption minimizing, as opposed to long term profit maximizing alternatives.

This disinclination to efficiently modernize moreover is reinforced by the anticompetitive market structure of the Soviet system. Managers are not driven to innovate by competitive pressures. Changes in marginal costs have little effect on prices of established goods which are fixed for long intervals and managerial bonuses are not contingent on market share. Fear of diminishing profits, or insolvency which

propel modernization in competitive firms exert virtually no beneficial influence on Soviet managerial behavior.

The leadership has attempted to deal with these obstacles to technological change by deemphasizing modernization in established enterprises and by stressing the construction of new technology intensive industrial complexes. The merit of this approach is self evident, but it is not only suboptimal from a generally competitive standpoint, it also entails subtle locational costs, which may intensify with industrial congestion.

As with other aspects of Soviet economic activity, impediments to diffusion are apt to affect various sectors differently. Where purchasers' preferences count in heavy industry and the military sector, resistance to technological diffusion in established firms may be diminished through negotiation, and resolute administrative intervention. Likewise, insofar as these sectors are accorded locational priority, the indirect costs of "turnkey" diffusion may be reduced. Thus, while inefficient diffusion provides a primary explanation for the sluggishness of aggregate Soviet technological progress, vigorous State action in the heavy industrial and military sectors may well make it possible for the Soviets to compete effectively with the West in these restricted arenas.

IX. Optimization and the Command Paradigm

It has been argued that the economic and technological inefficiencies entail by bureaucratic planning are mitigated generally in the Soviet Union through the use of bonus incentives and performance indicators, and are diminished further in some sectors by the direct, negotiated coordination of supply and demand between buyers and sellers. The

quantitative significance of these theories depend on the real locus of control in the Soviet system. If, as Gregory Grossman hypothesizes (but has never proven) the Soviet economy is best characterized as a command planning system in which operational authority is concentrated centrally in the hands of the administrative bureaucracy, then the practical significance of the foregoing analysis is slight.¹⁰ Central directives thwart managerial efforts at bonus maximization, and the negotiated coordination of supply and demand is precluded because buyers and sellers are institutionally held at arms length.

Alternatively, if the command planning hypothesis is fundamentally misconceived, if the Soviet system is more accurately depicted as a non-competitive market regime, with fixed accounting prices, where effective microeconomic decisionmaking is decentralized, then the Soviet economic system is far more technically efficient than most analysts appreciate, and has developed institutional mechanisms that permit heavy industry and military authorities to effectively assert their expert preferences.¹¹

This is not the occasion to rigorously examine the merit of these contending hypotheses, but it needs to be clearly recognized that any final resolution of the technology issue requires a prior determination of the operational properties of the Soviet economic system.

Empirical Implications

An interim appraisal of the characteristics of Soviet technology can be ventured however by econometrically estimating the technical efficiency of Soviet enterprises; by scrutinizing the sectoral pattern of Soviet technological progress; and by comparing the relative quality

of civilian and noncivilian goods. The microeconomic data required to test the first hypothesis is only available for cotton refining enterprises. Stochastic production frontier estimates for these firms indicate that they are 93 percent technically efficient.¹² This statistic requires considerable qualification, but nonetheless is consistent with the hypothesis that measurable enterprise efficiency in the Soviet Union is surprisingly high.

Likewise empirical studies suggest that technological progress in the heavy industrial and military sectors is more rapid than in consumer oriented activities, but this hypothesis cannot be definitively confirmed because of diverse econometric and databased uncertainties.¹³ The superior performance of these sectors is relatively pronounced if official Soviet industrial statistics are employed, but becomes more obscure when the CIA's hidden inflation adjusted statistics are utilized. This problem is particularly acute in the military machine building sector where agency estimates appear to suggest negative rates of technological progress, while official Soviet data place the figure closer to 6-7 percent per annum, 1970-82.¹⁴

Finally, numerous classified and unclassified case studies have revealed that although the quality of Soviet civilian goods and many civilian technologies are decades behind the Western norm, the engineering properties of a wide array of heavy industrial products and processes, as well as military hardware are much closer to the state of the art.¹⁵ This duality may have many alternative explanations,¹⁶ but it is clearly consistent with the noncompetitive market theory of Soviet system control.

XI. Growth Potential

The foregoing evidence, together with the theoretical literature stretching from Bohm Bawerk to Wiles demonstrating the inherent inoperability of the command paradigm strongly suggest that the growth potential of the Soviet economy is not limited to the extent usually supposed. Economic arrangements long in place facilitating negotiated interindustrial and customized final product supply may well permit embodied technology to achieve surprisingly high standards and encourage the second best technical interfirm use of inputs. Similarly, the optimizing rules governing technological choice and intrafirm factor utilization may well spur technical efficiency. As a consequence, it should be anticipated that Soviet enterprises may well continue to operate close to their production frontiers; that the technological quality of inputs and outputs may well exceed the standards of pure command regimes; and that the pace of future technological progress may well be rapid, given the scale of the Soviet R&D effort; limited for the most part by anticompetitive impediments to technological diffusion and the leadership's technological conservatism.

Assessed from this perspective, the widely held view that Soviet economic growth will slow to 1-2 percent during the eighties because the command system cannot cope with increasing factor scarcities and flagging technological progress, appears greatly exaggerated;¹⁷ especially with regard to the military sector where recent intelligence estimates indicate that weapons growth ceased after 1976.¹⁸ Alternative estimates derived from official Soviet data, unadjusted for the conjectured effects of hidden inflation, suggesting aggregate growth of 3 to 4

percent per annum, and weapons growth of 6-10 percent per annum seem far more plausible,¹⁹ and imply that the Soviet's ability to wage a sustained economic and military competition with the West is greatly underestimated.²⁰

XIII. Conclusion

Although it is generally agreed that the Soviet economic system affects the pace and character of Soviet technological progress, surprisingly little attention has been paid to the systematic analysis of these effects. This essay has attempted to provisionally remedy this omission, and has tentatively found that existing arrangements may constitute a far more effective engine of technological and economic growth than is commonly recognized, especially in the heavy industrial and military sector. The implications of these broad findings for the assessment of the East-West economic, technological and military competition require no elaboration.

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8. Soviet designers are often rewarded for the number of blueprints they produce, instead of the quality of their designs. This practice however should not be construed to imply that designs selected are inherently inferior either because designs are uniformly poor, or the criteria of choice are defective.
9. This result is not a theoretical necessity, but arises because Soviet officials are loath to reward managers as richly as if they were entrepreneurs. See Bergson, Welfare, Planning, and Employment, pp. 249-63.
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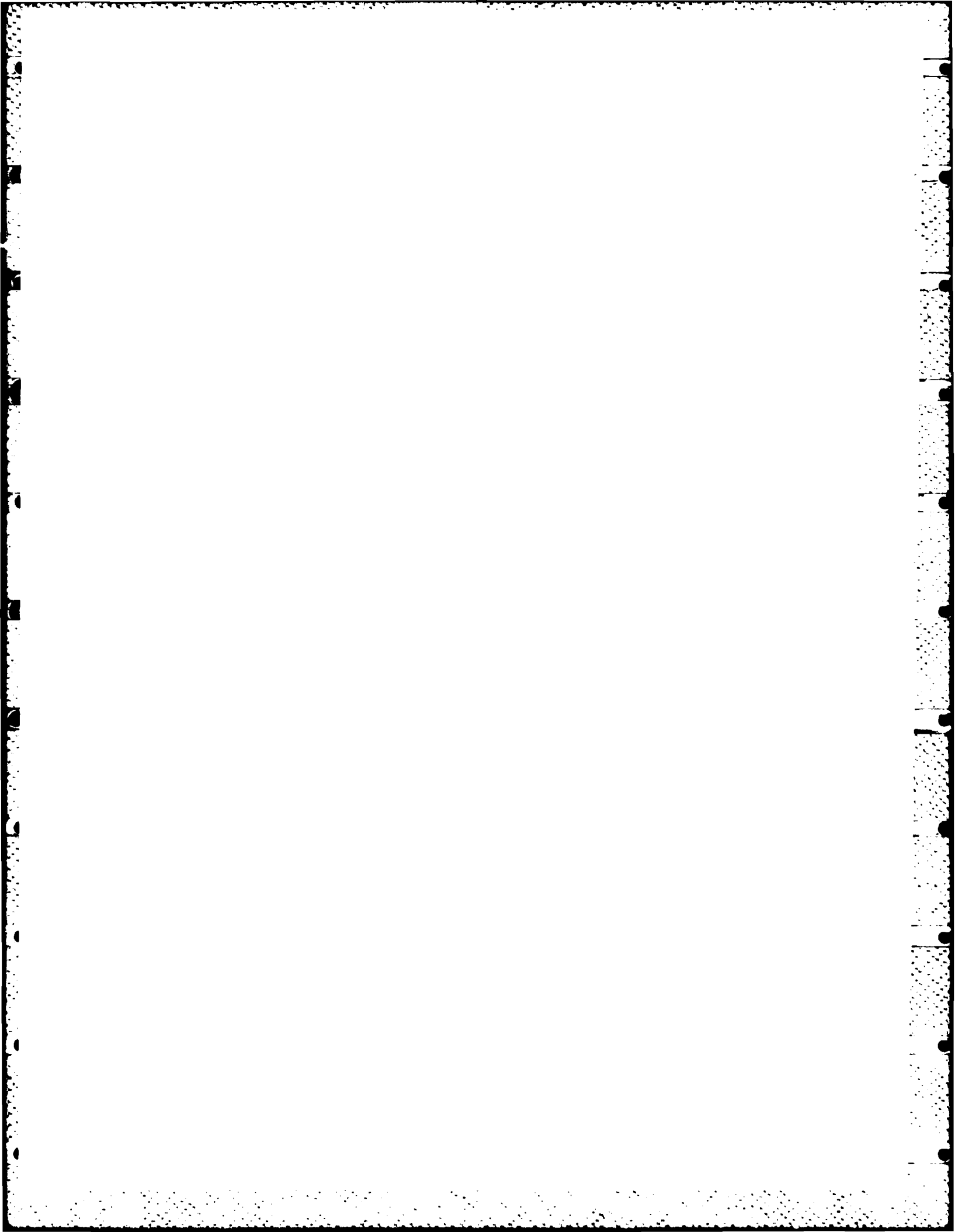
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THE REVOLUTION IN MILITARY AFFAIRS AND THE SOVIET SYSTEM

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The development of Soviet military power has been the subject of endless discussion (and alarm) in the United States and the Western alliance. The Soviet Union is one of the two superpowers, possessing impressive military strength of the most technologically advanced character. Yet, this is a society which undeniably lags several years behind the West in most areas of scientific and technological endeavor. A number of scholars have commented on the gap between Soviet technological prowess and its military might.¹ One is tempted to believe that there are two, separate economies; one which produces sophisticated military hardware and one which produces consumer goods which lag some twenty to thirty years behind those produced in the West. While enough of a gap exists in the production of goods to encourage the "two-economies" model, this is a false dichotomy which obscures a very important fact: The Soviet military is as dependent on the basic level of Soviet technological and scientific development as are its civilian counterparts. Research in the basic sciences and the exploration of basic technological possibilities takes place in the economy as a whole. What the Soviet military seems able to do that its civilian counterparts cannot, is incorporate new technological possibilities into military research and development more quickly and efficiently.

The development of weapons systems which draw on new technological possibilities is but one part of the story. The military must also exploit the potential of the advances through revision of military

thought and operational strategy, organization and training of troops. Taken as a whole, the process from the identification of a military technological possibility to the deployment and integration of new forces in the field is a formidable task. It is a formidable task for any military organization, but in a system which is slow moving, hierarchical and where, even in the military sector, there are strong disincentives for innovation, this is especially difficult.² In recent years, this has also been a system with a stagnant economy with bottlenecks and limited resources. The pressures are even greater to guard against mistakes through conservatism. Even if the military is a preferred customer these are problems which cannot be easily overcome.

One could argue that necessity has driven the Soviets to find ways to make their system respond when new possibilities are presented. Indeed, the pressure to respond in the military sphere is great. Symbolic, political and above all, military exigencies dictate that the Soviet Union cannot afford to be caught behind military-technical improvements. This is especially true because the Soviet Union is relatively on its own in the scientific-technical field. While the United States numbers among its allies the most technologically advanced states of the world, the Soviet Union has no such friends. In fact, it appears that even in those areas where Soviet allies could be most helpful, chemical industries, microelectronics and optics development, the much heralded COMECON and Warsaw Pact cooperation in technology has been wanting. The Soviets, it seems, are rather stingy in the exchange of information and sensitive and chauvinistic about the incorporation of developments which take place outside the Soviet Union.

In spite of the numerous handicaps that it faces, the Soviet Union has managed to meet every technological challenge which has been posed to it in the military field. These are ongoing challenges for the Soviet system. The potential for military-technical improvements is almost daily. Major improvements, according to one Soviet commentator, which require substantial rethinking and reorganization occur roughly every five to ten years.³ But even more taxing for the system are those technological possibilities which are revolutionary in nature. Rather than enhancing existing capability there are technological breakthroughs which can transform the nature of warfare. Here the Soviet Union would be faced with the need to rapidly identify the technological possibilities and incorporate them into weapons design, military thought and training. One way in which this has been done is through "mobilization." The command economy and centralized political leadership are important advantages in this strategy since a decision can be taken to devote massive resources to the attainment of some goal. But the mechanics of mobilization are not well understood in the military sphere. How is a decision made to pursue a particular technological development for military reasons? What extraordinary arrangements are needed to force innovation on a system that is, for the most part, non-innovative? Since choices must be made, how is the direction of such programs set, monitored and maintained? In short, how are revolutions in military affairs carried out in the Soviet Union.

Generally, Western scholarship has focused on two important case studies in Soviet military history, the mechanization of the armed forces in the late 1920s and early 1930s in response to the full-scale

acquisition of Intercontinental Ballistic Missile (ICBM) capability in the late 1950s and early 1960s. The Soviets themselves suggest that these two technologies were the transforming ones for their forces. This brief study draws upon that work and examines another small piece of the puzzle: The role of a single senior military man in these cases. It proceeds from the contention that it is important to explore alternatives to existing organizational arrangements to explain these great leaps in Soviet military development. In extraordinary times, extraordinary arrangements are needed. The interest in the role of senior military men is not to suggest that personalities are the overriding determinant of policy. On the contrary, the argument is that in these cases the career paths of very senior military at these crucial times suggest that the Soviets were trying to achieve union of theory (including theoretical potentials of new technology), doctrine, operational art, weapons design and training early and efficiently. Obviously personal clout is important and can be of tremendous assistance in obtaining resources and political support for programs. But the use of a single senior officer provided unity of doctrinal and operational requirements in the military forces, development of weaponry, revision of strategy and reorganization of training and force structure. This may be one response to the hierarchical nature of a system which makes coordination difficult. Moreover, this desire for unity is also indicative of how the Soviet view the role of technology in military affairs.

Scientific-Technical Progress and Military Might in Soviet Thought

The Soviets discuss the problem of the efficient incorporation of new technologies a great deal. The Soviet preoccupation with technology is firmly grounded in Marxist ideology in which economic conditions play the critical role in social development. According to Engels,

Nothing is more dependent on economic conditions than the army and the navy. Armament, military structure and organization, tactics and strategy, depend permanently on the existing level of production and on communications. It is not the "free creations of the intellect" of generals of genius that have revolutionized things here, but the invention of better weapons and changes in the human material, the soldier; at the very most, the part played by generals of genius is limited to adapting methods of fighting to the new weapons and fighting men.⁴

Early in their history, the Soviets realized and fully admitted that their own technological level was far inferior to that of the "imperialistic" armies that they would face. Mikhail Frunze, perhaps the most influential man in determining the form of the Red Army, admired and feared the technological might of the West. Nevertheless, Frunze believed that the "technological dependence" of "imperialistic" armies was ultimately a handicap.⁵ The key for Frunze was to achieve unity of tactics, training, strategy and political will. This desire for unity never deterred Frunze and his successors from trying to make the technological level of the Red Army "second to none," but they were convinced that technology alone was sterile.

Modern Soviet thought incorporates both strains of Frunze's thinking; the importance of technological innovation and the need to revise and adapt tactics, strategy, training and organization to the new conditions which technology presents. Military-technical improvements are but one part of military power. In fact, Soviet thought distinguishes

between military-technical progress (voenno-tekhnicheskii progress) "on the basis of scientific-technical breakthroughs" and revolutions in military-affairs (revolutsiia v voennom dele) of which military-technical progress is but one part. The revolution in military affairs is a much broader concept which includes organizational and training reform and the revision of strategy, doctrine and tactics.⁶

There have been but two revolutions in military affairs; mechanization and nuclear weapons, but the Soviets claim that they constantly seek unity of technology and military thought. The Soviets seem to believe that it is in achieving this unity that they enjoy an advantage over the West. They argue, for instance, that monopolistic production under capitalism is inefficient. This stems from the basic desire of capitalist to extract profit, slowing down the dissemination of discoveries and advances into wide-scale production. But in the production of military technology, the West has created a few powerful monopolies which "serve the military machine of imperialism significantly more rapidly and with greater scope than the development of technology in nonmilitary production."⁷ The outcome is that the capitalists are able to produce military technological advances rapidly. Nevertheless, with profit still the driving force, weapons are produced for profit, not to serve the interests of military missions and tasks. It is not possible to full achieve unity of strategy, organization and weapons development in the West.

