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CAPABILITIES AND TRENDS OF SOVIET SCIENCE AND TECHNOLOGY

Submitted by the

DIRECTOR OF CENTRAL INTELLIGENCE

The following intelligence organizations participated in the preparation of this estimate: The Central Intelligence Agency and the intelligence organizations of the Departments of State, the Army, the Navy, the Air Force, The Joint Staff, and the Atomic Energy Commission.

Concurred in by the

INTELLIGENCE ADVISORY COMMITTEE

on 9 October 1956. Concurring were the Special Assistant, Intelligence, Department of State; the Assistant Chief of Staff, Intelligence, Department of the Army; the Director of Naval Intelligence; the Director of Intelligence, USAF; the Deputy Director for Intelligence, The Joint Staff; and the Atomic Energy Commission Representative to the IAC. The Assistant Director, Federal Bureau of Investigation, abstained, the subject being outside of his jursidiction.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

CAPABILITIES AND TRENDS OF SOVIET SCIENCE[1] AND TECHNOLOGY

THE PROBLEM

To assess current capabilities and trends in Soviet science and technology and to estimate future potential in this field.

CONCLUSIONS

1. Science and technology are energetically fostered by the Soviet regime, as instruments of the Communist program and particularly as means for developing the physical power of the state. Soviet education heavily emphasizes scientific and technical subjects, and scientists are a privileged group held in high esteem. Strong financial support has been provided for Soviet research and product development. We foresee continued high emphasis on science and technology. *(Paras. 12, 14, 23–26, 27–33)*

2. The USSR has about four-fifths as many living scientific and technical graduates as the US. We believe that the USSR has a slightly greater number of scientific and technical graduates than has the US actually employed in scientific and technical positions of all kinds, with a higher proportion in physical sciences and engineering. This comparison of present numbers may be misleading as a measure of relative scientific and technical strength, as it does not reflect, among other factors, the broader US supply of scientific and technical personnel who hold no degrees. Our estimates for the next five years, however, project a high rate of increase in Soviet scientific graduations and a considerable increase in the supply of technicians having subprofessional skills. *(Paras. 34–37, 59–62; Appendix D)*

3. The USSR probably devotes only about half as many man-hours to research as the US does, and a considerably smaller proportion of these to research in the physical sciences and engineering. Soviet research personnel, on the other hand, are concentrated in support of heavy industry and military development, while

[1] "Science" is used in this estimate to denote the natural sciences including such fields as mathematics, biology, and the agricultural and health sciences. The estimate is focussed, however, on scientific capabilities related to national power, and most of the detailed discussion in its appendices is devoted to the physical sciences and their applications.

a large percentage of those in the US are working in the consumer goods field. Existing studies do not permit any accurate comparison of the magnitude of the current effort of the two research establishments in support of programs directly related to national power. *(Paras. 38–41; Appendix D)*

4. The Soviet scientific effort, closely controlled in line with state planning and party direction, has been focussed preponderantly on the building of a strong industrial base and the development of modern weapons, to the relative neglect of other fields. Although close research controls and the high priority of military-industrial development will continue, we believe that increasing Soviet scientific resources will permit greater flexibility, and that individual initiative will be encouraged, basic research in new fields will be undertaken, and more scientific and technical effort will be allocated to agriculture and the consumer sector of the economy. *(Paras. 12, 15–21, 57–58, 63)*

5. The quality of Soviet science and technology as measured by personal competence, training, research facilities, and achievements varies widely. In all these aspects, the best in the USSR compares well with the best in the Western world, but the average, though good, is still below Western standards. In general, quality is high in fields related to military and heavy industrial development, where some outstanding advances have been made. We believe that the unevenness in the quality of Soviet science and technology will gradually diminish. *(Paras. 42–45, 54–56, 62–63, 65–67; Appendices)*

6. In priority fields the USSR is progressively less dependent on foreign research and development. Nevertheless, a new policy of acknowledging foreign achievements and encouraging maximum use of foreign experience has been adopted in order to make Soviet scientists fully conversant with developments in the West and to take advantage of the possibilities of international scientific interchange. We believe that this policy, which has been accompanied by a reduction in ideological interference with scientific work, will be an aid to further Soviet progress. *(Paras. 13, 22, 46–49, 50)*

7. The Soviet foreign technical aid program will probably be selectively expanded. Soviet scientific and technical resources will almost certainly be adequate to support a continued and moderately expanded program of scientific and technical aid to underdeveloped countries without serious detriment to domestic programs. *(Paras. 51–53, 61, 64)*

8. We believe that the USSR will continue to make important progress in the fundamental sciences, probably breaking new ground in physics, nuclear physics, geophysics, and electronics. The poor quality of Soviet biological-agricultural sciences will almost certainly be improved. *(Paras. 54, 65; Appendix A)*

9. We expect Soviet heavy industrial technology to become more uniform in quality. For the immediate future, we estimate that the over-all level of Soviet technology will remain below that of the US, although the most modern Soviet plants will be on a par with those in the US. Research and technology in the consumer

goods field will almost certainly continue to lag far behind. *(Paras. 55, 66; Appendix B)*

10. In the military field, significant Soviet advances are probable in electronics applications, nuclear energy, guided missiles, and aeronautics. We estimate that the USSR will continue to show capability not only in developing new individual weapons but also in organizing the development of integrated weapons systems. *(Paras. 56, 67; Appendix C)*

11. In at least some strategic fields, the best Soviet scientists are estimated to be as gifted and competent as the best in the West and must be conceded a similar potential for wholly new discoveries. However, we believe fewer technological breakthroughs in the sense of successful attacks on recognized barriers are likely to occur in the Soviet Bloc than in the West because the West has more first-rank scientists and scientific resources. *(Para. 68)*

DISCUSSION

I. ADMINISTRATIVE FACTORS AFFECTING SOVIET SCIENCE AND TECHNOLOGY

Basic Attitude of the Regime

12. The Soviet regime has consistently placed great stress on science and technology, in part because its Marxist ideology is materialistic and most of its leaders have been convinced that science is the key to progress, but particularly as a means for developing the physical power of the USSR. As one of the state's most valuable tools, science and technology are geared to planned objectives and subject to close administrative control. They have been directed preponderantly toward the building of a strong industrial base and the development of modern weapons.

13. Despite an impressive tradition of scientific research in prerevolutionary Russia, the Soviet regime inherited a technologically backward state and was forced to borrow heavily from the West. As the intensive industrialization program gained momentum, however, the premium placed on strengthening native scientific-technological capabilities was reflected in increasing Soviet technological independence. Under Stalin Soviet scientists were largely cut off from direct contact with the rest of the scientific world, to the detriment of Soviet scientific progress. More recently, however, Soviet leaders have recognized and taken steps to overcome the deleterious effects on their scientific development of this extreme insularity. They have emphasized that scientists must learn from abroad, as well as from Soviet experience. They have instituted a far wider and more systematic dissemination of foreign scientific information and a new policy of encouraging contacts and exchanges between Soviet scientists and their professional counterparts outside the Communist sphere. These changes from the restrictive policies of the Stalin period have probably stimulated creative work in many fields.

14. Scientists as a class constitute one of the privileged groups within the USSR. They enjoy a high social position and are well paid. In addition, many scientists receive large monetary prizes, honorary awards, and other benefits such as houses in town and country, limousines, paid vacations at exclusive resorts, and special stores in which to shop. Since the death of Stalin, Soviet scientists have enjoyed a new degree of personal security and professional freedom from ideological interference with their work, and relations between the scientific community and the regime have improved.

Organization

15. *Academy of Sciences.* All Soviet research institutions are administered by the state and there is no organized private research in the USSR. The heart of scientific endeavor in the USSR is the Academy of Sciences, which has affiliates and associated academies in 13 of the 15 Union Republics.[2] The academies are working institutions with research and teaching facilities, and employ about 10 percent of all Soviet natural scientists, including much of the best scientific talent. Their attention is focussed on theoretical work, although some applied research is also performed. The academies take an important part in formulating national scientific objectives, in coordinating research with other institutions, and in selecting and training promising scientists. Membership in the academies is generally based upon high professional standards and is achieved through election by Academy members after nomination by scientific groups.

16. *Ministerial Institutes.* In addition to institutions under the academies, there are a large number of research institutes under individual ministries. The emphasis in these is on applied research and development in support of the industrial, military, or other functions of each ministry. We estimate that these institutes employ about two-fifths of all Soviet scientists, who concentrate heavily on research and are relatively free of other responsibilities. Facilities range from plant laboratories engaged in the more routine production problems of individual plants to large research institutions serving all or a large part of their respective ministries and capable of the type of basic research normally found in the academies. For example, under the Ministry of Aviation Industry there is the Central Aero-Hydrodynamics Institute (Ts AGI), comparable in the scope of its work to our National Advisory Committee for Aeronautics laboratories, where both basic and applied research are conducted. The ministerial institute category also includes the Academy of Medical Sciences under the Ministry of Public Health, and the Academy of Agricultural Sciences under the Ministry of Agriculture.

17. *Higher Educational Institutions.* Since World War II, higher educational institutions have devoted increasing attention to research in both theoretical and applied sciences. Nearly half of all Soviet scientists are employed in such institutions. Since they are concerned primarily with teaching, they devote proportionately less time to research than the scientists employed by the academies and ministerial institutes.

Planning and Control

18. *Administrative Control.* Soviet scientific research and development, like other Soviet activities, is subject to centralized planning and party control. On the basis of established broad plans, each research organization works out its own annual program and coordinates it with appropriate bureaus of the Academy or ministerial directorates. The precise nature and extent of party control is not known, but all scientific organizations are known to have party units, which probably participate in developing the research programs as well as exercise general supervisory and troubleshooting functions. In addition, research programs are subject to approval by operational planning agencies such as the State Economic Commission for Current Planning.

19. The effects of the attempt to apply planning principles to scientific enterprise are mixed. The large size and diversity of the total scientific effort complicates the coordination of research plans. Moreover, research planning is compartmentalized by administrative organization and in practice there is a great deal of duplication. As a partial remedy, in the past year the Academy of Sciences has set up committees to coordinate a limited number of specific activities between various ministerial institutions and the Academy.

[2] The Academy of Sciences, USSR, is directly responsible to the Council of Ministers, USSR, and the Union Republic academies are responsible to the councils of ministers of their respective Union Republics (see organization chart, following page). In addition to natural science as discussed in this paper, the Academy and its affiliates are also responsible for similar activities in the humanities, law, and social sciences.

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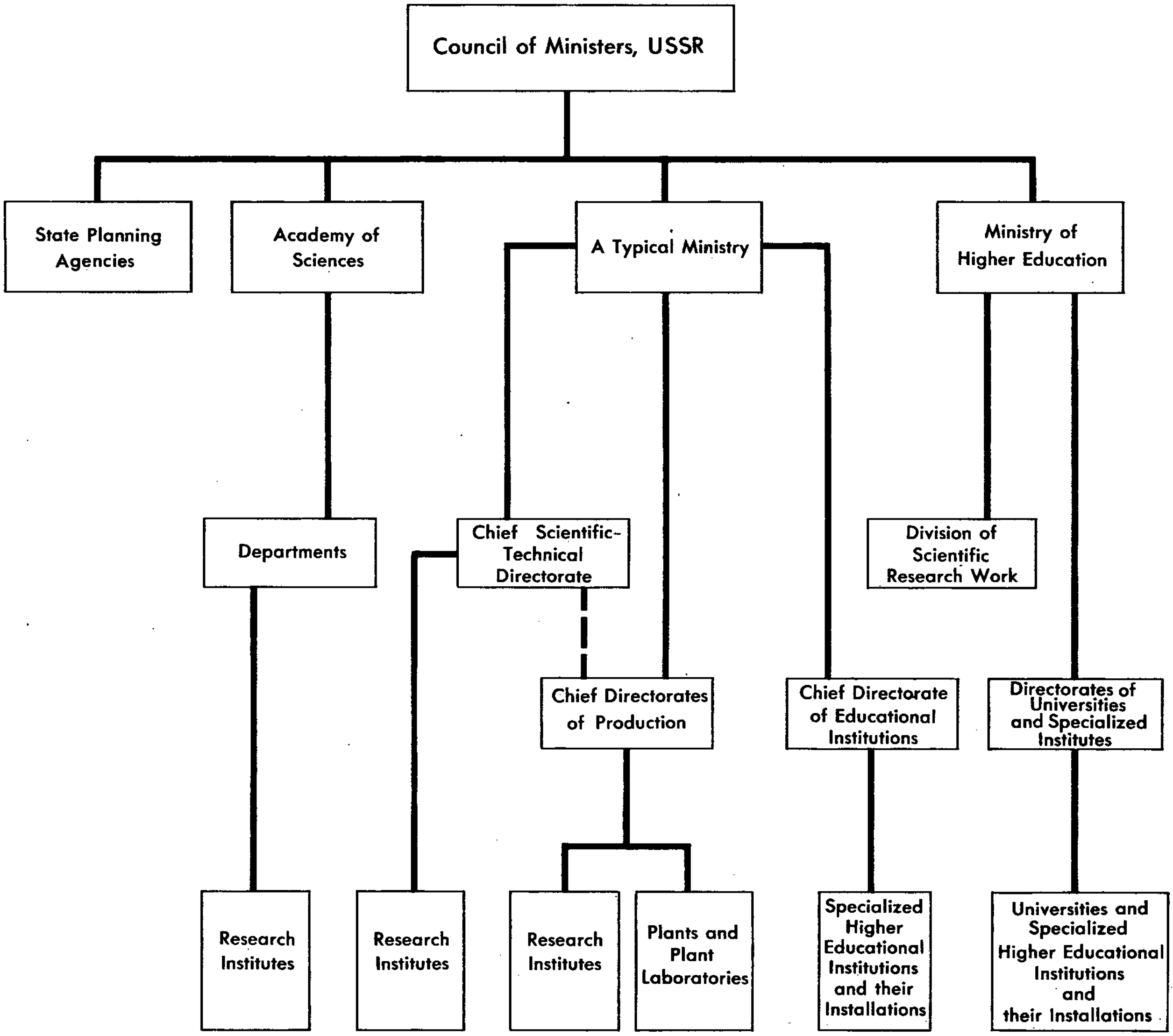
GENERAL ORGANIZATION OF SOVIET SCIENCE



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20. The general Soviet tendency to overplanning and excessive bureaucracy is likely to hamper the enterprise, creativeness, and cross-fertilization which contribute so heavily to progress in scientific inquiry. Constant pressure for fulfillment of planned goals may also tend to lower the quality of Soviet scientific output. While failure of fulfillment is not always punished, it is an invitation to criticism and possibly serious consequences. Meeting planned schedules sometimes leads to poor quality work and a tendency to undertake only easily-accomplished projects. The Soviet government has recently attempted to make scientific plans more flexible in order to encourage more initiative and responsibility.

