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SOVIET SCIENCE AND TECHNOLOGY

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Submitted by the

DIRECTOR OF CENTRAL INTELLIGENCE

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Concurred in by the

UNITED STATES INTELLIGENCE BOARD

on 21 July 1959. Concurring were the Director of Intelligence and Research, Department of State; the Assistant Chief of Staff for Intelligence, Department of the Army; the Assistant Chief of Naval Operations for Intelligence, Department of the Navy; the Assistant Chief of Staff, Intelligence, USAF; the Director for Intelligence, The Joint Staff; the Atomic Energy Commission Representative to the USIB; the Assistant to the Secretary of Defense, Special Operations; and the Director of the National Security Agency. The Assistant Director, Federal Bureau of Investigation, abstained, the subject being outside of his jurisdiction.

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SOVIET SCIENCE AND TECHNOLOGY

THE PROBLEM

To assess the current situation and probable future developments in Soviet science and technology during the next 10 years.

CONCLUSIONS

1. The Soviet regime will continue to place great stress on scientific and technological progress as basic to the growth of its military, economic, and political power. The regime is allocating a substantial and increasing part of the national product to the Soviet scientific and technological effort which is focused primarily on the building of a strong industrial base and the development of modern military power. As a consequence, the USSR's achievements in certain areas of critical military and industrial significance are comparable to and in a few cases exceed those of the US. We believe that over-all the West still enjoys a scientific lead, but this lead will be increasingly threatened during the period of this estimate. (*Paras. 9–12, 52–53*)

2. During the past three decades, the USSR has laid a solid foundation for scientific advance. The more spectacular Soviet achievements to date have resulted primarily from the concentration of resources in a few high priority programs. However, the USSR now has the capability and apparently the intention to advance on a much broader front. The rate at which scientific and technical resources are increasing will permit some greater attention in the future to consumer goods fields, and perhaps significantly increased technical aid programs abroad. The current Seven-Year Plan, which relies heavily on scientific and technological achievements, probably will lead to a considerable increase in the Soviet scientific effort affecting all important disciplines. (*Paras. 23–26, 35, 39–47, 49, 52–53*)

3. Significant Soviet advances in science and technology are likely to occur with greater frequency than in the past, and we believe that over the next decade the USSR may achieve world leadership in an increasing number of scientific areas. By concentrating effort and resources, the USSR may also achieve a number of "firsts" in certain prestige fields such as direct conversion of heat to electricity, manned exploration of space, and controlled thermonuclear reactions. In ad-

dition to their economic and military implications, a series of such spectacular successes would have great psychological and political effect throughout the world which would undoubtedly be used by the USSR to support a claim to world scientific supremacy. (*Paras. 48–53*)

4. The number of scientific and technical graduates in the USSR has increased approximately threefold in the postwar period, and is now significantly larger than that in the US. However, we believe that the over-all capability of Soviet scientific-technical professional manpower is still inferior to that of the US. Soviet numerical superiority results primarily from the large numbers of engineers and agricultural experts; the US leads in numbers of physical and biological scientists. The USSR makes extensive use of scientific-technical professionals for tasks which would be handled by nontechnical graduates or even nongraduates in the US. The work of the best Soviet scientists is on a par with that of leading Western scientists, and postwar training in the USSR has steadily improved. However, the majority of Soviet professionals have less experience than their Western counterparts. US graduations in scientific and technical fields are expected to increase, but the USSR almost certainly will continue to enjoy a numerical superiority. On the basis of current trends, by 1964 the USSR would have about one-third more graduates of scientific and technical curricula than the US. At that time, the quality of the Soviet scientific-technical manpower force probably will be generally comparable to that of the US. Soviet numerical superiority will continue to derive from the large number of graduates in engineering and the agricultural sciences. (*Paras. 35–40, and Appendix D*)

5. Since 1957, the Soviet leaders have undertaken major reorganizations of industry, education, agriculture, and science. In science, the major changes to date involve an administrative and geographic decentralization directed toward greater emphasis on practical results of research, closer ties between science and technology, improved planning and coordination of the entire Soviet research effort, improvement in the effectiveness and timeliness of technological innovation, and increased support for regional economic development. We believe that generally the reorganization of science will produce the results desired by the Soviet leaders. The educational reforms chiefly concern primary-secondary schooling, and provide that almost all Soviet children of secondary school age are to have some work experience. The reforms on this level appear to be designed to better prepare the majority of Soviet youths for jobs in industry and agriculture, and should result in an improvement in the quality of Soviet workers. The requirement for work experience in higher education probably will improve training in engineering and applied science. It may have a retarding, but not very serious, effect on studies in pure science. (*Paras. 13–22, 27–34*)

6. Soviet capabilities in the basic sciences are generally good, particularly in the theoretical aspects. Soviet science shows particular strength in physics, mathematics, and the geophysical sciences, and it is in these fields that major Soviet advances are most likely to occur. The USSR generally lags behind the West in chemistry, biology, agricultural sciences,

and some aspects of medical research. However, we believe that by the end of the period of this estimate, Soviet backwardness in chemistry will be eliminated in most important fields, and Soviet medical research and clinical medicine will be raised to a level approaching Western standards. Due to increased official support, research in the biological and agricultural sciences is also expected to improve appreciably. (*Paras. 54–61; and Appendix A*)

7. The USSR is continuing its strong emphasis on military weapons research and development. Recent tests have revealed further advances in Soviet nuclear weapons technology in meeting diversified military requirements. The high priority accorded to the Soviet missile and space programs has assured the availability of capable personnel, high quality research and development facilities, and strong support from associated fields. We expect rapid advances in the Soviet missile and space programs including the achievement of manned space flight within the next few years. Development of ground, air, and naval weapons continues, although lack of sufficient experimental facilities has hampered aeronautical development to some extent and may continue to do so in the future. Soviet electronics research and development has been outstanding, and notable advances in military electronics will continue. The USSR has comprehensive chemical and biological warfare research programs, and future research probably will emphasize new and improved agents, means for dissemination, and equipment for defense. (*Paras. 61–65 and Appendix B*)

8. Soviet industry is characterized by marked qualitative unevenness in technological practices between industrial sectors and even within certain sectors generally well developed. In heavy industry, such as steel making, industrial techniques, and equipment often compare favorably with those used in Western practice. However, industrial practices generally are behind those of the West and often are crude by Western standards. Industrial applications of automation techniques appear to be limited to a few experimental installations, but such techniques probably will be introduced widely in many sectors of the economy over the next 10 years. We believe that the USSR will make important advances in the average level of its industrial technology during the next 10 years. However, in spite of the effort and resources being devoted to this task, the magnitude of the problem is so great that Soviet industrial technology will remain generally behind that of the West during the period of this estimate. (*Paras. 66–67 and Appendix C*)

DISCUSSION

I. ADMINISTRATIVE FACTORS AFFECTING SOVIET SCIENCE AND TECHNOLOGY

Attitude of the Regime

9. The Soviet regime has for many years placed great stress on scientific and technological progress as basic to the growth of its military, economic, and political power. Specific scientific and technological goals and the means of their achievement are carefully planned, and progress is closely monitored by the central authorities. Although some increased share of the scientific and technological efforts has been devoted to raising the

standard of living in recent years, by far the major part continues to be directed primarily to the building up of a strong industrial base and the development of modern weapons.

