A Study of Soviet Science

December 1985

A STUDY OF SOVIET SCIENCE

THE WHITE HOUSE

WASHINGTON

During my four and a half years as Director of the Office of Science and Technology Policy, I have urged that the US scientific community develop a better understanding of Soviet basic sciences. Knowledge of their strengths and weaknesses should be a helpful guide to those who establish policy about US support of science and to those in the scientific community who carry on the research. In addition, such knowledge obviously must precede any mutually beneficial interactions or exchanges between US scientists and Soviet counterparts.

The attached Study was prepared with my encouragement. It is based on interviews with approximately 100 US scientists.

I commend the Study to your attention and suggest further studies of this type by the scientific community.

Very truly yours,

G. A. Keyworth

G. A. Keyworth
Science Advisor to the President

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SCOPE NOTE

This study addresses the sector of Soviet society at the very leading edge of future technology development—the sciences. The sciences, under which we include fundamental and applied science, are concerned with the discovery and conceptual development of new laws of nature and the preliminary steps taken to explore possible applications of these discoveries.

Science, and in particular fundamental science as distinguished from applied science, is so far removed from weapon systems, products, and processes that have an obvious effect on our relations with the USSR that it is difficult to convey with clarity the far-reaching and long-term effects it has on societies. Science, however, serves as the wellspring of new concepts and theories from which new technologies and, finally, products and processes evolve. An understanding of Soviet science, consequently, can provide the first indications of fundamentally new approaches to problems of defense and the economy. These early indicators can serve to alert the United States to areas where the Soviets are particularly strong and where surprises may likely be in store. More generally, an overall sense of the state of Soviet science, as well as how it couples to industry, can contribute a background of reality against which to evaluate the viability of policies and programs initiated by the Soviets.

The intent is to develop, in a broad sense, an understanding of the current health of Soviet science and to speculate on the implications of its current and likely future course. This entails an understanding of the environment within which Soviet science is conducted, in addition to a general assessment of the relative strength of Soviet scientific research in various fields of science as compared with that in the United States. We have tried to identify and discuss the implications of the striking differences between the Soviet and US research environments in such areas as organization and management, resources, science policy and education, and the nature of the Soviet scientist.

We have limited this study primarily to science, sponsored by the Soviet Academy of Sciences, and, furthermore, primarily to the physical sciences. We have also collected data and impressions on applied science in industrial research institutes as well. We believe, however, that the environmental factors identified are generally applicable in describing the conditions for all of Soviet science. In addition, we have explored somewhat the transition of science and technology to industry.

The information presented here is derived from interviews with nearly 100 active US scientists (from November 1984 to May 1985) in approximately 10 fields of physical science who have knowledge of Soviet science through visits with colleagues in the Soviet Union (the time frame of the visits ranged from about 10 years ago to the present), personal contacts with Soviet scientists at international conferences, or familiarity with Soviet scientific literature.

From the interviews with the scientists, a set of common themes was identified and judgments were made on the status of research. These themes were supplemented by and compared with information from Soviet scientists. Finally, the judgments were cross-checked against several other studies/reports/surveys. We found the themes to be largely consistent among these various sources.

We do not attempt to provide an in-depth analysis of Soviet scientific capability. Rather we have focused on the research environment, policy, resources, and scientists that affect science in the Soviet Union.

This study is intended to break the ground toward developing an understanding of Soviet science and serve as a basis on which further analysis may build a more complete and detailed picture.

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SUMMARY

Soviet science may undergo a gradual evolution over the next two decades that could result in a more effective system for responding to the technology needs of the country. Over the next decade, party policy initiatives from the new-generation leaders designed to focus Soviet scientific talent on economically and militarily relevant research could result in a reduction or leveling off of Soviet research in areas of fundamental science having little or no obvious applications. Beyond that time, an improved technology base could result in a significant reduction in the problems imposed by their traditional lack of instrumentation and computing power. This coupled with their massive applied science effort could allow them to more easily overcome future technical deficiencies in their military systems and civilian products, thus increasing their competitiveness.

The transfer of science to technology and application is difficult for the Soviets because of:

— An incentive system that does not strongly support technical innovation and implementation.

— Restricted communication.

— A rigid hierarchical bureaucracy that does not easily allow interministry scientific projects.

The new generation of Soviet political and scientific leaders will institute substantive changes in the Soviet system affecting both the S&T administrative bureaucracy and the research environment that could improve the science to technology transition problems and the inadequate instrumentation infrastructure:

— We expect that substantial impact resulting from any changes will be slow and gradual, and that the current research problems will most likely continue for the next 10 years.

— Beyond that time, however, if the new generation of leaders is successful in instituting changes, we may expect to begin to see substantial impact on their technology base.

— Many new leaders in the scientific community are also of the new generation and have made their careers in applied science. They may be expected to perpetuate any changes over at least two decades.

There will probably be a further shift of Soviet scientific research toward applied sciences in the future:

— Should the Soviets be successful in improving their ability to move science to technology and application, the expected increasing focus on applied science combined with their demonstrated ability to come up with new scientific concepts could lead to an increased likelihood that the United States may be surprised by an unanticipated applied scientific development. The occurrence of such a surprise in applied science could in a short time impact on militarily and economically important technologies.

— This shift will probably substantially affect the Soviet Academy of Sciences and result in a reduction or leveling off of fundamental science, particularly experimental science, although a smaller core of scientists can be expected to continue to produce world-class scientific results.

— Some areas of fundamental science that have traditionally been closely coupled to applications, such as condensed matter physics and semiconductors, may in fact receive greater emphasis.

— A greater reliance on the West for fundamental scientific research can be expected in the future.

— Even after the technology base begins to substantially respond to the new policies, vigorous Soviet efforts to acquire Western technology can be expected to continue.

The best Soviet *theorists* have capability comparable to that of their Western counterparts in all fields of physical science.

The scope and quality of Soviet theoretical research is largely comparable to that in the West:

— The Soviets are particularly noted for their strength in turbulence, plasma physics, laser physics, mathematics, and astrophysics.

— The Soviets' lack of large-scale scientific computers for computational physics may limit their contribution in the future.

— US scientists have attributed the Soviet absence in, for example, the band theory of conduction to inadequate computer power.

The best Soviet *experimentalists* are just as good intellectually as their Western counterparts:

— The Soviets have been lauded for their contributions in materials science and laser physics.

— They are, however, frequently limited by problems with quality, availability, and maintenance of instrumentation.

— Nevertheless, they frequently surprise Western scientists with the quality of the data they obtain with relatively crude equipment and often demonstrate a deeper physical insight.

The scope and quality of Soviet experimental research is generally not on a par with their theoretical research. The Soviets have been conspicuously absent in some fields, in large part because of the lack of necessary techniques and equipment:

— Such has been the case in surface physics, where the availability of ultrahigh vacuum techniques is essential.

— Lack of sophistication in vacuum and cryogenic technology has limited Soviet contributions in low temperature physics.

— Although ultrafast laser spectroscopy has been a major interest in the United States, the Soviets have been slower to achieve extremely short-time resolutions.

The presence of just a few very bright scientists can, and has, made the difference between very significant Soviet contributions in a field and the virtual absence of a Soviet contribution. Even where the Soviet contribution is significantly poorer than that of Western countries, as in biological sciences and molecular biology in particular, it is possible to find specific examples within the broad field, such as biophysical chemistry and protein conformation, that are regarded as world class by Western scientists.

Soviet scientists generally show an overall excellence in mathematics education, which exceeds that of their Western counterparts. This has:

— Contributed to excellence in theoretical physics.

— Allowed them to circumvent inadequate computer capability, to some extent, thereby allowing analytic solutions where Western scientists would be more likely to pursue a numerical solution.

— Allowed adequate numerical results to be obtained on computers of comparably lesser capability in some cases.

Should state-of-the-art computers become available to the Soviets, the possibility of a surge in Soviet scientific computation capability exists because of their excellence in mathematics:

— This surge could be mitigated to some extent because of the need for special programing knowledge and experience.