21. On the other hand, the Communist Party and the Soviet state have powers of intervention and command which are unparalleled in free societies. For projects of high priority they can make personnel and resources rapidly available without the normal play of competing demands common in other countries, and can exert pressure at all levels to expedite these programs at the expense of those of lower priority. Soviet accomplishments in the nuclear field, in weapons development, and in industrial technology demonstrate that the Soviet system is capable of concentrating its scientific potential in a highly effective way in fields of primary concern to the state.

22. *Degree of Ideological Control.* Before the death of Stalin there was a strong tendency to apply ideological tenets in the evaluation of scientific hypotheses and to judge the validity of a scientific theory by the political authority of its proponents. Scientists were required to accept such doctrines as that of Lysenko in biology on the inheritance of acquired characteristics, and to reject such theories as those of the resonance bond in chemistry and Heisenberg's uncertainty principle in physics. These dogmatic requirements probably hindered research to some degree, but do not appear to have caused serious harm except in some of the biological sciences, where ideological interference was more pronounced. At its 20th Congress the Communist Party reiterated its intention to rid Soviet science of "cliques and dogmas," and the demotion of Lysenko signified a changing atmosphere. We believe that during the next few years ideological interference in scientific research will further diminish.

II. SCIENTIFIC AND TECHNICAL RESOURCES

Financial Support

23. The Soviet government classifies research and development expenditures in two main groupings: (a) the financing of scientific research establishments, and (b) product development (i. e., outlays for "mastering the production of new products" and for technical improvements and inventions). The first group is believed to cover primarily research and development in the strict sense of the term, which includes basic and applied research and its application to new uses up to the point of design and production engineering. Funds appropriated for this purpose are included in the Soviet budget category concerned with expenditures on education, health, and social welfare. The second group (product development) includes design and production engineering, experimental production, testing, prototype production, and a variety of associated activities; funds appropriated for these purposes are not explicity indicated in the Soviet budget.

24. Announced expenditures for scientific research establishments in 1955 were 11.6 billion rubles. The plan for the present year calls for an increase to 13.6 billion rubles, which is 70 percent greater than the amount allocated in 1951 (eight billion rubles). Over the last few years these announced expenditures have increased at a slightly greater rate than the gross national product, and now represent about one percent of GNP.[3] However,

[3] US *government* expenditures for research and development, in categories comparable to the Soviet "scientific research establishments" category, totalled $2.1 billion in FY 1955 and are expected to be about $2.6 billion in FY 1957. The latter figure is about 0.6 percent of US GNP. It is roughly estimated that the comparable US nongovernment expenditure is about equal to these figures. Thus, total US expenditures in these categories are probably somewhat more than one percent of US GNP.

it is not known whether these expenditures cover all outlays for scientific research (excluding product development). A considerable portion of the explicitly indicated funds is probably devoted to military research, but additional amounts for research on military projects may be included elsewhere in the Soviet budget. Consequently, total expenditures on research and development in the strict sense may be larger than the amount explicitly appropriated for "financing of scientific research establishments."

25. We have no direct indication of the size of Soviet product development expenditures. The only available index to a ratio between these outlays and "research establishment" costs lies in US military experience, where expenditures falling within the Soviet concept of "product development" are probably at least equal to those the USSR would label as "financing scientific research establishments." If this one-to-one ratio is applied to Soviet expenditures in both military and nonmilitary fields, it yields a total for all Soviet research and development expenditures on the order of two percent of GNP.[4] This procedure for estimating product development costs is a very rough one and would yield only approximate results even if research expenditures proper were known with greater certainty. Although the allocation of 13.6 billion rubles for product development might account for a large part of the undisclosed scientific costs in the 1956 Soviet budget, there remains some uncertainty on this point. Hence, our estimate of total Soviet research and development expenditures is probably on the low side.

26. 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.

Educational Institutions

27. Continued expansion of Soviet scientific and technical manpower reserves is assured by the Soviet educational system. This system concentrates heavily on training scientists, technicians, and skilled labor. The Soviet 10-year school system, which, in terms of classroom hours, is roughly equivalent to the American 12-year system, is under expansion. The Soviets have announced that by 1960, 10 years of primary and secondary education will be universally available.

28. We believe the average graduate of a regular Soviet 10-year school to be somewhat better trained in the elements of science than an average American high school graduate. Training in mathematics and other sciences is emphasized (comprising more than 40 percent of total course work in the upper grades), teacher training is improving, and the ratio of students to teachers is decreasing. Since many graduates of the greatly enlarged 10-year school must now enter nonprofessional jobs, the curriculum has been changed to include vocational subjects such as machine operation and practice farming.

29. The Soviet educational system includes various levels of special schools in addition to the regular 10-year school. 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 specialized training over a three or four-year period to young people who have finished seven years of the regular 10-year program. There are also *tekhnikums* on the junior college level which offer training to the increasing numbers of 10-year school graduates who do not enter higher educational institutions. *Tekhnikums*, administered by the Ministry of Higher Education but supported by the various other ministries, train personnel for work in industries under a particular ministry's control.

30. Only graduates with 10 years of schooling are admitted to higher educational institutions, and competition for entrance is keen. Selection is by competitive examination. There is some evidence of favoritism, especially for entry into Moscow University, but this probably has slight effect in the scientific and technical fields. On the whole, the USSR has

[4] No attempt is made to arrive at a comparable percentage for the US because of the difficulty of estimating US nonmilitary product development expenditures.

a highly effective system for selecting the most promising young students and sending them on to higher educational institutions. Finally, students are channeled into fields of study in accordance with the needs of the state, by means of propaganda, draft exemptions, quotas, and stipends which vary according to priorities of fields. Under Soviet law, all graduates of higher educational institutions are subject to State direction of employment for a period of at least three years following graduation.

31. Higher educational institutions number about 800 and are administered or have their standards controlled by the Ministry of Higher Education. About two-thirds of all Soviet graduates of higher institutions are in scientific and technical fields. About half of such Soviet institutions specialize in training scientific and technical personnel, and provide training that is roughly equivalent to that required for the average US Bachelor of Science degree. There are three general types of institutions offering such training:

a. Specialized engineering and technical colleges, which offer instruction for a period of four to six years to prepare specialists in such fields as machine building, construction, medicine, and agriculture. Most Soviet higher technical educational institutions are of this type.

b. Polytechnical institutions, which offer five and one-half years training in a wider variety and slightly broader fields of science and technology such as metallurgy, electrical engineering, and civil engineering. Students graduate as engineers and production specialists. There are 25 such institutes.

c. Universities offer much broader training. Courses of study last five years. Graduates enter the teaching profession or become research scientists. There are 35 universities.

32. Standards in these institutions are generally high, and the over-all student-teacher ratio is similar to that in the US. Graduates in science and technology possess good theoretical background, although their practical training generally appears to be inferior to that of their US counterparts. Only in some areas of the biological sciences, particularly in the agricultural field, does the present quality of Soviet higher education in science and technology appear to be decidedly below US average standards.

33. At the post-graduate level, there are nearly 500 institutions authorized to conduct training for the *Kandidat* degree, and 60 percent of these are authorized to accept dissertations for the higher degree of *Doktor*. Both of these degrees are conferred by a special commission of the Ministry of Higher Education. The *Kandidat* degree requires at least three years of graduate study, two foreign languages, and a dissertation. In the physical sciences, engineering, and some of the health sciences, it represents training roughly equivalent to or slightly lower than that of the US Ph.D. or D.Sc. In some of the biological sciences, notably in agriculture, however, the *Kandidat* is believed closer to the US master's degree. The degree of *Doktor* has no exact equivalent in the US.

Manpower[5]

34. While the USSR has slightly less than half as many living college and university graduates in all fields of study, both scientific and nonscientific, as the United States, a greater relative emphasis on science and technology raises the number of Soviet graduates in scientific fields to more than 80 percent of the United States total. Moreover, since Soviet citizens have less opportunity to change to professions other than those for which they were trained, we believe that the USSR has slightly more graduates actually employed in scientific and technical positions than the US. (See Appendix D, Figure 1.) Of these, the proportion in the physical sciences and engineering is somewhat higher in the USSR than in the US. (See Appendix D, Figure 2.) On the other hand, many Soviet scientific graduates, though employed in scientific and technical positions, are believed to perform technical duties which in the US would be handled by nongraduates.

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[5] For a discussion of the basis for estimates of scientific manpower, and the probable accuracy of these estimates, see Appendix D.

35. In number of scientific graduates per year, both the USSR and the United States show wartime losses and rapid postwar increases, which in the United States, because of the veterans education program, reached a peak in 1950. Between 1950 and 1955, graduation trends in the physical sciences and engineering heavily favored the USSR. In 1956, the number graduating in these fields rose in the US, but was still only slightly more than half the number of Soviet graduates. (See Appendix D, Figure 3.)

36. Soviet holders of the *Kandidat* degree in scientific fields are estimated to total about 79,000 (including several thousand *Doktors*). In the physical sciences and engineering, where the degree requirements are comparable to those in the US, the USSR has about 41,000 *Kandidats,* as against about 35,000 Ph.D's and D.Sc's in the US. (See Appendix D, Figure 4.) Of greater significance than any comparison of present totals is the fact that in the period 1950–1956, the number of *Kandidat* degrees granted per year in the USSR has more than doubled, whereas the number of Ph.D's and D.Sc's granted per year in the US has remained about the same. (See Appendix D, Figure 5.)

37. Although considerable progress has been made during the past decade in training the skilled technicians and mechanics also needed in modern technology, the USSR is not as well supplied with them as are Western countries, where broader sections of the population have acquired mechanical skills over a considerably longer period. The USSR is currently intensifying its training program to increase the supply of such technical personnel.

Distribution of the Scientific Effort

38. Of the nearly 1.4 million Soviet graduates employed in scientific and technical positions — slightly more than in the US — the bulk appear to be used for technical work in engineering, control testing, inspection, maintenance, etc. Only about 190,000, or fewer than 15 percent, are engaged in research and teaching. The comparable US figure is 280,000. (See Appendix D, Figures 6 and 7.)

39. In terms of man-hours devoted to research as opposed to teaching and administration, we estimate that the USSR uses only the equivalent of about 125,000 full-time scientists for research of all kinds, only about half the research effort of the US. The US also has a considerably greater proportion of its research scientists in the physical sciences and engineering than the USSR. However, in the USSR there is a great concentration of research effort in support of heavy and military-related industries, while a large part of US research is in support of consumer-related industries. Hence, the comparison of numbers alone is not an indication of the extent of effort of the two scientific research establishments in support of programs related directly to national power. Existing studies do not permit any accurate comparison on this subject.

40. Of the total Soviet research effort represented by the equivalent of about 125,000 scientists, about one-fifth is devoted to basic research, divided about equally between the physical and biological sciences. Imponderables in the allocation of basic research effort among fields of potential application make it impracticable to define the proportion of basic research which supports military and heavy industrial programs as against other possible applications.

41. In terms of distribution among Soviet institutions, about 15 percent of the total research effort is conducted by establishments of the Academies of Sciences, 25 percent by higher educational institutions, and 60 percent by the ministerial institutes, where applied science and development work are emphasized. The Academies stress basic research and perform about 50 percent of the work in this area, with educational institutions handling about 15 percent and the ministerial institutes about 35 percent.

Quality of Scientific and Technical Manpower

42. The quality of Soviet scientific and technical manpower is good but uneven. A relatively small group of older scientists, who were closely associated with prerevolutionary

teachers, has continued much of the best of Russian scientific tradition. Among persons outside this group, quality tends to vary according to age, since standards of higher education, low until the early 1930's, have improved considerably during the last 20 years. In many fields, there is no apparent difference in quality from the Western level. 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. In broader areas of engineering and technology the average quality of Soviet personnel remains below that of their Western counterparts because of the large number of persons less well trained in earlier years.

Research Facilities and Equipment

43. The USSR has a large number of laboratories and institutes engaged in research and development in science and technology. Literature identified with about 9,000 different Soviet institutes, departments of higher educational institutions, laboratories and research stations was received in the US during 1955. Facilities appear generally adequate, though perhaps in many cases cruder than those of the West. Among major institutions recently observed, the Institute of Epidemiology and Microbiology (Gamaleya) of the USSR Academy of Medical Sciences had facilities comparable to those of US National Institute of Allergy and Infectious Diseases; an important Soviet electronics research complex at Mytishchi, near Moscow, resembles in many respects the US Army Signal Corps Engineering Laboratories at Ft. Monmouth; and the Moscow Higher Technical School (Bauman) has laboratory facilities comparable to those of the best US colleges. The facilities of average Soviet institutions probably compare much less favorably with average US institutions than those cited, but we estimate that laboratory facilities are sufficient for effective utilization of Soviet scientific manpower.

44. We believe that although programs of routine priority may still suffer a considerable shortage of scientific instruments and equipment, those of major importance are little hampered in this respect. After World War II, the USSR at first drew heavily on equipment designed or produced in the industrialized Satellites and the West, but made rapid progress in developing a native instrument industry, gradually introducing improvements on foreign design and designs of its own. Soviet orders for East German optical and scientific instruments, at first the mainstay of this East German industry, have declined to a very modest volume for the past two years.

45. Soviet industry now produces rapidly increasing quantities of many kinds of instruments, some of them showing considerable originality and excellent design and workmanship, notably in the electronics and optics fields. The USSR is known to have several advanced high-speed electronic digital computers. Although a portion of Soviet equipment requirements is still filled by imports, and some specialized instruments will continue in the future to be obtained from the Satellites or the West, the establishment of 30 new instrument factories called for in the Sixth Five-Year Plan will probably make the USSR substantially independent of outside sources.

Collection and Dissemination of Information

46. The USSR's acquisition of foreign scientific and technical information is many-sided and constantly expanding. Foreign books and journals are purchased through representatives abroad, and through library exchanges. The Library of the Academy of Sciences in Leningrad exchanged literature with nearly 2,500 scientific institutions in 84 countries during 1955, receiving about 70,000 individual publications during the first half-year. Since the death of Stalin the USSR has increased its efforts to establish direct contacts with Western scientists. In 1955, Soviet representatives attended some 34 international scientific or professional conferences, and Western groups were invited to attend 10 scientific congresses in the USSR. Collection of information is also accomplished by espionage operations, and we believe that

in some cases the USSR has gained significantly from such operations.