10. The regime has allocated a substantial and increasing part of the national product to the strengthening of science and technology. Over the last three decades, research facilities have been greatly expanded, the quality of Soviet scientific training has been improved, and the number of graduates in scientific and technical subjects has constantly increased. In terms of social position and financial status, Soviet scientists as a class have long constituted one of the privileged groups in the USSR. However, under Stalin, Soviet scientists, like all other elements in Soviet society, were subjected to increasingly rigid and arbitrary controls and ideological interference which had a stultifying effect in certain fields.

11. In the general relaxation which followed the death of Stalin, relations between the scientific community and the regime improved, and political and ideological interference diminished markedly. In contrast to the extreme insularity of the Stalin regime, the Soviet leaders adopted a policy of acknowledging foreign achievement and encouraging maximum use of foreign experience, including contacts and exchanges between Soviet and foreign scientists.

12. More recently, official criticism of Soviet scientists for their "isolation from life" indicates that the attitude of the regime is now being modified somewhat. There are indications that greater emphasis is being placed upon application of the results of scientific research and even that pay scales for scientific research may be more directly related to practical results. Trofim Lysenko, the controversial biologist who apparently epitomizes Khrushchev's ideal of the "practical scientist," has been returned to official favor. Party control of science appears to be tightening. However, despite the check in the post-Stalin trend toward liberalization, there will probably not be a return to the extreme interference which characterized the late Stalin period.

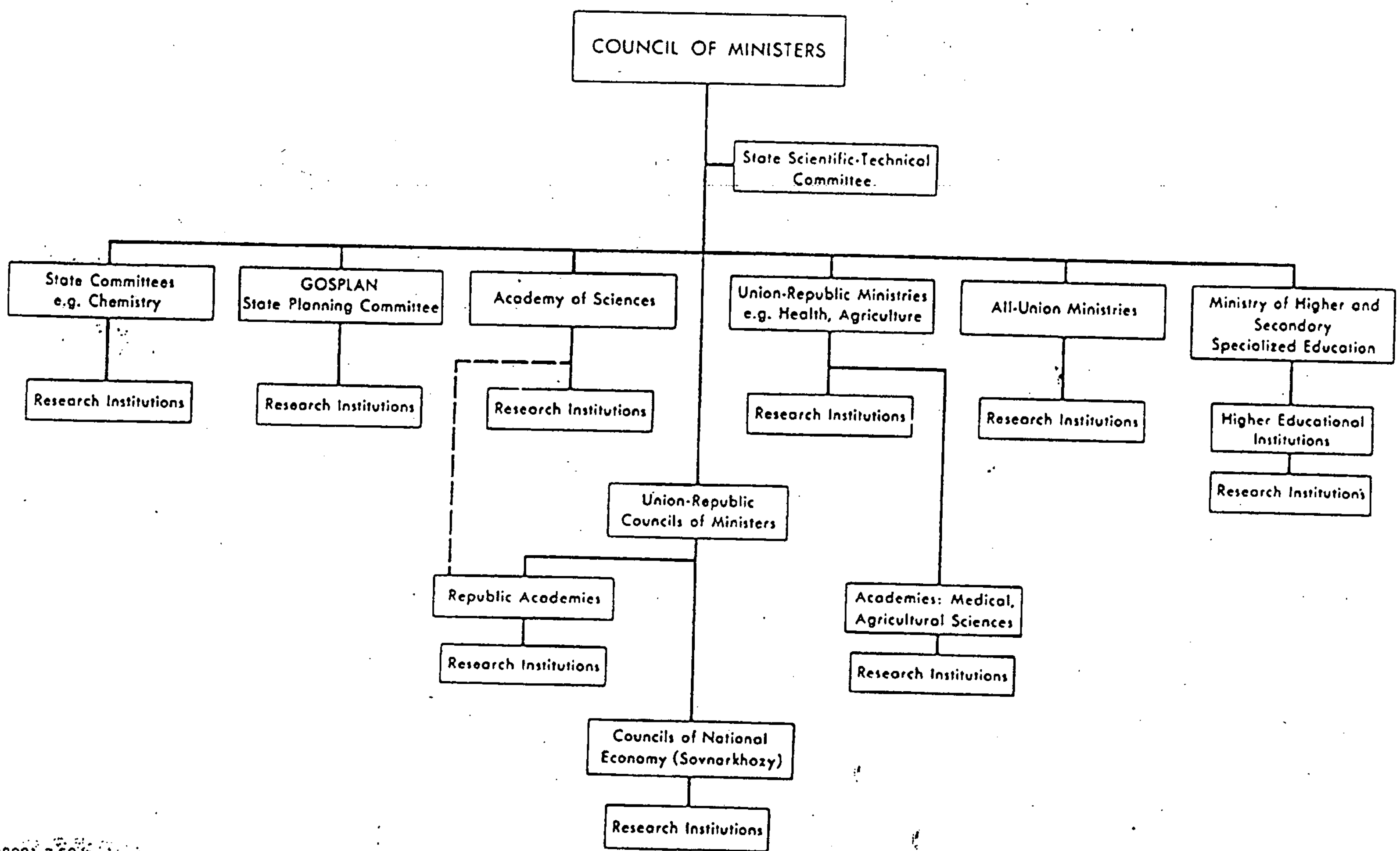
Policy, Organization, and Planning

13. Since 1957, Soviet leaders have undertaken major reorganizations of industry, education, agriculture, and science which appear to be motivated by both political and economic reasons. Politically, these changes point to the shifting of functions away from the central bureaucracy to other organs, the strengthening of the Party's dominant role, and the reduction of the influence of other elite groups in Soviet society. Although these measures are given a deep ideological coloration, they are also justified on the grounds of greater efficiency and increased productivity and thus related to the ambitious Seven-Year Plan. In science, the major changes have involved an administrative and geographical decentralization which, apart from political aims, is apparently directed toward a greater emphasis on practical results of research, closer ties between science and technology, improvement in the effectiveness and timeliness of technological innovation, improved coordination among research facilities, and increased support for regional economic development. We believe that generally the reorganization will produce the results desired by the Soviet leaders.

14. *Academy of Sciences.* The Academy of Sciences, which is directly responsible to the Council of Ministers, remains the most important scientific body in the USSR. The Academy's membership, some 167 Academicians and 361 Corresponding Members, includes the nation's most eminent scientists. Through its 10 departments the Academy of Sciences controls about 130 scientific institutes, and there are associated academies with affiliated institutions in 13 of the 15 Union Republics. This entire complex employs 10 to 15 percent of all scientists in the USSR. The Academy emphasizes theoretical research, and its scientists carry out more than half of all fundamental research done in the USSR. This emphasis probably will continue, but Academy institutes are expected to provide increased scientific support to applied research institutes.