Soviet scientists are often the first to come up with a new scientific concept, but generally lag the West in fully developing the idea. Such has been the case, for example, with the Tokamak for controlled thermonuclear fusion and optical phase conjugation that can be used in correcting atmospheric distortion of electromagnetic wave propagation.

Restricted freedom of communication is a fundamental flaw in the Soviet scientific research environment that results in:

— Reduced synergism among scientists.

— Duplication of effort despite central planning.

— Slow diffusion of new ideas and technologies.

— Errors resulting from inadequate peer review.

The best Soviet students have had depth, breadth, and quality of scientific education comparable to that of their US counterparts, however, the Soviets generally have greater mathematical expertise.

Because teaching and research are largely separated institutionally, the interchange of ideas between researchers, professors, and students is reduced:

— Soviet awareness of this situation has resulted in efforts to decrease the separation, but the problem persists.

— Students often need substantial retraining to participate effectively in a research institute.

DISCUSSION

Research Environment

1. The formal organizational structure of Soviet scientific policy, administration, and research entities has been described at length in other studies. For the interested reader, the essential elements of this structure have been briefly summarized in the annex to this study. The fundamental perspective that should be carried into the following chapters is the critical role played by the leading members of the State Committee for Science and Technology (GKNT) and the Soviet Academy of Sciences (AN SSSR) [1] (see figure 1 and the foldout, figure 2) in formulating, coordinating, and executing Soviet science policy as defined by the Communist Party of the Soviet Union.

Concentration

2. In the Soviet Union, research activity is highly concentrated organizationally and geographically. The Academy dominates the republic academies both in terms of numbers of people and the overall quality of research (see table 1). Similarly, the Moscow area dominates the other major scientific centers (Leningrad, Novosibirsk, Kiev). Politburo member V. V. Grishin recently noted that over half the scientific personnel of the Academy are located in Moscow's research institutes and laboratories and nearly 35 percent of all doctorates and 30 percent of all candidates of science are in Moscow.

Table 1
Manpower in the Academies of Science [a]

	Total in Academy System [b]	Percentage in Soviet Academy of Sciences
Academicians [c]	2,955	25
Scientific workers	129,000	40
Doctors	10,300	50
Candidates	60,300	40

[a] The academies represent about 10 percent of the country's scientific manpower.
[b] 1983 figures.
[c] Including corresponding members.

Rigid Hierarchy

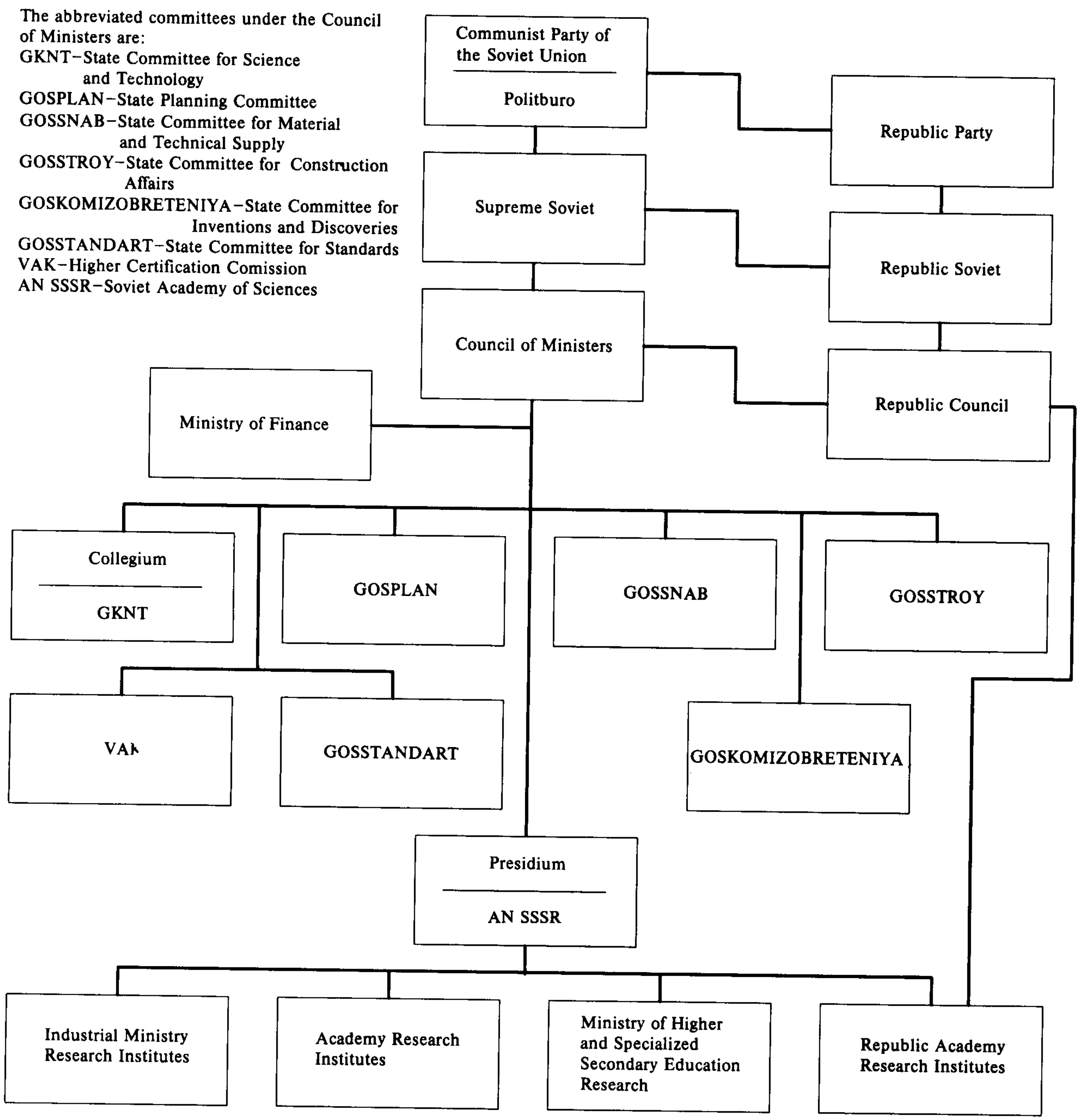
3. Many characteristics of the Soviet research environment that have a strong impact on the effectiveness and efficiency of how research is conducted in the Soviet Union can be tied to the rigidly hierarchical lines of authority. Of central importance is the strong role of the institute director. The director has vast authority in deciding what projects will be undertaken, by whom, and what resources will be made available, as well as authorizing travel to scientific meetings, especially those overseas. The influence is so extreme that the director's own scientific or ideological views can dominate those of all the researchers in the institute. This was the case for example with V. V. Belousov's suppression of work on plate tectonics in geology. Throughout an institute, there is a tendency toward ossification because of the pervasive inability to challenge superiors even, in some cases, on the technical validity of an argument. The management structure in the institutes tends to be very shallow with sometimes 10 or more laboratory chiefs reporting to one director. The director spends most of his time in committee meetings with financial and administrative matters and has difficulty in effectively providing technical direction for the laboratory chiefs. Furthermore, a director can easily remain in place for life. Consequently, the suppressing effect on the younger, upcoming scientists is, in the words of one Soviet scientist, "like ice on the water."

4. Conversely, in the hands of a strong scientist/administrator, such as Lev Landau was, an institute can greatly flourish, developing a tradition of excellence. Furthermore, the director can shield researchers from the bureaucracy, allowing considerable autonomy in what projects may be undertaken once the researcher gains the director's support. This leads to a general trend in which it is easier for Soviet scientists to work off the beaten track and maintain funding over many years than it is for their US counterparts.

5. The strong hierarchical lines, which run not only through the institutes and the academy structure but also through the various industrial ministries, lead to a severe isolation of institutes and laboratories. This isolation hinders Soviet ability to carry on "big science," such as the construction of large, forefront high-

[1] Unless otherwise specified, Academy will refer to the AN SSSR as distinct from the republic academies.