47. The most obvious exploitation of non-Soviet Bloc scientific-technical knowledge has been in military equipment, especially nuclear energy, electronics, guided missiles, and aircraft. The USSR exploited equipment which it received under lend-lease or which fell into its hands during World War II. In the Korean conflict it acquired many US items of recent design. It also benefited greatly in postwar years from the transfer of German scientists and technicians into the USSR, and from the declassification and release of information by the US and the UK, particularly in electronics and radar. Western technical and trade publications, particularly those of the United States, continue to contain a wealth of detail concerning the development and characteristics of new military equipment, and are readily available to the USSR. These factors have saved several years of development time in some fields.

48. The USSR currently assists research workers by an extensive program for the dissemination and exchange of both foreign and domestic scientific information. Scientific and technical meetings and conferences are held frequently. Numerous scientific books, journals, and monographs of domestic and foreign scientific information as well as translations, abstracts, and indexes are now readily available. The All-Union Institute of Scientific and Technical Information of the Academies of Sciences publishes monthly abstract journals surveying several thousand Soviet and foreign journals, and also weekly information bulletins for industry. Thus, at least in high priority fields, Soviet scientists have access to the full range of published worldwide scientific research.

49. A considerable portion of Soviet research, including military and other sensitive projects, is not published in open literature. This restriction probably does not seriously hamper the dissemination of information among those persons having an obvious and direct need to know. However, secrecy denies useful information to investigators in related fields and thus hampers general scientific progress. This problem was recognized at the recent 20th Congress of the Communist Party, where removal of secrecy restrictions on scientific information was urged wherever possible.

Utilization of Satellite and Chinese Resources

50. East Germany and Czechoslovakia, and to a lesser extent Poland and Hungary, provide a significant increment in scientific and technical manpower and facilities to the total resources at the disposal of the USSR. East Germany is strong in pharmaceuticals, electronic instruments, optical equipment, and synthetic fibers; Czechoslovakia in communications equipment; and Hungary in electronics and pharmaceuticals. On the other hand, Communist China, because of an extreme shortage of scientific and technical manpower and facilities, is unlikely to contribute to Soviet science for some time but on the contrary will be a drain on aggregate Bloc scientific resources. Although Satellite scientific and technological capabilities are growing, their relative importance to the USSR is likely to diminish because of the increasing Soviet scientific capabilities.

Foreign Aid Programs

51. The USSR has been sending substantial numbers of scientists, engineers, and technicians to other Bloc countries, including Communist China, since World War II. Since late 1955, the export by Soviet Bloc countries of scientific-technical personnel to underdeveloped, non-Bloc countries has been rapidly expanded both in numbers of persons, which now total several thousand, and in the number of recipient countries involved. Bloc technical aid has been concentrated mainly in Egypt, Syria, and the South Asian countries — India, Burma, Afghanistan, Pakistan, and Indonesia. Communist China's first offer of any magnitude was made to Cambodia in April 1956.

52. In addition to sending technical personnel abroad, the USSR has for some years been providing scientific and technical education at its own institutions to substantial numbers

of Chinese Communist and Satellite students. More recently, similar educational facilities in the USSR have been provided for students from countries outside the Bloc. The Sixth Five-Year Plan calls for continuation and expansion of the educational aid program.

53. The USSR assists Satellite and Chinese Communist nuclear energy programs. It has proposed aid to non-Bloc countries in this field, but only a few firm agreements have been made. The USSR would be capable of providing reactors and related equipment, and of providing training programs for foreign personnel.

III. QUALITY AND ACHIEVEMENTS OF THE SCIENTIFIC EFFORT

54. In the physical sciences, published Soviet research is of high quality and indicates that the authors are well informed on international developments in their specialties. It shows particular strength in a number of fields of physics and theoretical mathematics. In the geophysical sciences Soviet capabilities are generally comparable with those of leading Western nations, and the USSR has planned one of the most comprehensive programs of any of the countries participating in the coming International Geophysical Year. In the chemical field Soviet scientists have done significant original work, for example in organic synthesis and in combustion studies. They are somewhat behind the West in work on synthetic rubber, fibers, and plastics. Soviet metallurgical research is generally on a par with that of the West in fundamental aspects, but lags slightly in some practical applications, especially in the light alloy field. In electronics the USSR is closely behind the West in fields where equal effort has been applied. In medicine and the biological sciences quality ranges from very good in medical research to low, though improving, in genetics and biochemistry. A major effort is currently under way to overcome the serious lag in developing aids to agriculture and animal husbandry. (See Appendix A.)

55. The quality of Soviet industrial technology is much more uneven than that of the pure sciences. Even in the priority field of heavy industry, while the best plants and products are on a par with those in the US, the average is somewhat below the US average. These differences within the USSR, as well as differences between Soviet and Western practices, appear to lie less in the development of new techniques than in the extent to which universally known techniques are exploited, as for example in the Soviet emphasis on certain oil extraction procedures, in the lag in Soviet steel rolling and finishing technology, and in the USSR's thus far highly selective application of automation systems. Soviet success in shortening in some instances the development lead time on military products appears to be due to administrative factors rather than to any technological superiority. In areas of secondary priority, as in heavy electrical equipment, development is largely concentrated on the exploitation of Western experience, and Soviet technology generally lags behind the West by several years. In areas of low priority, as in the support of textile, canned goods, and footwear production, Soviet technology is far behind. Insufficient development of farm machinery and mineral fertilizers, along with unsound practices in seed and stock selection, have contributed to the persistent lag in Soviet agricultural production. (See Appendix B.)

56. The qualitative capacity of Soviet scientific and technical resources, however, is illustrated by current achievements in the military field. The high calibre of nuclear research is evident from the relatively early dates at which nuclear and thermonuclear explosions were achieved. The Soviet guided missile program is extensive and well advanced, and Soviet plans for earth satellite launchings are similar to those of the US. Aeronautical research in the USSR is generally equal to that in the US, with excellent capability in theoretical aerodynamics and improving competence in its applications. In hydrodynamics Soviet theoretical research has been equal and in some respects superior to Western research. However, the lack of an experimental research program has led to a failure to apply its results. Military end-products show effective adaptation and improvement of complicated foreign equipment

designs, and the latest advanced electronic equipment, in particular, appears to be primarily the result of Soviet research and development. More important, Soviet scientists have demonstrated the ability to develop and produce modern weapons systems of native design. (See Appendix C.)

IV. SOME FUTURE TRENDS IN SOVIET SCIENTIFIC PROGRAMS

Planning and Control

57. The basic framework of Soviet planning and control of science and technology will almost certainly continue along present lines. However, the directives of the Sixth Five-Year Plan emphasize the need for closer relationships between scientific research and industrial applications. The recently published results of the Fifth Five-Year Plan noted that "insufficient contact with production work is an important shortcoming in the work of many scientific institutions." Such criticisms have been repeatedly voiced in the past, and do not appear to indicate a drastic shift. Nevertheless, in the ministerial institutes, there will probably be a continuing trend in the direction of such closer ties to industrial application. While research and development programs will remain under strict administrative control, it is probable that programs will be more flexible, affording more scope for individual initiative and encouraging laboratory and institute directors to assume greater responsibilities for direction of their programs.

58. On the other hand, with respect to the USSR Academy of Sciences, its president indicated at the Twentieth Party Congress that steps are being taken to free the Academy and higher educational institutions from routine industrial problems so that they will be able to concentrate on "the most important and fundamental tasks of science and on scientific research in new directions which are little investigated but show much promise." In view of his subsequent statement that "the direct satisfaction of current production requirements is not the only or the main function of science," Soviet scientific researchers in the top scientific establishments will probably gain a freer rein in probing new channels of investigation, though still within the framework of the national economic plan and in accordance with the principle that the function of science is service to the state.

Manpower

59. As yet there have been no indications that Soviet rates of growth in scientific and technical manpower will slacken, and Soviet plans call for increasing the numbers of graduates and post-graduates. Reasons for this continued high rate of expansion are to be found in the needs arising from the rapidly expanding Soviet economy, in the belief of Soviet leaders that further increases in scientific and technical manpower will improve economic productivity, and in the Soviet intent to challenge the West in economic competition.

60. If present trends continue, the numbers of Soviet scientists, engineers, and technicians will increase, in the period through 1961, considerably more rapidly than in the US, and by about 1961 aggregate Soviet manpower in these categories would be about equal to that of the US. The number of Soviet scientific and technical graduates per year will probably continue to increase through 1961, leveling off for a period thereafter, in part because of the low birth rates of the World War II years. (See Appendix D, Figures 8 and 9.)

61. In the engineer category, we estimate that the Soviet supply will be generally adequate to carry out internal objectives, and that substantial numbers could be employed in export industries and in scientific-technical missions abroad without significant detriment to domestic programs. On the other hand, because of increased demands for nonprofessional technical personnel, the deficiency in this category will continue through 1961, although it will be significantly reduced by the large training program designed to produce such technicians. Similarly, because of increasing demands within the Bloc, as well as demands created by Soviet technical aid programs in non-Bloc countries, we believe that shortages of scientists will continue through this period.

62. As the large number of postwar graduates gain experience and assume positions of leadership there should be a general rise in the

quality of research. The increase in numbers will permit greater research coverage, and with more attention paid to fundamental research in the Academy, *ad hoc* research will become less necessary in supplying answers to specific problems. The utilization of scientific graduates and post-graduates will almost certainly become generally more effective as subordinate training programs produce an increasing number of technicians.

Distribution of Effort

63. The USSR will continue to give very high priority to research related to the development of weapons systems. Up to the present time, the Soviet leaders appear to have concentrated their highest-grade scientific resources in military and basic industrial fields at the expense of other areas of the economy, and we believe this policy will be continued when necessary for the attainment of priority goals. Increasing Soviet scientific resources, however, will probably make it possible for the USSR to devote greater efforts to basic research without hindering military development. In addition, more resources will probably be allocated to scientific effort in those fields which until the present have had relatively low priority, including agriculture, public health, and consumer goods.

64. The Soviet technical aid program will almost certainly expand in countries already receiving Soviet technical aid and will probably be extended to other countries. We estimate that the USSR will continue to expand its technical aid program on a selective basis in the underdeveloped countries of Eurasia and Africa and in Latin America. Soviet scientific and technical resources will almost certainly be adequate to support a continued and moderately expanded program of scientific and technical aid to underdeveloped countries without serious detriment to domestic programs.

Capacity for Future Advances

65. We believe that the USSR will continue to make important progress in the fundamental sciences. It is likely to break new ground in several fields of physics, nuclear physics, geophysics, and electronics. It is expected to overcome a current weakness in the application of theoretical mathematics to other sciences. The lag behind Western science in certain fields of metallurgy, such as the development of light alloys, will probably be reduced. The poor quality of Soviet biological-agricultural sciences will almost certainly be improved. (See Appendix A.)

66. In industrial technology the USSR also has the capability to make important advances over the next few years, in part through the further development and increased use of special-purpose tools and automation techniques. While Soviet industry is at present characterized by sharp contrasts in technology, the high growth rate of the economy and the introduction of more modern production techniques tend to indicate that the gap between "best" and "average" performance may narrow considerably in the future. (See Appendix B.)

67. The prospects for Soviet scientific and technical progress are particularly great within the high priority military and related fields. For example, significant advances are probable in electronics applications, nuclear energy, guided missiles, and aeronautical research and development. We have no reason to doubt that despite the increasing complexities of modern equipment, the USSR will be capable of continuing the successful design and development of modern weapons systems for its ground, naval, and air forces. (See Appendix C.)

68. In many fields of scientific endeavor, the likelihood of major Soviet advances beyond existing levels of science and technology — "technological breakthroughs" — must be considered. (A "breakthrough" may comprise either a wholly new discovery or a successful attack on recognized barriers to the application of existing knowledge.) We believe that first-rank Soviet scientists and engineers have the capability for such advances, and Soviet technology has shown itself able to develop new ideas and to realize their military or economic potential when priority is sufficiently

high. In at least some strategic fields, the best Soviet scientists are estimated to be as gifted and competent as the best in the West and must be conceded a similar potential for wholly new discoveries. However, we believe fewer technological breakthroughs in the sense of successful attacks on recognized barriers are likely to occur in the Soviet Bloc than in the West because the West has more first-rank scientists and scientific resources.

APPENDIX A

SOVIET CAPABILITIES IN MAJOR SCIENTIFIC FIELDS

Physics

1. The present capabilities of the USSR in important fields of physics are generally comparable to those of the leading nations of the West. While the scope of Soviet research in physics, in terms of range of problems under investigation, is less than in the US, its quality in areas given greatest priority is consistently high. For basic knowledge in fields of lower priority, reliance has been placed on the published work of foreign scientists.

2. The USSR has shown particular strength in theoretical physics (e.g., theory of quantum electrodynamics and elementary particles), solid state physics (e.g., semiconductors), and low temperature physics (e.g., first experimental observation of second sound in liquid helium, and Landau's theory of superfluidity). We believe that in these fields the USSR will continue to concentrate its efforts on key problems and will make significant advances.

3. We estimate that, if present trends continue, within a decade the USSR will have achieved equality with the US in scope, magitude, and quality of research in physics and that the number of active Soviet physicists will exceed that of the US. Emphasis has been given thus far to theoretical aspects at the expense of the experimental, but, as numbers of physicists increase, a better balance will probably result. Facilities for experimental work should be adequate to support research programs.

Nuclear Physics

4. Present capabilities of the USSR in nuclear physics research are estimated to be second only to those of the US. Work in high energy physics has been of good quality and comparable though probably not equal to that of the West. Cosmic ray research has been of particularly high quality and on a par with that of the US. In the low energy region the USSR has also shown considerable competence. Neutron physics research, for example, is also comparable to work performed in the US.

5. During the last year the USSR has announced that it has a number of particle accelerators, including a synchro-cyclotron, the largest machine of its type in existence, which was allegedly rebuilt a few years after its completion in 1949 to attain its present energy of 680 Mev. The USSR also announced that it expected to complete in 1956 a 10 Bev proton synchrotron; this would be the largest accelerator in the world. The US is presently operating a six Bev proton synchrotron, the largest currently operating; higher energy machines will not be completed until 1960. However, the US has more accelerators of lower capacity than has the USSR and is therefore able to carry on a greater volume of research in this field.

