~~SECRET~~ Nº 86

12 FEB 1959

SCIENTIFIC INTELLIGENCE REPORT

LONG-RANGE CAPABILITIES OF THE SOVIET UNION IN MAJOR SCIENTIFIC FIELDS 1957-67

MONOGRAPH I
SUMMARY ESTIMATE

CIA/SI 2-59
23 January 1959

CENTRAL INTELLIGENCE AGENCY

OFFICE OF SCIENTIFIC INTELLIGENCE

~~SECRET~~

C01057748

SECRET

Scientific Intelligence Report

LONG-RANGE CAPABILITIES OF THE SOVIET UNION IN MAJOR SCIENTIFIC FIELDS 1957–67

MONOGRAPH I

SUMMARY ESTIMATE

NOTICE

The conclusions, judgments, and opinions contained in this finished intelligence report are based on extensive scientific intelligence research and represent the final and considered views of the Office of Scientific Intelligence.

CIA/SI 2–59

23 January 1959

CENTRAL INTELLIGENCE AGENCY

OFFICE OF SCIENTIFIC INTELLIGENCE

SECRET

PREFACE

This Summary Estimate (Monograph I) on Soviet science is based on detailed material presented in the other monographs in the series listed below. It is intended to summarize Soviet capabilities in major scientific fields over the next 10 years and to draw certain conclusions about Soviet science in general. Emphasis is placed on trends in Soviet scientific fields. The paper also points out the significance of research, estimates the likelihood of the Soviets attaining their stated goals within the next 10 years, and includes some comparison with Western efforts in strategic and priority areas of work.

The general cutoff date for information in this report is that indicated in each Monograph. Where necessary, changes have been made to reflect recent reports, and all intelligence conclusions are valid as of 1 December 1958.

CONTENTS

CONTENTS (Continued)

FIGURES

FIGURES (Continued)

LONG-RANGE CAPABILITIES OF THE SOVIET UNION IN MAJOR SCIENTIFIC FIELDS 1957–67

MONOGRAPH I

SUMMARY ESTIMATE

SUMMARY AND CONCLUSIONS

The Soviet Union has established itself as one of the world leaders in many strategically important scientific and technological fields through a determined effort by its government, which has established the goals to be reached in each field by priority and date. All scientific research is controlled firmly by the government and is planned in detail to support national priority objectives.

The value of basic research is well recognized by Soviet planners who encourage such work mainly in areas that may lead to application or national prestige. The general emphasis under the Soviet system, however, is on applied research. This is not unexpected, since the strict priority system funnels the best scientific manpower, research facilities, equipment, and materials into important economic and military areas.

Probably the most surprising aspect to many has been the apparent success of the system of strictly controlled science in an atmosphere that is almost opposite to the one held sacrosanct by most Western researchers. The system has had tremendous growing pains and setbacks caused mainly by political and ideological interference in scientific matters. The system also has been beset with reorganizations, shifts in policy, and priority. Soviet science is currently undergoing a major reorganization, as part of the economic reorganization, which is aimed primarily at the better utilization of the tremendous scientific output for technological development. The new organization that will emerge is designed to achieve a more efficient division of labor among scientific, industrial, and educational institutions. The significant changes include an increase in the Academy of Sciences' theoretical support of economic or military projects, the establishment of State Committees under the Council of Ministers (Defense Technology, Aviation Technology, Radio-Electronics, and Shipbuilding), a greater control over non-defense research by GOSPLAN, providing direct research and technological assistance to industrial plants through Regional Economic Councils (SOVNARKHOZes), the establishment of a new Scientific-Technical Committee of the USSR Council of Ministers to advise GOSPLAN and to set policy on the application of new techniques in industry and on the national scientific technical information program, the designation of certain institutes as Head Research Institutes to coordinate research in specific fields, and an increase in the support of regional research programs by institutions of higher education (VUZes).