Figure 1
Soviet Science Planning and Management Structure



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energy particle accelerators. Many design/production bureaus and research institutes do not want to join large cooperative projects because it is not clear who will get the credit for the work. This has been part of the reason why large Soviet accelerator construction projects generally are completed after the Western research community has already explored the accelerator's attainable energy range.

6. Soviet attempts to deal with the problem of organizational isolation have included the establishment or proposal of special interministry organizations that can coordinate and direct large projects that cut across organizational lines. These concepts include:

- Scientific research institutes, similar to the Paton Electric Welding Institute, that cut across ministerial lines and can conduct applied research, engineering, and technology design.
- Interbranch Science-Production Associations (NPOs) and similar S&T centers that promote collaboration of scientific, educational, and production establishments in the development and diffusion of key technologies.
- Temporary project teams, developed to solve long-term complex S&T problems or to design new equipment and technology. If successful, they may be changed into NPOs. A decree in August 1983 explicitly calls for the creation of ad hoc collectives, and the USSR Council of Ministers in January 1984 adopted a resolution regulating their formation and operation.

7. The isolation also severely restricts Soviet ability to participate in the rapidly expanding multidisciplinary fields where, for example, biology and laser spectroscopy come together. In this case, the organizational isolation is aggravated by a restricted freedom of communication of scientific research (see inset on Freedom of Communication).

8. The size of Soviet scientific research institutes is one of the first and strongest impressions noted by visiting scientists. Many of the main research institutes are very large by US standards, with 500 to several thousand workers. The productivity in Soviet institutes is low compared with that of the United States. This is due to the necessity of devoting large numbers of people and amounts of time to instrument design, construction, and maintenance. Nevertheless, in a lab-to-lab competition between a Soviet and US lab, the Soviet lab can sometimes obtain results faster than the US lab through the sheer size of the effort that can be marshaled for a given topic.

Political Factors

9. The party bureaucracy plays an important role in staffing institutes with scientific personnel. The hiring decision is not made solely by the director, but rather the director, the secretary of the party organization, and the personnel department collectively make the decision. Often factors such as party membership, social activity, and nationality play a more important role than scientific qualifications.

10. Party membership becomes an increasingly important issue to career advancement as the level of institute director is approached. The ability to obtain approval for projects within an institute or funding for an institute from the academy depends to a large extent on the "old buddy" system. At the institute director level and higher, the lack of party membership becomes more and more conspicuous, and positions of higher authority are almost always filled with party members.

Military and Industrial Influence

11. The Soviet military has at least two basic mechanisms for tapping the talent in the Academy. A formal approach is via research contracts negotiated directly with an institute. Although we have no direct indication of the number of *military* contracts taken on by the Academy, V. V. Grishin, Moscow party chief and Politburo member, recently noted that "every year over 11,000 contracts between scientific research institutes and design bureaus and enterprises are implemented. A second, but more informal way, is through individual consulting agreements.

12. Scientific research done under military contract is probably attractive to many researchers because it allows them access to better funding and equipment, some of which they can use for their own fundamental research projects. It is avoided by some, however, because it limits the scientist's ability to travel and meet Westerners.

13. Many research institutes, particularly in the physical sciences, have some fraction of their budget, which varies from institute to institute, allocated for military-related work. Many institutes have a closed section (for example, a floor or building) that is devoted to military-supported work.

Science to Technology Transition

14. Incorporation of new scientific ideas into a development and product/process phase is difficult in the Soviet system. Formal review and approval must take place through the laboratory, institute, academy, and state committee levels of management. Implementation would then be called for through a ministry directive. Line managers, however, often ignore the directive for fear of not meeting short-term quotas as specified in the current plan. Furthermore, administrative boundaries are strict and tend to separate the

Freedom of Communication

An essential element of the Western scientific research environment that can greatly contribute to the quality and rate of progress of science is the capability to effect rapid and broad dissemination of ideas. This characteristic, which appears to be missing in the Soviet Union, is a fundamental flaw in the Soviet research environment. There are numerous reports of highly restricted communication between researchers, even to the point where scientists in a given institute may be unaware of relevant work going on in their own institute. Many US scientists have noted their Soviet counterparts asking for copies of Soviet papers that were apparently difficult for the Soviets to obtain. Access to scientific literature varies from institute to institute, but many examples of poor access have been cited. Furthermore, access to photocopying machines is highly restricted, requiring the authorization of a supervisor for each use. The use of electronic mail systems has been very rare, and limited in access and coverage. In addition, travel between institutes for collaboration, especially intercity travel, is restricted.

This lack of broad and easy communication leads to a number of effects. Because the wide dissemination of new ideas is slow, there is slow movement of the scientific community into new fields and slow diffusion of new technology to different research groups. It also leads to an inefficient use of people because of duplication of effort. Productivity is reduced because of the reduced synergism among scientists, both from an intellectual sharing perspective and from a joint experimentation perspective.

This difficulty is alleviated to some extent by the high concentration of scientific workers in Moscow, where results tend to be propagated through seminars held at the institutes rather than through journal articles. However, attendance at these seminars tends to be restricted to only persons from a few of the leading institutes in a given field.

All publications, such as journal articles, must pass through a series of committees before being published. This includes a special party censor and a censor who screens the material for sensitive military-related technical information. As a result, scientists heavily edit their own articles prior to submission for publication.

The Soviet solution to these problems has been to establish a centralized management structure that links a network of S&T information organizations into a single system. This system, known as the "State Scientific and Technical Information System" (GSNTI), is made up of a hierarchy of thousands of institutions involved in activities such as collecting, translating, indexing, abstracting, and disseminating primary S&T sources. The GKNT (State Committee for Science and Technology) is responsible for the supervision of the GSNTI, including its several all-union (national) information agencies. The most important national agency, the All-Union Institute of Scientific and Technical Information (VINITI), handles most of the literature in the natural sciences and technology. Other important agencies include the All-Union Center of Scientific and Technical Information (VNTITS) and the All-Union Scientific Research Institute of Interbranch Information (VIMI), which manages defense-related materials.

functions of academy, branch ministry, and university research, compounding the difficulty of integrating these efforts. Science-Production Associations (NPOs, nauchno-proizvodstvennyye obyedineniya) have been established to try to smooth this transition. These associations, however, have been in existence for 15 years and have not been successful. Academy President A. P. Aleksandrov recently called for more lateral communication between industry and Academy research institutes. To improve the Academy's participation in applying the results of research into production, CPSU General Secretary Gorbachev, at the June 1985 Central Committee Conference on S&T Progress, endorsed the new "technical center" concept developed by the Ukrainian Academy of Sciences. The technical centers consist of an institute, a design bureau, an experimental works, and a pilot production plant. The director of the institute carries out supervision of the center. Six of these centers have been established in the Ukraine. The technical centers have also been endorsed by USSR Academy President Aleksandrov and leading economist academician Abel Aganbegyan. Independently, examples have also been cited of large teams of engineers going to a research institute for several months to pick up a new process or technique. Conversely, research laboratories have been set up at plants; the Zil factory in Moscow has a laboratory where scientists from the Kurchatov Institute and the Scientific Research Center for Industrial Lasers come to test the use of lasers in the auto industry. Recent changes have been made that allow production quotas in the current plan to be reduced for a period of time following the introduction of a new instrument or process to encourage risk taking through implementation of technical innovations.