6. The USSR has recently organized the Joint Institute for Nuclear Research, which has as its announced purpose international cooperation in solving the most important problems of contemporary physics. The new organization will incorporate the Laboratory of Nuclear Problems and the Laboratory of High Energy Physics (sites of the 680 Mev and 10 Bev accelerator, respectively). The Joint Institute will also acquire a Laboratory of Theoretical Physics which will include an electronic computer department, and a Laboratory of Neutron Physics which will have a high neutron flux experimental reactor. An accelerator for multicharged ions will be built. Also being considered are cosmic ray laboratories and other facilities. All facilities of the Joint Institute will be located in the USSR. Representatives from all of the Soviet Bloc countries have signed an agreement to participate in this Institute, and it has been announced that membership will be open to non-Bloc countries.

7. We believe that establishment of this Joint Institute will result in a somewhat better organized attack on nuclear research problems, probably with greater stress on fundamental aspects. It will also provide increased training facilities for both Soviet and Satellite scientists at an advanced level in high energy physics. The Joint Institute program will serve to focus attention on the USSR as a world center of nuclear physics research. While we are unable to predict with certainty the future Soviet progress in nuclear physics research, rapid gains in this field in the past indicate that Soviet nuclear physicists will be able to furnish strong support to all phases of nuclear energy programs.

Mathematics

8. Soviet scientists display outstanding ability in pure mathematics, and have achieved international recognition in nonlinear mechanics, probability theory, and topology. Although top level mathematicians are probably fewer in the USSR than in the US, the Soviet lag in numbers will probably be considerably lessened in the next 10 years because of the emphasis on mathematics training during the last decade. Soviet weaknesses in applying theoretical mathematics to other branches of science and technology may be largely corrected by the growing emphasis on channeling the results of mathematics research into high priority areas such as weapons development. Thus Soviet over-all mathematical capabilities may be brought close to those of the US.

Astronomy

9. The science of astronomy appears to be developing rapidly in the USSR under an effort now comparable to that devoted to it in the US. Although Soviet astronomical instrumentation is not as fully developed as that in the US, astronomical facilities have been improving steadily. Soviet literature in astronomy touches on all phases of the science and shows emphasis on work in stellar astronomy, the study of variable stars, solar physics, the study of minor planets, and cosmogony.[1] One sub-field in which Soviet astronomy is significantly behind the US is that of astrophysical observations for the determination of physical and chemical properties of stars and nebulae.

10. Soviet work in positional astronomy and astronomical contributions to geodesy and gravimetry illustrate the full exploitation of studies which contribute to the more precise location of points on the earth and therefore to long-distance target positioning. Solar studies are emphasized for their importance to the interpretation and prediction of terrestrial phenomena, as in long-range forecasts of climatic trends, especially in polar and subpolar areas.

Geophysics

11. Soviet capabilities in the geophysical sciences, including meteorology, hydrology, oceanography, geology, and terrestrial and arctic geophysics, are generally comparable with those of leading Western nations. Among the geological sciences, the USSR has maintained outstanding capabilities in engineering geology, permafrost research, and geochemical and geological mineral prospecting methods. Soviet geophysical research conducted on ice floes in the Central Arctic and at many permanent stations has materially aided shipping operations along the Northern Sea Route and could be of great importance for military operations in the Arctic area.

12. The USSR has one of the most comprehensive and well-planned programs of any of the countries participating in the International Geophysical Year (1957–1958). The USSR will probably intensify its central Arctic research, and already has a large and well-equipped expedition in the Antarctic. During the next few years the already high Soviet capabilities in geophysics will almost certainly be substantially increased through procurement and analysis of the voluminous data arising from IGY activities, which will be available for the first time on a world-wide scale.

13. The USSR is currently engaged in the development of earth satellites for research at very high altitudes and we believe that its

[1] Radio astronomy is treated under electronics, in paragraph 26 below.

efforts will be intensified during the International Geophysical Year. Research of this nature is likely to enhance Soviet capabilities for further development of guided missiles and result in increased knowledge in many fields of geophysics. Rockets and guided missiles currently estimated to be within Soviet capabilities could also be effectively utilized in gathering upper atomsphere data. Important meteorological advances could result from a current Soviet program involving the use of high-speed electronic digital computers in weather forecasting, and from high altitude and weather control research that will probably receive high priority.

14. In terrestrial geophysics and geodesy the USSR is expected to expand observational programs, particularly during the IGY. Important advances are possible in Soviet knowledge of the precise size and shape of the earth which could increase Soviet capabilities for long-distance target positioning.[2] Possible Soviet advances in terrestrial geophysics could result in the development of a geomagnetic guidance system for missiles, and of instrumentation for aerial gravimetric surveys.

Chemistry

15. *Organic Chemistry*. Soviet organic chemists have contributed significant original research on the synthesis of organic materials. From the high quality of this work it is evident that the USSR has the capability to carry on programs of research and development necessary to produce new liquid fuels, petrochemicals, and lubricants. Soviet research on organosilicon components is conducted by outstanding chemists and offers promise of useful new materials, though it is slightly behind the US. Soviet products and publications indicate that US developments are studied closely, and that advantage is taken of extensive world-wide literature on the subject. In many fields, the Soviet economy has not required organic chemical research, and in these fields Soviet scientists appear satisfied to remain somewhat behind the US.

[2] This subject will be discussed in greater detail in the forthcoming NIE 11-5-56, Soviet Programs and Capabilities in Guided Missiles.

16. *Physical Chemistry*. The USSR has conducted important research on combustion, flame propagation, and detonation, occasionally in advance of Western research. Soviet physical chemistry is strongest in the study of fundamental mechanisms of combustion and reaction. In the well-developed field of basic combustion chemistry, further advances are probable which will be of use in combustion chamber design or in the selection of propellants. The USSR has for many years had both outstanding scientists and many workers generally versed in reaction kinetics, the concepts of free radicals, and the behavior of carbon, hydrogen, nitrogen, and oxygen systems at elevated temperature.

17. *Macromolecular Chemistry*. Soviet scientists have demonstrated their capability to do basic research in macromolecular chemistry, and their level of technology is only slightly behind the West in such fields as synthetic rubber and plastics. In the field of synthetic fibers, current Soviet practice is to rely on the European Satellites for research and development. Although the USSR once led the world in the research, application, and production of synthetic rubber, it has recently depended on published Western technology for such advances as oil extended rubber, low temperature polymerization, and cis-polyisoprene.

18. In the field of plastics, development and application efforts in the USSR have followed closely the pattern set by the West, though use has also been made of East German research. The USSR has been slow to adapt for general use much Western information on the newer and more important plastics (e.g., polyamides, polyethylene, polyesters, fluorocarbon polymers, and silicones), and has attempted to acquire plants and know-how from the West. Despite considerable research activity in the field of macromolecular chemistry, we believe that Soviet technology will not overtake that of the West during the next several years.

19. *High Energy Fuels*. The USSR is known to be interested in boron hydrides and other compounds as high energy rocket fuels. On the basis of present knowledge we estimate that the USSR is in an early stage of basic

research related to the synthesis and thermodynamic properties of boron hydrides. If adequate priorities were given, the necessary engineering technology could be developed to produce boron hydrides as rocket fuels. Research on hydrazine hydrate as a high energy fuel has been carried forward to the testing stage, but there is only limited evidence of any other extensive activity related to high energy chemical fuels.

Metallurgy

20. Soviet fundamental metallurgical research is generally on a par with that of the West, and has developed some original concepts. In physical metallurgy, Soviet metallurgists have been very active in the theory of elasticity and plasticity and its application to industry. Considerable research has been performed on creep and relaxation of metals at elevated temperatures. The theory of dislocations has been applied to the study of fatigue or endurance of metals under cyclic stress. Fracture, impact and notch brittleness of metals have also been given considerable attention.

21. Soviet metallurgy is presently devoted chiefly to meeting the requirements of heavy industry and the military forces. The USSR has an extensive ferrous metallurgical research program in progress to increase the productivity of related industries and to develop new alloys to alleviate the problems imposed by shortages of certain alloying elements. Research on high temperature materials for aircraft applications, while closely parallel to that of the West, indicates Soviet competence, particularly in alloy conservation.

22. In the field of light alloys, the USSR will probably continue to exploit Western aluminum and magnesium research, but it will probably make increasing effort toward original work in this field. Soviet publications indicate that the USSR is fully aware of the military and industrial significance of titanium metal and its alloys, which are in the pilot stage of production. The USSR has probably assigned a priority to research on titanium in view of its application, for example, to aircraft and guided missile components. Research on ceramic cutting tool materials has been outstanding though present Soviet materials are somewhat brittle.

Electronics

23. The USSR has a well balanced and extensive program in a number of basic science areas which contribute significantly to electronics research and development (e. g., dielectrics, crystallography, semiconductors, and ferrites). In addition, extensive and capable work is being done on theoretical studies and experimental research in areas which contribute more indirectly to electronics research and development (e. g., information and propagation theory). In other fields of basic science, electronics is extensively used as a tool in both instrumentation and in control applications. Recent Soviet radar designs reflect original work of high quality.

24. In phases of basic electronics research in which the USSR and the West have equal interest, the USSR is closely behind the West; and in at least one case in which the USSR has made special efforts, in communications theory dealing with noise studies, it now leads. We estimate that over the next 10 years Soviet scientists will be capable of making significant further advances in the electronics field, and will be generally on a par with the West in most areas.

25. *Communications Theory.* Soviet scientists have investigated the probability theory, correlation analysis, and information theory in an endeavor to obtain a comprehensive understanding of communications. The range and depth of published native research is on a par with unclassified research on the same topics in the West. The type of research implies that considerable classified research on novel communications techniques, such as squirt transmission and noise modulation, as well as speech encryption devices and band reduction systems, may be under way. While no specific information is available on the USSR's progress on these techniques, its classified research effort is probably also comparable to that of the US. We estimate that significant progress will be made in applying communications theory to such fields as data

transmission, data handling, and servo-mechanisms. One significant result may be the achievement of communications systems which are at once secure, reliable, and of high capacity.

26. *Radio Astronomy*. Soviet research capabilities in radio astronomy are believed to be comparable in quality to those of the West. Significant work has been performed in the detection of weak signals in radio spectroscopy and in meteor studies. This work indicates the attainment of a high level of experimental proficiency which could have direct applications in military fields of microwave radio reception.

Medicine and the Biological Sciences

27. The USSR has made impressive progress in medical research, and its work in this field is more advanced than in most of the nonmedical biological disciplines. In the field of hematology, the USSR has developed one of the world's largest and most complete research organizations for the study of blood, its derivatives and plasma extenders. Important advances have also been made in biophysics, epidemiology, radiobiology, and physiology. Major strength has been displayed in Soviet research on the physiology and functioning of the central nervous system. In certain subfields of Soviet microbiological research, such as those related to genetics and biochemistry, the quality of work is low, though improving.

28. The major problems investigated by Soviet clinical scientists will probably continue to be those of heart disease, cancer and infectious diseases, and those related to industrial hygiene. In the more fundamental areas of the medico-biological sciences the emphasis probably will be on using developments in the physical sciences for further research on the basic nature of living matter, disease, and radiation damage. In the aggregate, we believe that the USSR is now somewhat behind the West in clinical research but will advance at about the same pace as the West.

Agricultural Sciences

29. For several decades preceding 1953, agricultural science was accorded a very low priority in the Soviet Union, and progress was much slower in agriculture than in any other major segment of the economy. Research in agricultural science was further restricted during the last decade of this period by Lysenko's influence. Currently, however, Soviet agriculture enjoys a considerably higher priority. Present efforts to send agricultural specialists to the US, recent widespread applications of US research findings, published statements by Deputy Premier Matskevich on the superiority of US agricultural research and technology and direct observations made in the USSR by US agriculturists — all indicate that the USSR is attempting to make improvements from a relatively low base of agricultural research and technology.

30. The Sixth Five-Year Plan calls for a doubling of grain output, with 80 percent of the increase to be achieved by increasing per acre yield through utilizing the results of research and technology. Evidence indicates that major emphasis will be placed on improving fertilizer technology, on development and utilization of herbicides, new insecticides and fungicides, on developing disease-resistant and high-yielding varieties of crop plants, on improvement of vaccines and antibiotics for animal diseases, on food technology, especially preservation and storage methods, and on methods for improving livestock quality. In addition, the USSR will almost certainly continue to strive for a technological breakthrough in photosynthesis research in the hope of developing techniques for synthesizing food. In summary, Soviet progress in agricultural research and technology over the next five years may result in substantial means for improvement of the Soviet food supply.

APPENDIX B

SOVIET CAPABILITIES IN SOME IMPORTANT FIELDS OF INDUSTRIAL TECHNOLOGY

1. Soviet industry has demonstrated a capability for adapting and introducing modern techniques into the rapidly expanding industrial base of the USSR. To a considerable extent, however, Soviet progress has been made possible by duplication or adaptation of the machines and methods already in use in the West. Soviet industry is characterized by contrasts in technology, since new techniques are not generally extended to existing facilities as quickly as in the more competitive industries of leading Western nations. Thus while the best Soviet heavy industrial technology is in some cases as good as the best in the Western world, the average is somewhat below average practice in the US. Partly as a result of this, over-all industrial productivity in the USSR is only about one-third that of the US. This weakness, however, is related to a number of factors in addition to the scientific and technological capabilities of the USSR. We estimate that for the immediate future, the over-all level of technology in Soviet industry will remain below that of the US, although in its most modern plants technology will be on a par with that in the US.

Petroleum Technology

2. Soviet technical literature and statements by senior officials of the Ministry of Petroleum Industry, USSR, indicate that modern geophysical methods for locating and evaluating petroleum deposits have been in use for several years. In addition to gravitational, magnetic, and seismic methods already in use, a radioactive method (probably utilizing the scintillometer) was introduced in 1954. It appears that the theoretical development of geophysical methods of petroleum exploration in the USSR is approximately on the same level with that of the West. Although the Soviets are among the leaders in the field of geochemical exploration for oil, they appear to be several years behind the West in the efficient use and the relative extent of application of other modern techniques.

3. The Soviets seem fully cognizant of the latest advances in the techniques of petroleum production throughout the world. Soviet boasts of technological success, however, are at times nothing more than references to production techniques which have been applied for years in the US. Two examples of the above are hydraulic fracturing of the geological strata to increase the flow of petroleum toward the well, and contour flooding as a secondary recovery system to increase production from fields where strata pressures are low. The Soviets are currently claiming world leadership in developing new drilling techniques. While it is true that certain techniques are far more widely applied in the USSR than in other areas, this use seems to reflect peculiarities distinctive to the geology of the USSR rather than any great technological advance.