Soviet manpower training policies were established in the early 1930's with the intent to overtake the West. By the early 1950's Soviet technological strength was sufficient to challenge the West in strategic areas. As of 1957, there were 1,475,000 Soviet scientific and technical professionals as compared with 1,330,000 in the United States. In addition to being about 10 percent greater than the United States in total numbers, there are about 30 percent more Soviet holders of advanced degrees. The numerical superiority, however, stems entirely from the large number of Soviet engineers and agricultural scientists. Soviet manpower is actually less plentiful in health sciences and physical sciences and very much less in biological sciences. The majority in the Soviet force also lacks experience. For these and other reasons, we believe the overall capacity of Soviet scientific and technical manpower presently is inferior to that of the United States. If current trends continue, however, the Soviets will eventually have a greater number of scientific and technical professionals with more experience than those in the United States. The Soviet force is growing at a net yearly rate of between 6 and 7 percent, whereas the U.S. force is growing at between 3 and 4 percent. By 1961, Soviet manpower will probably increase to about 2,000,000, or about 25 percent larger than the anticipated U.S. strength of approximately 1,600,000. This disparity will probably continue through 1967.

The availability of scientific information to the Soviet researchers in important scientific centers has increased to the point where they now have access to almost all foreign and domestic publications. Moreover, the government greatly encourages the exploitation of foreign efforts.

We expect an expanded Soviet effort to integrate Bloc research for fuller utilization of Bloc resources. While this effort is still in the planning stage, complete integration would pose a serious technological threat to the West. The organization of science in Bloc countries is now modeled in the Soviet pattern which facilitates coordination with them. The Soviet Union can expect the Bloc countries to provide considerable support over the next 10 years.

Major scientific advances of possible military or economic significance are most likely to occur in the Soviet Union in the areas of electronics, geophysics, and physics. Soviet abilities in these fields are particularly strong and are supported by a high capability in mathematics. Some advances can be expected in other fields in certain restricted areas. Soviet research in chemistry and metallurgy is considerably behind U.S. research in the magnitude and level of effort, but the USSR should be relatively advanced in all areas of importance in 10 years. The USSR is still behind somewhat in the medical sciences, although the country is ahead in some priority areas, such as space medicine and basic work on human behavior. The veterinary sciences have advanced considerably since World War II, and the Soviets have good capabilities in several areas. The Soviets have demonstrated a fair competence in certain priority areas of biological and agricultural research, but their general capabilities in these fields are low.

A brief summary of present and future capabilities by major scientific field is provided in the following paragraphs:

PHYSICS — The USSR has very high capabilities in critical areas of physics. Soviet scientists are particularly outstanding in theoretical physics, as well as in the theoretical aspects of solid state physics, of low temperature physics, and of optics and photography. Soviet research in high-energy physics is of high quality, though somewhat deficient in originality.

By 1967, Soviet research in high-energy nuclear physics may be comparable with that of the United States in most respects. The Soviets currently have the highest energy particle accelerator in the world, a 10-Bev proton synchrotron. Their position as leader will be overtaken by the West by 1960 or 1961 with the completion of two 25-Bev machines. The Soviets may regain their position of supremacy by 1967 if their 50-Bev machine is completed by that time and if the United States does not begin construction soon on an even more powerful machine. Although the Soviets will have several high-energy particle accelerators of excellent quality, they will have considerably fewer than those available in the United States.

MATHEMATICS — The Soviet Union has an exceptionally high capability in both pure and applied mathematics which supports science on a broad front. Their engineers receive appreciably more mathematical training than those in the United States. There is no evidence that priority research and development is suffering from a lack of mathematical support.

By 1967, there should be increased utilization of mathematics and high-speed digital computers for solving engineering problems in the development of weapon systems of increasing complexity. High-speed calculation facilities are available now for a large number of high priority problems; the general research and development community should have access to them by 1967.

GEOPHYSICAL SCIENCES — The Soviet Union is one of the leading nations of the world in the geophysical sciences. It is approximately equal to the United States in most geophysical subfields including geomagnetism, geodesy, gravimetry, seismology, meteorology, hydrology, upper atmosphere research, and geology. The USSR is outstanding in polar oceanography, polar meteorology, permafrost science, geochemistry, seismic theory and instrumentation, research on seismic waves by means of explosions, theoretical geodesy, applied gravimetric technology, and upper atmosphere research by means of rockets and artificial earth satellites. It lags slightly in geophysical instrumentation, in oceanography, in practical application of engineering geology and soil mechanics, and in the application of computers in weather forecasting.