Policy

15. Decrees from the leadership of the Communist Party of the Soviet Union (CPSU), and their imple-

CONCEPT, THEORY, AND EXPERIMENTAL VERIFICATION

Examples of Topics First Conceived in the USSR, but Pushed Further in the West

Tokamak for thermonuclear fusion

Inflation Theory in Cosmology

Optics:

- Optical Phase Conjugation (having implications for correction of atmospheric distortion of electromagnetic wave propagation)
- Interaction of Fast Laser Light Pulses with Semiconductors Non-Linear Laser Techniques for Driving Chemical Reaction Pathways
- Brillouin Back-Scattering (scattering of light from sound waves)

Gerber-Markusev Methods for Velocity Inversions in Seismology

Radio Frequency Quadrupole Accelerator

One widely held view among US scientists is that the Soviets are often the first to come up with a new scientific concept. US experimentalists often find that a new measurement they have made has already been predicted by a Soviet theorist. Beyond the initial conceptualization, however, the Soviets begin to lag. They are generally slower to work out the details of a complete new theory from the initial concept. The Soviets, for example, were the first to note property changes of materials on the nanosecond time scale when illuminated by short light pulses. They attributed the property changes to phase transitions. Later, the US working with picosecond resolution showed the changes to be due to a rapid melting and recrystallization in an amorphous state. There is a large effort in this area in the US now, in part because of possible applications to semiconductor doping technology. Finally, the movement of new theoretical developments into applications has been particularly ineffective. We believe this is largely due to the strong split between theoreticians and experimentalists and the inadequate supply and maintenance of experimental equipment.

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mentation within the government, state the intended directions for current and future Soviet scientific work. Pronouncements from the 26th CPSU Congress indicate the high priority being attached to scientific and technical progress as a means for fulfilling the economic and social development of the country. During that congress, it was stipulated that S&T research in the future should be even more supportive of the economic and social needs in the Soviet society. With the general goal of increasing industrial efficiency and labor productivity, the CPSU Central Committee and the USSR Council of Ministers issued on 28 August 1983 a joint decree "On Measures on the Acceleration of Scientific and Technical Progress in the National Economy" that calls for increased demands on Soviet science to support the raising of Soviet standards of machine outputs, equipment, instruments, and other products to the highest world levels.

16. The trend toward pushing science to support economic needs was already present in the 11th Five-Year Plan (1981-85) with the implementation of a state-integrated scientific and technical program. A total of 170 state comprehensive scientific-technical programs were established by Gosplan (State Planning Committee),[2] GKNT, and the Academy, and incorporated as a component part of the 1981-85 development plan. These programs allow scientific workers to focus their efforts on developing and rapidly introducing into practice more advanced equipment and production methods. The majority of the programs pursue the development of the machine-building base (see tables 2 and 3). Most of these programs are under development for inclusion in the 12th Five-Year Plan (1986-90).

17. It is within this context that one can look at the Academy and ask what effect these programs will have on the Academy's research. The clear implication is that applied science will be heavily favored over fundamental science in the programs backed by the CPSU. Furthermore, according to Academy Vice President V. A. Kotel'nikov, "There does not need to be such a large increase in the number of those working in scientific institutions as took place in previous five-tear periods." Given the demand for applied research, greater pressure will be exerted on scientists in the institutes of the Academy to pursue applied research at the expense of fundamental science. Because the Academy now performs about 50 percent of all fundamental science, this portends a gradual reduction or leveling off of the fundamental scientific research effort in the Soviet Union.

18. The Academy has in the past been able to exert a substantially independent force in Soviet society largely through the great respect accorded academicians and, in some cases, through the personal actions of its internationally recognized scientists. This resulted in the ability of the Academy to protect its scientists pursuing fundamental science from party demands for research that can be directly tied to application. The percentage of academicians who are party members

[2] See the annex for a discussion of the organizations involved in Soviet S&T policy formulation, administration, and execution.

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Table 2
Priority S&T Topics in the 11th Five-Year Plan [a]

Biotechnology and genetic engineering
Anticorrosion protection (new lacquer coverings, new methods of electrochemical protection)
Highly filled polymers and composites
Powder metallurgy
Powerful superconducting magnet for industrial magnethydrodynamic electric power station
Fast breeder reactors and thermal neutron reactors for both heating and power
Robotics
Automation of scientific research and computerized design
Microelectronics and microprocessors
Plasma technology
Fiber optics
Industrial lasers

[a] Tables 2 and 3 illustrate the applied nature of the research we believe the party and government will be supporting heavily. This is not a comprehensive list of topics and is not meant to imply that fundamental research will be unfunded.

Table 3
Targeted S&T Programs Assigned to Academy of Sciences System

Program	Lead Agency
Lasers	Lebedev Physics Institute
	Scientific Research Center for Industrial Lasers
Powder metallurgy, composites, and coatings	Ukrainian Academy of Sciences Institute of Problems of Material Science
Experimental industrial powder metallurgy for the nuclear metallurgy complex	Institute of Metallurgy
Optical fiber light guides with low optical losses	Lebedev Physics Institute
Superconducting magnetic systems for industrial magnetohydrodynamic electric power stations	Institute of High Temperatures

has been rising steadily since the 1950s when the percentage was 33 percent. With the 26 December 1984 Academy membership elections, the fraction of academicians who are party members has exceeded 70 percent. There is little doubt that the influence of the party on Academy affairs will likely increase in the future for it now has sufficient strength to greatly influence future decisions made by the Academy membership.

19. These statements on S&T progress as a means of improving economic output are not new ideas, having been stressed throughout Soviet history. There has not since Brezhnev, however, been a leader in power long enough and with a solid enough political base to really push through to fruition the necessary changes. With the accession of the younger and dynamic Gorbachev, we expect these changes to move more rapidly from rhetoric into substantive action. The ability of Gorbachev to push for action from a strong position of power is underscored by his recent success in getting two strong political allies, Ligachev and Ryzhkov, who are relatively young, promoted directly to the Politburo, bypassing the usual candidate stage.

20. Gorbachev himself stressed the essential role of S&T progress in socioeconomic development in an 8 May 1985 speech at the Kremlin Palace of Congresses celebrating the 40th anniversary of the Soviet people's victory in the Great Patriotic War:

> "The party considers the main task of the present is to substantially accelerate the socioeconomic progress of Soviet society.... What it amounts to primarily is the intensive and dynamic growth of the national economy, *which relies entirely on the latest achievements of science and technology*. It is the basis that will make it possible to ensure the further growth of the people's well-being, to strengthen the economic and defense potentials of the country and comprehensively to perfect developed socialism....
>
> The principal way to achieve this goal is scientific and technical progress. The rate of our development and the course of economic competition with capitalism will depend to a decisive extent on how we resolve the problem of accelerating scientific and technical progress and on how efficiently and how timely we apply the achievements of science and technology in the national economy."

21. These ideas were reiterated at a special S&T conference held on 11 June 1985 in the CPSU Central Committee. In a speech delivered at the conference, Gorbachev specifically noted the role of science in the acceleration of scientific and technological progress:

> "Comrades, the frontline of the struggle to accelerate the scientific and technological progress in the national economy advances through science.... One can be proud of the pioneering achievements in space research, mathematics, mechanics, thermonuclear synthesis, and quantum electronics.... At the same time, comrades, we can and should obtain incomparably greater achievements from science. We should take a new look at the tasks of science

based on the requirements of our time, the requirements that science be turned decisively toward the needs of social production.... It is from these positions that all links in the chain that binds science, technology, and production ought to be analyzed and strengthened."

We believe that Gorbachev gave only lipservice to fundamental science in his comments and that the true thrust of his program will be demands for relevant applied research.

22. Furthermore, concrete indications of substantive change occurred in the Academy with the establishment of the Department of Information, Computer Technology and Automation in March 1983 under Ye. P. Velikhov who, like Gorbachev, is from a new generation. This is the first new Academy department to be created since 1968. There have also been decrees introducing provisions allowing short-term falls in plan production when technical innovations are introduced. Furthermore, a recent joint resolution of the Central Committee of the CPSU and the USSR Council of Ministers called for a change in the wage structure for scientific workers and engineers, increasing their salaries and adding bonuses for innovation. This measure was also intended to reduce the time of development and introduction of new technology and equipment.

23. Although we do expect changes to occur more rapidly in attempting to solve some of the traditional problems of the centralized Soviet system in regard to S&T progress and its impact on the Soviet economy, there will nevertheless be tremendous inertia to overcome. In addition, the continued influence of some "old guard" nonprogressives and the collective decisionmaking process will serve to make real improvements take place slowly and gradually.