Figure 1

THE ORGANIZATION OF SOVIET SCIENTIFIC RESEARCH



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15. Although the Academy of Sciences still dominates scientific research in the USSR, a trend toward decentralization of the Academy has been underway since the formation of the Siberian Department in May 1957. Steps are being taken to relocate some personnel of the Academy, now concentrated in the Moscow and Leningrad areas, by transferring them to new institutions in widely dispersed areas. The new constitution of the Academy, published in May 1959, reflects an administrative decentralization aimed at reducing the control exercised by the Presidium within the Academy in favor of the General Assembly, the Departments, and the local institutes.

16. *Higher Educational Institutions.* Nearly half of all Soviet scientists are employed in the universities, technical institutes, and pedagogical institutes. These institutions and their scientists are not subordinated to the Academy, but fall under the control of the Ministry of Higher and Secondary Specialized Education. In the higher educational institutions, scientists are concerned primarily with teaching, and have devoted proportionately less time to research than those in the academies and the research institutes. Since 1956 directors of research in higher educational institutions have been given greater administrative authority, and research is being increased to provide more scientific and technical support for regional economic programs. It has been announced that 80 well-equipped laboratories are being established in the leading educational research institutes to carry out interdisciplinary research on selected problems in radio chemistry, nuclear physics, electronics, transistors, computers, and other areas.

17. *Other Research Institutes.* The remaining 40 percent of Soviet scientists work for institutes which are attached neither to the Academy nor to the institutions of higher learning. Until the economic reorganization of 1957, most of these institutes were subordinated to All-Union and Union-Republic Ministries, and worked primarily on applied research in support of the industrial, military, or other functions of each ministry. With the abolition of many of the ministries, beginning in 1957, the research institutes formerly under their control were transferred to the control of governmental organs on the national, republic, regional, and local levels.

18. Most of the industrial research institutes were resubordinated to the new regional economic councils (*sovnarkhozy*). Institutes which are engaged in research and development programs of national significance are under the control of State Committees for Defense Technology, Aviation Technology, Radio-Electronics, Automation and Machine Building, Shipbuilding, and Chemistry. Central research institutes in certain basic industrial fields, such as steel, have been placed under the control of the State Planning Committee (GOSPLAN). A number of research institutes are still controlled by the remaining ministries, including the Ministry of Medium Machine Building, which controls all defense-connected atomic energy research, the Ministry of Health, and the Ministry of Agriculture. Generally, it appears that administrative control over institutions conducting high-priority research remains centralized, while administration of lower priority research has been decentralized.

19. Current plans to increase the number of scientific institutions reflect the trend toward geographic decentralization. Two new scientific centers, which will be subordinated to the Academy's Siberian Department, are now being constructed in Novosibirsk and Irkutsk. The Novosibirsk center, planned for completion by 1960, will have 14 new research institutes; the Irkutsk center, which is scheduled for completion in 1965, will have eight. Expansion is also underway or planned in a number of other cities. Plans for an expansion of the Academy system call for 34 new scientific institutions in branches of the Academy of Sciences USSR and 134 in the republic academies during the Seven-Year Plan period. A major effort is being exerted to attract competent scientific personnel to the new centers by creating favorable living conditions, establishing excellent research facilities, and assigning certain eminent scientists to these locations. Initially the drain on manpower and resources from the older centers will undoubtedly affect some research programs ad-

versely. In the long run, however, the increased number of scientific institutions, distributed over a wider area, probably will result in an improved scientific and technological capability.

20. The regime is also attempting to improve planning and coordination of the total Soviet research effort. In the past, the USSR has demonstrated its capability to plan centrally and carry out successful programs in high-priority fields such as atomic energy, guided missiles, and electronics. However, in fields of lesser priority, planning and coordination generally has been complicated by the large size and diversity of the total scientific effort and by administrative compartmentalization. With the reorganization there has been some improvement on the top level, at least in the formulation of long-range and nationwide scientific policies and goals. In connection with the Seven-Year Plan, the Academy of Sciences, the Ministry of Higher Education, and the State Scientific-Technical Committee for the first time jointly produced a document defining "major directions" of scientific research. At its annual meeting in May 1959, the Academy of Sciences proposed new procedures for planning and coordination of research. Determination of the most important scientific problems are to be made by five new interagency committees for different areas of science and technology. According to these proposals, basic problems are to be handled by "scientific councils" which will coordinate research work regardless of where that work is done.

21. A few of these councils already exist, but their use on a much wider scale was proposed in March 1959 by V. A. Kirillin, head of the Central Committee's Section for Science, Higher Educational Institutions, and Schools. Kirillin envisaged about 100 such councils each linking several dozen research institutes, laboratories, and higher educational institutions engaged in the same relatively narrow field of research. The council would be based at one of these facilities which would fulfill the functions of a head institute, and would consist of representatives from the member institutions, from industry, and possibly from "other interested organizations." The formation of additional scientific councils has also been endorsed by A. V. Topchiyev, vice president of the Academy. However, the future composition and number of such councils is not yet clear.

22. In June 1959, the party's Central Committee called for additional steps designed to "raise the role of science in technical progress, improve the organization of research and experimental work, and step up the introduction of scientific achievements." These measures were explicitly related to fulfillment of the Seven-Year Plan. In the course of a much publicized plenum on problems of automation and mechanization in industry, the Central Committee issued several decrees requiring implementation by appropriate governmental organs including, in most cases, the *sovnarkhozy*. The measures included: strengthening of scientific support to the *sovnarkhozy;* expansion of research work at the *sovnarkhozy* and local levels; improvement of supplies of equipment and materials at all research facilities; improvement in the organization of research and experimental work; and an acceleration in the pace of technological innovation. By 1 January 1960, plans are to be prepared for the establishment of more research institutes at plants, the transfer of certain industrial research institutes to higher educational institutions, and the formation of scientific councils. Also within six months, new estimates of future requirements for specialists with higher education are to be submitted together with plans for expanding the training of such specialists. The setting of deadlines, the unusual circumstances surrounding the convocation of the Central Committee plenum, and Khrushchev's speech before the plenum are indicative of a mounting concern within the party centered upon increasing the scientific contribution to technological advancement.