This discussion shows the degree of importance which the Soviets attach to their ability to incorporate new technologies and to forge a new unity of doctrine and strategy. The Soviets attempt to revise strategy and doctrine to take advantage of new technologies and clearly,

organizational reform is also a key element. "The appearance of qualitatively new types of weapons leads to a situation where the new weapons cannot be forced into existing organizational forms," according to one author. Therefore, technological breakthroughs present three problems for the Soviets, (1) the development of new weapons (2) the revision of strategy, doctrine and tactics (3) reform of organization and training. At each stage there is bound to be resistance and there is ample evidence from the cases to support this claim. The Soviets must therefore find a way to overcome natural institutional resistance as well as their own painfully slow system. They understand that speed is important. As one commentator noted, it is right to want technological potential to be firmly grounded scientifically before moving to exploit it in weapons development. But,

The experience of history teaches that in reinforcing the defensive might of a socialist state, one cannot lag behind the times . . . Stagnation in this area may be fraught with great consequences. Our own scientists, both civilian and military, must constantly think about and remember this. In this regard, the interests of reliable defense of the Soviet Fatherland demand that we not weaken the front of scientific exploration . . . and that we reduce the time needed to introduce results of scientific research into production.⁸

When there have been revolutionary breakthroughs the need to equip Soviet forces with it has been generally realized. There have, however, been bitter differences about just how revolutionary the breakthroughs were. There have been those who did not believe in the transforming nature of technologies, among them some from industry who probably saw potential disruption of planning cycles and perhaps exposed failings of the system and, not surprisingly, those in established services who stood to lose in reorganization. On the other side were those who were willing to push the system to its limits to make the technological leap

forward. In order to overcome inertia, in at least two cases, very senior military men followed new technological possibilities from inception to deployment. In doing so they apparently hoped to achieve unity of doctrine, strategy, training and organization quickly and synergistically so that when the technologies were deployed the Soviet armed forces would enjoy their maximum benefit.

Mikhail Tukhachevsky and the First Revolution in the Soviet Armed Forces

Mikhail Tukhachevsky was one of the really forceful personalities in the history of the Soviet armed forces. He was a man of undeniable genius and of equally unbounded arrogance. His outspoken and flamboyant style set him apart from his modern day counterparts. Tukhachevsky was a young Imperial Lieutenant when the Bolsheviks seized power. He became thoroughly converted and committed to that cause and commanded forces in some of the decisive battles of the Civil War. He was, at the age of twenty-eight made Director of the Military Training Academy. In 1925 he became Chief of the Red Army Staff, but in May 1928, he apparently fell out of favor and was sent to command the Leningrad Military District. In these early days the Red Army could not afford to waste talent. Tukhachevsky was brought back in June 1931 at Stalin's request to head the armament effort as Deputy Chief of the Revolutionary Military Council and as Director of Armaments. He became a Deputy Commissar for Defense in 1934 and Head of the Training Directorate in 1936. Eventually, Tukhachevsky's independence and arrogance proved to be his undoing. When Josef Stalin launched the massive purge of the Red Army in 1937, Tukhachevsky, at the age of forty-four, was tried and executed as a German spy.

The remarkable career of Tukhachevsky is interesting not only for what it teaches us about military politics in the early period, but because Tukhachevsky was instrumental in the transformation of the Red Army from a rag-tag remnant of the Civil War to one of the best and most highly mechanized forces in Europe. This was a period of a rapidly changing battlefield. The European military community was haunted by the costly trench warfare of World War I and new technologies, particularly the tank, provided potential answers to the problem. But the use of armor was not self-evident. Early solutions envisioned simply the incorporation of armor into existing battlefield arrangements, using tanks in support of infantry to break through enemy lines, for example. Slowly, the potential for revolutionary new forms of warfare was recognized. One of the more novel forms of warfare was developed during this period in the Soviet Union.

The first treatise on this new form of warfare was written in 1927 by the Head of the Operations Administration of the Red Army Staff, V. Triandifilov. Triandifilov was one of several young officers around Tukhachevsky who revolutionized Soviet thinking. He laid out a case for "successive operations" in battle.⁹ He argued that decisive victory could only be achieved if the enemy did not have an opportunity to regroup. He devoted considerable attention, therefore, not just to breaking through the enemy lines, but exploitation of the penetration to deliver a decisive and annihilating blow. This theory of "successive operations" recognized the potential that armor, with increased mobility and speed, held for deep operations. In World War I battle had been linear, concentrating on penetrating enemy lines. Triandifilov's

formulation recognized the importance of operations throughout the enemy's depth.

These ideas were further developed by Tukhachevsky and others. Though they believed Triandifilov too optimistic about the current potential for encircling and crushing the enemy, they formulated a plan to enable the Red Army to, in time, carry out such operations. The key contributions here were the concept of combined-arms operations for breakthrough, encirclement and decisive victory. Tukhachevsky envisioned the combined use of motorized rifle units, self-propelled artillery and aviation to achieve breakthrough. Bombers were to be used to interdict enemy reserves and a new kind of force, paratroopers, were to be used to seize targets and block the enemy's retreat, allowing a crushing blow to be delivered by the second echelon of forces.¹⁰

The Soviets also recognized the potential for mechanized formations incorporating various forms of armor which could move at the same speed. The Soviets denounced "one-weapon" theories, rejecting the idea of specialized, elite units in favor of mass armies. Nevertheless, armored formations also required specialized training and the Soviets accepted tacitly the need for elite, well-trained units, pushing them one step further away from mass armies and toward the elite units which they despised on ideological grounds.¹¹

This view of the new battlefield won adherents in the Soviet military hierarchy and plans for equipping and training the Red Army were increasingly formulated on the basis of combined-arms operations in depth. The attractiveness of this form of warfare doubtless lay in the concept of decisive and total victory and in its compatibility with the primacy of the offense. Tukhachevsky's ideological justification

probably contributed to the attractiveness of the option as well. He argued that victory the next war would depend on an offensive blow which would shock the weakened capitalist countries suffering from deep class divisions. The decisive blow and ultimate annihilation could then be delivered. But the role of ideology must not be overstated. The idea of operations in depth was above all a way to exploit the potential of new technologies. It bore resemblance to the thought of Guderian in Germany, another state convinced, in spite of World War I, of the importance of the offense.

There is substantial evidence that during his reign as Chief of Staff, Tukhachevsky was interested not just in the theoretical and strategic implications of tank warfare, but in how the technical requirements of the tank. He took considerable interest, for instance, in the question of mobility because in his offensive doctrine of operations in depth, mobility was a fundamental requirement.¹² Tukhachevsky's fascination with potential new technologies was not limited to armor. He was equally interested in exploiting the potential of aircraft and of new chemical combinations for warfare, in particular those involving phosphorus. The theoretical work of the young officers around him dealt with how new technologies made possible "combined-arms" operations or the use of all types of weaponry in a synergistic fashion.

When Tukhachevsky was sent to command the Leningrad District, even though it was probably a demotion, he was able to make good use of his new post as a vehicle to push the system to explore these technological possibilities. He apparently made the Leningrad District something of an experimental area. One biographer comments that he was not locked into "established patterns in his maneuvers" and it was here that he

first experimented with airborne forces (paratroopers).¹³ Moreover, Tukhachevsky was not isolated from Moscow. The sheer volume of memoranda with which he bombarded Klementi Voroshilov served notice that he was interested in far more than the Leningrad district. Among these were memoranda on reorganization of the armed forces and on the creation of new faculties within the Staff academy to study the implications of mechanization.¹⁴

Tukhachevsky's interest in technology led him to look for organizational solutions to the Soviet Union's general economic backwardness as well. During the first months of his command, in Leningrad, Tukhachevsky co-authored, with Peter Uborevitch, a memorandum on how best to speed up the incorporation of technological advances in armament. They suggested the creation of an entirely separate heavy industry base for armament and a new productive apparatus for its administration.¹⁵ This was an about face for Tukhachevsky who earlier had argued for complete unity of military and heavy industrial production with the military potential of technology driving priority decisions. The shift was apparently caused by Tukhachevsky and Uborevitch's belief that "balanced growth" would not lead to concentration of effort in areas of interest to the military. On June 15, 1929, in a report "The State Defense of the USSR," a revised version of the Tukhachevsky-Uborevitch suggestion was adopted, but their most radical suggestion was dropped. The industrial base was left as one, while Armaments Industries were split-off. From this time forth, the Soviet military became heavily dependent on the general level of technological development and the "productive forces" of the country. Tukhachevsky thus began to

work, as his successors would, to find a way to extract technological innovation from the general industrial base.

The Armaments Directorate was created with Peter Uborevitch at its head, but two years later, he was replaced by Tukhachevsky. The reasons for this are not clear, but apparently the slow pace of progress in creating successful Soviet prototypes of tanks was one reason. The Soviets were at this point almost completely dependent upon their collaboration with Germany as well as the foreign prototypes purchased from Britain, France and the United States. Perhaps Uborevitch lacked the organizational skill and personal prestige of Tukhachevsky. Whatever the case Tukhachevsky was able to extract resources that Uborevitch could not. He was able to extract tremendous resources for the Armaments sector, though in 1930 a request for a major increase in arms production was turned down. Stalin remarked then that the request would replace "socialist construction" with "red militarism."¹⁶ One year later, with Japanese activity building up near Manchuria, Stalin reconsidered and the request was granted.

But Tukhachevsky saw his role as more than the extraction of resources. His biographers suggest that he was interested even in the detail of weapons design and development. It is said that "though he sometimes lacked engineering expertise, he paid close attention to the possibilities for the exploration of breakthroughs."¹⁷ He even made a number of engineering suggestions which are kindly referred to as lacking in "real scientific understanding." But Tukhachevsky was clearly the driving force behind the rapid exploration of technologies for military purpose.

In his belief that technology was revolutionizing the battlefield, Tukhachevsky encountered opposition from several quarters. On the one hand, there were those who resisted his almost constant demands for better performance on research and development. Among those who were apparently unhappy with the implied criticism of industry was Voroshilov who was largely responsible industrial build-up. While admitting the importance of the new weaponry, Voroshilov, in an odd alliance with certain staff officers promoted the view that tanks and aircraft would not have a transforming impact and create the condition for a short, technological war. Rather, they argued, the next war would be one of attrition in which the overall "productive forces" (industrial mobilization of the country) would be the decisive factor.¹⁸ Total victory could not be achieved rapidly and the war would be long and protracted. The importance of the new technologies were therefore downplayed.

The opposition also disagreed with Tukhachevsky and the Red Army Staff on the use of armor. They believed that armor should reinforce the infantry and artillery units. One suspects that infantry and cavalry officers, threatened by the new technologies, played a role in the debate. Nevertheless, Tukhachevsky's line triumphed and by 1931, the concept of operations in depth governed Soviet thinking. Tukhachevsky's victory was not total. Those who wished to see tanks employed in infantry and cavalry support diverted some of the expensive new weaponry to that use. There is, according to students of armor development, no evidence that Tukhachevsky actively opposed the use of armor in this way, but the decision proved to be a critical mistake in the first two years of World War II. This is the first of several instances in which

those who saw technology as transforming would clash with those who were not ready for its whole scale and rapid adoption.

There were costs to Tukhachevsky's whole scale involvement in defense production. He did not, after 1934, maintain an active interest in the refinement of military thought. He seems to have relied more and more on his old friend Peter Uborevitch, now commander of the Byelorussian Military District, for experimentation in tactics. Moreover, after seeing a marked improvement in the equipment of the Red Army, Tukhachevsky's interest shifted to problems of training the Red Army. After the 1935-36 exercises, he wrote a scathing report on the training of commanders and redrafted the field regulations to reflect better his own ideas. He then moved from his post in armaments to become Head of the Training Directorate of the Red Army where his reforms were being implemented when he was arrested and liquidated in the blood purge of 1937.

Tukhachevsky interests in technology were not limited to "proven possibilities," like armor. As early as 1921, he became interested in the potential of rocketry and supported the creation of a laboratory to explore basic technologies toward its development. In 1928, he was singularly important in establishing the famous Gas Dynamics Laboratory which, after becoming Armaments Chief in 1931, he administered through his own apparatus. Tukhachevsky's interest in rocketry was enhanced by his own view of the battlefield and the potential for strikes deep into enemy territory which rocketry provided. One article on Tukhachevsky's role in rocket development makes clear that Tukhachevsky often fought for resources for his young laboratories, trying always to give them the benefit of his personal power. When a conference was organized in 1934 on the work in this area, he personally attended the opening

session. In 1932, Tukhachevsky wrote "special promise is held out by the Gas Dynamics Laboratory's experiments with liquid-propellant rocket motor In artillery . . . this will open up unlimited possibilities for firing projectiles of any power and range."¹⁶ He was the key actor in setting up the Reaction Research Institute which was later the center of rocket development. Rocket development was so tied to his personal fortunes, however, that it went into total eclipse during the purges. It reemerged after the war when many of the young scientists, trained in the labs under Tukhachevsky's auspices, became leaders in Soviet rocket development.

The role of Tukhachevsky should not eclipse the tremendous contribution of others. What can be noted is that he directed the course of the mechanization of Soviet forces and extracted resources for the exploration of other technological possibilities. He was not able to accomplish some things, like the creation of a separate industry for military aircraft production. His prejudices were also in evidence and he did not press for the development of submarine technology. Nevertheless, he did seem to try to achieve unity of theory, practice and equipment, moving in each stage of his career to push the Soviet Union toward the rapid exploration of the technological possibilities of the new battlefield.

The Transformation of Soviet Military Power in the Nuclear Age

The Soviet Union was not caught unaware of the military potential of atomic power, but interestingly it was not the military elite which first recognized it. According to accounts of the Soviet decision to build the atomic bomb,¹⁹ the Soviets were alerted by the fact that

American research had gone "underground" and that famous nuclear scientists were no longer publishing in the open literature.

The real impetus for the creation of a special mobilization effort was the use of American atomic bombs at Nagasaki and Hiroshima. Stalin was apparently convinced that the Soviet Union could not afford to be without this technological breakthrough. A council of some of the Soviet Union's best physicists and engineers was set up and headed by -- I.V. Kuratchov: Within four years the Soviets exploded their first nuclear device.

The military's input into this process was apparently minimal. Nevertheless, the parallel effort to exploit rocket/missile technology was proceeding at a rapid pace. The ground work which had been laid by Tukhachevsky was given new life when the knowledge of scientists from the defeated German Reich were suddenly available to the Soviet Union. The Soviets apparently resurrected many of the young rocket scientists and engineers who had been trained in Tukhachevsky's labs and created new institutes for the development of rocket technology in 1946. Apparently, the Soviets kept much of this work separate from labs where expatriot German scientists worked. This gave the Soviets the benefit of the German's knowledge without creating dependence.²⁰

Early Soviet rocket programs were devoted largely to perfecting the V-2 type rocket, but major breakthroughs were made and, after 1949, most work centered on developing short and intermediate range ballistic missiles. The preliminary work on ICBM technology was also begun. By late 1952, the Soviet were optimistic about the potential of ICBMs. Marshall of the Artillery N.N. Nedelin, formerly commander of the Artillery forces, was appointed Deputy Minister of Defense for Armament to oversee

the first stages of a development and testing program. According to his biographer, he worked diligently with rocket designers to understand technical problems and design difficulties. The reference to him as a "principled customer," however, suggests that he was not always receptive to explanations of delay and failures.²¹

When Soviet optimism about their ICBM program was at its height, Nedelin returned to command the artillery and authored a number of pieces on the implications of "very long-range" rocketry on military tactics and strategy. He set up a special staff, while he was still Chief of Armaments, to work out "the organizational-strategic bases for employing rocket carrying units." David Holloway has pointed out that the artillery officer's view of the missile dominates Soviet thinking: Missiles are seen as a part of the artillery.²² The concept of "operation in depth" may have encouraged this view as the Soviet sought to extend the range of their missiles so that they became large artillery pieces of increasing range able to strike ever deeper into enemy territory. Nedelin's group was made up primarily of artillery officers, some of whom were assigned for a short time to the General Staff to think through the implications of the new weaponry.