24. The combined party pressure for applied research, the newly created department in the Academy, and the advent of younger men to leading positions in the Academy who are oriented more toward applied work, should succeed in shifting the Academy toward a much more applied orientation. This shift will likely be perpetuated by the entering young generation of leaders who might be expected to remain in power for several decades. This implies that, in addition to the directed and intended impact of Academy contributions to the economy, there will be a long-term deterioration of Soviet fundamental science unless specific measures are taken to bolster and protect this aspect of Soviet science. It should be noted, however, that some areas of fundamental science that have traditionally been very closely coupled to applications (for example, solid state and semiconductor physics) may in fact receive greater emphasis.

Resources

Funding

25. Financial resources for conducting research in the Academy institutes are available through several mechanisms—the formal Academy budget, contract research, and consulting fees. We estimate that about 90 percent of the research conducted by the higher educational institutions is done under contract and that most of this is applied research.

26. Because Soviet official statistics report annual expenditures only for total science, the distribution of spending by R&D stage (that is, fundamental, applied, developmental) is uncertain. Soviet scholars, using unknown methodologies to calculate expenditures for individual R&D stages, provide disparate estimates of the distribution of R&D expenditures. These estimates, although seemingly consistent in their coverage of fundamental research as defined in this Estimate, appear to incorporate different definitions of activity in applied R&D. Therefore, we can estimate expenditures only for fundamental science.

27. Several Soviet authors have estimated that expenditures for fundamental research range from 9 to 14 percent of the total published science budget. By applying these ratios to official Soviet statistics, we estimate that 1984 expenditures for fundamental science probably totaled between 2.4 and 3.7 billion rubles. It should be noted that official Soviet statistics on science spending include a broad range of R&D work including work done in the social sciences and not included in the traditional Western concept of R&D. On basis of our knowledge of Soviet accounting systems, we believe that this total includes civilian and the majority of military fundamental research. A recent Soviet published source indicates that, of this total, about 50 percent was spent by Academy of Sciences institutes and the remaining 50 percent by ministry scientific organizations and by higher education institutions. The Academy share of expenditures for total fundamental research has decreased from an estimated 70 percent in the early 1970s to 50 percent in the 1980s.

28. The level of review for approval of funding for major scientific projects within the Academy is generally a function of the ruble amount of the project:

Project Cost (*rubles*)	Level of Review
0.5 million	Institute director
1 million	Academy level
Over 1 million	Council of Ministers

29. The contract and consulting research are generally for applied research with more obvious applica-

tions to the sponsoring industry or military service. The amount of contract work done by the Academy has increased steadily since the 1960s. Soviet sources report that, between 1960 and 1970, income from contracts grew from 8.5 percent to 12.6 percent of the Academy budget. US scholars estimate that today contracting provides 20 to 25 percent of the total budget.

30. Funding, however, is not the major difficulty in putting together a new research plan according to Soviet scientists. The problem is getting the people and equipment required for the project entered as a part of the plan.

Instrumentation

31. Science drives, *and is driven by*, technology. As much as new scientific principles are incorporated into new instrumentation and products, advances in experimental science often depend on advances in instrumentation technology.

32. There is a widespread lack of experimental equipment, parts, and maintenance personnel in the Soviet Union. Furthermore, the overall quality of the instrumentation is often far below that of Western laboratories. Even where Western equipment is available in Soviet laboratories, the equipment is often in disrepair because of the absence of spare parts or personnel to repair the equipment.

33. Research equipment is extremely hard to obtain. Generally, it is necessary to develop and maintain the equipment at the institute. This uses up a large fraction of the institute's time and personnel. In some institutes as many as half of the personnel are technicians devoted to building and maintaining instrumentation. This function is served to a large extent by private industry in the United States. In the USSR, there is no private sector pushing science through the development of new instrumentation. Some institutes have alleviated the equipment/manpower shortage problem by developing a large in-house shop. These institutes have gained some measure of self-sufficiency by not only building their own equipment, but also manufacturing equipment for outside use to generate funds (for example, small accelerators for medical purposes at the Institute for Nuclear Physics in Novosibirsk).

34. The formal means of obtaining equipment and other resources from sources outside an institute are so cumbersome that ways of working around the system have been widely developed. This "underground" bartering system introduces some flexibility into the otherwise rigid research environment.

35. This lack of instrumentation support not only slows the Soviet research effort, but, in some fields, leaves Soviet experimentalists unable to effectively participate in forefront research. They are unable to compete in many new experimental areas (for example, molecular biology) because they do not have as responsive an infrastructure of equipment and services as is available in the United States. Marked increases in publications have been noted from specific institutions when they have been able to obtain new pieces of Western-built equipment.

36. Lack of computing power is endemic in the Soviet Union and constitutes a severe handicap in their research capability. Soviet computers are typically not very powerful (the workhorse for Soviet computation, the BESM-6, is comparable to widely used US personal computers) and have severe reliability problems. Technicians needed to maintain these computers are in short supply. The use of scientists' time is inefficient because of the lack of adequate computing power that in some fields severely hinders their participation in forefront research.

37. There is a general shortage of office space for scientists. Most theorists, even at some of the best institutes, work in their apartments and come in to their institutes only once or twice a week. Consequently, they have reduced opportunities for informal interchanges of ideas with the experimentalists and other theorists.

38. In some cases, even basic supplies have proved to be significant stumblingblocks. A US scientist reported that, in his role as chairman of an international conference held in the Soviet Union, he was responsible for the distribution of the conference proceedings. He was told that the sponsoring institute did not have enough paper allocated to it in the five-year plan to publish the proceedings.

The Soviet Scientist

39. Science as a profession is highly respected in the Soviet Union. Senior scientists generally receive higher salaries and better benefits than people in other professions. The theoretical sciences stand above experimental sciences in prestige, and physics in particular has been referred to as the "queen of Soviet science." Recent changes in the wage structure now give equal pay to both experimentalists and theorists.

Compared With Western Counterparts

40. For most fields of theoretical physics, senior Soviet scientists are on a par with their Western counterparts in terms of depth and breadth of capabil-

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ity. Senior Soviet experimentalists in virtually all fields, although on a par intellectually with their Western counterparts, are generally unable to contribute to the advancement of their field at the same level as their theorist colleagues. This is because of the lack of adequate experimental instrumentation. Many of the secondary Soviet scientists and candidates are given tasks of an unimaginative nature, for example, laboriously measuring the physical properties of various new arbitrary combinations of materials.

Importance of Western Science

41. Soviet scientists, both theorists and experimentalists, are keenly aware of US experimental work and value it highly because the scope and depth of Soviet experimental work is not as great as that in the United States. Some Soviet theorists have even expressed concern to US counterparts about the credibility of Soviet experimental work in some fields (a widely held view among US theorists and experimentalists). Nevertheless, US scientists have noted that visiting Soviet experimentalists are often able to join international collaborative experiments and, even though they have never worked with some of the advanced instrumentation, they quickly become fully contributing members. This probably reflects the close scrutiny the Soviets give to Western literature, including instrumentation manuals. The Academy is known to have access to unclassified Western scientific data bases via computer.

42. Soviet scientists very highly prize the opportunity to travel abroad to conferences, universities, and laboratories—not only for the material learned and the feedback on their own work, but also for the peer recognition of their work. Soviet scientists feel that the West does not appreciate the value of Soviet scientific work. In meetings between US scientists and their Soviet counterparts, the visiting US scientists are left with the feeling of having been completely drained of information.

Participation in Military, Government, and Party Activities

43. Many senior Soviet scientists serve in advisory capacities to the military and have used their military connections in rising through the bureaucracy. Furthermore, some military scientists study or participate in research within the Academy institutes. Many Soviet scientists, however, completely shun military—and even applied—scientific work because this destroys their opportunities for traveling abroad and restricts the already limited means they have for communication and publication.

44. The Academy is regularly drawn on as part of the Soviets' S&T collection effort from the West, and, although the practice is distasteful to many Soviet scientists, these scientists respond to S&T collection requirements during trips to technical conferences abroad.