We expect the generally high capabilities in all fields to be maintained throughout the next 10 years. The USSR will continue to maintain its high capabilities in polar geophysics and its ability to conduct cold weather operations by its intensive polar geophysical research program. Significant advances in economic geology will probably be made during the period of this estimate. Rocket and artificial earth satellite investigations will be improved and expanded and probably will result in significant advances in knowledge of the upper atmosphere and solar-terrestrial relationships and will lead to further ventures into space research. Soviet geodetic work may improve their capabilities for positioning accuracy required for launching of missiles to distant targets, and upper atmosphere research may assist them in the design and operation of missiles and aircraft as well as improving communications techniques. The quality of oceanographic research is expected to improve and will probably become comparable to that of the leading countries engaged in oceanographic research.

CHEMISTRY — The Soviet Union is definitely behind the United States in the magnitude and level of the research effort in most fields of chemistry. Basic research in organic chemistry generally lags the United States by 3 to 5 years. Their capability in organophosphorous chemistry, which receives high priority, is probably greater than that of any other country. They are probably very advanced in combustion and chemical kinetics, catalysis research, exotic fuels, and applied and fundamental explosives research. The USSR lags in pharmaceutical research and in a few fields of spectroscopy. Chemical engineering research and development is considerably behind. The country also is significantly behind in petroleum technology.

By 1967, Soviet research in chemistry and chemical engineering will be relatively advanced in all fields of importance. Basic organic work will probably move forward in general. Research and development in ion exchange resins as applied to nuclear energy will reach parity with the United States. Physical chemistry will remain high; they will continue advances in nuclear chemistry and catalysis research and should equal the United States in spectroscopy. The USSR should approach near equality in chemical engineering research and development. Liquid and solid propellant research will probably parallel and equal U.S. efforts. The USSR will remain on a par with the United States in fundamental and applied explosives research. Petroleum technology will generally advance but will remain significantly behind the United States through 1967.

METALLURGY — Although the USSR is lagging in certain fields of metallurgical research, Soviet metallurgists have exhibited originality and research ability in most important areas of fundamental and applied work. Soviet capabilities in steel technology are high and their work on high-temperature alloys is creditable. They have achieved parity with the West in nuclear metallurgy and in ferromagnetic and semiconductor materials. They have given less research attention to aluminum and magnesium. Development work in extractive metallurgy has been relatively neglected until recent years; applied titanium technology is retarded somewhat.

By 1967, Soviet metallurgical research facilities will continue to be fewer in number than in the United States; however, these facilities will probably equal those of the United States in equipment and quality of research staff personnel. Some of their present deficiencies should be overcome. They will continue to follow Western progress in titanium technology, but research capabilities in extractive metallurgy will probably approximate those of the United States.

ELECTRONICS — The Soviet Union is presently one of the two or three leading nations in electronics research and development, both qualitatively and quantitatively. The Soviets have placed major stress on militarily important electronic research and development, as well as on broad investigations of fundamental scientific areas from which electronics development information can be obtained.

Soviet understanding of radiowave propagation appears to be at least equivalent to that of the West, as is their grasp of communications theory. The USSR ranks closely behind the West in radio astronomy. Investigations in information theory appear to lag somewhat, particularly in engineering applications. Soviet work is probably on a par with that of the West in automatic control theory, except that in non-linear control theory, where the Soviets have led the West for many years. Soviet fundamental work on electronic materials and components is more intensive than that of the United States, and their theoretical work in solid state physics has been excellent. The USSR can produce any type of electron tube developed in the West. Its transistor work is of high quality, although it is behind in production technology. Soviet work on thermoelectric effects is more advanced than that in any other country. Components for high altitude and high temperature have been developed in the Soviet Union, but the USSR is behind somewhat in printed circuitry and miniaturization. By 1967, the USSR should retain its present world leadership in some phases of electronics research and development and may possibly achieve parity or leadership in the few fields in which it presently lags. This situation should result from the high priority accorded by the Soviets to electronics research and development, and their high rate of training of scientists and engineers, and their high level of expenditures, especially for research into fundamental phenomena.

The USSR is expected to equal the leading nations in radio astronomy by 1967. In the next two or three years, the USSR will probably be on a par with the United States in information theory. Its position as a world leader in automatic control theory will be maintained. The Soviets will probably make technological advances in thermoelectric effects with far reaching military and economic applications. Their lag in printed circuitry and miniaturization will probably have been overcome by 1960, and the USSR possibly may surpass the United States in the development of highly reliable miniaturized components by 1967.