Steel Technology

4. Soviet steel making technology is generally on a par with that of leading Western nations, including the US. Results obtained by the application of technological advances to the various metallurgical processes have had a significant impact on product quality and on productivity in the Soviet steel industry. While most new steel plant technology is well known to all advanced industrial nations, the USSR, now engaged in building up its steel capacity in an effort to compete with the US in quantity production, is incorporating new

techniques on an ambitious scale in its newly constructed plants.

5. The Magnitogorsk and Kuznetsk plants and several others are the equal of the best in the US in terms of output of iron and steel per unit of productive capacity. Investment for technological improvements at these plants, above all in the furnace facilities, has been unstinted in a conscious effort to outstrip the best plants in the world and to serve as models for other Soviet steel works. Output per worker at Magnitogorsk is twice the average for the Soviet steel industry.

6. The application of new technology to different segments of Soviet ferrous metallurgy has varied markedly. The Soviet effort has been directed primarily to blast and open hearth furnace processes, and on high temperature alloy steels, widely used in military end-item production. In comparison, rolling mill and finishing line technology has lagged. The failure to broaden the range of finishing equipment has resulted in less variety of finished products to serve specific applications than in the US.

Automation and Mechanization[1]

7. In systematic knowledge about automation the USSR has at least kept pace with the West. A survey of the Soviet industrial applications of automation to date shows that the USSR has placed priority on selected industrial applications. The literature indicates that the Soviets are not satisfied with progress to date. It is apparent that a majority of existing automatic lines were set up by tying together existing machines by transfer mechanisms of various types. Thus many Soviet claims of achievements in automation involve only the elimination of hand labor by mechanization of materials handling and use of individual semi-automatic or automatic machines. In the production of components for motor vehicles, including trucks, automation and mechanization have proceeded extensively in both countries, with the USSR lagging behind the US in the extent of application for the most part.

8. During the recently completed Fifth Five-Year Plan, antifriction bearing output in the USSR increased greatly, partially through the establishment of semi-automatic lines. The first fully automatic line for roller bearings with new specially designed tools and complete transfer equipment between machines went into operation late in 1955. This line is set up to take forged parts of a six-inch diameter conical roller bearing and to perform automatically all the operations of machining, grinding, heat treating, testing, assembling, lubricating, and packaging.

9. During the period of the Sixth Five-Year Plan (1956–1960) additional semi-automatic lines are to be established using existing machinery. Plans for construction of fully automatic lines are not known. The indications are, however, that the USSR is counting on automation and mechanization to increase the productivity of labor. Soviet ability to enforce standardization and to control design changes is inherently favorable to the extension of automatic production methods.

Military Product Development Lead Time

10. In at least some areas of military production, the USSR has translated developmental results into initial series production in times shorter than those achieved by the US. For example, Soviet lead time, in this phase, on the BISON jet heavy bomber appears to have been substantially shorter than that for the US B–52. This appears to have been true in other cases of aircraft development as well.

11. Where the USSR has succeeded in compressing lead time, its success appears to have been due more to design choice, planning decisions, and a willingness to assume risks than to any inherent scientific and technological

[1] For the purpose of this section, automation is defined as the automatic direction, regulation, and control of industrial operations or processes by physical or chemical means. This involves not only mechanization of materials handling, but also automatic programming and regulation of a set of operations and the automatic detection, analysis, and correction of errors, so that acceptable end-items are produced in quantity with reduced human observation and intervention.

superiority. In general, components of even the latest Soviet air weapons systems are of less sophisticated design than similar US equipment. It appears that the USSR makes it a practice to use existing tested components to a maximum extent in developing a major air weapon system, in order to reduce the complexity of the over-all development program.

12. Soviet aircraft and other weapons systems reveal a wide range in the quality of the various parts and components. Those portions of the system that are critical to its performance are usually equal in quality to Western counterparts. Less critical portions may be designed and constructed in a manner that results in lower levels of quality than those required in the US. We believe that the Soviet philosophy is to obtain weapons "good enough" rather than "best in all respects." The result of this philosophy is the acceptance of small reductions in performance if those reductions effect significant savings in time and effort.

13. Soviet success in reducing lead time in air weapons systems has also been due to an ability to follow through without delay on high priority projects, and to a willingness to take shortcuts and risks such as those attendant upon starting series production before all features of the prototype have been completely tested and evaluated. In many cases, series production has been achieved more rapidly by holding design changes to a minimum, by using as few different materials as possible, by limiting the design of parts and components to the minimum loads and functional requirements, and by designing to maximize the use of semi-skilled labor and to eliminate bottlenecks in capital equipment and scarce skills. This procedure with its attendant risks, while generally rewarding to the Soviets, has not always met with complete success. In the case of the BISON, recent evidence indicates that, probably at least in part because of production difficulties, there has been substantial delay in achieving high-volume output after the initiation of series production.

APPENDIX C

SOVIET SCIENTIFIC AND TECHNICAL CAPABILITIES RELATED TO WEAPONS DEVELOPMENT

Nuclear Energy

1. Details of the Soviet nuclear energy program are discussed in NIE 11-2-56, published 8 June 1956.[1] In brief, the USSR has shown the ability to produce fissionable materials in quantity for the military and research phases of the nuclear energy program and to develop a variety of air-deliverable nuclear weapons with yields from a few kilotons to the megaton range. It has also demonstrated a generally well-developed capability for nuclear reactor design and operation. The announced Soviet nuclear electric power program for 2,000–2,500 megawatts of electric power by 1960 is of considerable magnitude but could be attained with a very high priority effort. Successful development of reactors for aircraft propulsion applications probably will not be realized for some time. It is also improbable that the USSR will produce economical power from thermonuclear processes for many years.

Guided Missiles

2. Detailed information on Soviet guided missile capabilities will be presented in NIE 11-5-56, now scheduled to be published in November 1956. To summarize briefly, we believe that the USSR is engaged in an extensive guided missile program and that it now has missile systems in all categories (air-to-air, air-to-surface, surface-to-surface, surface-to-air) in at least limited operational status. Guided missile testing facilities are believed to be well-equipped, modern, and operated by well-qualified personnel. The USSR is believed to be well advanced in the development of missile guidance and control and of propulsion systems. We believe it possesses, or is rapidly acquiring, the necessary data for attacking the aerodynamic, structural, and guidance problems of intermediate-range and intercontinental ballistic missiles. We also estimate that the USSR possesses the basic scientific capabilities, technical skills, and other resources required to develop, build, and launch an unmanned earth satellite vehicle.

[1] The Top Secret version of this estimate is NIE 11-2a-56, published 5 September 1956.

Aircraft and Related Weapons Systems

3. Soviet literature indicates that in its theoretical aspects aeronautical research in the USSR is generally equal to that in the US. The new and varied aircraft types observed in the USSR in recent years give evidence of sound practices in applying these aeronautical research capabilities, and indicate that the USSR has probably achieved better matching of airframes and engines than the US has. On the basis of Soviet research papers, the characteristics of current aircraft, and recent observations at the Zhukovskiy Air Engineering Academy, we believe the Soviet air weapons development effort is not restricted by lack of research facilities or high-quality equipment.

4. The USSR has an excellent capability in theoretical aerodynamics over the entire speed range. For example, its boundary-layer specialists are second to none. We have seen evidence of a high capability in the theoretical aspects of transonic and supersonic aerodynamics. We have not yet seen evidence that this capability has been applied as well as in the US, but recent observations indicate that rapid progress is being made in the development of advanced aircraft. Some Soviet aircraft, particularly fighter and light bomber types, show evidence of advanced transonic or supersonic concepts, although there are indications that some of the present operational and prototype aircraft are unstable at high speeds. We believe that the USSR will nar-

row the gap and may equal the West in applying theoretical aerodynamic knowledge during the next five years.

5. Two significant features of Soviet aircraft propulsion work to date have been the development of the 19,000-lb-thrust axial flow turbojet engine powering the BISON and BADGER bombers and the 12,000-equivalent-shaft-horsepower turboprop engine powering the BEAR. Improvements in both these engines are probable in the next several years, and in addition, we estimate that Soviet engine technology has progressed to the point where a 22,500-lb-thrust turbofan engine could appear in 1958. A major factor in Soviet turbojet engine development has been simplicity, dictated by the desire to obtain the necessary engines in the shortest possible time. We believe future turbojet development efforts will probably emphasize basic technical improvements in axial flow engines. The existing Soviet design for axial flow engines permits great flexibility in this effort, particularly with respect to high-thrust engines with a weight-thrust ratio of less than .25, necessary for the design of aircraft for extended supersonic flight.

6. Some experimental work on high-energy aircraft fuels, reportedly including metallic slurries, has taken place in the USSR during the past five years. Although little is known of this Soviet activity, we estimate that the USSR has the capability to develop within a few years an aircraft fuel system using either a combination of petroleum and high-energy fuels or high-energy fuel exclusively.

Ground Force Weapons

7. The Soviet research and development program in ground force weapons has yielded many new and improved designs which have appeared in weapons and other items of equipment in the last few years. The primary Soviet objective in the development of new ground force weapons is to increase firepower and mobility for ground troops. In this context, we estimate that over the next few years the USSR will be able to develop new weapons to fill the few existing gaps in ground force weapons systems, such as certain self-propelled artillery types and antiaircraft weapons for defense against low altitude attacks. In vehicle design, we believe it probable that Soviet experimentation with gas turbines for automobiles has been or soon will be extended to military vehicles. Soviet experiments with light-weight, high-strength metals and alloys suggest that these materials will be used to decrease the weight of military equipment. Further development of known Soviet capabilities in both solid and liquid rocket propellant could lead to high-performance field and antiaircraft rockets. Significant advances may be made in ammunition design.

Naval Research and Development

8. For about the last 50 years, Soviet theoretical research in hydrodynamics has been equal to, and in some respects superior to, Western research. Only recently, however, have there been enough model basins and other research facilities for an adequate experimental hydrodynamics research program to supplement theoretical research. Consequently, the failure of naval architects in some cases to incorporate refinements of design reflects the lack of an adequate experimental research program.

9. In the structural design of ships, Soviet theoretical work has been superior to Western work. Advances in the structural field have now become dependent on empirical research, however, and a lack of intelligence on Soviet structural test facilities and programs prevents us from determining the present status of the USSR relative to the West.

10. Published research in the field of marine diesel engineering has been voluminous, but known Soviet naval diesel engines are copies or derivations of Western designs. There are indications, however, that the engines in the largest of the postwar Soviet submarines are modern high-speed types, possibly of native design. A sizable amount of research has been published on naval gas turbines and a 2,000-HP plant has apparently been designed, but no shipboard gas turbine installations have been detected to date. Although Soviet

scientists continued German World War II developments in closed cycle hydrogen-peroxide submarine propulsion plants, and also did extensive work on a recycle diesel, we believe that progress in nuclear propulsion has probably been sufficient to permit the dropping of these two projects.

11. Soviet design of conventional propellers has been generally similar to US and Western practice. An original and probably significant advance was made in the 1940's, however, when a Soviet academician announced his theory of "supercavitating" propellers. Although we have no information permitting an assessment of Soviet progress in supercavitating propeller development, we believe that research on such propellers is continuing.

12. *Naval Ordnance.* The results of a strenuous postwar research and development program in naval gunnery have become evident in warships built or modernized since 1953. Gyroscopically stabilized fire control directors and gun mounts have received special emphasis with apparently successful results. A Soviet capability to provide servo-mechanisms, computers, and associated electronic equipment for modern automatically loaded guns with automatic tracking against air and surface targets is evident. While refinements to these systems will continue, naval guided missiles for AA defense also may be developed for use in large vessels and new naval construction.

13. The Soviets have the scientific knowledge which would enable them to develop sophisticated acoustic, magnetic, and pressure devices for use in underwater ordnance. A magnetic mine recovered in Korea (1950) was judged to be very good and reflected a knowledge of advanced World War II concepts. In the field of torpedoes, the Soviets have apparently developed a high-speed long-range weapon using a hydrogen-peroxide propulsion system; such a torpedo could be fitted for pattern-running. Since 1950 there has been evidence of a program for developing an acoustic homing head for an electrically driven torpedo and it is estimated that such a weapon is now available for operational use.

14. Soviet capabilities in the theoretical aspects of acoustics related to hydro-acoustic detection are believed to be excellent. Research and development in this field are strongly supported by the Acoustics Institute of the Academy of Sciences. Unclassified articles in Soviet journals reveal understanding of the acoustic principles underlying LOFAR and SOFAR, and the recent awarding of an Academy of Sciences prize for research on low-frequency hydro-acoustic emanations of ships indicates that the USSR attaches importance to this field. Available evidence does not permit an estimate of the degree of Soviet success in applying these principles.

Electronics and Communications

15. During the last five years, the USSR has made great progress in electronics research and development. In the initial years after World War II, Soviet electronics was heavily dependent on copying from the West. However, some recently developed electronic equipment appears to be primarily the result of native research and development, indicating that the Soviets have achieved considerable independence in this field. They have developed and put into production many types of radar and other electronics equipment comparable to the latest Western designs in operational use. Significant advances are believed to have been made in such militarily important fields as electronic countermeasures, missile guidance and control, high-speed digital computers, and airborne intercept radar equipment. Although the development of proximity fuzes is within Soviet capabilities, we have no evidence that it has taken place.

16. *Radar.* Some 40 types of Soviet radars have been reported during the past five years, including advanced types for air, ground, and naval use. Many older ground radar sets are still in use, but are rapidly being supplemented by more advanced types which should overcome some of the previous deficiencies, for example in height-finding. There is considerable evidence of advanced native Soviet research and development in naval radar, particularly for surface and air search and fire control applications. For example, the SEA

NET air search radar appears to be an advanced design based upon native effort. The airborne intercept radar set in the FRESCO "D" fighter, although of comparatively short range, has complex search and track characteristics not similar to those of any other known radar, and the FLASHLIGHT is equipped with an airborne intercept radar which is probably different and considerably larger than that of the FRESCO "D". We believe that Soviet research and development capabilities in the field of radar will be generally comparable with those of the West over the next few years.

17. *Communications.* Soviet electronics research and development establishments are capable of providing communications equipment equal in quality to that of the West. Although to date Soviet communications equipment designs have been conventional, with little indication of miniaturization, recent Soviet advances in semiconductor research and in the development of transistors should permit the design of lighter, more compact communications equipment. Improved Soviet competence in television research and development will probably result in a greatly increased industrial and military use of television.