45. Many senior Soviet scientists serve in high-level government and party positions. For example, G. I. Marchuk, who was formerly an Academy vice president and headed the Academy's Siberian Department, is currently director of the GKNT. His predecessor at the GKNT, V. A. Kirillin, had also been an Academy vice president. Yu. A. Ovchinnikov, who is a vice president of the Academy, is a candidate member of the Central Committee of the Communist Party of the Soviet Union; Academy President, A. P. Alexandrov, is a full member.

Education

46. The best Soviet students who have come to the United States have had depth, breadth, and quality of scientific education comparable to that of their US counterparts. One difference that has been unanimously noted by US scientists is that the preparation of new Soviet candidates (Ph.D. equivalent) in analytic mathematics is generally better than for their US counterparts.

47. Soviet universities tend to have more upper-level specialized laboratories (for example, in fluid mechanics, turbulence, lasers) than US universities. Their large scientific manpower pool enables them to add these specialized labs to the curriculum even though adequate equipment is often lacking. In the United States, the equipment can generally be obtained, but there are not enough people to teach the labs.

48. Access to computers in the universities, both large mainframes and personal computers, is very limited. According to a Soviet magazine article, the number of computers in preuniversity Soviet schools in 1983-84 was two. The Soviets have begun, however, to introduce compulsory courses on computer technology and programing into all primary, secondary, and vocational schools in September 1985. Furthermore, they intend to set up special classrooms in 200 middle schools, each with 15 to 20 personal computers, during the 1986-90 five-year plan. This, however, will have a negligible effect on increasing Soviet computer literacy because this only represents an average of less than one personal computer per 1,000 students.

49. Teaching and research are fairly distinctly divided with teaching taking place largely in the univer-

sities and fundamental research in the academy institutes. Some institutes award candidate degrees for research within the institute, and a small amount of fundamental research takes place in a few select universities (for example, Moscow State University). Because of this overall separation of teaching and research, active researchers generally have little contact with teaching and students, and vice versa. Furthermore, scientists teaching in the higher educational institutions lose touch with the excitement and vitality of forefront research, making it more difficult to convey these qualities to the students. Attempts have been made to get the researchers more involved in teaching, but the physical separation of university and institute facilities has strongly hindered this effort. The large number of candidates who receive their degrees in the universities require substantial retraining to become productive in the institute research environment.

50. Students have the freedom to apply to any institute or university. Although they may choose the field they want to pursue, each year the number of people for each field is determined by the government and then competitive examinations determine the cutoff. The entrance examinations are crucial and are taken at the institute to which the student is applying. Failure to be accepted within two years generally results in the student's being called into military service. The university entrance examinations for physics are separated out from the other subjects and given first because the field is so prestigious that the competition is very high. This staggering of examinations provides to the students who fail an opportunity to try other fields.

51. Decisions on the filling of faculty positions are strongly influenced by outside effects: ethnic origin, general ideological standing, and personal connections (see inset on Discrimination in Science). Faculty positions are routinely filled by the universities own graduates, which contributes to the lack of cross-fertilization among universities.

52. The party plays a strong role even in the granting of candidate degrees. As a formal part of the general examinations (even for the advanced degrees), a candidate must pass an oral section on political history and philosophy.

Soviet Scientific Research

General Considerations

53. The scope and quality of fundamental scientific research in the Soviet Union has to a large extent been determined by the conditions of the research environment discussed in previous chapters. Most notable is the striking difference in scope and quality between theoretical and experimental work in virtually all scientific fields.

Discrimination in Science

Discrimination against ethnic and regional groups in research institutes and in entering higher level educational institutions, though not an official policy, is widespread and takes on an almost systematic nature in the Soviet Union. This discrimination is perhaps most acute and most universal in the case of the Jewish group. Ironically, Jews make up a significant portion of Soviet scientists and intelligentsia. The discriminatory policies have reduced the effectiveness of the contribution of Jewish scientists and caused large numbers of them to leave the country in the late 1970s and early 1980s during the period of eased emigration policy. Furthermore, there are indications that Jews are being systematically excluded from entrance into the good technical schools irrespective of their ability. Although this filtering of Jews will certainly prevent highly qualified people from entering the Soviet scientific community, there is no firm evidence as yet that this has measurably reduced the productivity of Soviet science. This is due in part to the large pool of people available to draw on for scientific careers. In addition, in the case of mathematics, where discrimination has been particularly high, the Soviets have been successful in the past in identifying exceptional talent at an early age and pushing its development. We expect them to be able to continue such targeting in the future. It is nevertheless clear that the West, and in particular the United States, has gained some exceptionally good Jewish scientists in recent years, largely as a result of discrimination in the Soviet Union.

54. The scope of Soviet research in theoretical physics is by and large similar to that of the United States. The quality is as good as the United States in most fields and perhaps better in a few fields that have been traditional Soviet strengths (for example, turbulence and laser physics).

55. The scope of Soviet experimental science has frequently been limited by the availability of instrumentation, computers, and major research facilities. The effort has been further hindered by lack of an adequate infrastructure for servicing the available equipment and for developing new equipment that can advance the limits of knowledge. The quality of experimental work has correspondingly suffered and, if nothing else, the interesting discoveries are generally made by Western scientists simply because the equipment was available to them. Western scientists, however, are frequently surprised by the quality of Soviet scientific results obtained with relatively crude equipment. The Soviets compensate by paying much closer

attention to theoretical details and often demonstrate a deeper scientific understanding of the problem than is common in the West. One American theorist who spent several months in the USSR characterized the research he saw as "modern science in an underdeveloped country"—a tribute to the skills and talents of Soviet experimentalists. In addition, when hard currency is available, much of the laboratory instrumentation can be obtained from the West, although problems with maintenance still remain.

56. The Soviets have been conspicuously absent in some fields, in large part because of the lack of necessary techniques and equipment. Such has been the case in surface physics, where the availability of ultrahigh vacuum techniques is essential, and in low-temperature physics. This inadequacy probably resulted in the establishment in 1980, probably at Velikhov's insistence, of the Center for Vacuum and Surface Science. US scientists have attributed the Soviet absence in the band theory of conduction, and in theoretical high-energy physics Monte Carlo gauge theory calculations to inadequate computer power.

57. Given the frequent inadequacy of the available tools for doing forefront experimental research, the organizational difficulties in maintaining and building these tools and the societal bias that places the theorist on a higher intellectual plane than the experimentalist, and the differences in salary and benefits, it is not surprising to find the toughest competition for entrance to universities and institute research positions to be for positions in theoretical physics.

58. The excellence in mathematics demonstrated by Soviet scientists has contributed to excellence in theoretical physics. The Soviets often produce sophisticated theoretical solutions to problems in analytic form where the United States typically would rely on numerical computer solutions. Examples exist in the field of hydrodynamics where accurate solutions have been obtained on computers of significantly lower capability than US computers through insightful choices of boundary conditions and clever mathematical techniques, or efficient programing. Such was the case, for example, with a Soviet calculation of the magnetic field-induced compression of a thermonuclear fusion target that the Soviets suggested might have commercial power applications. The Soviets have been essentially forced into the position of having to rely on clever theoretical approaches to computer calculations because of their lack of the most advanced computer systems. On the other hand, it can also be suggested that if state-of-the-art computers do become available to them, a potential exists for a surge in their computational capability that could go beyond the effects of just the improved computer capability. Such a surge, however, might be mitigated or slowed by inadequate preparation to handle advanced programing techniques used for supercomputers.

Relative Strengths and Weaknesses

59. Beyond these overall trends that have a far-reaching impact on many fields, it is difficult to find a means of summarizing the relative status of science in the Soviet Union as compared with that of the United States. Even in cases where there is a significantly smaller Soviet contribution, as in biological sciences and molecular biology in particular, specific examples within the broad field, such as biophysical chemistry and protein conformation, can be found that are regarded as world class by Western scientists. Furthermore, we note that Soviet publications in molecular biology have increased greatly in the past five years, suggesting that the Soviets are currently investing heavily in this field. Another example of this nonuniformity across a field is in fluid dynamics, which we have assessed as being comparable to the United States. Current Soviet work in experimental plasma physics, particularly in their fusion energy program, is not keeping pace with the West. On the other hand, Soviet experimental work in shock physics is greatly respected. In contrast, some field areas have traditionally had massive resources allocated to them, such as oceanography, but the overall results produced have not greatly impressed Western scientists. The presence of just a few very bright scientists can, and has, made the difference between very significant Soviet contributions in a field and the virtual absence of a Soviet contribution.