II. SCIENTIFIC AND TECHNICAL RESOURCES

Financial Support

23. Current Soviet expenditures for research and development are estimated to be at least

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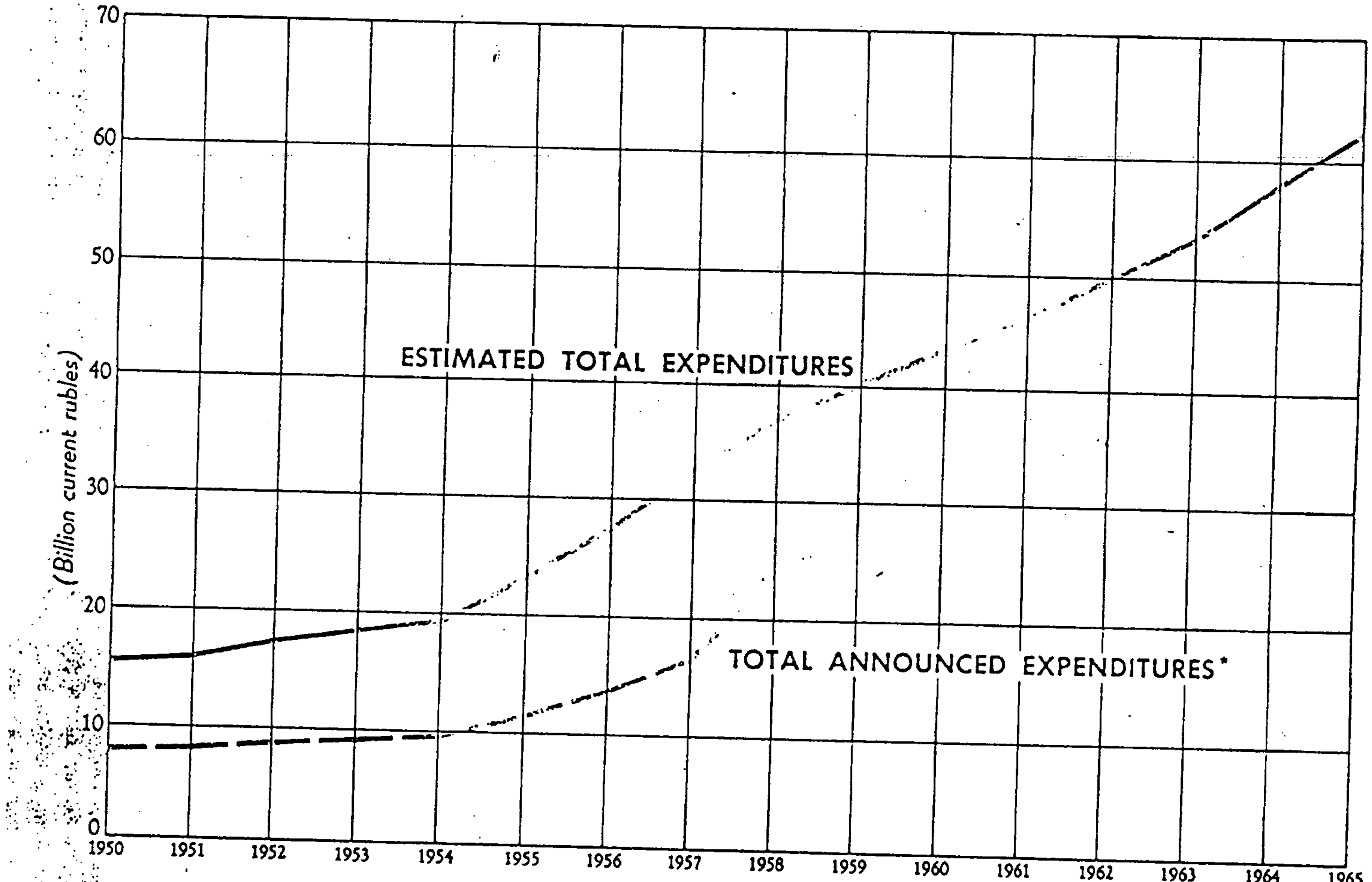
SOVIET EXPENDITURES FOR RESEARCH AND DEVELOPMENT, 1950-65



*The budgeted part of these outlays is part of the broader allocation for social-cultural activities; those funds not from the budget are from the resources of enterprises. Most of these funds are budgeted.

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40 billion rubles[1]—twice the 1953 level. These expenditures represent about two and one-half percent of the USSR's Gross National Product (GNP) which is roughly the same share expended by the US.[2] Although the size of the Soviet research and development effort, in absolute terms, is smaller than that of the US, we believe it to be larger in real terms than the GNP relationship would imply. The Soviet effort has been far more highly concentrated on fields related to national power, while research in consumer products has been proportionately much less. We estimate that about two-thirds of the total Soviet effort is for military or related purposes. As a consequence, the USSR's achievements in certain areas of critical military and industrial significance are comparable to, and in some cases exceed those of the US.

24. Over the last few years, Soviet expenditures for research and development have increased at a slightly greater rate than the GNP. The rate of growth seems to have been particularly rapid during the period 1954–1959 (see figure 2). We believe that the rate of growth over the next five years probably will be somewhat lower than the current rate, but still appreciable. In any event, past trends and announced Soviet plans give reason to believe that strong financial support will continue to be provided for the scientific and technical effort in the USSR and that Soviet expenditures probably will permit full utilization of new personnel and facilities.

[1] Approximately one-half of this amount is included in the Soviet Budget under the general allocation for social-cultural activities and labeled as being for "financing scientific research establishments." We estimate that an equal amount is appropriated for "product development," which includes design and production engineering, experimental production, testing, prototype production, and a variety of associated activities. Funds for these purposes are not explicitly indicated, but are believed to come largely from the budgetary category for financing the national economy.

[2] We estimate Soviet GNP to be about 40 percent of US GNP.

Research Facilities and Equipment

25. Scientific research in the USSR is carried out in about 3,000 scientific and technical institutions. The adequacy of these research facilities varies considerably. In general, the research related to defense and heavy industrial development receives the best facilities and equipment on a priority basis; and in a few fields the USSR has facilities which are comparable, if not superior, to corresponding installations in the West. In priority areas of physics, for example, facilities are excellent and include a 10-BEV proton synchrotron, currently the highest energy accelerator in operation in the world. The average Soviet laboratory is less well-equipped than the average US laboratory, but we believe that scientific facilities in the USSR are generally adequate for the effective utilization of Soviet scientific manpower.

26. Shortages of research instruments continue to exist, particularly in low priority fields, but they probably do not significantly hamper research programs of major importance. Although Soviet produced equipment is often the equal of foreign-produced equipment and occasionally its superior, the USSR will probably continue to import equipment over the next few years for reasons of expediency. At the same time, the USSR will continue to improve its own capabilities in scientific instrumentation. There is evidence that a number of new instrument factories have been established or are planned, and a substantial increase in instrumentation research has been indicated by the recent appearance of a number of new, high-quality publications and the establishment of new institutes in this field. An increasing amount of Soviet scientific equipment will reflect native design concepts, and by the end of the period of this estimate we believe that Soviet development and production of scientific equipment will be sufficient to meet their needs.

Educational Institutions

27. The Soviet educational system, more than any other in the world, concentrates on training scientists, technicians, and skilled labor. This emphasis will be intensified by the edu-

cational reorganization now underway. The Soviet 10-year school is roughly equivalent to the US 12-year school, but the average Soviet 10-year school graduate is better trained in science and mathematics than his US counterpart. The Soviet curriculum is heavily weighted on the side of science and mathematics which comprise more than 40 percent of total course work in the upper grades. The curriculum was changed somewhat in 1954–1955 to include vocational subjects such as shop training, largely at the expense of courses in the humanities.

28. In addition to the regular 10-year school, the Soviet educational system includes various levels of special schools. At the lowest level are short-term factory and trade schools which develop labor skills. At the next level are *tekhnikums,* roughly comparable to technical high schools in the US, which offer on a competitive basis three or four years of specialized training to students who have finished seven years of the regular 10-year program, and which offer two-year training on the junior college level to 10-year school graduates. The *tekhnikums* play a vital role in the training of technicians in almost all occupational categories.