18. *Navigation.* In the development of air navigation equipment, the USSR has relied rather heavily on conventional and dependable instruments, the principles of which have been proven through wide use by Western nations. Improved airborne navigational aids, including automatic astronavigation and visual omnirange systems, will probably come into more extensive use during the next several years. Future Soviet techniques for long and short range air navigation are expected to be adaptations of well-established basic theory for the most part.

19. *Electronic Countermeasures (ECM).* The USSR has devoted substantial efforts to the development of electronic countermeasures equipment since the end of World War II, and we believe that ECM activities will almost certainly continue to receive priority consideration. The USSR is currently employing groundbased, shipborne, and airborne signal detection equipment, probably extending from the very low to the microwave frequencies. We believe that Soviet researchers have investigated the potential of antiradar coating and are continuing to extend their efforts in this direction, but we believe that these efforts will be only partially successful. Although evidence is scarce, we believe that the USSR is devoting considerable effort to the development of active jamming equipment in many forms for the entire usable radio spectrum. Intelligence reports reveal that Soviet scientists are aware of the recent development of the carcinotron, which has great potentialities in the development of highly effective jamming equipment, and that they have directed that development work be done on it in East Germany. Although CHAFF techniques have been known since World War II, the USSR has only within the past year or so become actively engaged in developing techniques for its production, dispensing, and tactical employment.

20. *Infrared.* Although intelligence information on Soviet work in infrared is scanty, we believe the USSR's military infrared program includes the development of equipment for air-to-air detection systems, guidance, homing, and fuzing systems for missiles, and near-infrared night vision equipment for ground forces. Infrared communication equipment is probably in use by Soviet ground and naval forces at the present time. We believe the USSR will remain approximately on a par with the US in infrared research and over the next several years could surpass us in operational employment of certain applications of infrared such as terminal guidance for ground-to-air missiles, if the necessary effort were allocated to them.

Chemical and Biological Warfare

21. *Chemical Warfare (CW).* The USSR has a well-established CW research and development program which we believe to be capably staffed. The program probably emphasizes the development of more effective nerve gases. Soviet scientists have also conducted research on phosgene oxime, tabun, fluorine-containing organophosphorus compounds of the sarin

type, and sulfur-containing organophosphorus compounds of the "V" agent type. They are probably conducting research on psychochemical agents. Research to increase the effectiveness of older known gases is also probably being conducted to a limited extent.

22. We have evidence of Soviet research in aerosols (applicable to dissemination of toxic agents and smokes under field conditions), the acetylcholine-cholinesterase enzyme system (essential to an understanding of the biochemical and physiological action of nerve gases and the development of antidotes for them), surface chemistry (applicable to the removal of toxic agents from the atmosphere), detection and identification of industrial toxic vapors (applicable to detection devices for CW agents), aluminum soaps (usable as thickeners in fuels for flame weapons), and therapy for industrial poisoning. The accumulated results of this research will probably add significantly to Soviet CW capabilities.

23. *Biological Warfare (BW)*.[2] Accumulated evidence shows that the USSR almost certainly has an active BW research and development program which encompasses antipersonnel, antilivestock, and possibly anticrop agents. Relatively little is known, however, about the nature and magnitude of this program, particularly its offensive aspects. The causative organisms of at least four human diseases (anthrax, tularemia, plague, brucellosis) and of two animal diseases (foot and mouth disease, rinderpest) are believed to be under consideration as BW agents. The USSR has conducted research and development in fields which have direct application to BW, including aerosol production, decontamination, micrometeorology, air sampling for organic materials, and storage of micro-organisms. In these fields, Soviet scientists are considered to be competent and their research is of much potential value to the defensive and offensive aspects of BW. The USSR also possesses the facilities, scientific personnel, materials, and experience in related fields which could be used for the mass production of BW agents. Future Soviet BW research and development probably will be on suitable agents and method of dissemination.

24. Soviet developments in the field of immunology, such as the vaccines of brucellosis, tularemia, and anthrax, are of potential significance to the BW defensive capabilities of the USSR. The USSR probably will continue the emphasis given to medical research and other fields which will improve Soviet BW defensive capabilities.

Weapons Systems Development

25. In addition to its capabilities for developing individual weapons and items of equipment, the USSR has shown the capacity to develop complete weapons systems, by timing and integrating individual developments in vast and complex programs using resources and scientific and technical skills from many contributory fields. A good example is the postwar development of a modern air defense system, which now includes a series of jet interceptors equipped with airborne-intercept radar, modern early-warning and ground control equipment, communications and data-processing equipment, radar-directed antiaircraft artillery, and surface-to-air guided missiles. Similarly, Soviet development of a long-range nuclear-air offensive weapons system includes not only the long-range bombers themselves, but also air-deliverable nuclear weapons and facilities for refueling the delivery aircraft in flight. In general, we estimate that Soviet weapons systems development capabilities are well advanced and compare favorably with those of the West. Despite the increasing complexities of modern warfare, we estimate that the USSR will be capable of continuing the successful development of weapons systems necessary for up-to-date air, ground, and naval forces.

[2] Soviet BW capabilities have been treated in detail in the Scientific Estimates Committee estimate SEC 3-56, dated 17 September 1956.

APPENDIX D

SCIENTIFIC MANPOWER ESTIMATES

1. This appendix presents data in graphic form comparing Soviet and US scientific and technical manpower as to numbers of living graduates from higher educational institutions (Figure 1), field of employment (Figure 2), annual rates of graduation, by field (Figure 3), annual rates and distribution of higher degrees (Figures 4 and 5), numbers employed in research and teaching, by field and place of employment (Figures 6 and 7), projected annual rates of graduation (Figure 8), and trends (for the USSR only) in the number of living scientific and technical graduates (Figure 9). In the interpretation of the graphical data the following points should be borne in mind.

2. Personnel statistics are not by themselves accurate measures of national scientific and technological strength. There are a number of factors, some of which are discussed in the body of this estimate, which must also be noted. Among these are the number of nonprofessionally trained individuals working in professional positions, the general utilization of scientific and technical manpower, including the availability of technicians to support the professional scientists and engineers, the stage of development of the economy and general technological level of the country. These are factors which are not amenable to numerical treatment but which nevertheless have a great bearing on the comparative scientific and technological strength of nations.

3. The data used in the calculations for the USSR are drawn from open Soviet literature — statistical year books published up to 1940, and postwar journals and newspapers. The following considerations support the reliability of the Soviet data:

a. Data from the prewar statistical compilations have proved consistent in other respects with subsequently ascertained facts.

b. The manpower figures in the 1941 Soviet plan, which was classified by the USSR but seized by the Germans and later published, agreed well with the information which had previously appeared in open Soviet publications.

c. Data since the war, while generally scarce, are consistent with prewar trends.

While an analysis of the Soviet Statistical Handbook published in 1956 has not been completed, a preliminary examination reveals no significant discrepancies with the data used in the calculations.

4. The Commission of Human Resources and Advanced Training of the National Research Council and the Department of Health, Education and Welfare supplied most of the material upon which the US figures are based. Some adaptations and extensions of US and Soviet materials have been made in order to reduce them to comparable categories.

5. The data for both the USSR and the US are, in some places, estimated or incomplete. During the postwar period up to 1956, data for the USSR have become increasingly scarce, while for the US the reverse is true. In breaking down raw data into more useful form and in supplying data to fill gaps in certain categories or for certain years, statistical methods have been used. The numerical data on scientific and technical personnel are believed to be correct within plus or minus 10 percent.

6. While every effort has been made to arrive at comparable categories of scientific personnel in the US and USSR, there are inevitably differences in the definitions of corresponding

groups in the two countries which make exact comparison difficult. For the purposes of the breakdown among scientific fields illustrated in Figures 2, 3, 4, and 7 the sciences have been categorized as follows:

a. *Physical sciences and engineering*
   - Physics
   - Chemistry
   - Mathematics
   - Metallurgy
   - Astronomy
   - Meteorology
   - Geology and geography
   - Engineering (mechanical, chemical, civil, electrical, etc.)
   - Other fields based on physics, chemistry, or the earth sciences (e.g., seismology)

b. *Agricultural Sciences*
   - Agriculture (agronomy, animal husbandry, forestry, entomology, etc.)
   - Other biological sciences related to agriculture (e. g., plant genetics)

c. *Health sciences*
   - Medicine and medical sciences
   - Dentistry and dental sciences
   - Other fields supporting health and sanitation (excluding nursing unless based on 4-year curricula)
   - Other biological sciences relating to health (e. g., epidemiology)

Persons in residual fields of biology not clearly associated with agricultural or health sciences (e. g., microbiology) have been divided equally between these two categories.