60. We expect Soviet work in a number of theoretical fields to suffer in the future as a result of inferior large-scale scientific computing capability. Fields such as fluid dynamics, astrophysics, and some calculations in high-energy and condensed-matter physics will become increasingly computer intensive in the next five years—as much as 25 percent of astrophysical work may be based on computer simulations in this time frame. Fields such as astrophysics and high-energy physics will most likely suffer further under the party and government pressure for relevant applied research. On the other hand, condensed-matter physics, because of its close connection to semiconductors and electronics, and molecular biology, because of possible genetic engineering applications in agriculture and other areas, may receive considerably greater support. This may be particularly true for molecular biology given Ovchinnikov's active role in this field and considerable influence in the party and the Academy.

61. The interest, or value, of Soviet work to Western scientists may not necessarily reside so much in the sophistication of the research as in the access to data unavailable through any other source, such as in geology. This has also been the case in oceanography, where the huge fleet of Soviet oceanographic research vessels has gathered a vast amount of data. And, in materials science, the Soviet brute force approach to research has resulted in a wealth of data on physical properties of new materials with possible application to, for example, new lasers.

62. With these points in mind, we can nevertheless ask where the Soviets stand relative to the United States in a given field of science in an overall sense. We are relying largely for this comparison on the assessment of primarily US, and, to some extent, European and Soviet scientists. Table 4 summarizes these subjective overall assessments for the limited set of fields on which we have focused in this study.

Table 4
Relative Strength of Specific Fields of Science Compared With the United States

Field	Comparable	Weaker
Mathematics	X→	
Atmospheric physics		X
Oceanology		
Theoretical	X	
Experimental		X
Materials science	X	
High-energy physics		
Theoretical	X	
Experimental		X→
Fluid dynamics	X	
Condensed-matter physics		
Theoretical	X	
Experimental		X
Astrophysics		
Theoretical	X→	
Experimental		X→
Molecular biology		←X
Laser physics		
Theoretical	X	
Experimental	X	
Computer science		X

Note: An arrow indicates the estimated direction of change of the future relative status where we are reasonably confident. Some fields have not been divided into theory and experiment because of lack of data.

The Soviets were not found to be grossly stronger than the United States in any of these fields.

Future

63. We expect that the ongoing Soviet drive for scientific and technological progress directed toward meeting specific economic and military needs will play a major role in shaping the nature of their science over the next 10 to 15 years. The advent of Mikhail Gorbachev as General Secretary of the CPSU represents the beginning of the transfer of power from the "old guard" to the younger political leaders. The initiatives for accelerating S&T progress that began formulation in the late 1970s will now begin to receive the political support from the top leadership required to implement necessary changes in the Soviet system. These changes may be slow and gradual, as Gorbachev faces a bureaucracy with a substantial "old guard" element. He has already, however, shown a surprising ability to accelerate political allies into top leadership positions.

64. Several changes have already taken place over the last several years. These include: the creation of the Academy Department of Information, Computer Technology, and Automation in 1983; changes in the wage structure for scientists and engineers; new monetary incentives for technological innovation; allowance for adjustments in plan quotas to allow for downtime during the introduction of new technologies; and the creation of cross-disciplinary/interministry groups with the authority to coordinate large technical projects. We expect such changes to continue to receive support from Gorbachev and his allies in the future, providing the necessary backbone for what had been hollow rhetoric in the past.

65. The implication for science, as a whole, will be a gradually shifting emphasis further toward applied research, even within the premier organization historically dominating fundamental Soviet science—the Academy. Younger men such as G. Marchuk, Ye. Velikhov, and Yu. Ovchinnikov, who have to a large extent climbed to the top because of their work in applied science, are gaining positions of great responsibility in terms of science planning and management within the GKNT and the Academy. Velikhov is reported to be in weekly contact with Gorbachev, serving in essence as his science adviser. Fundamental scientists had dominated the Academy leadership from 1960 until recently. These men can be expected to influence strongly the nature of Soviet science for at least the next decade, and the results of their influence will continue into the years beyond.

66. In the short term, the emphasis on applied research will further focus the attention of the high-quality scientists in the Academy on the priority economic and military problems of the country. In terms of manpower, however, this will be a small addition to the already enormous Soviet applied science effort.

67. In the long term, given the smaller fraction of scientists devoted to fundamental science, we expect to see a gradual reduction or leveling off in Academy fundamental science having little or no obvious applications and, consequently, in the pool of new ideas generated by Soviet scientists. The Soviets may feel that, with easy access to Western literature on fundamental science, they can accept a minimal fundamental research effort in order to accelerate their drive for technology development. We expect, consequently, an increasing Soviet reliance on Western science, as well as technology, as a source of new ideas. This will come at the price of reduced international prestige, and there will be a time lag before the Soviets can pick up and exploit Western science.

68. Regardless of the extent to which applied science encroaches on the Soviet fundamental science research effort, basic research in general will continue to suffer from two major handicaps that we believe will remain largely unremedied over the next decade.

69. The first handicap is the lack of the necessary tools for conducting research, particularly in experimental science. This includes instrumentation, computers, large-scale research facilities, and the people and parts needed to maintain them. Although the Soviets have demonstrated the ability to do surprisingly good research with equipment considered relatively crude by Western standards, the lack of a broad infrastructure for producing and maintaining high-quality, reliable instrumentation will slow their progress and continue to absorb the time of large fractions of the personnel of their research institutes. In some cases, the lack of sophisticated instrumentation and/or computer support may completely exclude them from effective participation in forefront research. This lack of equipment may be alleviated to some extent when the equipment can be purchased in the West, although the problem of the availability of parts and maintenance personnel will remain. The structural and incentive changes that the new, younger political leaders are exploring, even if successful, will probably not begin to show a major effect on the instrumentation problem for another 10 years.

70. The second problem, that of restricted communication and travel among scientific researchers, is a particularly thorny issue for the Soviets. The strong penchant for secrecy and sharp institutional boundaries that are at the heart of the communications problem are unlikely to loosen in the near future and, if there is a further shift toward applied science, are likely to tighten even further. The importance of the control of information in Soviet society is so high, and the threat from uncontrolled publications, so great that a vast opening up of communications is almost inconceivable. As a result, even with the help of a centralized scientific information distribution center, duplication of effort, reduced synergism among scientists, and the slow diffusion of ideas and techniques will continue to hamper Soviet scientific research.

71. Even though the research environment has led to many negative effects, there may be some effects that are advantageous to the Soviets. Several factors suggest that the probability of Soviet technological surprise, resulting from work in the leading edge areas of applied science, may increase in the future. This prospect stems not from any particular strength or excellence of Soviet scientific research, but rather from the systemic conditions under which it operates.

72. It has been widely noted by US scientists that the Soviets frequently work in areas considered to be off the beaten track by Western scientists. Furthermore, Soviet scientists working in these areas can often get continuing support over many years. Although much of this work never leads anywhere, it is from these areas that an unexpected development might arise, as well as from the Soviet brute force approach to exploring scientific problems. If the Soviets do move even further toward applied research, we would expect some of their best scientists to spend more time on applied problems. Fundamental science in areas not pursued by the Soviets but still needed to fuel applied science developments will continue to be available to the Soviets through Western literature, but will come at the cost of a delay in the assimilation of fundamental science into their scientific community.

73. The lack of adequate computing power and instrumentation available to Soviet scientists has imposed constraints on them that force careful study of a problem in order to deal with it within those constraints. This has created an environment that puts a premium on analytical mathematical ability, physical insight, and insightful design of experiment. Thus, Soviet research is characterized by cleverness of approach and design. They are often able to squeeze more performance from their computers and instrumentation than that which is normally associated with the level of technology embodied in that equipment. Thus, given upgraded computers and/or instrumenta-

tion, a surge in Soviet performance beyond that expected is likely. The probability of technological surprise will increase faster than their level of technology, and further technological surprise is more likely to manifest itself in the form of clever designs based on technology inferior to that of the West's than on technological breakthroughs.