29. Graduates of the 10-year schools are selected by competitive examination for admission to higher educational institutions. During the past few years there have been many more applicants than vacancies in higher institutions, and standards of admission have been raised. Students are channeled into particular fields of study by various means such as propaganda, draft exemptions, quotas, and differential stipends. All graduates of higher educational institutions must accept state directed employment for a period of three years following graduation.

30. There are about 750 higher educational institutions in the USSR. Of these, some 39 universities and 375 technical institutes provide scientific and technical training that is roughly equivalent to that required for a Bachelor of Science degree in the US. Some scientific and technical training is also provided to students in the 200 pedagogical institutes. Soviet higher educational institutions have a total enrollment of about 1,250,000 full-time students, and about two-thirds of all Soviet graduates are in scientific and technical fields. The institutes offer five to six-year courses of study which are geared to the specific requirements of a particular industry (e.g., mining, aviation) or a well-defined vocation (e.g., medicine, agronomy). The universities offer much broader training centered around a major field (e.g., physics, chemistry, mathematics). Courses of study last five years, and graduates may enter the teaching profession or become research scientists.

31. The standards of higher educational institutions, set by the Ministry of Higher and Secondary Specialized Education, have improved considerably over the past 20 years, and today, Soviet higher education in scientific and technical fields is considered to be generally of good quality. Soviet higher educational curricula differ from those in the US primarily in imposing a much heavier load of scheduled hours over a longer period of years. In certain fields such as agriculture, the quality of training appears to be below US standards, but in others, such as the physical sciences, Soviet standards appear equal to those of a good US college. The Ministry of Higher Education is currently engaged in reducing overspecialization in engineering courses, and is encouraging schools to allow students more time for independent research and reading. Various new procedures, such as giving entrance preference to applicants who have had two years work experience, are designed to give more emphasis to practical training than in the past. US educators now tend to evaluate the current Soviet graduates in science and engineering as equal, if not in some respects superior, to US graduates.

32. *Educational Reforms.* The reforms recommended by Khrushchev in September 1958 and approved by the party and government are planned for execution within the next three to five years. Basically the legislation involves a shift away from a system of secondary education which emphasized college-preparatory training to a system in which preparation for college is only one of several

objectives. Eight years of full-time schooling will be required, which may be followed by three years of study in various types of secondary schools. Under present plans, almost all children of secondary school age are to have some work experience. The great mass of the students either will attend the new "labor-polytechnical schools" and receive part-time job training, or will go directly to work and continue their schooling in after-hours training. However, some students will continue full-time schooling at the *tekhnikums* or other schools. Students in higher educational institutions will also be expected to work full-time during a part of their enrollment period. Khrushchev's original proposals have now been modified somewhat, and additional changes probably will be effected in practice.

33. Soviet leaders have justified the reorganization of Soviet secondary schools on educational, ideological, and economic grounds. Among other things, the reforms appear to be designed to better prepare the majority of Soviet youths for the jobs in industry and agriculture which they will eventually hold. Eventually, the major economic effect of the educational reorganization will be a significant improvement in the quality of industrial and agricultural workers. Requiring engineering and other students in applied science to work in the economy during part of their higher education, usually in fields related to their study, is likely to improve the quality of their training, which in the past has often been too theoretical. Work requirements on students in pure science may prove to be a hardship. Nevertheless, the requirements are to be less stringent in their cases, and professors will probably find ways of assigning these students to academically useful work.

34. *Postgraduate Training*. At the postgraduate level, some 460 institutions are authorized to conduct training leading to the *Kandidat* degree, and 250 of these accept dissertations for the higher degree of *Doktor*. Both of these degrees are conferred or confirmed by a special commission of the Ministry of Higher and Secondary Specialized Education. The *Kandidat* degree requires at least three years of graduate study, two foreign languages, and a dissertation. In the physical sciences, engineering and the health sciences, the quality of the *Kandidat* degree is roughly equivalent to or slightly below that of the US Ph. D. or D. Sc. In the agricultural and some areas of the biological sciences, it is closer to that of a US Master's degree. The degree of *Doktor* represents a qualitative level beyond that of the *Kandidat* or Ph. D. range.

Manpower

35. The number of scientific and technical graduates in the USSR has increased approximately threefold in the postwar period and is now significantly larger than that of the US. As of mid-1959, there are about 1,750,000 employed graduates of university-level scientific and technical curricula in the USSR, about 20 percent more than in the US. The USSR also has nearly 20 percent more holders of advanced scientific-technical degrees than the US. The number of Soviet scientific-technical graduates will continue to increase through 1964. Although US graduations are also expected to increase, the USSR almost certainly will continue to enjoy a numerical advantage. On the basis of current trends, by 1964 the USSR would have about one-third more scientific and technical graduates than the US.

36. As indicated by the accompanying table, Soviet numerical superiority results primarily from the large numbers of engineers and agricultural scientists. Soviet college graduates are less plentiful in the physical sciences, the biological sciences, and medicine. Soviet numerical weakness in physical science is compensated in large measure by the large numbers of engineers who in general have more training in the physical sciences and hold more advanced degrees than their US counterparts. The USSR has more physicians per capita than the US, but fewer personnel with higher education in auxiliary fields of medicine (e.g., pharmacy, dentistry, and nursing), which in the USSR make wide use of technicians with only secondary education. Generally, the same relative positions of the US and the USSR are expected to prevail through at least 1964 although the Soviet lead in engi-

neers and the US lead in physical and biological scientists are expected to increase.

COMPARISON OF MAJOR SCIENTIFIC AND TECHNICAL GROUPS, USSR AND US [a]

Estimated Numbers of Employed Graduates of Scientific and Technical Curricula (in thousands) [b]

	1959		1964	
	USSR	US	USSR	US
Science				
Physical	112	201	136	297
Biological	22	87	24	117
Medicine [c]	399	461	468	500
Technology				
Engineering	976	522	1,422	638
Agriculture	239	167	331	187
Totals	1,748	1,438	2,381	1,739

[a] Such numerical estimates provide only a rough basis for comparison since: (a) the professional categories are not precisely equivalent in the two countries; (b) the figures do not reflect the broader US supply of scientific and technical personnel who hold no degrees; (c) they give no weight to qualitative differences in training and experience; and (d) practices in the utilization of personnel differ widely.

[b] Estimates of the current total of Soviet scientific personnel are believed to be correct within plus or minus 10 percent. The probable error of certain groups, however, may exceed this amount.

[c] The figure for US medical sciences includes 213,000 persons such as nurses, optometrists, and pharmacists who hold BS degrees, while a significantly larger number of Soviet personnel are excluded because they are not graduates of higher educational institutions.

37. The numbers in the above table provide at best only a rough basis for comparison because of data limitations in both the US and the USSR, greatly differing educational requirements for comparable duties in the two countries, and widely differing practices in utilization of personnel. In engineering and agriculture, for example, the Soviet Union makes extensive use of scientific-technical professional manpower for tasks which would be handled by nontechnical graduates or even nongraduates in the US, such as positions in administration and management which in the US are filled by graduates of business or liberal arts colleges, and positions as foremen or farm managers which in the US are filled by people without extensive college training.