Figure 1

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RELATIVE SIZES OF MAJOR GROUPS OF SCIENTIFIC MANPOWER

AS OF MID-1956

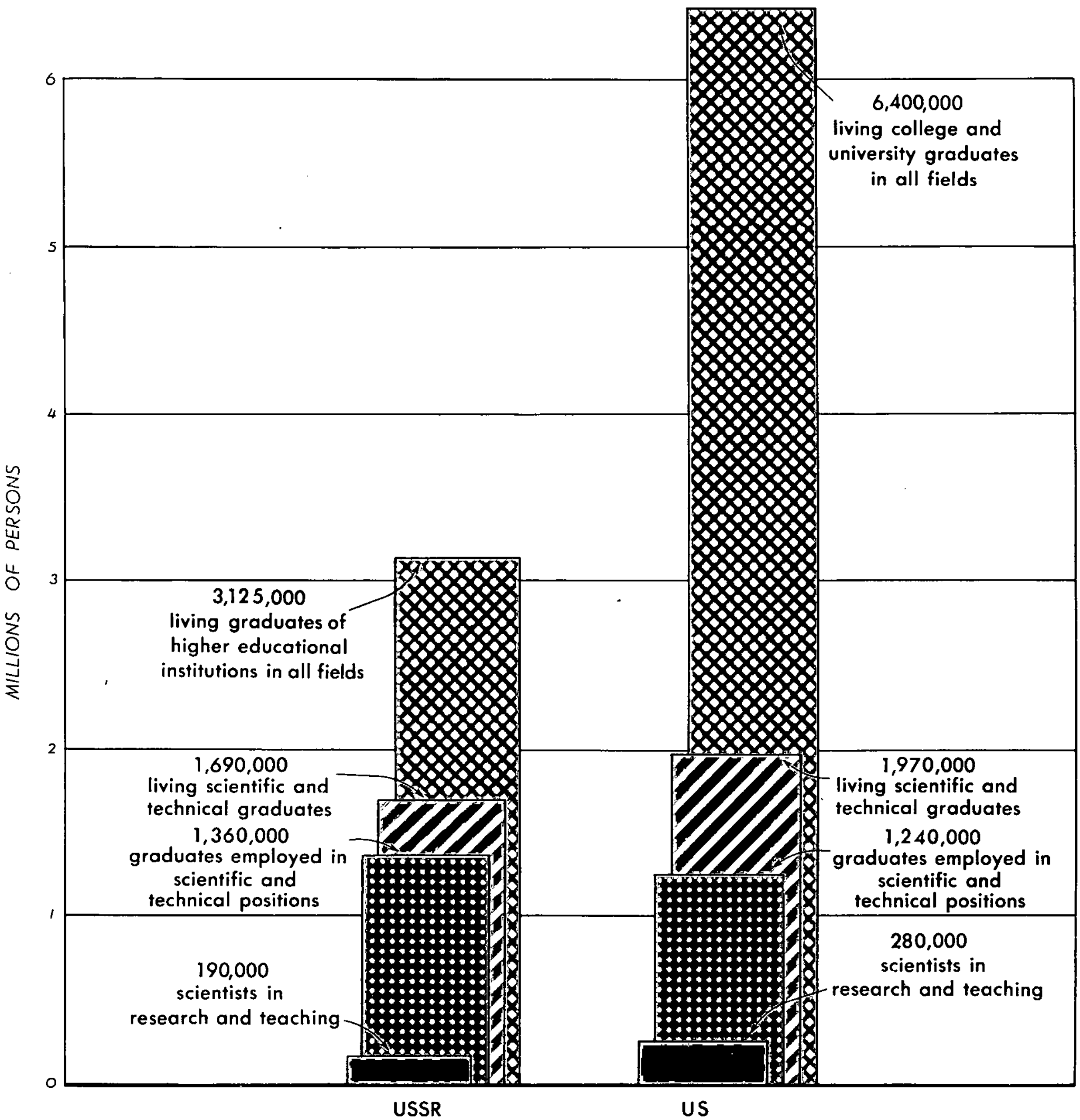

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Figure 2

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NUMBER OF GRADUATES ACCORDING TO FIELD OF EMPLOYMENT

AS OF MID-1956

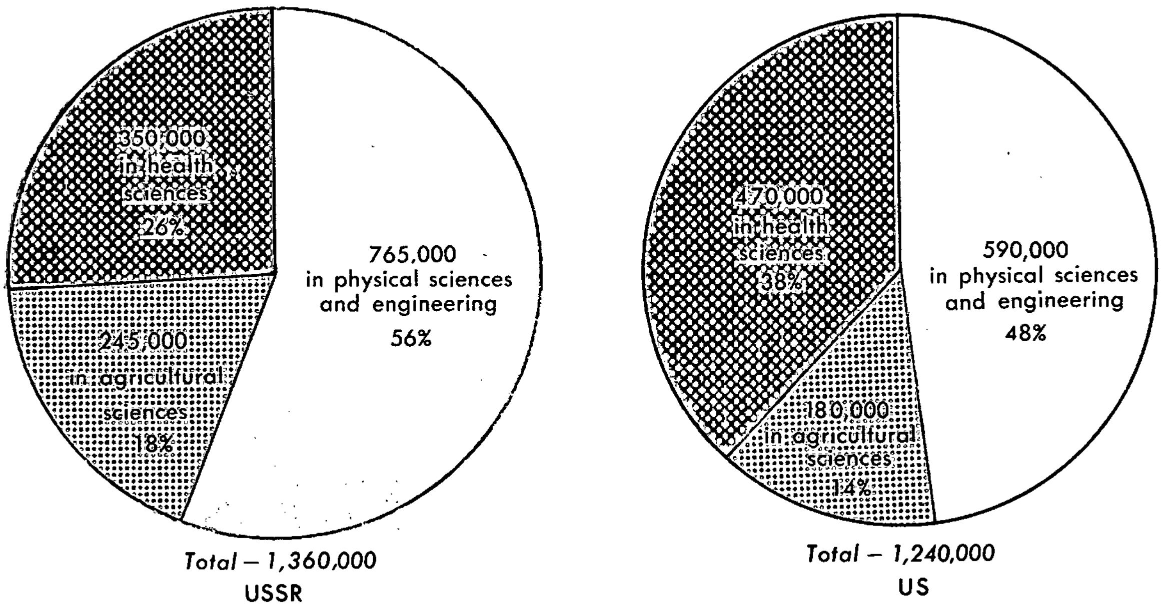

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Figure 3

NUMBER GRADUATING PER YEAR FROM HIGHER EDUCATIONAL INSTITUTIONS ACCORDING TO FIELD 1930-56

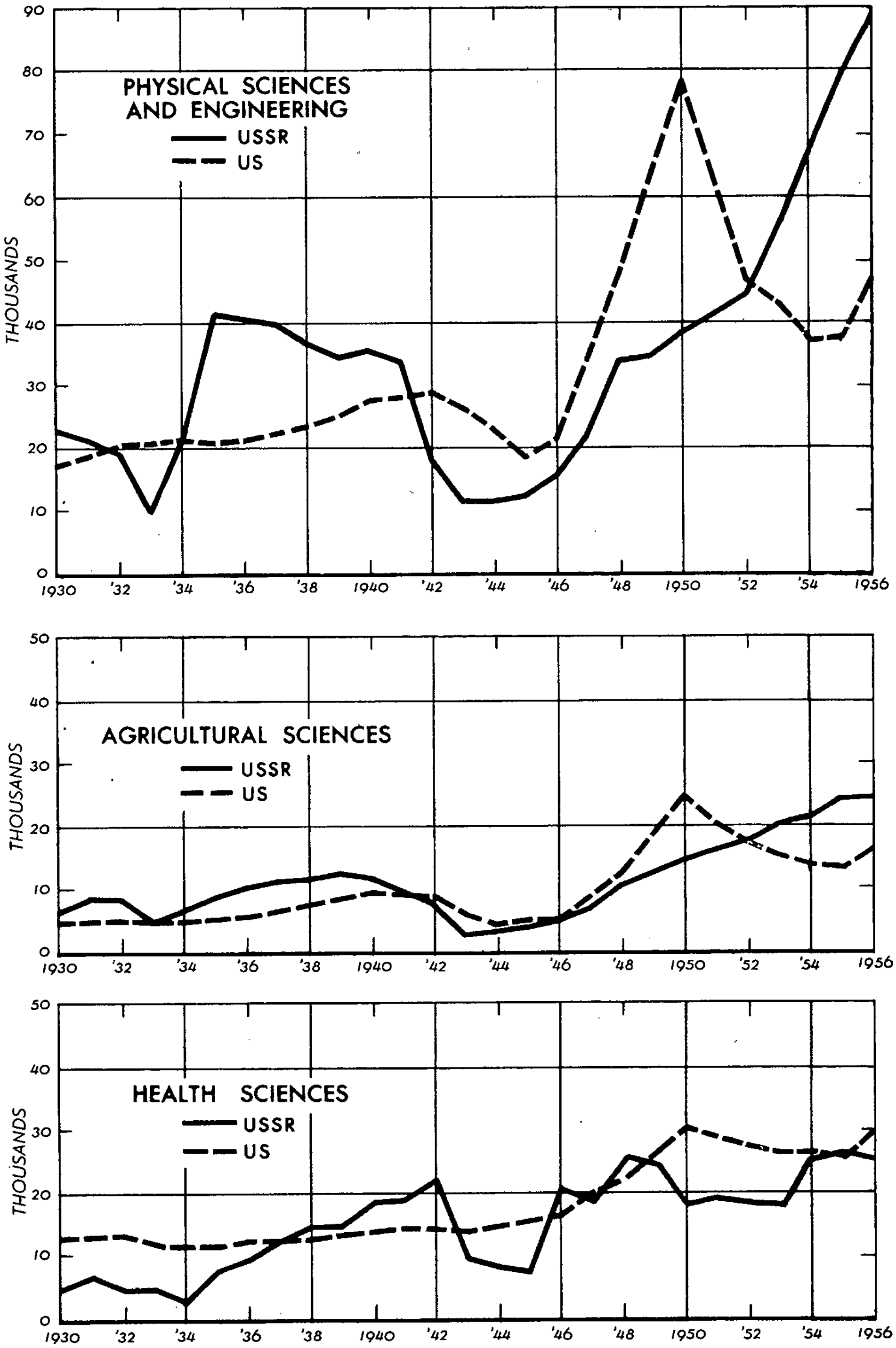

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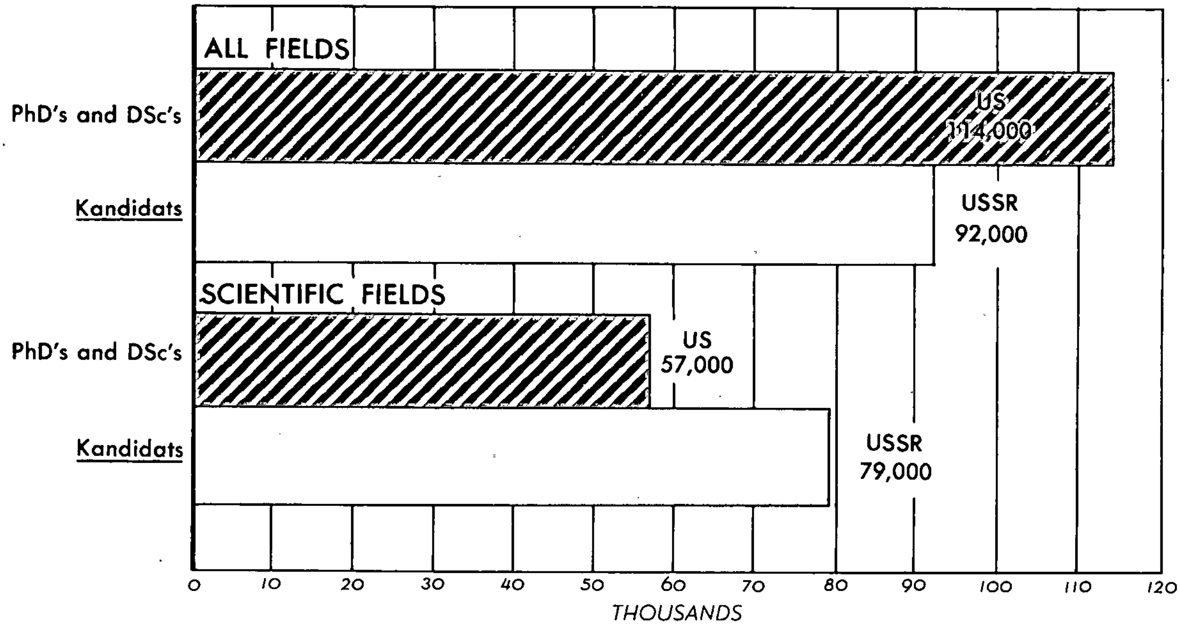
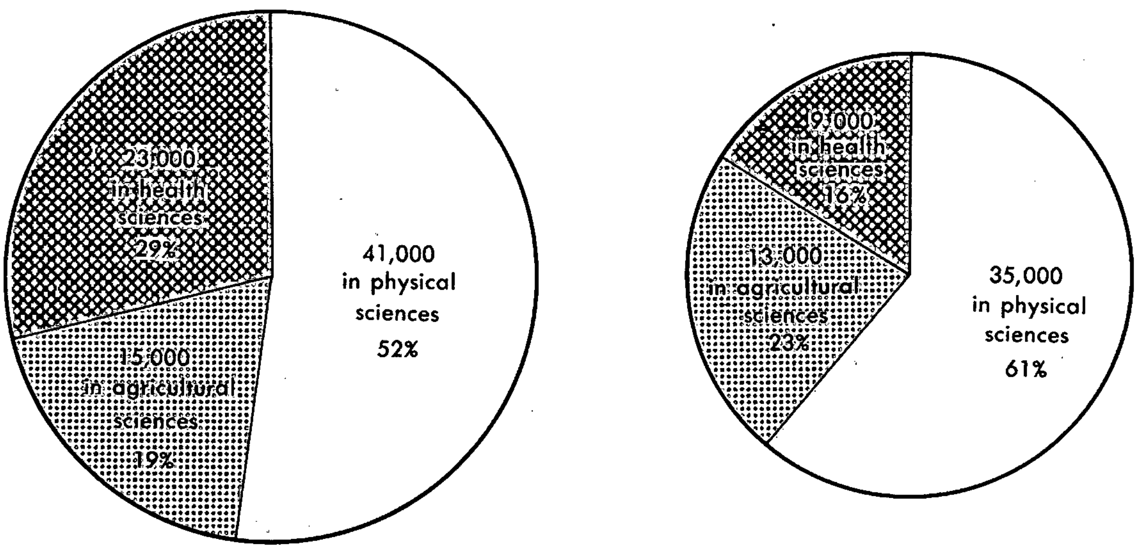
Figure 4

NUMBER OF PERSONS HOLDING HIGHER DEGREES AND DISTRIBUTION WITHIN SCIENTIFIC FIELDS

AS OF MID-1956





USSR
Kandidats
Total-79,000

US
PhD's and DSc's
Total-57,000

These charts do not take into account the fact that in some biological sciences, which make up a part of the agriculture and health sciences, the Kandidat degree is more nearly equivalent to the US master's degree than to the Ph. D. or D. Sc. Figures for US holders of master's degrees are not included.