The Soviets apparently began to encounter new problems in long range missile development in the period after March 1954. Raymond Garthoff has noted that the Soviet's early optimism was muted in Soviet writings from March 1954 until the Spring of 1955.²³ This might explain the decision to bring Nedelin back to the Armaments post in March 1955 where he remained until December 1959. The Soviets did achieve breakthroughs in this period with the development of the SS-7 by the Yangel Bureau and the beginning of work on the SS-9. Nedelin's biographers

suggest that in his second term as Armaments Chief, he was an even more attentive customer. Moreover, he is said to have had excellent access to the political leadership. Army General U.F. Tolubko, now Commander in Chief of the Strategic Rocket Forces command states that "when questions were insoluble at the ministerial level, Nedelin, with the knowledge of the Minister of Defense, turned for help directly to leaders of the Party and Government. Leonid Brezhnev was, at this time, responsible for Heavy Industry and was apparently in close contact with Nedelin. Nedelin maintained "a kind of staff where important problems of rocket building were solved and meetings held with . . . notable scientists, designers and specialists from different fields of science, technology and production."²⁴

There is no evidence of resistance to the full-scale work on rocket development. But when the Soviet turned to the problem of the implications of nuclear rocketry, resistance surfaced in response to the idea that the new technology was revolutionary in nature. The issue of how to marry means of delivery with the atomic warhead and the problem of how to organize and prepare the Soviet military in the nuclear age produced one of the most contentious periods in Soviet military history.

The death of Josef Stalin in 1953 and Khrushchev's subsequent "de-Stalization" campaign in 1956, created the conditions in which an assessment of military strategy in the nuclear age could take place. Josef Stalin had held absolute power in the Soviet Union and his word was the final authority in the affairs of state. Stalin had been dubious about the transforming impact of nuclear weapons. Now without him, institutions responsible for various aspects of government were

strengthened enormously and those in the military who held contending views could afford to speak.

The debate on the nuclear revolution was protracted and proceeded in stages. From 1953 until de-Stalization, cautious studies were begun under orders from the Ministry of Defense and the General Staff began to revise its teaching and research program. A series of articles on nuclear weapons appeared in Red Star in 1954 -- the first articles of their kind. When de-Stalization was launched by Khrushchev, the debate intensified and in May 1957, the Defense Ministry organized a conference to discuss Soviet military science. The General Staff sponsored a set of similar conferences for senior commanders the next year.

The critical issue was the impact of nuclear armed rockets on warfare. But for Khrushchev, a maverick given to sweeping solutions, the issue was already settled. He saw nuclear weapons as decisive both politically and militarily and as transforming the nature of warfare. Any major war would now be one in which the decisive element would be missile strikes deep into the enemy's rear. Generally, the Soviet military saw in nuclear missiles the potential for surprise and for deep penetration and destruction of enemy targets. Military discussion was circumspect but the impact of Khrushchev's view was immediately felt. Missile development was the prime beneficiary as long-range aviation, beset with technical and doctrinal liabilities, was eclipsed completely. Khrushchev was also anxious to take advantage of the relative low costs of nuclear weapons. He intended to slash Soviet defense budgets and to cut manpower in half. Khrushchev appointed a high level commission chaired by former Chief of the General staff V.D. Sokolovskii

to rewrite Soviet doctrine. Eventually Military Strategy, the Commission's findings, recognized the decisive character of nuclear weapons.

But it was the impact of Khrushchev's beliefs about nuclear weapons on the organization of the Soviet military which is most memorable. After 1955, discussions began about what organizational reforms would need to be made. The Ground Forces Command, watched nervously the growing independence and influence of the artillery commanders. Like the cavalry before them they argued that new weapons could be incorporated into existing organizational structure; distributing nuclear weapons to the Navy, Air Force and Ground Forces. The group which Nedelin had formed, however, argued that a new form would be needed which could combine "all potential for deep strikes into enemy territory."²⁵ Nedelin's view won out and the Strategic Rocket Forces Command was created as an independent service with Nedelin at its head. Therefore, the man who had been a critical factor in the development of Soviet missile technology and thought became the first commander of those forces. The Ground Forces Command, now considered an anachronism was eventually abolished.

But resistance to these ideas was not dead. Seizing upon Khrushchev's ouster in October 1964 by Leonid Brezhnev and Alexei Kosygin, the opposition regrouped and eventually the Ground Forces Command was reestablished. The "one-variant" war with nuclear weapons decisively ending the conflict in short order was replaced by detailed consideration of other potential variants including protracted war. Nuclear weapons never lost the distinction of being the weapon most able to cripple the enemy, but their "decisiveness" was questioned. The Soviets finally settled on the notion that no one-class of weapons was

capable of total victory. As a brief history of the Soviet Strategic Rocket Forces states,

the Strategic Rocket Forces cannot solve all problems of modern warfare, on its own. Their function is to launch a decisive blow against the enemy and clear the way for all other services. Final victory will be reached by concerted actions of all the services of the armed forces.²⁶

Nedelin's role in the development of the Soviet ICBM force was cut short by his death in 1960. He was one of several officials killed in an accident during a Soviet rocket test. His role was not as wide ranging as that of Tukhachevsky and certainly his impact was not as far reaching in directing Soviet technological development. But the pattern of moving an operational commander to the post of Deputy Minister for Armaments and then to a position which allowed him to oversee deployment and integration of the new forces was repeated in this case. Nedelin, like Tukhachevsky, also created a group of staff officers to think through the implications of the new weaponry. In both cases, the support of the political leadership was a precondition for Tukhachevsky and Nedelin to do their work and changes in those political conditions had enormous consequences for the former. Nedelin died with political support for ICBM development at its height and we will never know how Khrushchev's ouster would have affected him. Given subsequent support for ICBMs and the Strategic Rocket Forces Command, one suspects that it would have had little effect. Taken together the cases show that with the general support of the political leadership, these senior officers played a critical role in bringing these revolutionary developments to deployment. There was, however, resistance from those who stood to lose in the creation of new organizational forms and doctrinal revision.

The Soviets have used this pattern of moving senior military officers at other times, though less extensively and less coherently than in these cases. One of the most interesting is the case of Colonel General N.N. Alekseev whose background made him a knowledgeable and respected member of the Soviet delegation to SALT I. Interestingly, he was, after 1960, Head of the Scientific-Technical Committee of the General Staff which is believed to set the technical requirements for Soviet design bureaus. In 1970, Alekseev was appointed Deputy Minister for Armament, a post which had not been filled (or had been abolished) for about six years. With no real revolution in military affairs taking place, perhaps the Soviets desired unity of arms control policy and arms production. In this way, arms control would work synergistically with Soviet defense requirements.

There is some evidence that the concept of one officer with responsibility from a system's birth to its deployment is employed even if the system is not revolutionary. One Soviet author has noted the importance of the "first leader principle"²⁷ in the Soviet military for the achievement of unity of scientific-technical and military-technical requirements. Not enough has been written about this principle to know whether it is analogous to the American "program manager" or a more comprehensive role. But given the Soviet propensity to use senior military officers to achieve unity of technology and military requirements, it is probable that it is a comprehensive role.

In sum, one way that the Soviets can compensate for their relative technological inferiority is to shorten the time from the identification of military technological potential to deployment of new weaponry. More importantly, when these technologies are revolutionary, the Soviets try

to achieve efficient and rapid reorientation of their military thought, organization and training. This is not an easy task since their are entrenched interests that are bound to lose in the process of reform. It appears that powerful military officers have been used to bridge the gap between theory and practice and development and deployment. These men can bring both personal political clout and lend direction to Soviet programs.

The Next Revolutionary Frontier

The stories of Tukhachevsky and Nedelin are much more than lessons in Soviet military history. The problems which they faced may well be surfacing for the Soviet military again. One such problem is how to identify the next revolution in military affairs. Obviously hind sight is perfect and we now know that mechanization of forces and nuclear weapons were indeed revolutionary. But there were those who had their doubts and it took enormous effort to push the Soviet system, which is temperamentally conservative, over the threshold of change.

There are signs of a new debate about new military technologies and their impact. Recently dismissed Chief of the General Staff Nikolai Ogarkov suggested that a new revolution in military affairs is facing the Soviet Union. Ogarkov identified two potential revolutionary frontiers: "rapid changes in the development of conventional means of destruction" and "the emergence, in the very near future, of previously unknown types of weapons based on new physical principles."²⁸ Ogarkov's subsequent discussion suggests that in the first case he was talking about "smart weapons" and the use of sophisticated microelectronics to increase the yield ("by an order of magnitude") of conventional

weapons. He was also discussing, the development of "automated-strike" complexes by which Ogarkov apparently meant drones which have reconnaissance and real-time photo-processing capability. Ogarkov also made note of technologies which figure heavily into NATO's plans for the conventional defense of Europe. Ogarkov spoke of "unmanned flying machines" (cruise-missiles and drones) and "electronic control systems" which will be revolutionizing. Finally, Ogarkov made his preference for conventional weapons clear, stating, "You do not have to be a military man or a scientist to realize that a further buildup (of nuclear weapons) is senseless."

Ogarkov also left no doubt that he considered these new weapons to be not incremental or evolutionary, but breakthroughs of revolutionary proportions.

This is a qualitative leap in the development of conventional means of destruction (and) will inevitably bring a change in the nature of the preparation and conduct of operations, which will in turn predetermine the possibility of conducting military operations The traditional ways of thinking about the responsibilities of the services may not hold A new war, should the imperialists unleash it, will certainly be strikingly different in nature of the last war.²⁹

Ogarkov then turned to the development of weapons (directed energy weapons perhaps) based on new physical principles. He warned that work on these weapons is already advanced in the United States. "Their development is a reality in the very near future, and it would be a serious mistake not to consider it right now."³⁰ He concludes that this "cannot fail to change established notions of the methods and forms of armed struggle and even of the military might of the state."

Clearly, for Ogarkov these changes potentially fit into the category of "a revolution in military affairs" rather than "military-

technical progress." He was apparently imploring the Soviet system to mobilize once again to support the full-scale development of radically new military weaponry. Earlier, Ogarkov took a thinly veiled swipe at inertia in the Soviet system using the failings of the system at the outset of World War II as a point of departure. The Soviets, he said, had not completed their retraining and reorganization in response to mechanization. "We cannot," he stated, "afford to be caught reorganizing ourselves again."³¹

Ogarkov also admonished his colleagues to be innovative.

The Soviet armed forces cannot rest on their laurels. The emergence of new weapons systems demand the constant improvement of existing forms of combat operations and the elaboration of new ones. Bold experiments and solutions are necessary, even if this means discarding obsolete traditions, views and prepositions."³²

There is little public evidence of resistance to this line. Minister of Armaments V.M. Shabanov recently suggested that the defense sector will be best served by strengthening the economic and technological base of the country.³³ One suspects that Ogarkov had more in mind, perhaps an all-out push in certain areas of technological development of interest to the military, while Shabanov's list seems to be a rather standard set of industrial concerns -- transportation, communications and agriculture. One could take as, at least indirect evidence of resistance to Ogarkov's ideas, his recent dismissal as Chief of the General Staff. He was rumored to have differences with Dmitri Ustinov, the late Minister of Defense and a veteran of defense-industries work. Moreover, some in the service commands were said to dislike Ogarkov's high-handed use of the General Staff and constant pressure for reorganization. Some have suggested that his advocacy for diversification of

nuclear forces (a dyad or even triad) might be a threat to the prestige of the Strategic Rocket Forces Command under Tolubko. A deemphasis of nuclear weapons which Ogarkov seemed to be suggesting in his most recent article would also not endear them to him either. Finally, his particular view might also have been considered a threat or at least a severe criticism of the Soviet defense industries base. Certainly, he would have demanded of it more than it may be able to deliver. Ogarkov argued that the Soviet Union would have to "pursue scientific quests . . . even if necessary . . . taking justifiable risks."

One problem for the Soviet system in the areas that Ogarkov identified is that they require broad effort on a wide range of technologies; albeit technologies related to microelectronics and directed energy weapons in one way or another. This means that the kind of directed effort which brought about the mechanization of forces or the development of ICBMs would not be enough. Ogarkov's challenge for the system is probably one which would require an even greater devotion of resources than the revolutions in military affairs of the past have required.

Nevertheless the former Chief of the General Staff did place himself firmly on the side of those who foresee a new revolution in military affairs coming -- and one which could place great strains upon the Soviet system. Because the Soviet recognize that military-technical progress can only be translated into military might through reform of strategy, training and organization, any revolution in military affairs potentially threatens entrenched interests. Those who look to incorporate technology in an incremental, evolutionary way, forcing it into existing patterns and organizational forms have inertia on their side.

They would also seem to be more at home in a system which is suspicious of innovation and extremely cautious. In order to break through this inertia and to avoid lagging behind when military-technical progress takes on revolutionary proportions, senior officers who understood the full measure of these developments were used to push the Soviet system forward. It will be interesting to see whether this pattern, employed successfully in the past, will be adopted again in the future.

NOTES

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R&D CONTRACTS IN THE SOVIET UNION

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Contracts in the USSR Economy

Economic contracts (khozyaystvennye dogovory) have long played a role in the management of business relations among Soviet enterprises and organizations. State agencies frequently use contracts in defining the details of the economic obligations placed on them by the central planning authorities. The traditional types of economic contracts involve the immediate sale or purchase of goods (kuplya-prodazha), arrangements for the delivery of future production (postavka), and the performance of services (podryad).¹

Economic contracts for research and development work have existed since the First Five-Year Plan. However, early R&D contracts were relatively uncommon, marginally important and functioned more as a means for adjusting state budget allocations than as financial incentives for scientific organizations.² Following World War II the Soviet Communist Party devoted considerably more attention to programs for developing and using new technologies. Part of this increased attention led to a series of measures that promoted economic contracts for research and development as instruments for obtaining more industrially useful technologies from scientific and engineering organizations.

This paper examines the evolution of research and development contracting in the post war Soviet Union. In particular, the paper analyzes the legal and economic discussions that accompanied numerous changes in the rules for R&D contracts in light of Soviet goals for

improving the research, development and innovation performance of the economy.

The Rise of R&D Contracting

1. A First Step: The Model Contract for Experimental-Design Work

In the mid-1950s, Soviet national leaders concluded that past economic policies were insufficient for achieving proper rates of technical innovation, and they began searching for a special mechanism for securing technical progress.³ Great importance was attached to increasing the scientific and technological interaction among ministries and to applying the talents of the scientists and engineers of the educational establishment to industrial objective.⁴

Many ministries and central agencies, recognizing that their enterprises frequently need quick access to the technical expertise of their central design facilities or to the production line experience of other related enterprises, had established internal regulations for model design and development contracts.⁵ Innovations, however, frequently showed little respect for ministerial boundaries and considerable difficulties still existed when enterprises needed to enlist the services of research or design organizations subordinated to other ministries. These problems were exacerbated by separate -- and, perhaps, contradicting -- ministerial decrees. Consequently economic policy makers began to standardize R&D contracting practices on a national level.

In mid-1955, addressing the problems of inter-ministerial cooperation in technical innovation and prodding those agencies that had neglected to establish internal regulations for their own organizations, a national model contract for experimental-design (opytno-

konstruktorskiy) work was promulgated.⁶ The absence of any standard contract in an area where traditional economic contracting practices often proved inapplicable had likely discouraged broader participation of design and development organizations in significant innovation.⁷ This model contract standardized important considerations -- e.g., definition of and recourse for non-fulfillment, establishment of performance schedules, identification of responsible parties, regulation of cost estimates, etc. -- for the contracting parties and probably removed many of the uncertainties that had plagued experimental-design contracting.⁸

The creating of a model experimental-design contract signalled the start of the use of contracts as part of the state-wide efforts to promote enterprise innovation. The model experimental-design contract of 1955 was followed several years later by a vigorous expansion of national legislation for general research and development contracting.

2. Expanding Coverage:

a. Contracts for research and development (1961)

Party leaders, in reforming industrial innovation, decided to shift the financing of R&D away from the state budget and toward independent accounting or self-financing (khozraschet). Economic officials viewed state budget financing as the cause of a number of the problems encountered in moving new technologies out of the state's laboratories and into production. For example, the central administrative personnel who managed the research projects funded from the state budget frequently neglected to consult carefully with the potential using enterprises. The shift from budgetary allocations to self-financing brought the creators and users of new technologies closer together, for enterprises

now contracted their R&D work directly with research facilities.⁹ Financing from budgetary allocations also made R&D facilities financially independent of their customers, i.e., the enterprises using the new technical developments. This independence seriously undermined the R&D facilities' concern about quality or costs. Self-financing R&D facilities were, however, expected to finance operating expenses out of the revenues earned through contracts. These contracts, therefore, brought R&D facilities directly into formal contact with their customers and became instruments for controlling both quality and costs.

In 1961, the Council of Ministers issued a series of decrees and model contracts for both research and development work, thus strengthening the decision to make R&D facilities into self-financing organizations.¹⁰ In establishing contracts for R&D, Soviet legislators confronted some thorny problems. First traditional Soviet contracting practices proved of limited use, for many of them were simply geared to specifying the details of centrally planned deliveries. Economic contracts for planned deliveries differ significantly from the contracts for R&D projects, for unlike the arrangements for the delivery of a standard industrial product, the final results of contracted research or development work are often unpredictable and difficult to describe accurately. Consequently, Soviet legislators had to develop a model contract that established an equitable sharing of the risks of failure. Second, the quality and stage of completion of research work is often difficult to ascertain, and guidelines for adjudicating these issues had to be created. Third, the material incentives for both parties had to be established in such a way as to promote the eagerness of institutes

to engage in important R&D projects and to create a willingness of enterprises to use the results of the contracted work.