MEDICAL SCIENCES — The Soviet Union has a lower capability for medical research than the United States in most areas, although most leading Soviet medical scientists are equal in competence to those of the West. The USSR leads the United States by a significant margin in certain areas, such as space medicine and some phases of behavioral research. Their capabilities are approximately equal to those of the United States in medical aspects of polar operations. The Soviets are notably behind, however, in the medical use of radioisotopes and in some aspects of health physics. They also remain somewhat backward in most aspects of microbiological, nutritional, and basic protein research.

By 1967, the Soviets will still have strong capabilities in their priority areas and will show considerable improvement in others. They will continue to lead in some aspects of space medicine and in the control of human behavior; especially in conditioning techniques, "functional" neuropathology, and their use in psychological warfare. In addition, the Soviets will probably lead in radiobiological research on the nervous system and the possible effect of cosmic radiation on organisms.

Soviet and U.S. capabilities will be approximately equal in defensive medical aspects of human BW; production of biologicals and equipment for civil defense; and research and production of whole blood, plasma, and plasma extenders.

The Soviets will remain behind in the general use of radioisotopes in medicine and most aspects of microbiological research, although they will show considerable improvement in research on virus and rickettsial diseases and the development of broad spectrum vaccines. The USSR will also retain deficiencies in medical defense against CW, antibiotic research and production, and advances in nutrition.

VETERINARY SCIENCES — Veterinary research capabilities and resources have advanced and expanded considerably since World War II. Basic research is given less emphasis than are applied and developmental investigations. Major emphasis is on improved field application of research findings. A reasonably good capability exists in research on infectious livestock diseases, disinfection, and parasitology; but, in general, their research is inferior to that of the United States. An important trend has been the approach to problems of livestock disease through control rather than eradication. Major emphasis has been placed on the development of more effective vaccines and improved diagnostic agents. The Soviets already have a strong capability to support an antilivestock BW program.

By 1967, Soviet veterinary research capabilities will have increased considerably but there still will be a lag in practical application. Some achievements, especially in virology, are expected. There may be a shift from control of diseases to eradication. More effective biologicals will probably be available generally. Further, the continued expansion of research resources and scope of interests will give the USSR a formidable scientific capability to support antilivestock biological warfare efforts.

BIOLOGICAL AND AGRICULTURAL SCIENCES — Although the Soviets are fairly competent in certain priority areas of biology and agricultural research, their general capabilities are low in basic work in these areas. Research facilities are generally poor, but they are improving gradually. Genetics research, which had fallen considerably behind, recently has shown indications of notable improvement. Interest in astrobiology is also gaining momentum and extensive research is planned. They are considerably behind in industrial fermentation, most of the basic sciences supporting agriculture, and engineering technology in agriculture. They are retarded in many fields of livestock research and production.

By 1967, Soviet biological facilities should be capable of supporting quality research, but a long time may be required for the Soviets to approach Western capabilities in biology. Soviet genetics should improve, and they possibly will equal U.S. work on the effect of radiation on microorganisms. The lag in industrial fermentation should be narrowed somewhat but is not likely to disappear.

Significant improvement in agriculture engineering research and technology are expected during the period of this estimate. Increases in crop production will probably result from the expected progress in the plant sciences and in agricultural practices. Improvement is also expected in the livestock situation and in food technology.

DISCUSSION

INTRODUCTION

Basic to Communist philosophy and policy is the precept that science and technology are keys to military, economic, and political power. The Soviet Union gives priority support to science and technology and utilizes their fruits primarily to improve and strengthen the military establishment and basic industry. Science and technology are also fully utilized to gain domestic support, and support in other countries, with the promise of material progress.

Soviet efforts to industrialize rapidly and to surpass the West have been vigorous for over 25 years. Imported technology has been used freely to this end. Stalin noted the necessity for greater technology and stated the slogan "trained manpower decides everything" in 1935. The technological gap has since narrowed and present Soviet scientific and technological activities give increasing evidence of strength and maturity. The Soviet technological establishment has now matched or surpassed that of the West in some areas.