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Figure 5

HIGHER DEGREES IN SCIENCE AWARDED ANNUALLY
1933-56

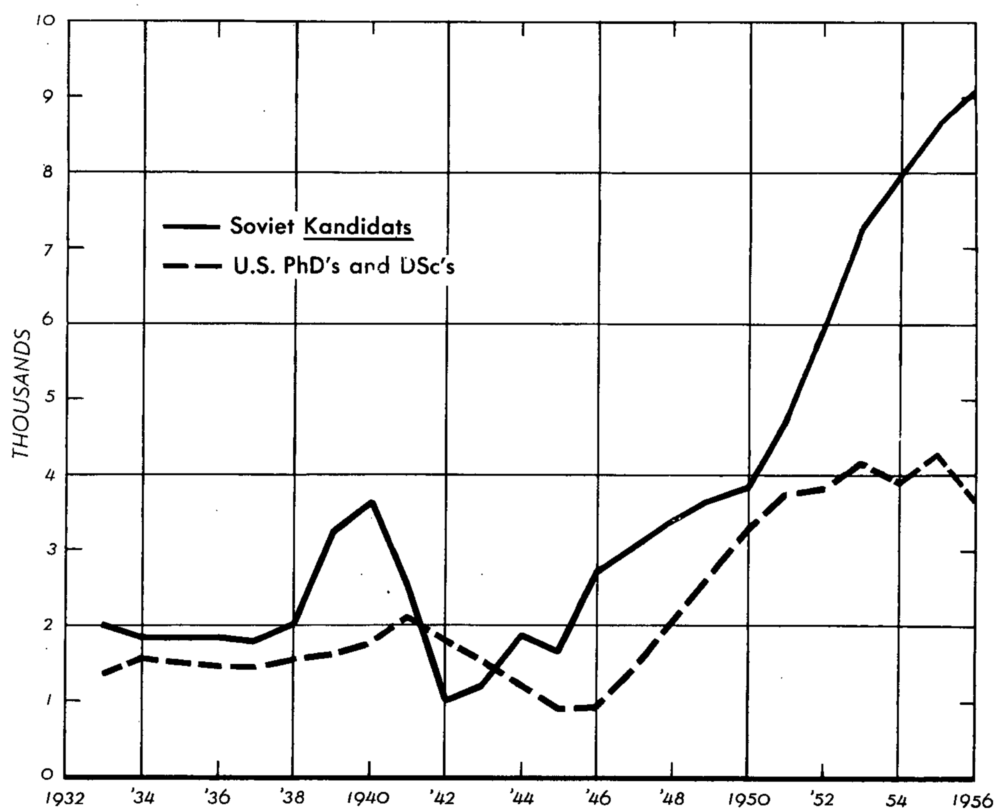

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Figure 6

NUMBER OF SCIENTISTS IN RESEARCH AND TEACHING
1930-56

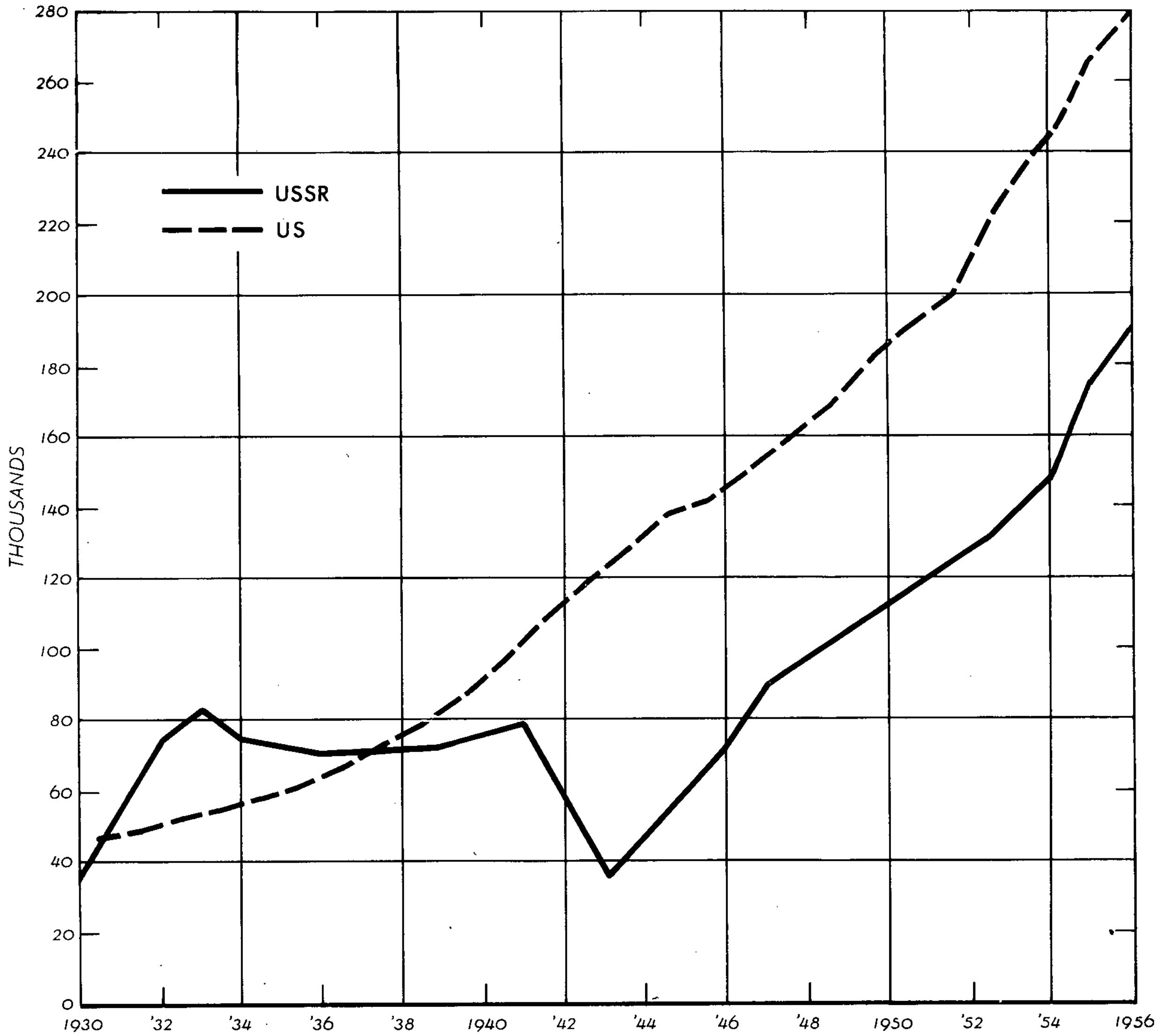

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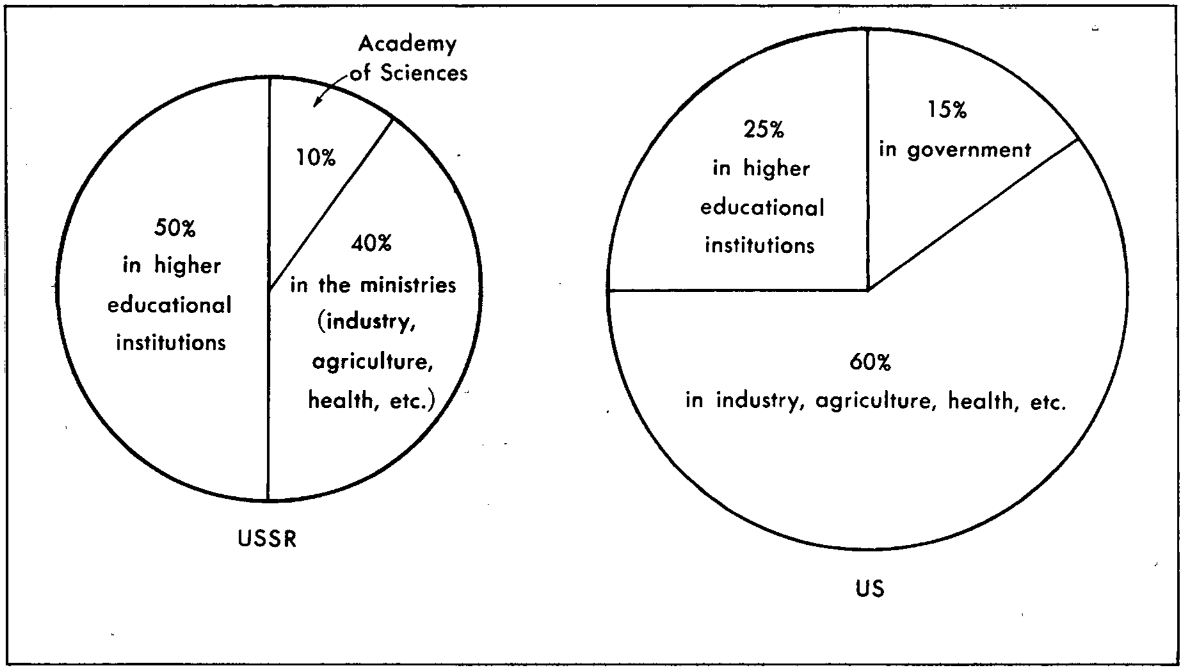
Figure 7

DISTRIBUTION OF SCIENTISTS AND ENGINEERS ENGAGED IN RESEARCH AND TEACHING

AS OF MID-1956

By Place of Employment



By Field of Employment

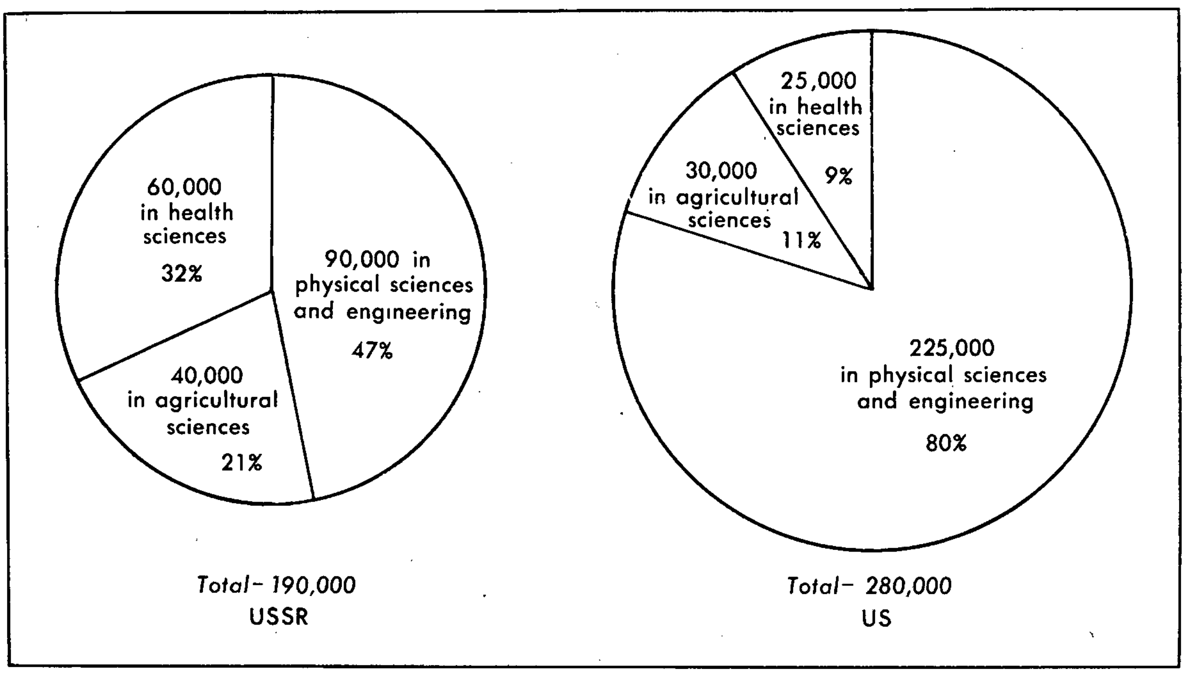


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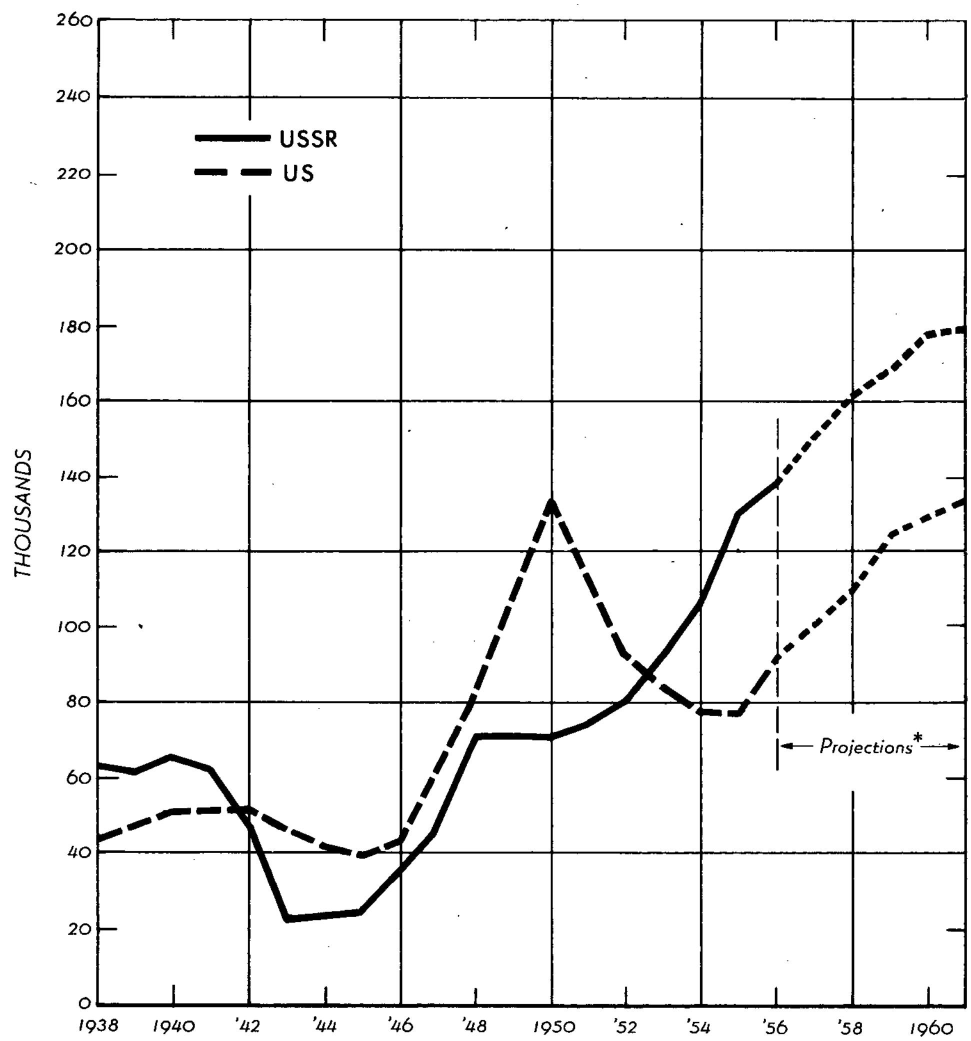
Figure 8

NUMBER OF SCIENTIFIC AND TECHNICAL GRADUATIONS PER YEAR 1938-61



*Projections are based on current enrollments adjusted for attrition on the basis of past experience.

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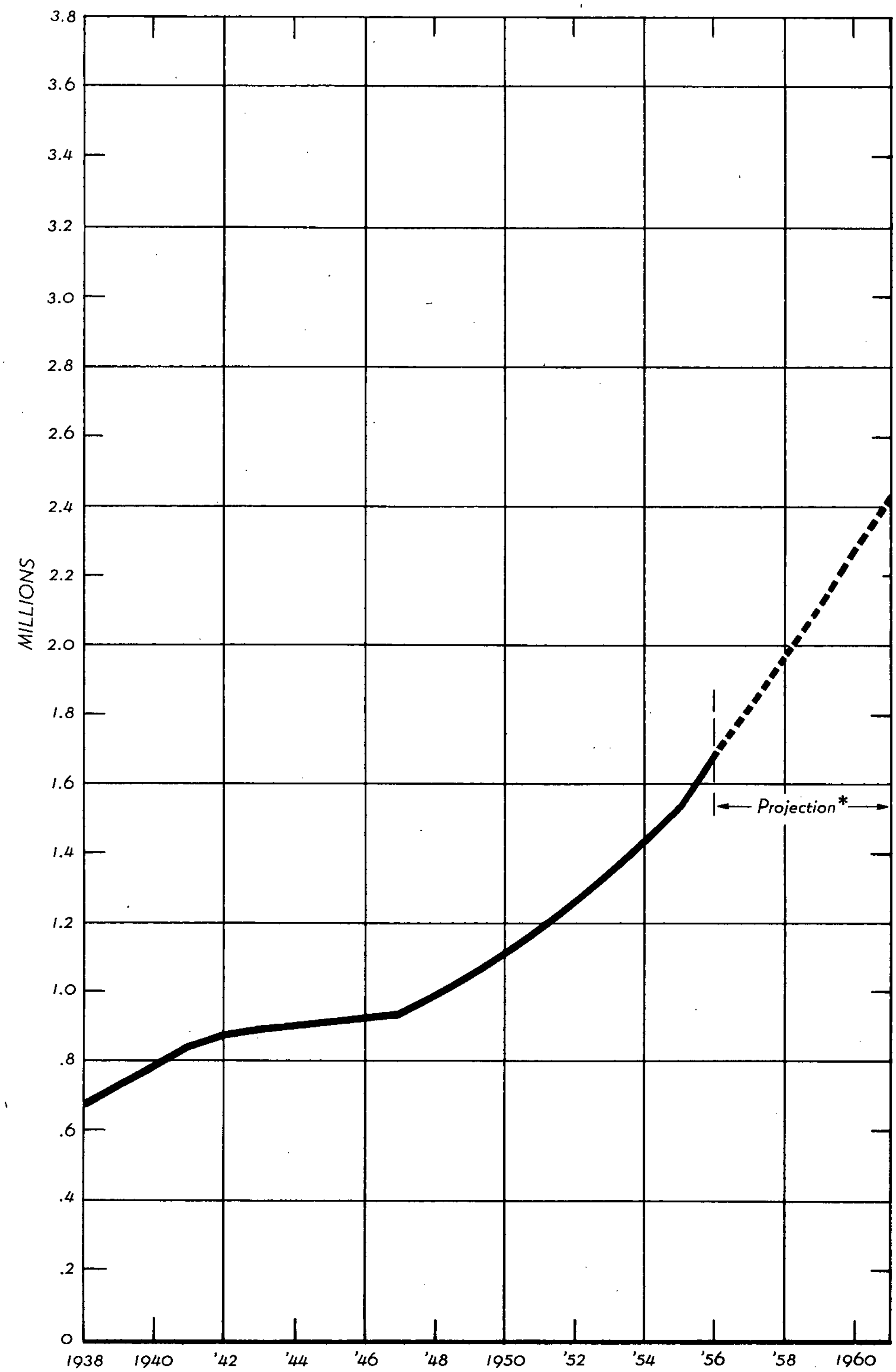
TREND IN THE NUMBER OF LIVING SCIENTIFIC AND TECHNICAL GRADUATES IN THE USSR



*Projection is based on current enrollments adjusted for attrition on the basis of past experience.

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