Soviet legislators evidently considered the timidity of R&D facilities to be the greatest danger to expanding the use of contracts, for in 1961 legislation carefully attempted to encourage risk taking by research and development organizations. For example, a sponsoring enterprise was still required to pay an R&D facility for any unsuccessful research and development work. In the words of one Soviet jurist, the 1961 legislation made "a presumption of unconditional goodwill on the part of the contractor."¹¹ Furthermore, the sanctions against low quality work performed by an R&D facility were considered toothless.¹² Finally, a sponsoring enterprise's payments to an R&D facility were not affected by the economic value of the research results, nor by the length of time required to implement the research work into production.¹³

In the West, contracting usually involves a considerable amount of negotiation. The actual degree of negotiation possible during the conclusion of Soviet R&D contracts -- especially when the research formed part of the annual plans for both -- is unclear. An important element of a party's bargaining power in many negotiations can be the right not to conclude a contract. Prior to the shift to self-financing, most R&D related contracts were planned and seemed obligatory for both parties. The refusal of one party to conclude a contract was already considered a violation of the other party's rights and could be submitted to state arbitration.¹⁴ After the shift to self-financing, the planned nature of R&D contracts seems to have changed somewhat, for contracted R&D needed to be included in the plans of only one of the parties.¹⁵ Whether the

party without the planned requirements could refuse to enter a contract with impunity is not clear.

Negotiations seemed to center most on the financial arrangements. While R&D facilities felt pressure to cover their costs, bankruptcy was probably never a concern, for cost overruns could likely be covered by budget allocations. The financial concerns of the R&D facilities centered largely on their desire to obtain the bonuses that resulted from operating at a profit and to acquire new equipment.¹⁶ The model contract of 1961 closely regulated the financial terms for the R&D contracts, effectively guaranteeing profits to the R&D facilities and generally placing them in a good position to obtain favorable financial terms.¹⁷

Although the model contract of 1961 sought to place the R&D institutes in a favorable financial bargaining position, it did little to undermine the real bargaining position of the enterprises. R&D contracts were largely concluded for small R&D projects, i.e., tasks that were unlikely to endanger the fulfillment of their production plans. Thus, enterprises preserved their bargaining position by remaining relatively independent of the results of the contracted R&D. Bargaining in R&D contracts likely became the search for modest results that enable both parties to satisfy their respective success indicators.

b. Reform of R&D in the higher educational establishment

Soviet higher educational establishments (VUZy) employ almost one-third of total Soviet scientific workers. During the early post war period, many Soviet policy makers considered the VUZy to be too divorced from solving major economic problems and enacted legislation to redirect the VUZy scientific work more towards industry. One important

legislative change allowed ministries and other national agencies to establish branch laboratories in the VUZy.¹⁸

Economic contracts were a major tool in redirecting the scientific and engineering focus of the VUZy and were prominently mentioned in early legislation. A 1957 internal order regulated economic contracting.¹⁹ Subsequently, a 1962 decree on scientific research work in higher education was passed, with the 1961 model contract for R&D work appended to it.²⁰ R&D contracts were made quite attractive to the VUZy, providing them with sources of new equipment, capital investment funds, and even recreational facilities.

According to one thorough cataloguing of VUZy contract research during the 1960s, the early Soviet legislative efforts brought results. "Increases in the amount of contract work done by VUZy started around 1957. Between 1957 and 1960, the total increased three times, and between 1960 and 1965 it increased two and a half times. Since 1965, the acceleration was markedly less -- 20 percent between 1965 and 1967.²¹

3. An Innovative Proposal: Socialist Licenses

Against a background of major economic reform and constant calls by Communist Party officials for more significant technical innovation in industry, a relatively novel idea for R&D contracts surfaced -- a proposal to establish a "socialist license." The legislation for R&D contracts was targeted primarily at creating new technologies and implicitly assumed that valuable results would be used. Further, R&D contracts were usually concluded between two parties and did not address the task of disseminating the new technologies to other interested, outside parties. In fact, under Soviet law any outside parties -- if

state organizations — had the right to free access to any technology developed by other state organizations in the Soviet Union. Soviet officials implicitly assumed that state organizations would automatically avail themselves of newly developed technologies.

The diffusion of new technology did not, in fact, occur automatically and the Soviet press began to publicize suggestions for promoting the more efficient spread of domestic technologies. One such suggestion, the proposal for a system of domestic licenses, was made by a senior official of the State Committee for Inventions and Discoveries.²² He proposed "socialist licenses" that would give state organizations the exclusive rights to the technologies they develop, including the right to sell them to other organizations within the Soviet Union. This official claimed that Soviet legislation had put those Soviet facilities creating world level technologies on an equal footing with those facilities that remained technically backward. He implied that the backward facilities were parasitic. "Is it just that collectives working creatively and collectives that simply use the results of someone else's work should have equal rights?," he asked.

The original suggestion for a socialist license was cautious and opposed giving the licensor unlimited rights to establish prices. It suggested instead that the payment period for royalties be limited to five years and the amount be limited to 10-15 percent of the savings created by the new technologies. Further, it proposed that both civil and criminal sanctions be imposed on officials responsible for violating the organization's exclusive rights.

An official at the Riga Electric Building Factory (REZ) strongly supported the creation of socialist licensing and joined the public

discussion with a detailed account of his factory's experience in developing and selling an important new technology (the economic savings exceeded one million rubles per year).²³ His factory developed plastic collectors for direct current electric machines. The research and development costs for the collectors totalled over 300,000 rubles. Outside contracts with the Latvian Institute of Mechanics and Polymers, the Kuybyshev Aviation Institute and the Riga Polytechnical Institute cost 52,000 rubles. The factory's own special design bureau spent 216,000 rubles over a ten year period on salaries for 15 designers, while the factory spent over 32,000 rubles building specialized equipment.

In selling its new technology, REZ could use the 1961 model contract only if new research and development work was necessary for adapting the technology to the specific conditions of the user. Thus, when REZ contracted to transfer its new technology, it was unable to charge more than 7,000 rubles, even though some of the users saved more than 200,000 rubles per year. Since the original research and development was already completed, it could not be included into the price of the contract. REZ's contract for selling the new technology could only charge for the wage costs of preparing the documentation, travel expenses to the new site, overhead and planned profits for the transfer. The REZ official, summing up his dissatisfaction with the financial terms, wrote: "We consider that our profit was much lower than what our factory justly deserved as the creator of an invention and as the pioneer of its assimilation."²⁴

The REZ official proposed that innovating organizations be allowed to draft contracts that charge a client a percentage of the savings generated by the innovation. The income from these contracts — rewards

for risk-taking -- would support employee bonuses and fund new R&D projects. Such a system, according to this official, would go far in addressing the present problems of diffusing new technologies throughout Soviet industry.

The proposal for a socialist license evoked considerable opposition. One prominent jurist flatly declared it "incompatible with the basic principles of socialist economics."²⁵ He objected first to what he envisioned as a struggle among enterprises to grab those inventions belonging to individuals, presumably making their owners wealthy.²⁶ Secondly, he believed that socialist licensing contradicted planning and would lead to financial disarray as funds travelled from branch to branch with no central guidance.

The discussion about a socialist license occurred at the same time that economic officials were analyzing the results of the push for greater R&D contracting. Although one Soviet jurist carefully mentioned that a form of socialist licensing existed in the GDR, Poland and Romania, he concluded that "the introduction of licensing relations among Soviet organizations was presently premature."²⁷ He suggested that Soviet organizations needed more experience in compensating each other for domestic transfers of technology and that a traditional economic contract for such transfers would be a more cautious approach.

4. Revising the Legislation on Contracts

After almost a decade of using R&D contracts as a means to improve industrial innovation, Soviet legislators issued new regulations that addressed problems caused by the past legislation, made adjustments for the reappearance of the industrial ministries, and extended the scope of

contracts to cover the transfer and use of new technologies among organizations.

The model contract of 1961 had emphasized the creation of new technologies and implicitly assumed that the results of contracted research would be used. However, a 1968 Central Committee decree, "On Raising the Efficiency of the Work of Scientific Organizations and Accelerating the Use of the Achievements of Science and Technology in the National Economy," preceded the new legislation on R&D contracts and stated prominently "that the shortcomings retarding the use of new technologies had to be eliminated" to achieve the Party's goals.²⁸

Evidently the sponsors of R&D contracts did not sufficiently use the resulting technologies. One jurist described the situation under the model contract of 1961 as follows: "Almost no enterprises carry the responsibility for the use of the work they order, and the scientific institutes carry none of the actual results from implementation."²⁹ New regulations prominently promoted the use of the technologies from contracted research. For example, the new model contract for R&D required that the sponsor state where and how the new technology was to be used.³⁰ Clients could also make the obligation to use the resulting technology a condition of the contract itself.³¹ More importantly, Soviet legislators followed up their revisions of the model contract for R&D with a separate model contract for the transfer of technologies.³²

At the same time the contracting R&D facilities received more legal tools to force the use of their new technologies, they also lost some of the advantages they had enjoyed over their sponsors in the previous model contracts. R&D facilities now became responsible for the quality and timeliness of their work. Technical indicators could be put into

contract and outside experts could judge whether the resulting work met the agreed-upon indicators. Furthermore, if a sponsor deemed it fruitless to continue the R&D work, it could terminate the contract and only pay actual expenses incurred up to that moment. Finally, material sanctions could be applied to R&D facilities that failed to perform the contracted work.

In 1965, Khrushchev's economic regions (sovnarkhozy) were disbanded and the ministerial branch system of organizing the economy was reintroduced. The new legislation on contracts carefully distinguished between R&D that was conducted entirely within a ministry from R&D that crossed ministerial boundaries. The former was subjected to internal ministry orders (vnutriministerskiye zakazy) and the latter, to contracts. Further, point 4 of the 1969 model contract clearly stated that industrial ministries would determine the details of their own self-financed R&D work. R&D contracting was technically applicable only for projects that crossed ministerial boundaries or for projects outside of the national economic plan (point 6). Thus, the reestablishment of industrial ministries left the national campaign for greater use of R&D contracts concentrated primarily on the Academy of Sciences and VUZy research facilities, for their greater involvement in solving national economic problems automatically caused them to deal with other ministries.

The revised regulations for R&D contracting did not establish a socialist license. However, the new model R&D contract addressed some of the problems raised by the proponents of socialist licensing and allowed for small profits (1 1/2 to 6 percent of estimated savings). The contract for the transfer of scientific-technical achievements

rejected making any additional payments to the developer of a technology stating flatly that (point 7): "The cost of the work for the creation of the transferred scientific-technical development is not subject to compensation." Both of the new contracts were more generous to individuals and established sources for considerable bonuses for those involved in creating and disseminating new technologies. The refusal to implement a socialist license likely rests in its perceived threat to centrally planned industrial priorities. Significant license royalties, if used to create material reserves for research organizations, could redirect resources away from priority technologies and simply channel them toward successful entrepreneurs.

The Use of R&D Contracts

1. The Ministry for Higher and Specialized Secondary Education

The campaign to make VUZy R&D programs an integral part of the Soviet industrial R&D effort, aided by the use of R&D contracting, appears to have succeeded. The number of branch and specialized (problemnye) laboratories grew rapidly during the 1970s, from 900 to 1270. If the relative proportions between the branch and specialized laboratories remained constant, there would now be over 700 branch laboratories in the VUZy. Since the work at these branch laboratories is conducted on the basis of economic contracts, the rapid growth in the number of branch laboratories seemingly indicates a broad acceptance of R&D contracting by many industrial ministries.³³ Furthermore, R&D contracts now comprise a significant share of total expenditures on scientific research at the VUZy. One Soviet writer stated that about 80 percent of all VUZy R&D in 1976 was conducted on the basis of economic

contracts.³⁴ The Gubkin Institute for the Petrochemical and Gas Industry reported that 7 million rubles of the financing for its scientific research came from economic contracts, while only 302,000 rubles (about 4 percent) came from the state budget.³⁵

Economic contracting has taken many VUZy far beyond their traditional role as educational establishments. In a sense, economic contracting has brought production to science and made many of the VUZy into seeming extensions of the Soviet industrial R&D effort. The Khar'kov Aviation Institute is one of the more successful VUZ contractors and, perhaps, illustrates the "industrialization" of the VUZy. The Institute's Aircraft Production Department specialized in the explosive working of metals and has obtained a "significant amount" of money from 18 economic contracts. (The Ministries of Ferrous Metallurgy, Heavy, Energy and Transport Machine Building, and Ship Building were mentioned as sponsors.) Furthermore, the Khar'kov Aviation Institute's technical successes led the Ministry of Ferrous Metallurgy to establish a one-million ruble laboratory complex there. In explaining the reason for the Institute's success at obtaining such generous funding, one of the Institute's professors stated, "The VUZ is a nice 'neutral territory' for permitting the adjustment of relations between different ministries that are interested in solving inter-branch problems."³⁶

The initial legislation that brought VUZy scientific research closer to production clearly implied that this effort would involve both civilian and defense-industrial ministries.³⁷ Since Soviet publications rarely discuss the detailed activities of the defense-industrial ministries, it is difficult to establish the extent to which the defense-industrial ministries have participated in economic contracting with the

VUZy. One Western study showed that about one quarter of the unclassified VUZy inventions used by outside organizations were used by defense-industrial ministries.³⁸ If these used inventions are in any way indicative of R&D contracting, then the "industrialization" of the higher educational establishments has likely benefitted both the Soviet civilian and defense industrial research efforts.

2. The Academies of Science

The campaign to use R&D contract also touched the research institutes of the Academy of Sciences system. Although the USSR Academy has a generally recognized mandate to conduct fundamental research, it has participated in economic contracts. By the mid-1970s contract research "accounted for 12 percent of the overall resources of the USSR Academy (excluding capital construction)."³⁹ A number of the USSR Academy's institutes have their own special design bureaus and are, therefore, well-positioned to help industry solve technical problems. The A.V. Shubinkov Institute of Crystallography, for example, did important contract work for the Ministry of the Chemical Industry -- developing laser elements -- and the Ministry of Electronics -- developing film materials.⁴⁰

Republic Academy institutes have traditionally conducted more applied scientific research than have the USSR Academy's institutes. Consequently, the Republic Academies participate more actively in contract research. By 1975, economic contracts accounted for almost 40 percent of the Ukrainian Academy's expenditures on R&D and almost 20 percent of the Siberian Division's expenditures.⁴¹ The Republic Academies also have specialized and branch laboratories, bringing the research institutes into direct contact with industrial enterprises.⁴²

The Paton Institute for Electro-Welding is, perhaps, one of the Academy's greatest users of economic contracts. Although subordinate to the Ukrainian Academy of Sciences, the Paton Institute resembles in many ways a major industrial research facility. It has more than 7,000 employees, a lead research institute, a special design bureau, experimental test facilities, and two experimental factories.

The Soviet press lists the following industrial facilities as recipients of Paton Institute technologies:

Siberian Electro-Thermal Production Assoc., Novosibirsk
Izhorsk Factory, Leningrad
Power Machine Building Factory, Belgorod
Turbine Factory, Khar'kov
Power Mechanics Factory, Zaporozh'ye
Dorogobych Drill Bit Factory, L'vov
Oil-Gas-Geology Production Assoc., Poltava
Oil Machinery Production Assoc., Volgograd
Dnepro Specialty Steel Factory, Zaporozh'ye
A-U Soyuz Specialty Steel Production Assoc., Moscow
Iron Alloy Factory, Nikopol'sk
Metallurgical Factory Azov Steel, Zhdanov
Metallurgical Factory, Zlatoust'
V.V. Kuybyshev Pipe Casting Factory, Makeyev
Pipe-Rolling Factory, Chelyabinsk
Titanium-Magnesium Kombinat, Zaporozh'ye
Kuybyshev Diesel Locomotive Factory, Moscow obl.
Heavy Machinery Production Assoc., Elektrostal'
Heavy Machinery Production Assoc., Zhdanov
V.I. Lenin Heavy Machine Building Production Assoc., Sverdlovsk obl.
Automobile Factory, Bryansk
Experimental Mechanics Factory, Kiyev
Lenin Machine Building Production Assoc., Petrozavodsk
Ordzhonokidze Machine Building Factory, Podol'sk
Red Giant Production Assoc., Moscow
Vatra Production Assoc., Ternopol'
Babushina Factory, Dnepropetrovsk
Kakhovsk Factory for Electro-Welding Equipment, Kherson
Heavy Electro-Welding Equipment Factory, Pskov

In addition facilities of the Ministries for the Radio Industry and Aviation Industry have also received Paton Institute technologies.