38. The quality of Soviet scientific and technical professional manpower is generally good. There are a few very competent Soviet scientists with prerevolutionary training, but the majority of older personnel, who received their training during the earlier years of the Soviet regime, are considered qualitatively inferior to US professionals. Even persons trained under recent higher standards, who now comprise the majority of Soviet scientific-technical manpower, lack the experience possessed by the generally older US professionals. However, in the USSR as in the West, scientific advances are made by a few brilliant individuals, and the work of the best Soviet scientists is generally comparable to that of their Western counterparts.

39. We believe that the over-all capability of Soviet scientific and technical professional manpower is still inferior to that of the US force. However, this inferiority will diminish and, in some cases, disappear during the next 10 years as the number of Soviet skilled technicians and nonprofessionals increases, as the quality of Soviet training improves, as the older Soviet personnel are replaced by younger, better-trained professionals, and as the postwar graduates acquire more professional experience. As qualitative differences diminish, Soviet quantitative superiority will present a growing challenge to the West.

40. *Nonprofessional Manpower.* Although the Soviets have made considerable progress in training the skilled technicians and mechanics needed in modern science and industry, the USSR is not as well supplied with them as are Western countries where broader sections of the population have acquired these skills over a considerably longer period. The shortage of skilled technicians in the USSR probably will persist at least in certain areas, but the number available should increase significantly as a result of the high proportion of scientific and technical subjects in the lower grades, the increased vocational training on the secondary level, and the emphasis on specialized training after lower school.

Exploitation of Non-Bloc Resources

41. The USSR has an outstanding program for collection and dissemination of scientific and technical information. Thousands of foreign publications in 50 languages from 88 countries pour into the Soviet Union every month. To deal with this flood of information, the USSR has established the world's largest scientific and technical information center, the All-Union Institute of Scientific and Technical Information (VINITI). This center now receives about 3,500 titles and about 12,250 foreign journals every month and publishes about 450,000 abstracts annually. Scientific-technical committees which have been established in the Union Republics and technical information bureaus in a number of the *sovnarkhozy* are responsible for following domestic and foreign developments and channeling the information to appropriate research or industrial groups. As the result of this large-scale effort, Soviet scientists in important research centers now have access to almost all scientific developments reported in unclassified Soviet and foreign language publications.

42. The Soviet information program for exploitation of foreign literature utilizes enormous manpower resources in a centralized system. The USSR is now devoting considerable efforts to mechanization of this program which should be aided by the expanding network of computer centers throughout the USSR. Evidence of Soviet work on such new methods as machine translation, data searching, and data processing indicates that Soviet information handling facilities will improve significantly during this period.

43. In addition to the benefits derived from exploitation of open foreign sources, the Soviets have also profited from espionage in a few key fields. However, on an over-all basis, the performance of Soviet science—especially the number of original concepts and discoveries—reinforces our belief that the aggregate contribution of espionage to Soviet scientific progress has been far less important than the USSR's own achievements.

44. Partly as the result of Western embargoes in the postwar period, overt Soviet purchases of Western technological developments have been largely confined to the acquisition of sample items which the USSR hoped to copy or further develop. The USSR is now attempting to acquire Western breeding stock, seeds, prototypes of agricultural machinery, and technical information on production practices. In a few fields, such as the ferrous metals industry, the USSR has also attempted to buy equipment in quantity, and even whole plants. Soviet efforts to purchase Western equipment in quantity are expected to be intensified by the demands of the current Seven-Year Plan. Noting the need for large amounts of new equipment, Khrushchev has stated that it would be "expedient" to order part of this equipment from capitalist countries, primarily the US, the UK, and West Germany. Fulfillment of the 1965 goals for plastics, synthetic fibers, and synthetic rubber will depend in large measure on importation of equipment from the West. The USSR probably will also attempt to purchase electronic and automation equipment, including controls for use in the chemical industry, microwave communications systems, digital computers, and specialized test equipment.

Utilization of Satellite and Chinese Resources

45. The European Satellites, particularly East Germany and Czechoslovakia, have provided a significant increment to the scientific and technical resources at the disposal of the USSR. They are increasing the number of higher educational institutions and improving their quality, and in 1956 contributed about 15 percent of the Bloc's total of new college-level graduates in scientific and technical fields. The substantial Satellite support of Soviet technology has involved blueprints, production processes, technicians, equipment, and whole plants. Contributions have varied considerably according to the level of science and technology in the individual Satellite. East Germany is strong in pharmaceuticals and biologicals, optical equipment, and synthetic fibers; Czechoslovakia, in electronics and computers; and Poland, in radar, chemistry, and medicine. Hungary, whose scien-

tific capabilities are believed to have been greatly impaired by the 1956 revolt, has made contributions in electronics and pharmaceuticals in the past and probably will do so again. Rumania, Bulgaria, and Albania have provided little support.

46. In the past few years, the USSR has attempted to integrate Soviet and Satellite efforts in science and technology under the Council for Economic Mutual Assistance (CEMA). There is evidence that national jealousies and CEMA's lack of authority to discipline its members have impeded effective coordination. However, new agreements concluded in 1958 provide for greater coordination and exchange in research and development activities. CEMA member-nations are assigned major research, development, and production responsibilities for the entire Soviet Bloc in specified fields. Synthetic organic chemicals, railway transport equipment, special machine tools, telecommunications, and food processing have been singled out as areas for contributions by the Satellites in the near future. Satellite scientific and technical resources will continue to grow and to contribute to the Soviet effort, but because of growing Soviet capabilities, these resources will become less important to the USSR.

47. Communist China, because of an extreme shortage of scientific and technical manpower and facilities, is unlikely to make important contributions to Bloc science for some time. The number of Chinese graduates in scientific and technical fields each year roughly equals those graduated by the European Satellites. Although China has made considerable progress in these fields, the number of graduates is exceedingly low in view of China's population and needs. Furthermore, there is evidence that the quality of higher education in Communist China is inferior to that in the USSR and the Satellites. We do not expect Communist China to achieve scientific self-sufficiency within the next 10 years.

Science and Technology as Instruments of Soviet Foreign Policy

48. Soviet achievements in science and technology have greatly enhanced the international prestige of the USSR. The launchings of the earth satellites and the moon rocket, in particular, have provided impressive evidence of the present high level of Soviet scientific capability, and these successes have been exploited by tremendous propaganda campaigns which stressed the theme that the USSR was fast becoming the world's leading scientific power. These achievements have also served to bolster Soviet claims of successes in other fields, particularly in weapons development. This propaganda has been particularly effective in underdeveloped areas, where Soviet scientific successes have been held out as proof of the superiority of the Communist system and its achievements in a nation which was itself underdeveloped some 30 years ago.