74. Over the next decade, we see Soviet science overall as transitioning to an even greater focus on applied science that can directly contribute to economic growth and military strength. Despite its problems, Soviet science constitutes a formidable force in many fields and should be closely monitored, if for no other reason than its vast size and potential and because of the high priority attached to scientific and technological progress by the Soviet leadership. Nevertheless, we expect Soviet science to continue to be hampered by low productivity compared with that of the West as a result of the existing research environment. It will be of crucial importance to the United States and its allies, however, to observe to what extent the new generation of Soviet leaders is successful in modifying and changing the Soviet scientific research environment over the next 10 years, thereby releasing its enormous potential. The consequences of such successful political and administrative initiatives will be felt for decades to come.

ANNEX

Formal Organizational Structure

Basic scientific research in the Soviet Union, as with most activities, is centrally planned. The organizations responsible for policy guidance, administration, and performance of research are embodied in a rigid hierarchical structure that provides a mechanism whereby Communist Party Central Committee policy initiatives can directly influence the direction, scope, and level of effort in all fields of research. (See figure 1, page 8.)

The USSR Council of Ministers serves as the top administrative body of the government responsible for day-to-day operations of the economy and the development of an integrated economic plan, which includes basic science. It is also responsible for reflecting broad policy initiatives, as set forth by the party, in its planning and administrative activities. The Council of Ministers exercises its responsibility for planning and administrative duties through a series of state committees, reporting to the council, which are oriented toward specific functions (for example, finance, planning, supply, and S&T).

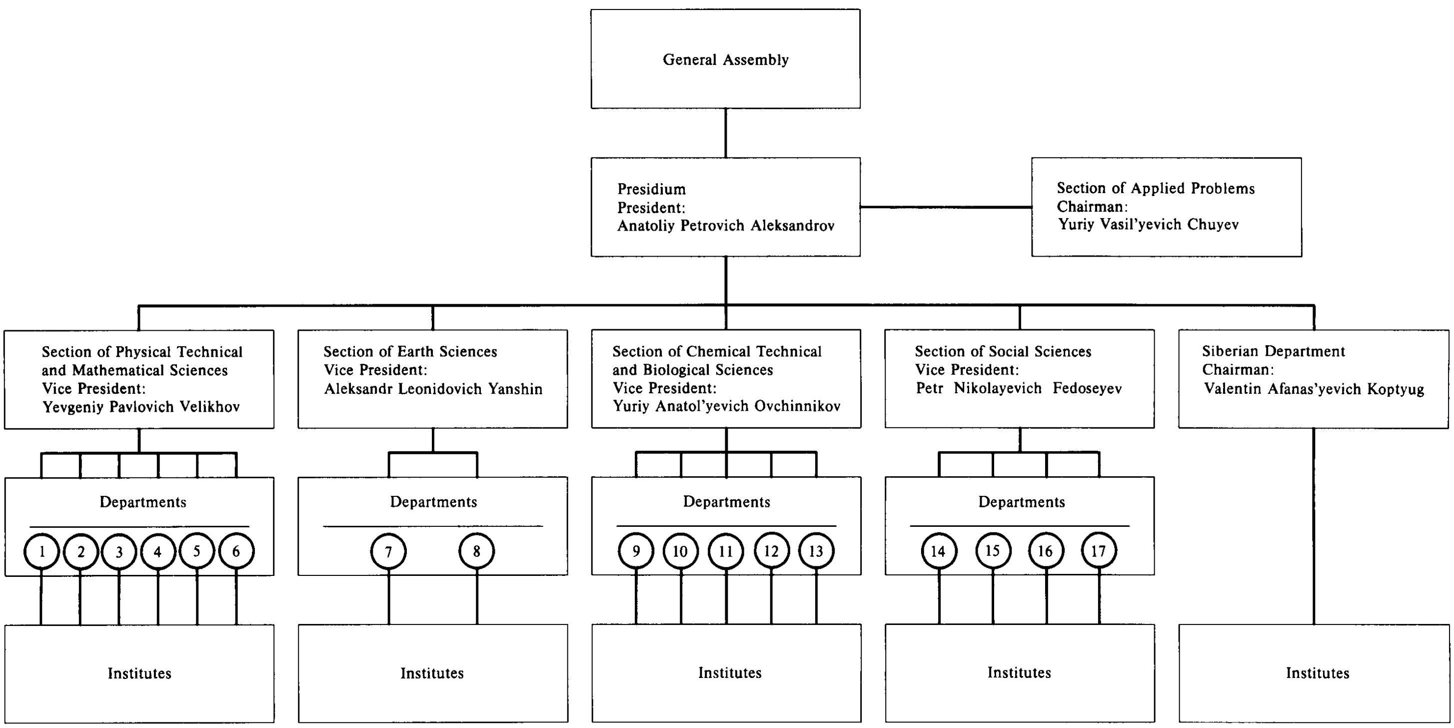
The primary players who coordinate the overall scientific research plan for consideration by the Council of Ministers are the State Committee for Science and Technology (GKNT, an All-Union state committee under the Council of Ministers chaired by G. I. Marchuk) and the Presidium of the Academy of Sciences of the USSR (AN SSSR, A. P. Aleksandrov, President). The State Planning Committee of the Council of Ministers (Gosplan) and the Ministry of Finance participate with the GKNT and the AN SSSR in setting the overall funding levels. For projects that require major resource allocations, other committees under the Council of Ministers, such as the State Committee for Construction Affairs (Gosstroy) and the State Committee for Material and Technical Supply (Gossnab), also participate.

The GKNT is charged with the coordination of a unified state S&T policy. It prepares S&T forecasts, drafts a list of major S&T problems to be solved during the next five-year plan, develops proposals with the AN SSSR and Gosstroy for inclusion in the five-year S&T plans and longer range S&T programs, and works with Gosplan and the Academy in developing proposals for the introduction of R&D results into the economy. The GKNT has little direct managerial control over the actual conduct of institute research.

The AN SSSR plays a pivotal role in the planning, management, and conduct of fundamental science in the Soviet Union. In addition to the overall planning functions performed in collaboration with the GKNT noted above, the AN SSSR maintains direct managerial control over the bulk of the fundamental research programs in the country. We estimate that about 50 percent of the research conducted in fundamental science in the Soviet Union takes place in the scientific research institutes of the Academy system, with the remainder taking place mostly in the universities and other institutes of higher learning (VUZy) under the Ministry of Higher and Specialized Secondary Education, and to some extent in the research institutes of the industrial ministries. In addition, the AN SSSR by charter is given responsibility for overseeing and coordinating *all* fundamental scientific research in the country, although its direct managerial control only extends to its own institutes. Thus the research plans of the Union-Republic Academies of Sciences, for instance, must be passed through the AN SSSR via its Union Republic Academies of Science Coordination Council. (See figure 2.)

Each Academy institute generates a proposal for its own research plan that forms the substance for the deliberations of the upper levels of the AN SSSR (department, section, and presidium) and the GKNT in formulating the overall research plan for the country.

Figure 2
Organization of the USSR Academy of Sciences



1. Department of Mathematics
2. Department of Nuclear Physics
3. Department of General Physics and Astronomy
4. Department of Mechanics and Control Processes
5. Department of Information Science, Computer Technology, and Automation
6. Department of Physical Technical Problems of Power Engineering
7. Department of Geology, Geophysics, and Geochemistry
8. Department of Oceanology, Atmospheric Physics, and Geography
9. Department of Biochemistry, Biophysics, and Chemistry of Physiologically Active Compounds
10. Department of General Biology
11. Department of General and Technical Chemistry
12. Department of Physical Chemistry and Technology of Inorganic Materials
13. Department of Physiology
14. Department of Economics
15. Department of History
16. Department of Philosophy and Law
17. Department of Literature and Language

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