While the above list of facilities is certainly not exhaustive, it illustrates the wide-ranging, inter-branch role that the Paton Institute

occupies and is likely indicative of the goals of the Party's campaign for bringing the Academy's research closer to industrial needs.

3. Successes and Failures

Economic contracting seems to have increased the ties of many of the VUZy and Academy of Sciences research institutes to the overall Soviet industrial research effort. Further, the use of contracts within ministries for above plan R&D work seems to have added a degree of flexibility to the R&D programs of the industrial ministries. The incentives for contracts -- new equipment, larger staffing, broader research possibilities, and political contacts -- differ from the general motivation of Western entrepreneurs, but are, perhaps, no less successful. Thus, the introduction of greater R&D contracting bears the marks of an administrative success.

R&D contracting has not, however, overcome a number of the problems endemic to the Soviet economy. First, many Soviet writers assert that most economic contracts are related to petty, insignificant research themes.⁴³ For example, one writer observed that only 2 percent of the inventions created by the Academy and VUZy facilities resulted in economic savings greater than 100,000 rubles.⁴⁴ Another notes that the uncertainties of dealing with outside organizations work against contracting for anything of major importance to the enterprise.⁴⁵ Second, the actual industrial implementation of and broader dissemination of contracted R&D is fraught with many of the familiar roadblocks to innovation in the Soviet economy. The Soviet press has published little on the model contract for the transfer of R&D work, and it has likely proven a weak motivator.⁴⁶ Third, calculations of estimated or actual economic effectiveness form the heart of the R&D contracts, determining

both the contracts' profitability and the incentives. yet, these calculations have always been a source of controversy, and it is doubtful if they can be accurately made in most cases.⁴⁷ Fourth, the formation of branch laboratories and the ability of some research departments to exist on outside funding have caused some internal organizational problems. Some heads of VUZy have felt their authority diluted, and some organizations have seen their subordinate design bureaus overly occupied with the work of others.⁴⁸ Fifth, the majority of R&D contracts are limited to one year, a period considered by many Soviet scientists and engineers to be too short for serious, long-term research and to be a cause of many premature cancellations.⁴⁹ Finally, a large amount of contracting, especially the above plan work, is viewed by some specialists to be poorly coordinated and a source of much duplication.

Thus, R&D contracts, while significantly improving organizational interrelations, failed to solve many of the systemic problems that thwart industrial innovation in the Soviet Union.

NOTES

1. Ya. A. Kunik (ed.), Sovetskoye grazhdanskoye pravo, Moscow: "Vysshaya shkola," 1974, pp. 161-319.
2. Louvan Nolting, unpublished manuscript on Soviet Research, Development and Innovation, (1984), pp. 29-30. See also Vysshaya shkola, Moscow: Sovetskaya nauka," 1957, pp. 229-230.
3. Ronald Amann and Julian Cooper (ed.), Industrial Innovation in the Soviet Union, New Haven: Yale University Press, 1982, pp. 493-494.
4. Approximately 40 percent of Soviet scientific workers are employed by the Academy of Sciences and the Ministry for Higher and

Specialized Education. See Table 32 in Louvan E. Nolting and Murray Feshbach, Statistics on Research and Development Employment in the U.S.S.R., Series P-95, No. 76, U.S. Department of Commerce, Bureau of the Census, June 1981.

5. M.P. Ring, Dogovory no nauchno-issledovatel'skiye i konstruktor-skiye raboty, Moscow: "Yuridicheskaya literatura," 1967, pp. 40-41. Several of the Soviet defense-industrial ministries (Ship Building and the Radio Industry) and one of the "quasi-civilian" ministries (Heavy and Transport Machine Building) were evidently leaders in the implementation of rules for design contracting. A.S. Pribluda, "Dogovor no opytno-konstruktorskiye raboty," Sovetskoye gosudarstvo i pravo, 1958, No. 1, p. 26.
6. Tipovoy dogovor no vypolneniye opytno-konstruktorskikh rabot of April 6, 1955. See A.S. Pribluda, "Dogovor na opytno-konstruktor-skiye raboty," Sovetskoye gosudarstvo i pravo, No. 1, 1958, p. 26.
7. Science and technology related contracts have differed considerably from the ordinary types of economic contracts concluded in the Soviet Union. A.Yu. Kukrus, "Dogovory o provedenii nauchno-issledovatel'skikh rabot v vuzakh," Sovetskoye gosudarstvo i pravo, No. 10, 1975, p. 65.
8. Pribluda, op. cit. 27-32.
9. See point 1 of "O perevode otraslykh nauchno-issledovatel'skikh i konstruktorskikh organizatsii na khoyaystvennyy raschet," Postanovleniye Soveta Ministrov SSSR of 1 April 1961, No. 282. In M.Ya. Chernyak (ed.), Zakonodatel'stvo o kapital'nom stroitel'stve, Vypusk 1, Moscow: "Yuridicheskaya Literatura," 1970, pp. 472-477.

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SCIENCE AND TECHNOLOGY IN THE SOVIET UNION: PROCEEDINGS 3/3
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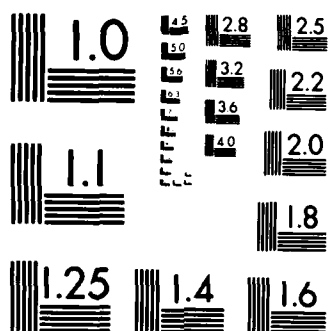
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10. "Polozheniye o proyadke zaklyucheniya dogovorov na provedeniye nauchno-issledovatel'skikh i konstruktorskikh rabot nauchno-issledovatel'skimi i konstruktorskimi organizatsiyami, sostoyashchimi na khozraschete," of 7 September 1961; "Tipovoy dogovor na vypolneniye nauchno-issledovatel'skikh rabot," of 7 September 1961; and "Tipovoy dogovor na vypolneniye konstruktorskikh rabot," of 7 September 1961.
11. V.S. Venetskiy, "Dogovory o sozdaniy i ispol'zovaniy novykh tekhnicheskikh resheniy," Voprosy izobretatel'stva, 1970, No. 12, p. 62.
12. Ibid., p. 63.
13. R. Amann, M.J. Berry, and R.W. Davies, "Science and Industry in the USSR," in Science Policy in the USSR, Paris: OECD, 1969, p. 468.
14. Pribluda, op. cit., p. 26.
15. Ring, op. cit., pp. 48-49.
16. The acquisition of new equipment was evidently a prime consideration for many clients. See example of the Khar'kov Aviation Institute on page 13.
17. The financial position of R&D facilities created by the model contract of 1961 was considered so favorable as to lead one Soviet legal specialist to conclude: "Legal writings are completely justified in emphasizing that these laws (the 1961 decree and the model contract) contradict the principles of self-financing, don't help the struggle for lowering the costs of R&D work, and don't provide economic incentives for fulfilling the plan." Ibid., p. 158.
18. Point 4 of "O merakh uluchsheniya nauchno-issledovatel'skoy raboty v vysshikh uchebnykh zavedeniyakh," Prikaz Ministra vysshego obrazovaniya SSSR of 24 April 1956, No. 357, in Vyssheyaya shkola, op.

- cit., p. 216. The branch and problem laboratories subsequently received model statuses from Minvuz in 1965.
19. "Instruktsiya o porydke vypolneniya i oplaty khozdogovornykh nauchno-issledovatel'skikh rabot v vysshikh uchebnykh zavedeniyakh Ministerstva vysshego obrazivaniya SSSR," 12 October 1957.
 20. "Polozheniye o nauchno-issledovatel'skoy rabote v vysshikh uchebnykh zavedeniyakh," Ratified by an order of the Ministry for Higher and Secondary Specialized Education on 9 July 1962. For a list of other relevant decrees see N.S. Barabasheva, Pravovoy status vuzov v SSSR, Moscow: Izdatel'stvo Moskovskogo Universiteta, 1979, pp. 110-111 and M. Chernyak, op. cit., p. 479-481.
 21. Amann, Berry, and Davies, op. cit., p. 367.
 22. I.L. Mittrakov, "Voprosy stimulirovaniya razrabotki i vnedreniya izobreteniy," Voprosy izobretatel'stva, 1967, No. 6, pp. 9-11.
 23. D.I. Dumesh, "Dogovor- put' dlya shirokogo vendreniya izobreteniy," Voprosy izobretatel'stva, 1969, No. 5, pp. 39-42.
 24. Ibid., p. 41.
 25. V.A. Dozortsev, Pravovoy rezhim avtorskogo svidetel'stva v usloviyakh novoy sistemy planirovaniya i ekonomicheskogo stimulirovaniya, Moscow: TsNIPI, 1969 quoted in V.P. Rassokhin, "O dogovore vozmezdnoy peredachi tekhnicheskogo opyta," Voprosy izobretatel'stva, 1970, No. 9, p. 11.
 26. V.P. Rassokhin commented wryly on this prediction: "A situation whereby enterprises would fight for the right to be the first to implement an invention appears to be a hard to achieve situation about which only investors and the government employees responsible for technical progress can dream." Ibid., p. 13.

27. Ibid., p. 14.
28. "O meropriyatiyakh po povysheniyu effektivnosti raboty nauchnykh organizatsiy i uskoreniyu ispol'zovaniya v narodnom khozyaystve dostizheniy nauki i tekhniki," Postnovleniye TsK KPSS i Soveta Ministrov SSSR of 24 September 1968.
29. S.D. Voloshko, Dogovor na peredachu nauchno-tekhnicheskikh dostizheniy, Khar'kov: Izdatel'stvo "Vishcha shkola," 1978, p. 9.
30. Point 6 of Tipovoye polozheniye "O poryadke zaklyucheniya khozyaystvennykh dogovorov i vydachi vnutriministerskikh zakazov na provedeniye mauchno-issledovatel'skikh, opytно-konstruktorskikh i technologicheskikh rabot," Postanovleniye GKNT of 5 August 1969 with attached "Tipovoy dogovor na provedeniye nauchno-issledovatel'skikh, opytно-konstruktorskikh i technologicheskikh rabot."
31. Venetskiy, op. cit., p. 63.
32. "Tipovoy dogovor na perdachu predpriyatiyami i organizatsiyami svoikh naughno-tekhnicheskikh dostizheniy drugim predpriyatiyam i organizatsiyam i na okazaniye im pomoshchi v ispol'zovanii zaimstvovannogo peredovogo opyta," Postanovleniye GKNT of 31 December 1971.
33. M.I. Piskotin, V.A. Rassudovskiy, and M.P. Ring (ed.), Organizatsionnopravovye voprosy rukovodstva naukoy v SSSR, Moscow: Izdatel'stvo "Nauka," 1973, p. 319 and Voprosy ekonomiki, 1981, No. 11, p. 138.
34. "Vazhneyshaya zadacha vysshey shkoly," Vestnik Vysshey shkoly, 1976, No. 4 in Barabasheva, op. cit., p. 128.

35. V.N. Vinogradov, "VUZ i proizvodstvo- tesnyy kontakt," Voprosy izobretatel'stva, 1973, No. 10, p. 45.
36. V.G. Kononenko, "Razrabotka i ispol'zovaniye izobreteniy v usloviyakh VUZa," Voprosy izobretatel'stva, 1969, No. 3, p. 43.
37. Point 8 of "O merakh ulushcheniya nauchno-issledovatel'skoy raboty v vysshikh uchebnykh zavedeniyakh" of 24 April 1956 stated that before industrial equipment related to defense could be given to VUZy, agreement from the Ministry of Defense had to be obtained.
38. John A. Martens and John P. Young, "Soviet Implementation of Domestic Inventions: First Results," in Soviet Economy in a Time of Change, Volume 1, Joint Economic Committee, Congress of the United States, October 10, 1979, p. 488.
39. Thane Gustafson, Selling the Russians the Rope? Soviet Technology Policy and U.S. Export Controls, The Rand Corporation, R-2649-ARPA, April 1981, p. 65.
40. B.K. Vaynshteyn, V.A. Kuznetsov, and I.N. Tsigler, "Fundamental'naya nauka- proizvodstvu," Voprosy izobretatel'stva, 1984, No. 3, pp. 13-14.
41. V.I. Kushlin, Uskoreniye vnedreniya nauchnykh dostizheniy v proizvodstvo, Moscow: Ekonomika, 1976, p. 138 in Gustafson, op. cit., pp. 61 and 65.
42. B. Paton, "Plodotvornoye vzaymodeystviye," Kommunist, 1981, No. 2, p. 31.
43. Barabasheva, op. cit., pp. 110 and 122 and V.P. Rassokhin, "Pravovoy mekhanizm yedinoy politiki razvitiya nauki i tekhniki," Sovetskoye gosudarstvo i pravo, 1980, No. 4, p. 94.

44. L.Ye. Komarov, "Sovershenstvovaniye izobretatel'skoy raboty v akademicheskikh nauchnykh uchrezhdeniyakh i vuzakh," Voprosy izobretatel'stva, 1982, No. 12, p. 4.
45. Dumesh, op. cit., p. 39.
46. The Institute of Economics of the Ukrainian Academy of Sciences surveyed 300 scientific organizations on work implemented and discovered that about 80 percent was used at only one or two enterprises and 0.6 was used at more than five enterprises. Ya. Akhundov, M. Krasnokutskiy and Sh. Nuradinov, "Spetsilizirovat' vnedreniye tekhnicheskogo progressa," Khozyaystvo i pravo, 1979, No. 1, p. 56.
47. In the early 1930s there was an investigation of 984 calculations made for economic effectiveness. More than 300 were "Phrases that only stated bluntly the savings" and more than 600 were done "unsystematically." Only 36 calculations were done thoroughly. Savitskiy, "Raschety effektivnosti," Izobretatel', 1933, No. 11, pp. 37-38. Between 1957 and 1967 calculations for economic savings were made for only 52 to 58 percent of all inventions and rationalization proposals implemented. Ye. G. Kiriyeenko, "Nekotorye problemy ekonomiki izobretatel'stva," p. 71 in Ekonomika izobretatel'stva "Materialy nauchnoy konferentsii/4-6 Marta 1968," Kiyev: Znaniye, 1968.
48. Barabasheva, op. cit., pp. 120-121 and G.A. Nesvetaylov and L.N. Rutskiy, "Kurs na vnedreniye nauchnykh razrabotok," Voprosy izobretatel'stva, 1983, No. 2, p. 50.
49. A.Yu. Kukrus, "Kogovory o provedenii nauchno-tekhnicheskikh rabot v vuzakh," Sovetskoye gosudarstvo i pravo, 1975, No. 10, p. 70.

AD-P004 570

CLOSE ENCOUNTERS WITH S&T IN THE SOVIET UNION

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This paper attempts to convey a number of personal observations, impressions and conclusions gathered and formulated during a two-year Foreign Service assignment at the American Embassy in Moscow. I was Chief of the Embassy's Science and Technology Section during the Ford Administration.² This period coincided with the peak and initial decline of detente, a time of relaxed relations between the United States (US) and the Soviet Union (SU), when rivalry and competition were replaced by cooperation, and occasionally even collaboration, in areas of potential common interest.

In order to provide some historic perspective and background for understanding the content of this paper, an overview of detente and a description of the principles on which the cooperation in Science and Technology (S&T) was based, have been included. These are followed by a discussion of the organizational structure of US-SU cooperation in S&T.

After examples of S&T cooperation, I will attempt to explain a number of important differences between doing science in the SU and in the US. Attention is also paid to those peculiarities of Soviet management that seem to impact industrial practices and could contribute to slowing the rate of innovation and modernization.

The paper concludes with a few recommendations for obtaining a better balance of mutual benefits while cooperating with Soviet institutions.

Rise and Decline of Detente

In the early 70s a rare conjunction of internal and external conditions in the US and SU led to a rash of new bilateral agreements negotiated by the Nixon and Brezhnev Administrations. The removal of barriers to official travel of businessmen, scientists and technologists from both countries was the result of attempts to consummate mutual commitments made in what Ball calls "a handful of lesser agreements -- largely of a technical nature."³ These exchanges produced some of the more tangible fruits of what is otherwise considered to be quite a controversial set of events -- the US-SU detente.

This conjunction involved several strongly coupled political components. The United States government, entrapped in an increasingly unpopular war in Vietnam, was facing severe domestic problems. Large segments of the population demanded that the government arrange a troop withdrawal from Indochina. The Nixon Administration was hoping that the Soviet Union would intervene on its behalf and help extract it from this quagmire. It also desired to keep the Soviets from gaining further ground in the Middle East. Furthermore, France and the Federal Republic of Germany, America's important NATO allies, had already taken the lead in formulating their own deals with the Soviet Union.