49. The USSR has also undertaken technical assistance programs in underdeveloped countries of Asia, Africa, and the Middle East, which are primary targets of Soviet expansionist aims.[3] At least 4,000 Bloc technical experts were present in underdeveloped countries for one month or more during 1958. About 70 percent of these were working on economic development projects. Military advisors and technicians comprise the remaining 30 percent. The USSR has offered technical assistance to India for establishing a pharmaceutical industry and is aiding in the construction of a steel mill. Soviet scientists and technicians are also assisting local personnel in establishing technical educational institutes in India and Burma, irrigation, mapping, and hydroelectric power projects in Afghanistan, and a nuclear physics research laboratory in Egypt. The competence of Soviet personnel involved in these programs has been generally of a high order.

50. *Foreign Students in the USSR.* About 12,000 foreign students are studying in Soviet higher educational institutions, the majority in scientific and technical fields. Most of these students are from nations of the Bloc, including about 5,500 from Communist China. The number of new students sent from Com-

[3] NIE 100-3-58, "The Nature of the Sino-Soviet Bloc Economic Threat in the Underdeveloped Areas," dated 5 August 1958.

munist China has decreased sharply in the last two years, from about 2,000 in 1956 to about 200 in 1957 and 1958. There are less than 700 students from non-Bloc nations, including more than 500 students from the UAR and India. Egypt, Indonesia, and Afghanistan have accepted Soviet scholarships for the study of atomic energy. In 1958, there were also a few students from the US, Western Europe, and Latin America enrolled in Soviet higher education institutions.

51. Soviet participation in international scientific meetings and conferences and in exchanges of scientific delegations has increased markedly during the past two years. The USSR was one of the largest contributors to the International Geophysical Year (IGY) and is still engaged in a worldwide program under the International Geophysical Cooperation—1959 (IGC). Under the IGY and the IGC, the Soviets probably have acquired a tremendous amount of data of strategic value. They have released a considerable volume of general and operational information on these activities, but have withheld data in fields such as gravity and geomagnetism which would be of direct military value to the West. The increased Soviet participation in international scientific activities has, in general, enhanced Soviet scientific prestige and has helped the USSR keep abreast of developments in the West.

III. PRESENT CAPABILITIES AND FUTURE TRENDS IN SOVIET SCIENCE AND TECHNOLOGY

52. During the past few years, the Soviet Union has strikingly demonstrated to the world its maturity in science and technology. This relatively rapid progress reflects directly a spirit of intense competition with the US and the controls and incentives applied by the regime. The USSR is now one of the world leaders in some strategically important scientific and technical fields such as nuclear energy, ballistic missiles, and electronics. However, we believe that their capabilities in other important areas are advancing more slowly, and that their technology is still behind that of the West. In our judgment, this significant disparity from field to field largely results from a present Soviet inability to carry out simultaneously all the increasingly complex research and development necessary for modern military weapons and industrial programs with the same degree of success that the US is achieving.

53. During the past three decades, the USSR has laid a solid foundation for scientific advance. The more spectacular Soviet achievements to date have resulted primarily from the concentration of resources in a few high priority programs; however, the USSR now has the capability, and apparently the intention, to advance on a much broader front. The current Seven-Year Plan, which relies heavily on scientific and technological achievments, probably will lead to a considerable increase in the Soviet scientific effort affecting all important disciplines. Significant Soviet advances in science and technology are likely to occur with greater frequency than in the past, and we believe that the USSR may achieve world leadership in many scientific areas by the end of the period of this estimate.

54. *Physics and Mathematics.* Soviet research shows great strength in a number of fields of physics and mathematics, particularly in theoretical mathematics, high energy nuclear physics, solid state physics, and acoustics. The competence of Soviet mathematicians and the excellent mathematical training of scientists and engineers has been a major Soviet strength for many years. The USSR has placed greater reliance on mathematical methods for solving engineering problems than on the empirical methods used in the West, and probably will place even greater emphasis on such methods in the future. In physics research, the present emphasis on nuclear physics and solid state physics probably will continue, and major efforts will be devoted to problems related to the nuclear power industry. Soviet research toward controlled thermonuclear reactions has been very impressive and could produce results on a limited scale at any time, although the production of energy in useful amounts cannot be expected for a long time. Research in

physics and mathematics will be materially aided by the wider availability of high-speed calculation facilities which are now available for high-priority problems. Such facilities should be generally available to the research and development community by the end of the period.

55. *Electronics.* The USSR is one of the leading nations of the world in quality and quantity of electronics research and development. Soviet work on radio wave propagation, noise phenomena, nonlinear control theory, and the theoretical aspects of materials research has been outstanding. Soviet research on thermoelectric effects appears to be on the threshold of technological advances in the direct conversion of heat to electricity having far-reaching military and economic application. Generally, Soviet electronics research will probably continue to emphasize the development of equipment of military and economic importance and instrumentation for other scientific investigations.

56. *Geophysics and Geodesy.* Soviet capabilities in geophysics and geodesy are believed to be generally equal to those of the US and superior in some fields, particularly polar geophysics. Soviet work is also outstanding in seismology, gravimetry, geomagnetism, geoelectricity, and geochemical prospecting. The USSR is working toward the establishment of a world geodetic datum which would be of great importance to Soviet long-range missile capabilities. They have already succeeded in establishing a connection between the Soviet-Satellite geodetic net and the Western European datum. A covert tie to the North American datum, probably has also been made across the Bering Strait. Also of strategic importance is the tremendous amount of geophysical data acquired by the USSR during the IGY. The Soviets are continuing a large program under IGC and probably will make increased efforts in the future to collect geophysical data on a worldwide basis. Emphasis in geophysics will continue to be placed on problems of great economic and military importance and upon support of the Soviet space program. Studies in geomagnetism will probably receive high priority for such application as improving communications and developing military detection devices. Geodesy research probably will continue to be focused on improving geodetic positioning accuracy required for launching long-range missiles. The Soviets have indicated their intention to use earth satellites for establishing intercontinental geodetic ties. Soviet research in weather control and long-range forecasting probably will be expanded. Work in geology will continue to be primarily directed toward developing mineral resources and aiding military and capital construction. By the end of the period, the USSR may have achieved a position of world leadership in additional fields of geophysics including astronomy and seismology.

57. *Chemistry.* The USSR generally lags behind the US in most fields of chemistry. However, Soviet research is of high caliber in certain areas, and in organophosphorous chemistry, critical to the development of nerve gases, the USSR may lead the West by a significant margin. Soviet research in combustion, chemical kinetics, catalysis, and explosives is generally comparable with that of the West, but the USSR lags in pharmaceuticals and in several important areas of nuclear chemistry. There will probably be a major expansion of all chemical research in the USSR, with particular emphasis on areas where the West now leads, such as petrochemicals, plastics, and synthetic fibers. We believe that Soviet backwardness will be completely eliminated in most important fields of chemistry within 10 years.

58. *Metallurgy.* The Soviet program of metallurgical research is extensive, but uneven, due to a concentration of effort on meeting the requirements of industry and the military forces. Soviet research has concentrated on ferrous metallurgy, but less attention has been given to the important light alloy field in which Western progress has been exploited through an extensive monitoring effort. This exploitation probably will continue, although Soviet research is expected to make increasingly important contributions.