The Soviets in turn were interested in preventing the United States from regaining its lost nuclear superiority and driving up the cost of continuing the nuclear arms race. They hoped to institutionalize their

political successes of the post-Krushchev years. They wanted to prevent the People's Republic of China from forming an anti-Soviet alliance with the United States. Most importantly, a fundamental shift was taking place in the thinking of a number of Soviet top leaders. The US landing on the moon and the continuing growth of Western economy, science, technology and education supported the nontraditionalists' views that the Soviet Union was in a very serious situation and that this situation was getting worse.⁴ A fierce ideological battle, which spilled into many publications, was fought between the nearly evenly divided nontraditionalists and the traditionalists. On the traditionalist side were the following leaders and supporters: Suslov, Shelepin, Shelest, Mazurov, Kovaleva and Demichev. Aligned against them were: Brezhnev, Kosygin, Podgorny, Kirilenko, Inozemtsev and Arbatov. The Kosygin-Brezhnev belief in the Soviet need of Western trade and technology won an important victory when, despite Nixon's stepped up military actions against Hanoi, the May 1972 summit was not cancelled. To the nontraditionalists, the US offered the best prospects for trade in grain and high technology goods. For openers, they were willing to settle for scientific and technological information exchanges.

Many articles and books have been written on detente.⁵ There is little agreement among their numerous authors as to what detente is, who benefits from it and why. I follow the Political Dictionary's⁶ definition of detente -- a condition of an easing of confrontations and reduced strain between two or more countries. Following Albert Weeks,⁷ I take 1971 to be the beginning of the Brezhnev initiated SU-US detente; its high point I take to be July 1975 when, following the successful Apollo/Soyuz docking mission, the Soviet press stopped all criticism of

the US and carried only positive news about the friendly SU-US relations. Not since World War II had there been such an outpouring of affection for the United States of America throughout the USSR! A Leningrad paper even compared the handshakes in space with those exchanged 30 years earlier when the Soviet Army met up with the American Army at the Elbe river in Germany, ending the European phase of the war. This high point can also be considered the midpoint of US-SU detente. Brezhnev began to suffer setbacks in 1974 when the US Congress increased the Soviet price for most-favoured-nation status by demanding that Jewish emigration be expanded. The traditionalists and the Soviet military grew in political strength, and by the end of 1975 the euphoria over SU-US relations disappeared from the Soviet press. In the US opponents of detente also gathered strength. When in 1976 President Ford dissociated himself from the controversial detente label, the US-SU cooperation in the S&T bilaterals lost some of its Washington support. The Carter Administration instituted performance reviews of the S&T bilaterals. The worsening political relations between the two superpowers led to open expressions of misgivings and criticisms of management of the S&T bilaterals, apprehension about violations of human rights of Soviet scientists and concerns about transfers of sensitive technology. With the Soviet occupation of Afghanistan in 1979, most of US enthusiasm for joint scientific and technological activities evaporated.

Today, five years after the collapse of detente, we are beginning to gain some historic perspective and understanding of the reasons that led to its demise. Both sides expected too much too fast. The US Congress attached too severe conditions on the trade agreement

negotiated with the SU. Thus, with the exception of US sales of grain, the hoped for expansion of US-SU trade did not materialize. The Ford Administration began punishing the Soviets for their involvement in Angola by withdrawing cooperation in scientific exchanges. The Soviet science bureaucracy was denying American scientists access to sites and laboratories and trying to short-change them in some of the exchanges. The Soviets also continued to exercise political control over attendance at joint meetings and workshops by their scientists. The hoped for improvements in human rights to which the Soviets apparently committed themselves by signing the 1975 Helsinki Security Accord did not materialize. The 1976 election campaign caused the Ford Administration to toughen up its demand on the Soviets when implementing the bilateral S&T agreements.

Principles of S&T Cooperation

The Joint Declaration of Basic Principles of US-USSR Relations, signed during Nixon's May, 1972 visit to Moscow, contains five principles which were intended to establish the basis on which the other US-SU bilateral agreements should rest. The principles: (1) assert the necessity to avoid confrontation; (2) demand a showing of mutual restraint; (3) reject the exploiting of tensions; (4) renounce expansionist claims; and (5) express a willingness to coexist peacefully in order to build a firm, long-term relationship.

The 1972 summit included: several agreements related to SALT, an agreement to institute measures to prevent air and sea vehicle collisions, the ill-fated trade agreement, which never came into effect because the SU would not accept the Jackson-Vanik amendment, and the

first four of eleven so-called S&T agreements. The last were an agreement for the Apollo-Soyuz space-ship docking project, an agreement for cooperation over a broad scope of fields in Science and Technology, an agreement to cooperate in the field of Medical Science and Public Health, and an agreement to cooperate in the field of Environmental Protection. By the end of 1974 all eleven S&T agreements were signed.

Figure 1 contains a chart of the eleven bilateral agreements of cooperation in nine specific fields of science and technology. All of these S&T agreements were concluded during the three Nixon-Brezhnev summits: 1972 (in Moscow), 1973 (in Washington) and 1974 (in Moscow). Not included in the chart are agreements signed during the Eisenhower administration on cultural and scientific exchanges and between the Soviet and American Science Academies, which were also in force and active during the detente years of 1971-1979.

All of the Nixon Administration S&T agreements were to be implemented following three principles of cooperation: (1) equality, (2) reciprocity and (3) mutual benefit. The monitoring and coordination of the joint scientific activities under the S&T agreements was the responsibility of the US Department of State. Ten years ago, when I was being briefed on my Foreign Service assignment to Moscow, the need to pay meticulous attention to these three principles of joint work was stressed to me. Helping to safeguard these principles was one of my main duties at the Moscow post. We all understood that the performance of implementing the eleven S&T agreements was under close scrutiny in both countries.

Besides serving as a political test of good intentions, the bilateral S&T agreements were also very expensive. During my tenure in

Moscow, US-SU cooperation expenditures reached nine digit dollar levels. (By far the largest contribution came from NASA, which invested about \$200 million into the joint space docking project.) With such a large commitment of resources it became important to insure against unauthorized technology transfers and breaches of national security. The cooperation also taxed both sides' abilities to live up to their agreed upon commitments while coordinating activities at many levels of their respective institutional structures. As far as I was able to monitor, the cooperation the United States received from the Soviet lead agency, the State Committee for Science and Technology (SCS&T), was very good and quite comparable to that we accorded to the Soviet side. This, I believe, resulted in no small measure from the management skill and dedication to the cause of detente of its chairman, Academician Vladimir Kirillin.⁸

In contrast to the professional and business-like cooperation received from the administrators in SCS&T, the Soviet Academy of Sciences (SAS) had administrators which were less efficient and less cooperative. While many of the US-SU exchanges involving the Academy came under the old Interacademy agreement, which was not subject to the principles of equality, reciprocity and mutual benefit, a number of the joint S&T projects were administered through the usual Soviet Academy channels. It was not always clear whether the inferior handling by the SAS was targeted against the American or Soviet side of the exchange.

To measure reciprocity, the Embassy Science Section developed a database program called ZNATOK.⁹ It was designed to track progress of over 1000 yearly exchange events. It enabled us to compare American and Soviet participation in the various exchange programs.

Assessments of mutual benefit were derived from site visits, participation at meetings, interviews of the American exchanges and analyses of several types of official reports. We also benefitted from information exchanges with many of my science attache colleagues at the other embassies in Moscow. We held regular meetings with our counterparts from the UK, FRG and Japanese embassies. On occasion we also met with science attaches from the French, Swedish and Mexican missions.

Interpreting the principle of equality was a more difficult task. With the exception of a small number of scientific and technical fields, such as controlled thermonuclear fusion and electrometallurgy, US technology was, and remains, more advanced than that of the SU.¹⁰ It was therefore seldom possible to select specific areas of science and technology that had arrived at an equal stage of development in both countries. It was less difficult, though still troublesome, to find comparable areas which, while removed from military applications, had matched levels of technological development. Nevertheless, we did see to it that each cooperating side supplied nearly equal contributions and received nearly equal benefits.

It may be of interest to note that in a number of cases where we discovered imbalances in favor of the Soviet side, they were traced to inadequacies caused by the American side. When one of the Working Groups organized a large number of long term exchange visits, the Soviets sent seasoned and knowledgeable scientists to the US. In return, we sent young Ph.D. graduates who were not able to find jobs at home and satisfied to obtain a postdoctorate assignment in the SU. Inability to fill exchange slots with comparable talent and inadequate funding of our programs were shortcomings for which we alone were

responsible and which were not willfully caused by our Soviet counterparts. A likely cause for this imbalance was due to inferior accommodations and living conditions in the SU.

Cooperating Institutions

Most of the S&T bilateral agreements were headed by a Joint Committee or Commission that was obligated to meet once a year to receive reports and authorize next year's activities. The Committees were jointly chaired by high-level leaders in both countries. The composition of the chairmanships in early 1978 is indicated on the right side of Figure 1.

Each agreement was composed of several Joint Working Groups. The names of the 84 Joint Working groups associated with the ten Bilateral Committees at the end of 1976 are listed on Figure 2. (The Artificial Heart Agreement was administered through one of the Medical Science and Public Health Agreement Working Groups, since its US chairman came from the private sector.) The term Working Group is a misnomer. Most Working Groups were committees that supervised other joint groupings and had the responsibility of reporting the results during the yearly meetings of the Joint Committees of each of the S&T bilateral agreements. Under some of the more active agreements, such as the Environmental Protection Agreement and the Medical Science and Public Health Agreement, the organizational structure branched as low as four levels below the Working Group level. I counted 1300 nodes on the hierarchy established by the leadership of the eleven S&T bilateral agreements. Each node of the organizational tree of these agreements represented an organizational unit of bilateral cooperation in some field of science,

technology or environment. Each of these units was jointly chaired by an American and a Soviet.

Chairmen were positioned within the organizational hierarchy of the bilateral S&T Agreements by the rank they held in their respective countries. Each pair of joint chairmen was also matched by rank, when forming the joint chairmanships. This ranking and ordering within the agreement organizations of individuals belonging to US and SU institutions enabled a number of significant comparisons. It became possible to identify corresponding or equivalent institutions in the two countries and gain some understanding of their differing internal structures and characteristics and, on occasion, relative strengths and weaknesses.

Figure 3 shows a chart of the structure of the American government. The lead governmental agencies for the eleven S&T Agreements are identified by a double asterisk, **, while those responsible for activities at the Working Group level or below are identified by a single asterisk, *. All of the asterisks appear in the Executive Branch, whose organization is represented in four tiers: the first being the Office of the President; the second, the so called "White House" agencies; the third, the Departments that are headed by full cabinet rank Secretaries; and the fourth, the semi-autonomous agencies charged with narrower and more technical missions and headed by subcabinet rank individuals.

Figure 4 shows a chart of the Soviet Government, arranged to correspond in structure to that of the American Government. Its lead agencies for the S&T Agreements are similarly identified. Just as in the American case, all the asterisks are confined to the branch of the Soviet government that is charged with administrative functions. The organization of the Soviet administrative branch is represented in seven

tiers; the first is the Council of Ministers, which corresponds to the American Office of the President; the second and third tiers contain organizations with functions analogous to those of the second American tier -- of coordinating activities across the numerous ministries; the fourth and fifth tiers, the All-Union and Union Republic Ministries, correspond to the third American tier, with the important difference that they also include many of the functions carried out by the American private industrial sector; the sixth tier, the Republic Ministries, corresponds to the American State Governments; the seventh tier, contains the more narrowly focused, mission-oriented organizations, which correspond rather closely to the American fourth tier agencies.

It seems worthwhile to note that the American executive branch is more streamlined and concentrates more power at its two top tiers than its Soviet counterpart. In contrast, the Soviet Union concentrates some of the power and control in the party leadership, which combines some of the powers of the American Presidency with those of the American Congress.

The above structural differences did affect the implementation of the S&T Agreements. The US institutions, charged with the responsibility of implementing the S&T bilaterals, were located within the branch that exercises more independent decision making power and therefore can be more decisive than its Soviet counterpart. A common complaint of the American side, during my stay in Moscow, was that American decision makers seldom dealt directly with their corresponding Soviet decision makers. These often remained hidden in their powerful Politburo posts. On the other hand, the Soviet side voiced the complaint that they were frequently deprived by the Americans from direct dealings with

individuals from the seat of US industrial might, the American business, which controls a significant portion of non-military US S&T resources.

The distribution of double and single asterisks on the charts in Figures 3 and 4 reflects similarities and differences in the division of authority among those American and Soviet institutions that participated in the S&T bilateral cooperation. It can be inferred that the Soviet side concentrated more responsibility at the coordinating top tiers while the US relied more heavily on the cabinet level tier for high level control of the eleven agreements. For the actual implementation, the Soviet side concentrated the working assignments within their fourth and fifth tier ministries, while the US has more nearly divided the load between the third and fourth tiers. Also noteworthy is the heavy concentration of authority and work in two Soviet organizations: the SCS&T and the SAS. Neither the Office of Science and Technology Planning (OSTP) nor the National Science Foundation (NSF) or even the semi-private National Academy of Sciences (NAS) have power or status that compare with those of these two Soviet bodies.¹¹

Since the quality of an institution is directly related to the quality of individuals that make it up, a description of observations, based on broad contacts with individuals from both sides may here be in order. From interactions in many high- and low-level meetings during which negotiations, exchanges of information, reports on past accomplished work and planning of future work took place, consistent patterns could be discerned in the differential characteristics of American and Soviet government officials.

Americans at the lower levels of the hierarchy appeared to know their technical and administrative tasks much better and were also much

better informed on matters important to their activities than their Soviet counterparts. On the other hand, the high ranking Soviets were more informed about detailed and crucial matters than their American counterparts. The cross-over points appeared to occur at the Soviet Deputy Minister's level and the American Assistant Secretary's level respectively.

The lack of experience at the upper levels of government did significantly disadvantage the American side. This disadvantage is presumably due to well known facts of American political life. Because of the relatively higher rewards for individuals working in the private sector, a greater proportion of high caliber persons tends to be attracted to it. Furthermore, because of the two party system in America, individuals appointed to the higher echelons of American government, remain in their posts for shorter times than their Soviet counterparts. Therefore, for a good portion of the time, American novices faced Soviet experts across the negotiating table.

Examples of S&T Cooperation

The evaluation criteria of US-SU S&T cooperation differed widely from US organization to US organization. Each had its own set of objectives for cooperating with its counterpart Soviet organization. Furthermore, the White House and the State Department also had their own perspective on evaluations.

In 1977, Dr. Richard Garwin of IBM chaired a National Research Council Review Panel that evaluated for the White House the five-year performance of the Joint Commission supervising the Bilateral Agreement in Science and Technology. The Panel interviewed a large number of US

participants in the joint activities under this agreement as well as outside experts. As a result of the Panel's evaluation it concluded that only one of the eleven Working Groups should be terminated because its exchanges had little or no beneficial effect on US Science. The two highest ranked Working Groups were Applications of Computers to Management and Electrometallurgy. The judgments of the Garwin panel agreed closely with my own. The only addition which I would make concerns my belief that for the most part those unbalances that favored the Soviet side were due to our own behavior.

A year later Joseph S. Nye, Jr., at that time Deputy to Under Secretary for Security Assistance, Science and Technology, discussed the State Department approach to the exchanges. It was to use scientific and technical cooperation as a tool for promoting closer bilateral relations with Eastern Europe and the Soviet Union. He mentioned four objectives for developing sustained cooperation: (1) a relative equivalence of input and a balance of "output" benefits; (2) a broad access to Soviet S&T, individuals, data and institutions; (3) promotion of commerce; and (4) application of export controls.

A complete overview of US-SU programs during detente is beyond the limits of this paper. However a brief mention of a few examples is necessary for the establishment of concrete notions about the S&T exchanges. These examples have been picked from among several dozens of research programs and other joint activities with which I had more than a fleeting acquaintance during my Moscow assignment.

James Muller, lecturer at the Harvard Medical School, worked under the Working Group of Cardiovascular Disease of the Medical Science and Public Health Agreement with a Soviet physician on a study to determine

the efficacy of hyaluronidase to limit the size of myocardial infarction. The study took full advantage of the superior Moscow ambulance system, as well as a specially created network of five hospitals, to provide access to heart attack patients within forty-five minutes of the attack. The Moscow project provided quick and reliable results which led to a larger study in Boston.

William Jackson, Director of ERDA's MHD Division, codirected with Academician Sheyndlin, director of the High Temperature Institute, joint R&D in Magnetohydrodynamics (MHD), a promising new method to generate more efficient commercial electrical power by making the magnetic field-encased fossil-fuel flame conducting in a parallel open cycle system. The complementary aspects of the joint effort were based on a division of labor and common access to unique resources provided by each R&D partner.

Brian Tucker, Research Associate at MIT's Department of Earth and Planetary Sciences, carried out joint earthquake hazard research at the Seismological Expedition in Garm, Tadzhikistan for over 18 months. The field station is located near the Surkhob river, in a region that has an earthquake frequency four times that found near California's San Andreas fault. Together with his Soviet colleagues, the MIT researcher collected and analyzed standing seismic wave patterns in a small valley at the foot of the mountain range known as Zeravshans.

Unquestionably the highlight of US-SU cooperation under the S&T bilaterals was the Apollo-Soyuz docking mission. It was also one of the most exciting experiences of my stay in the Soviet Union. It is important to recognize that the Soviet Union does not have separate space installations for civilian and military missions, the way the US does.

Thus our cooperation strained to the limit the Soviet ability to provide proper access to our side without leaks to their security. In this close encounter game the Soviets seemed to have done rather well. Three Americans accompanied Ambassador Stoessel to the rocket launch area at Baykanur near the "closed" space city of Leninsk. I was one of them. It was only after our return to Moscow, when Soviet TV replayed the news of the preceding day, that I realized that there were two VIP parties at the military base. Besides the US Ambassador, Baykanur's commanding General was also hosting his own boss, Marshal Tolubko, Commander of the Soviet Strategic Forces. No wonder that our hosts were so concerned that we get to each station on time. They were touring two VIP parties and making sure the American and Soviet parties did not bump into each other.

One gains a bit of respect for Soviet technologists as one contemplates the technical problems of rocket transport and fueling in a place where the ambient temperature varies between summer and winter over a range greater than 160°F. We were not able to assess Soviet instrumentation. The place was swept clean of all but the equipment required under the negotiated terms of the agreement. While we were watching the punctual lift-off, the TV monitor lost its picture and our host, the late Academician Petrov, Chairman of Interkosmos became so embarrassed that he turned the monitor off. Only after loud complaints, voiced by his own subordinates, to allow at least the sound to come through, did he turn the equipment back on.

When, several seconds after lift-off, I tried to congratulate my host on his success, the Technical Director of the Baykanur base, cautioned with the words: "Not yet, not yet." Soyuz 19 had not yet

reached the point of no return. When the rocket finally reached orbit, he relaxed. I was very surprised to hear him mumble faintly 'dopolnyil' (fulfilled). This seasoned veteran of manned space flight, who had worked with Korolev and Gagarin, was telling himself that he fulfilled his part of the planned mission. From then on the Moscow Control Center took over, and this media exposed event became somebody else's problem. A few days later I saw on TV Cosmonaut Leonov, the spaceship commander of the successful Soyuz 19 mission, reporting to Brezhnev in the Kremlin and using the very same word: 'dopolnyil.' This experience showed me that members of the Soviet elite are bound by a high degree of dedication and a strong drive to accomplish their assigned missions. Throughout my travels I met other Soviets who took extraordinary pride in their work.

Peculiarities of Soviet Science

Soviet Science differs from American Science along two dimensions. The first dimension is its content. By that we mean the systematized knowledge which science provides us about the world that surrounds us. The second dimension is its method. By that we mean the ways and means by which we gain that knowledge.

The differences in content between American and Soviet Science are well known. They are visible to all who read Soviet and American Science journals. These differences are minor when comparing mathematical and physical sciences but increase rapidly as one moves from the physical toward the social end of the science spectrum.

In contradiction, substantial differences are found along the second dimension -- the methods used for doing science. This is not

surprising, since large differences in social and economic settings should produce large differences of doing science in them.

Science plays a significantly different public role in the SU from that in the US. This is partly the result of the greater attention that it gets from Soviet political leaders. They are more concerned about science activities than their American counterparts. They strongly believe that science-based R&D is the chief factor that governs industrial growth. Thus Soviet leaders often blame science for stagnation and shortfalls in agricultural and industrial outputs. They expect tangible contributions from their huge investments into big science projects.

These high expectations, which are constantly reinforced in Soviet mass communication media, provide Soviet scientists with a relatively higher social status than that accorded to American scientists by their society and government. Viewers of Soviet TV expect their scientists to provide the means of raising their living standard and not just the means of building a military machine that will secure them from enemy attack. Compare that with the image of wizardry and lust for controlling events that the US mass media provide about scientists. In the US the dedicated scientist's image is being relegated to science fiction and to education. On the other hand the Soviet public sees a dedicated corps toiling away on problems important to national survival. Is it a surprise that it shows little sympathy and understanding for the renegade dissidents who are not appreciative of the perks that the society allows them?

In actuality the large mass of Soviet scientific workers perceive their daily tasks as routine jobs not relevant to the country's economy.

They see them as futile busy work similar to that carried on in other governmental offices. This however is not the whole story. One also finds a small number of extremely dedicated individuals who pursue science with unremitting religious fervor.

Another peculiarity of doing science in the SU is that even the most advanced and sophisticated activities have to be carried out in an environment typical of a technologically semi-developed country, where latest high technology coexists with levels of development characteristic of the early years of this century. Institutes and national programs achieve excellence through self-sufficiency under the command of a single, extremely capable leader. Seldom is there a second-in-command who can fully replace a departed leader. Thus the Soviet landscape of science is dotted with peaks of excellence rising from a plane of mediocrity and backwardness. Soviet science leaders such as Korolev, Kurchatov, Landau and Yoffe are exceptional exemplars superbly combining of management skills with deep understanding of scientific matters. They would have been major contributors under different circumstances or in different countries as well.

In the US, where there is a much greater professional mobility, concentrations of excellence as large as those in the SU are rare. They appear mostly during times of war or other stressful situations. Top US scientists and science administrators are subject to strong incentives to disperse. While this provides a more uniform distribution of talents and capabilities it also weakens the few centers of excellence in existence.

By setting up an export embargo, the US has been successful to compel the SU to divert its resources into areas it has not planned to

expand into. This can, however, at times, become counterproductive of the aims of the embargo architects. A former Princeton University physics professor informed me that Academician Kapitsa told him that the Soviet optical instrument industry traces its rapid and successful development to US President Eisenhower. Without the embargo imposed by the Eisenhower Administration, Soviet optical instrument design and manufacture would not have developed in the 60s.

The strong preference that Soviet Science gives theory over experiment is not just due to the lack of needed instruments. It has also a lot to do with a perceived need to avoid personal risks. It is unhelpful to depend on others in a society which is riddled with a large number of economic and political constraints. I believe that Soviet excellence in mathematics, theoretical physics, cybernetics, control theory and economics is a direct result of social and economic conditions.

In a paper, written in Moscow,¹² I implied that there may be an answer to the question "why was the transistor not invented in Leningrad?"¹³ In my description of the early Soviet contributions to the discovery and study LED phenomena I pointed out that in fact the Russians had come very close to making the transistor invention. If, during the late 30s, B. Davydov, Ya. Frenkel, V. Loshkarev, O. Lossev, and A. Yoffe, all living at that time in Leningrad, had gotten together, they could have invented the transistor by sharing the pieces of the knowledge puzzle that were in their respective possessions. Unfortunately for the Soviets, lateral communication was and continues to be strongly inhibited among research workers. This is especially true for communication between theoreticians and experimentalists. In my view,

it is the social infrastructure of doing science in the SU that impedes discovery and invention.

Soviet Management Practices

Among the more important differences between Soviet and American management practices is the strong vertical alignment that permeates nearly every working place in the Soviet Union. By this I mean that in the Soviet Union, equally ranked middle managers do not communicate directly with each other. They deal with each other through strict organizational channels. If one were to suggest to a Soviet middle manager that, in order to solve a tricky red tape problems, he should communicate with his counterpart at another ministry, he would either show contempt or fear in response to such a suggestion.

This vertical alignment of nearly all organizational communication has both economic and social roots. Each industrial ministry in the Soviet Union corresponds economically to an entire industry in the US. All chemical, all optical, all electronic, etc., enterprises find themselves under a single management in the SU. They therefore differ radically from Western industrial organizations, by being devoid of strong intra-industrial competition.

Instead Soviet industry is subject to inter-industrial competition. If the power industry's R&D budget gets cut, it is usually because the funds and resources have been allocated to a different industry, such as health. For this reason a Soviet middle manager in the chemical ministry will find it as difficult to discuss business with his Soviet counterpart in the pulp ministry as an American manager from General Electric would find sharing know-how with his American counterpart at

Westinghouse. Naturally the CEO's of those firms will meet and exchange information, just as ministers will in the SU. But neither pair of top level managers will trust their underlings to carry on profit- or budget-sensitive conversations.

I recall a situation which occurred during the US-SU joint activities under the Agreement for Environmental Protection. The Soviet side was finding it very difficult to prepare a schedule for a one week tour of the Joint Working Group on Water Pollution. It has been nearly one year since they promised to provide an itinerary and they continued to provide what looked to the American side to be transparent and unsatisfactory excuses. It eventually became clear that the sources of the problem was that middle managers from the Chemical, Gas, Petroleum, Pulp and Paper, Coal, Ferrous Metal and Non-Ferrous Metallurgy ministries, all regulated river polluters, were unable to communicate with each other to agree upon a schedule of visits that suited their top managers. Upon my suggestion, they all met with us in the office of the Secretary of the Agreement, who worked for the Hydrometeorological Service and had no organizational jurisdiction over the managers. It became clear to me that this was the very first instance when they faced the uncomfortable situation of having to talk to their counterparts in other ministries.

My own observations of the workings and decision makings within single ministries, whether in the industrial sector, such as the various fossil fuel power ministries, or the service sector, such as health and transportation ministries, are that, on the whole, the operations of the Soviet Government are more efficient than the operations of the American Government. What accounts for our superior performance and efficiency

is due to our private sector. It is the economic competition of many firms within each of our industries, such as chemical, electronic, communications, etc., which provide the mainspring for innovation. It is the monopolistic industrial structure within Soviet industries and the captive market which stifles innovation and slows down the upgrading of products and services.

The Soviet economy is further disadvantaged by interministry rivalries and competition for resources. Inadequate incentives to keep their delivery schedules are provided for ministries that supply components to ministries that build systems from these components. Phone calls or letters from one deputy minister to his counterpart at the delinquent ministry about poor quality or bad design of goods are seldom effective. It may take months to chase down the complex cause of each deficiency through the labyrinths of organizations and networks of responsibilities. That is why we see sporadic attempts to cut through the Gordian knots of entangled Soviet bureaucracies with the journalistic pen. In comparison, coordination across industries is self-regulating in the United States by free market forces which control vendor/customer relationships.

The more highly politicized Soviet high-tech enterprises continue to exist and proliferate, whether they are efficient or not. While Soviet S&T enterprises do have a surprisingly large share of capable entrepreneurs, they seldom benefit from customer feedback as a natural regulatory force which could help control the growth rate of their enterprises.

The Unresponsive Academy

An example of an organization that at times can get out of control is the Soviet Academy of Sciences. The following account of what happened nearly ten years ago illustrates facts that do not fit a stereotypical image of the SU.

The Academy of Science of the SU celebrated its 250th jubilee in 1975. The spectacular opening ceremony in the Kremlin Palace of Congresses included a tough speech by Leonid Brezhnev. I listened to every word from the visitors' gallery. In his address to the scientific elite the Soviet leader criticized their aloofness from and non-involvement in industrial R&D. Listening to his admonitions, I became convinced that the Government-funded Academy and its high technology institutes will be obligated to respond speedily to his call. I expected that, within a short time, much of Soviet fundamental research would be replaced with more practically oriented development. I was therefore incredulous when, a month later, one of the key scientists at the Yoffe Technical Physics Institute in Leningrad assured me that there would be no changes and that fundamental work would continue as usual.

At that time (in the Fall of 1975), the Academy's acting President was Academician Kotelnikov. He replaced President of the Academy Keldysh, who had to resign due to a heart ailment. Having met both men, I judged Kotelnikov to be the weaker of the two. However, by the time of the 26th CPSU Congress, in February 1976, the Soviet Academy had a new strong leader, President Alexandrov. I watched with fascination an exchange of views between Alexandrov and Brezhnev on Soviet television. To my surprise, Brezhnev openly retreated from his original position.

He agreed with Alexandrov that theoretical work of the Academy must go on. I heard him quote an old communist slogan: "There is nothing more practical than a good theory." My Leningrad contact turned out to be right after all! The Science Academy had won one more skirmish with the Communist Party.

I also learned another lesson. This largest and richest scientific organization in the world continues to retain a large degree of independence. It is yet to be fully tamed by either the Soviet Government or the Communist Party. I believe, as does Graham¹⁴ that the Soviet Union is psychologically more committed to support science than any other country; East, West or South.

On another occasion I witnessed an event that signaled a relatively safe but powerful expression of defiance by the rank and file scientists employed by the Academy. This happened when Academician Peter Kapitsa delivered a lecture during one of the symposia organized to celebrate the Academy's 250th anniversary. His talk was strongly at odds with the official Soviet position that a so called "Energy crisis" was just a political invention of the United States. Kapitsa, who has since received a Nobel prize in physics, had survived the Stalin era, despite his open nonconformism. In his 1975 talk, Kapitsa declared the energy problem to be mankind's number one problem. He also argued that nuclear fission cannot be a viable solution to the energy problem. He based his argument on the fact that insurance companies in the United States are not willing to insure nuclear reactors against accidents. Kapitsa's talk drew a long ovation from the audience of Soviet scientists, who packed the Academy auditorium. After the talk one of the Soviet scientist came over and told me: "What a bombshell!"

On Constructive Criticism

The Soviet economy is currently under substantial stress, produced in part by rapidly but unevenly accelerating computerizations in many of its industrial sectors. Strains are most evident in those infrastructures that have to support computerized industries and service organizations, and that tend to respond poorly and adapt slowly. Information about Soviet industrial maladjustments of all kinds can be gleaned by assessing newspaper and magazine contributions of muckrakers. This channel is not just an important safety valve that on occasion reduces stresses and strains of the Soviet organizational fabric, but also an effective means of communication that reaches the political elite directly under conditions which optimize its responsiveness. However, such airing of scandals in public is a relatively severe step, undertaken only after weighing carefully the political consequences of actions against inaction. Depending on circumstances, it can give rise to mild effects, such as reprimands, or to profound ones, such as dismissals and reorganizations. A few cases are described below.

The June 1984 issue of the Economics Journal carried an article by the Director of the Central Planning and Design Bureau in charge of Mechanization and Automation in the Ministry of Instruments, Automation and Control Systems (Minpribor). He blames bureaucracy for the low efficiency of Soviet R&D. His vertically integrated organization is alleged to be perpetually hamstrung by the nondelivery and nonavailability of computer technology, peripherals and automation equipment. He complains about rapid proliferation of new low quality and inadequate capability research institutes and design bureaus. He laments the

creation of unnecessary overhead and the dispersion of talent. He also blames the authorities for unjustifiable restrictions and petty non-relevant regulations and thus the stifling of initiative and innovation in his bureau.

In the February 3, 1984 issue of Izvestiya, a nation-wide newspaper second only to Pravda, a Siberian Academician attacks the inadequacies in vocational training of programmers. He desires professionalization with a code of ethics similar to those established by the medical and teaching professions. He believes that the solution to the problem of how to write highly reliable programs for an extensively computerized economy lies in economic incentives and professional status for programmers. He complains that Applied Mathematics departments are not updating their curricula in the 1980s and that higher level engineering education curricula neglect applied mathematics. In thinly disguised fashion, the author, presumably associated with the Siberian Institute of Computer Science, calls for propping up the vocational education reform sponsored by the Central Committee of the Communist Party. This he thinks should be done through research and experiments on teaching computer understanding of the kind carried out at his own Institute.

The above articles relate to specific organizations and are penned by individuals who, through attack on other organizations, may want to deflect criticism from themselves and their operations, and thus spread the blame. Such openly aired conflicts can serve many purposes. Besides being a warning to accused officials, whether anonymous or identified by name, these muckrakings are intended to keep a great multitude of officialdom in check by providing concrete instantiations of public exposure. Caution should be exercised not to generalize what

could be isolated incidents of ineptitude and inefficiency into a sweeping epidemic that effects a wide range of technologies and industries.

Another instance of broad criticism is found in a front page editorial of the May 16, 1984 issue of Pravda, the main Communist Party Communication link and required reading for every Communist Party functionary. It addresses shortcomings of New Technology Introductions. The editorial focuses on R&D as the mainspring for solving S&T problems crucial to economic growth, echoing the 1983 Party-government resolution on this topic. It singles out for criticism the rate by which results of R&D on laser and powder metallurgy are being introduced into the economy. A major culprit of this inadequate introduction rate is alleged to be that "the old habit of viewing plan indicators for S&T development as secondary when compared to ongoing production plans is causing inadequate allocation of financial, material and labor resources needed to establish new plants and introduce new products." Notable exceptions, mentioned in the editorial, are microprocessors and microcomputers, whose yearly rate of production increase, since 1980, is reported to have been 50 and 26 percent respectively.

Broad criticism is also presented in a January 28, 1984 article of TRUD (Labor), the organ of the Labor Union. Issues relating to computer manufacture and servicing are addressed. An army of several million operators and repair persons is reportedly needed to keep hundreds of thousands of installed medium size computers in operating condition. The article alleges that this army is necessary to cover up poor reliability, bad design and faulty manufacture of these computers. Proliferation of agencies, involved in the manufacture of computers and the mushrooming of production organizations of specialized devices, is

claimed to be responsible for the poor quality of products. Design and production of optoelectronic computers are singled out to show how inadequate coordination across ministries and superficial reorganizations impede the introductions of this, in some Soviet eyes, highly promising new technology. Another specific criticism is directed at the Soviet Electronic Computer Service Organization which hinders self-repair by customers through its parts distribution monopoly. The Ministry of Communications is berated because of its inflexibility impedes establishment of long-distance data transmission networks.