The USSR has made considerable progress in the development of fissile and nonfissile materials for use in nuclear weapons and reactors, and continued emphasis is expected in this field. Research probably will also be pushed in those areas of metallurgy related to solid state physics, particularly in semiconductors and materials for use in research on direct conversion of heat to electricity.

59. *Medical, Biological, and Agricultural Sciences.* Except in a few specific fields, the USSR still lags behind the US in the medical, biological, and agricultural sciences. In medicine, research assets have been concentrated in areas of military and economic importance, such as infectious diseases which cause significant labor losses. However, Soviet research in space medicine, underway for about seven years, probably leads that of the US in several respects. Although the Soviets appear to be fairly competent in certain areas of biological research, their general capabilities in basic work are considered low. Biological research has been accorded lower priority than most of the physical sciences and still suffers somewhat from the effects of ideological interference. Soviet agricultural research is also significantly behind that in most Western countries, despite the existence of a large research establishment and a large number of professional personnel.

60. Soviet medical research and clinical medicine probably will be raised to a level approaching Western standards by improvement in the quality and quantity of research facilities and equipment. The Soviets will probably increase their research efforts on human space travel, submarine medicine, radiation effects, viral diseases, neurophysiology, veterinary medicine, biologicals, and drugs. Capabilities in the agricultural and biological sciences are also expected to improve appreciably over the next 10 years as the result of increased official support. However, marked advances in Soviet agriculture can be effected without a major research effort, by applying scientific knowledge and technological achievements already available in the USSR. Biological research probably will place new emphasis on the application to biology of the concepts and techniques of the physical sciences, and will continue to support the space program. We believe that, as the result of a concerted research program, the USSR will be able to perfect a closed biological system by the time that manned space flight of more than limited duration can be accomplished.

61. *Nuclear Energy.*[4] Although Soviet research in nuclear technology is not comparable in diversity and scope to that of the US, it is highly competent in specific fields. There is substantial evidence that the USSR is continuing a high priority expansion of its program for the application of atomic energy to both military and peaceful uses. Evidence from Soviet tests indicates that they have made steady progress in nuclear weapons research, particularly in the design and development of thermonuclear weapons. If testing is resumed they will probably make further significant progress in such areas as weight reduction, higher yields, antimissile applications, and economies in use of fissionable material. They have also made considerable progress in the development of nuclear power and have displayed much interest in nuclear propulsion. The only known application of such a system is in the icebreaker Lenin; however, there is evidence which indicates the application of nuclear propulsion to submarines and the existence of an active nuclear aircraft project. The USSR is also constructing several large nuclear power plants and by 1963 should have an installed nuclear generating capacity of 2,000 electrical megawatts.

62. *Guided Missile and Space Programs.*[5] In the field of guided missiles and space vehicles, the USSR continues to press ahead with an extensive research and development program. There is ample evidence that very capable personnel and high quality research and de-

[4] For further details see NIE 11-2-59, "The Soviet Atomic Energy Program," dated 16 June 1959, Limited Distribution.

[5] For further details, see NIE 11-5-58, "Soviet Capabilities in Guided Missiles and Space Vehicles," dated 19 August 1958, TOP SECRET, or the forthcoming NIE 11-5-59.

velopment facilities are available to the missile and space programs and that they enjoy extremely high priorities. They are supported by extensive Soviet research in related fields, including electronics, meteorology, space medicine, astrobiology, astrophysics, and geophysics. Soviet achievements in surface-to-surface ballistic missiles and space vehicles have been particularly impressive. Substantial progress is also evident in the development of surface-to-air and air-to-surface missiles. The Soviets are also believed to have air-to-air missiles operational, although considerably less evidence is available on this type. The Soviets are expected to press forward with their guided missile program in all important categories. We have estimated a considerable Soviet capability for early accomplishments in space, and believe that a major effort will be made to achieve manned space flight ahead of the US.

63. *Other Weapons Development.* The USSR has also made rapid progress in other areas of weapons research and development. The extensive re-equipment program in the Soviet ground forces attests to an impressive development effort in all ground weapon categories, directed primarily to increasing firepower, mobility, and amphibious capabilities. Soviet capabilities in theoretical aeronautical research are generally very good, but their aircraft development capabilities are significantly behind those of the US due to a lack of adequate research facilities and a manufacturing technology generally comparable to that which existed in the West during World War II. Soviet naval research and development is also significantly behind that of the West, although the caliber of their experimental research is improving. Good theoretical work is evident in hydrodynamics and hydroacoustics, and great emphasis is being given to submarine development. There is firm evidence that the USSR is conducting extensive chemical and biological warfare research programs staffed by capable scientists and involving numerous research institutes.

64. Soviet weapons research and development will continue to receive a very high priority during the period of this estimate. The USSR is expected to design and produce advanced aircraft for both civil and military use, but Soviet aircraft development probably will continue to lag behind that of the US over the next 10 years. Although we have no direct evidence, a Soviet decision to emphasize missile and space activities may have resulted in a lessening of effort on military aircraft. In naval weapons development, we believe that significant technological progress will be made in developing guided missile submarines, in the application of nuclear propulsion, and in submarine hull design. Soviet development efforts in antisubmarine warfare probably will be accelerated due to the increasing threat of US missile-carrying submarines. Ground weapons development probably will continue at a rapid pace, with emphasis on defensive weapons against low flying aircraft, air transportable weapons and equipment, weight reduction of existing equipment, and improved armor. Research emphasis in chemical and biological warfare probably will be placed on development of new and improved agents, means for dissemination, and equipment for defense.

65. Electronics development has been proceeding at a rapid pace and there is evidence of a steadily increasing native Soviet capability in all important aspects. More complex and capable ground radars are now being developed, and with the advent of faster aircraft and newer airborne weapons, improved airborne radar is expected to appear. Communications advances are likely to include more complex automatic data handling systems for use in air defense, and possibly for use in the space program. We also expect continued Soviet progress in jamming techniques.

66. *Industrial Technology.* The quality of Soviet industrial technology is very uneven between industrial sectors and even within certain sectors generally well-developed. In many areas of heavy industry, practices are on a par with the best technological practices in the West. In some cases, such as petroleum extraction, blast furnaces, machine building, and prestressed concrete, the Soviets have made pioneering adaptations and developments of note. However, Soviet technological

practices in agriculture, forestry, food processing, textiles, rail and inland water transport, civil telecommunications, and certain aspects of the construction industry are far below Western standards and in some areas lag behind the West by as much as 25 years. Even in the most advanced Soviet industries, some practices which border on the rudimentary or the primitive exist side by side with the most advanced industrial techniques.

67. The USSR has the capability over the next decade to make important advances in raising the average level of its performance. Some indication of the possible magnitude of this advance is the planned capital investment for 1959–1965, which is equal to twice that of the preceding seven years. It is almost certain that the gap between the "best" and "average" practice will narrow considerably over the next 10 years by the broader exploitation of many universally known techniques as well as several Soviet pioneering advances. However, in spite of the effort and resources being devoted to this task, the magnitude of the problem of catching up with the West is so great that Soviet industrial technology will remain generally behind that of the West during the period of this estimate.