I believe that it is very important to translate such "constructive criticisms" into our own terms of reference, using our own concepts of efficiency, bureaucracy and success. The ability to provide such translation can only be kept up through broad-based contacts between individuals who hold comparable positions at many diverse levels of authority in both countries. Without high quality comparisons, we could easily underestimate or overestimate the difficulties that the Soviets are experiencing in their drive to upgrade their government controlled industrial and service sectors.

What Next?

Helpful advice about how to achieve improved US-SU relations was given recently by a former colleague of mine at the Moscow Embassy, John Joyce.¹⁵ Some of his advice may strike a dissonant note with those Americans who know the Soviet Union from what they select to read and believe. However, I find it sound and accurate and hope to have presented some basis for his beliefs through accounts based on my experiences.

Joyce's advice is sixfold: (1) Americans must stop denying the Russians the right to their own view of reality; (2) since the Russian State's exaggerated need for security can make it dangerous, the United States must maintain an adequate defense force, but should not assume that the Soviet Union is a world devouring monster; (3) threatening the Soviet Union is often counterproductive; (4) Russians are risk averters and find the dizzying speed of US policy shifts highly unsettling; (5) the United States should push Soviet leaders to improve the civil rights of the country's people, but should expect only slow progress; and (6) Americans should resist the temptation to punish the Russians whenever their actions do not measure up to Western standards, since they are already very effective in punishing themselves.

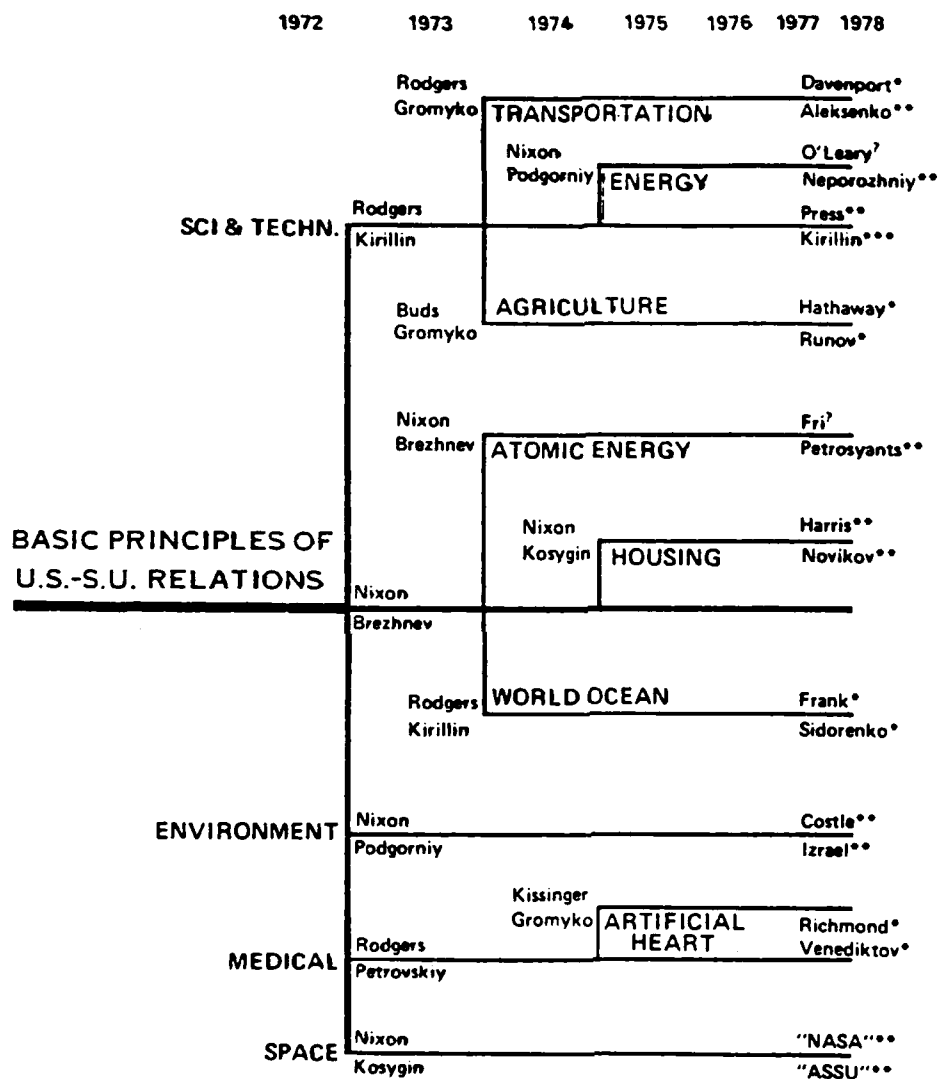
After 1979 US-SU relations continued to deteriorate and now are at their lowest level since the Cuban crisis. This causes a problem if one wants to recapture the ambiance of bygone detente days and give a true to life rendition of 1974-1976 scientific and technological cooperation between the two countries. However, if we are, as I believe, at the threshold of an upswing in US-SU relations, then this contribution is timely. Cooperative strategy has been shown by Axelrod¹⁶ to become optimal if two adversaries have to interact for a very long time. This game-theoretical result, while counterintuitive, may be the only alternative to eventual destruction of the players. If in the future the US is to deal with the SU from a more equal position, it will be necessary to concentrate more resources and authority at one of these three agencies: the OSTP, the NSF or a much strengthened and reorganized Department of State. I believe that the Department of State, invigorated with new scientific talent, should be the preferred locus to coordinate US involvement in foreign science and technology.

NOTES

1. Former Counselor for Scientific and Technological Affairs, U.S. Embassy, Moscow, USSR.
2. The opinions expressed in this paper are the author's alone. They are not necessarily shared by the US Government or the Hewlett-Packard Company, the author's present employer. These opinions are the result of direct personal contacts with hundreds of high-ranking and low-ranking Soviet and American officials, scientists, technologists and business people.
3. George W. Ball, Diplomacy for a Crowded World, Little, Brown and Company, 1976, p. 119.
4. Bruce Parrott, Politics and Technology in the Soviet Union, The MIT Press, 1983, see especially Chapter 6: The Brezhnev Administration 1969-1975, pages 231-293.
5. G.R. Urban, Editor, Detente, Universe Books, 1976; Albert L. Weeks, The Troubled Detente, New York University Press, 1976.
6. Jack C. Plano/Milton Greenberg, The American Political Dictionary, Fifth Edition, Holt, Rinehart and Winston, 1979.
7. Op. cit.
8. According to newsreports, Kirillin became a detente casualty in 1979, when he resigned his posts as Chairman of SCS&T and as Deputy Prime Minister of the Soviet Union. This occurred at the time Academician Sakharov was banished to Gorky, and Afghanistan was occupied by the Soviet Army.
9. The term ZNATOK was acronymized from Zippy Name Agreement Time Organization Keeper. It named the rapid storage and retrieval of information of directories of projects authorized under the

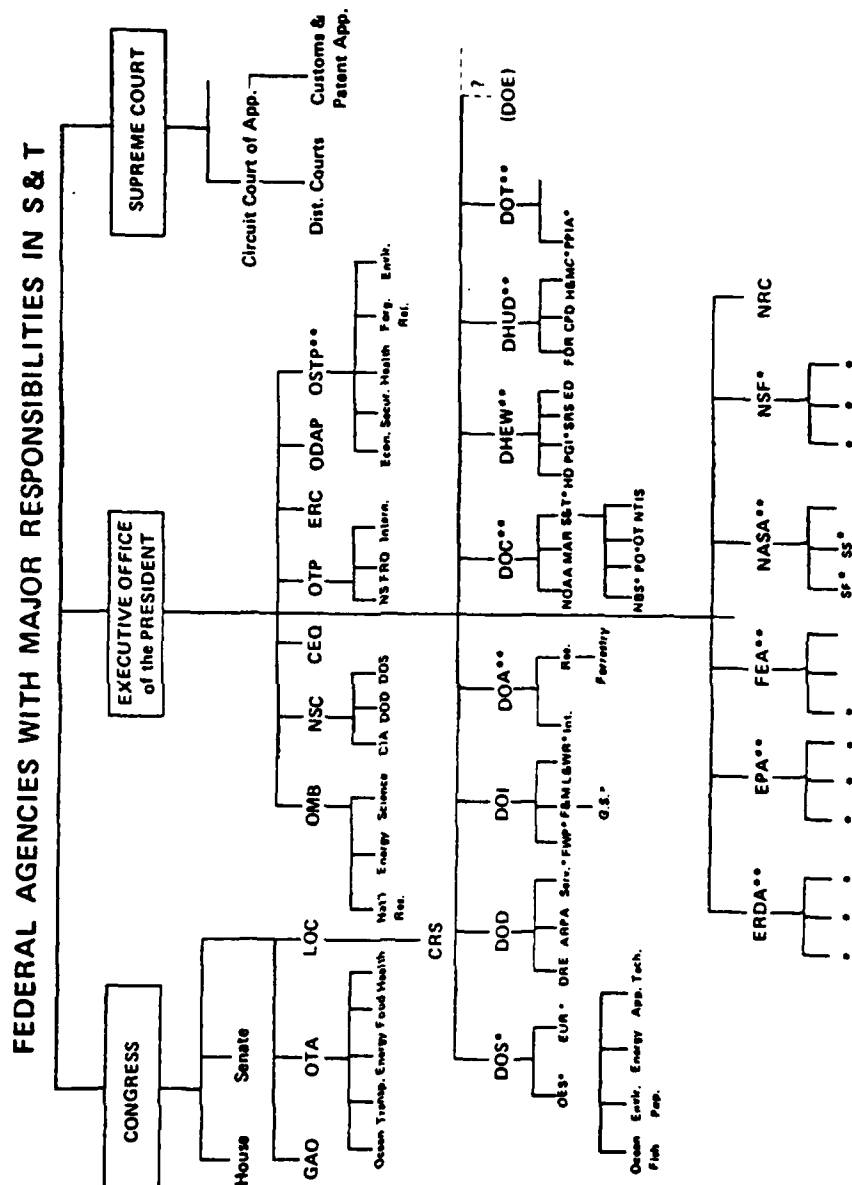
bilateral S&T Agreements, the names and affiliations of their participants and a calendar/tracker of to be monitored events. The Russian word "znatok" derives from znanie (knowledge) and signifies in English "expert." The ZNATOK software was built at the Embassy by Hugh Matlock.

10. A realistic overview of Soviet science was given in an article by Moscow and New York reporters for Newsweek on pages 54-59 in the October 10, 1977 issue on the occasion of the 20th anniversary of launching Sputnik.
11. The above analysis postdates this author's employment with the State Department by several years.
12. Egon E. Loebner, Subhistories of the Light Emitting Diode, IEEE Transactions on Electron Devices, Volume ED-23, pp. 675-699, (1976)
13. This question was raised by Kosygin during the XIIIth CPSU Congress. He wanted to know why Yoffe's Semiconductor Institute, which began work on the physics of semiconductors many years ahead of other laboratories, failed to accomplish what the Bell Laboratories did in the United States.
14. Loren R. Graham, The Soviet Academy of Sciences and the Communist Party, 1927-1932, Princeton University Press (1967).
15. John M. Joyce, The Old Russian Legacy, in Foreign Policy, Summer 1984.
16. Robert Axelrod, The Evolution of Cooperation, Basic Books, Inc. Publishers (1984).



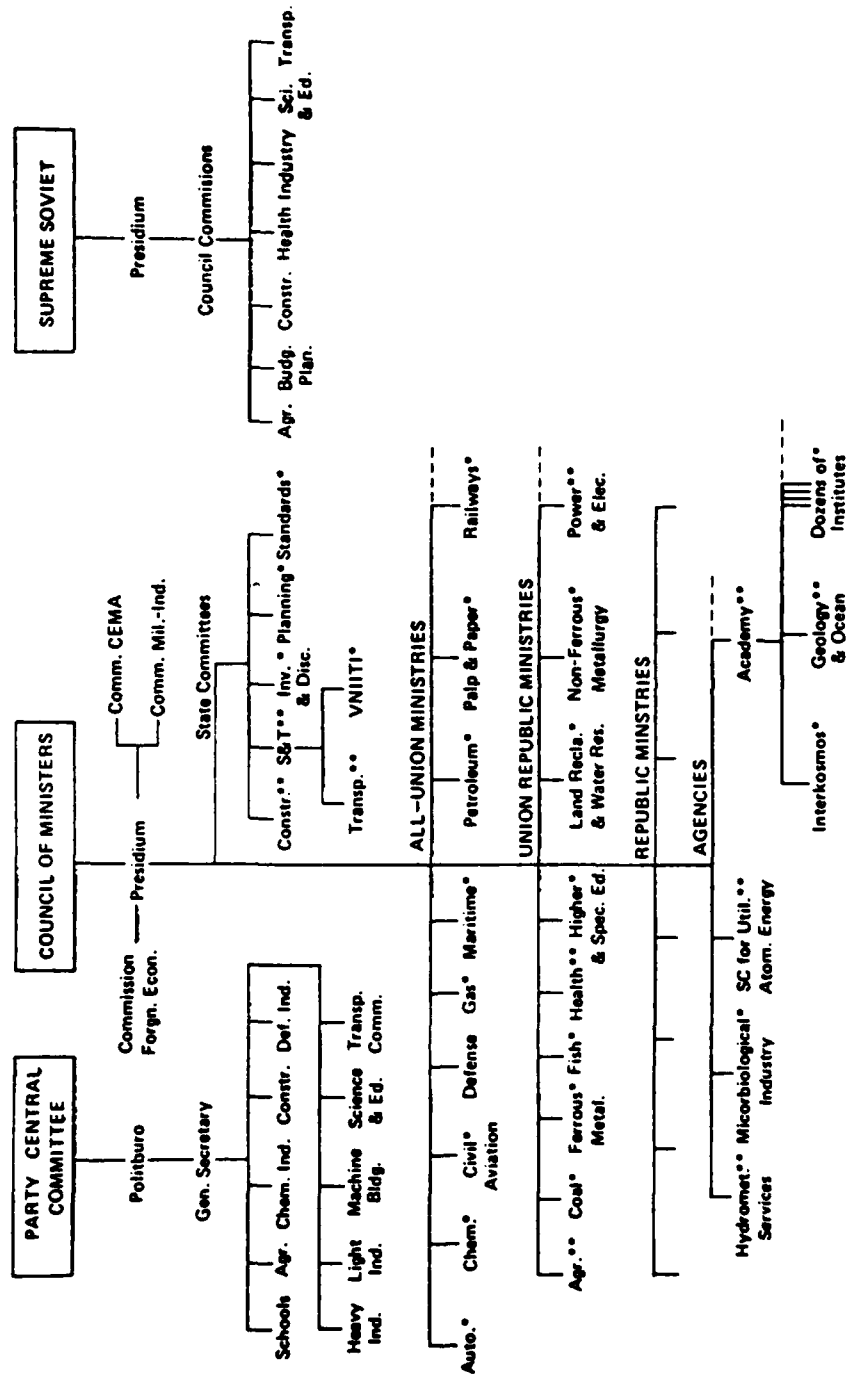
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S & T	ENVIRONMENT	MEDICAL SCIENCE	SPACE	TRANSPORT	OCEAN	ATOMIC ENERGY	ENERGY	AGRICULTURE	HOUSING
Software for Management	Air Pollution	Cardiovascular Disease	Rocket Meteorology	Future Transport	Atmosphere Interaction	Fast Breeder Reactors	Information	Plant Science	Building Design
Chemical Catalysis	Water Pollution	Artificial Heart	Satellite Meteorology	Construction	Current Dynamics	Particle Physics	Thermal	Animal Science	Industrialized Systems
Electrometallurgy	Agriculture Pollution	Malignant Neoplasia	Space Science	Railway	Geology	Controlled Thermonuclear Fusion	Hydroelectric	Soil Science	Materials
Forestry	Urban Environment	Environmental Health	Space Biology	Civil Aviation	Biology		Heat Rejection	Mechanization	Seismic Considerations
Patents	Nature & Preserves	Arthrides	Manned Flight	Marine	Standardization		Air Pollution	Agri-Business	Extreme Climates
Metrology	Marine	Acute Respiratory Diseases		Automobile	Date Dissemination		UHV Transmission	Forecasting	New Towns
Microbiology	Biological & Genetic Effects	Schizophrenia		Facilitation			Systems Planning	Economic Information Exchange	
Science Policy	Climatic Changes	Occupational Health		Urban			Superconducting Transmission	Library Exchange	
STI	Earthquake Prediction	Organizations & Delivery					Magneto-Hydrodynamics		
Standards	Arctic Ecology	Biomedical Communications					Solar		
Water Resources	Education						Geothermal		
							Coal		
							Oil		
	Assessment						Gas		
							Oil Pollution		



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