As Soviet technological capabilities increase, foreign technological advances are becoming less profitable to exploit and are now being more carefully and extensively reviewed than heretofore. The present availability of technically competent personnel releases the Soviet Union from its heavy dependence on Western technological advances and enables the development of production models of native conception. Indigenous developments already have been accomplished in many fields. Foreign advances which appear suitable for Soviet use will continue to be exploited. For this purpose, the Soviet Union has created the world's largest scientific information service. The Soviets also have profited from espionage, particularly in priority fields where they were behind. Espionage helped shorten lead-times and permitted a concentration of scarce resources. Espionage still serves to warn the Soviet government of foreign capabilities and advancements, but we believe it is of little significance for the continuation of general Soviet technological progress.

In the attempt to excel the West, the Soviets did not have to start from scratch in basic fields of science. The Soviet Union inherited a notable scientific tradition which dates back to the time of Peter I. The Academy of Sciences was founded under his patronage in 1725. Since that time, there have been eminent Russian scientists in most fields of scientific endeavor and they have made many original contributions to world science. Accomplishments have been notable in areas of physiology, mathematics, organophosphorous chemistry, celestial mechanics, radio astronomy, geophysics, and physics, including nuclear physics. The father of Russian physiology was Ivan M. Sechenov (1829–1905). His "Reflexes of the Brain" (1863) provided the stimulus for researches of I. P. Pavlov. D. I. Mendeleyev (1834–1907) is credited with the periodic system of classifying elements. The names of other great Russian scientists are sprinkled throughout most fields of endeavor: Mechnikov, Butlerov, and Lobachevskiy, to name a few. Today, L. D. Landau is one of the world's two or three best theoretical physicists. Peter Kapitsa is the pioneer in cryogenics. Igor Kurchatov is the leading Soviet atomic physicist. Alexander N. Nesmeyanov, a leading chemist and President of the Academy of Sciences, USSR, is often compared with Vanevar Bush of U.S. fame. These, incidentally, and many other Soviet scientific leaders have received some Western training.

The major factors which influence the progress of Soviet science will allow Soviet scientific capabilities to grow through the next 10 years. In the following sections, we will explain these factors in terms of Soviet policy, the organization and administration of science, scientific and technical information, research coordination among Bloc members, and scientific and technical manpower. Following these, we will assess the present and future Soviet position in fields of basic research. Comparisons are frequently drawn between the Soviet effort and that of the United States or the West. These comparisons primarily serve to judge Soviet capabilities against a known base line and are not intended as proof of inferiority or superiority. The fact that the situation in both the United States and the Soviet Union is changing rapidly should be kept in mind in reviewing these comparisons.

SOVIET POLICY ON SCIENCE AND TECHNOLOGY

Science and technology in the Soviet Union are fully supported by the government, because they are considered an indispensable basis for overtaking and surpassing the United States in material and political strength. World leadership in science and technology is an ultimate objective. The desire for rapid industrial development is a prime goal; and, although present emphasis is on applied science, the value of adequate fundamental research is well recognized by planners. Fundamental work is channeled as much as possible to areas which may lead to application or to areas which hold promise of major advances for prestige purposes. Progress in some fields has lagged seriously due to coordination problems, political interference, and the imposition of changing priority requirements. The relative isolation of all Soviet scientists also has had its unfavorable effects. These deficiencies have been recognized, and positive steps have been taken to alleviate them. The regime now endorses and even encourages free exchange of scientific information and is making changes in the organization and control of science and technology. Significant emphasis is being placed on increasing research output and on better utilization of this output for technological development. Relations between scientists and the regime are improving, and scientists are being given a larger part in planning the Soviet research and development program.

ORGANIZATION AND ADMINISTRATION OF SCIENCE

The Soviet government has taken advantage of the recent economic reorganization to make changes in the organization and administration of science, in order to achieve an increasingly expanded research output to meet growing military and economic needs. Under the already partially implemented reorganization plan, research is to be administered so as to achieve a more efficient division of labor among scientific, industrial, and educational institutions.

Responsibility for scientific policy, planning, and control will be allotted as follows:

1. The Academy of Sciences, USSR, will develop broad, long-range scientific policy, control fundamental research in a few external high-priority areas in addition to the Academy's own broad program, and will be required to furnish increasing theoretical support to applied research institutes and to assist in expanding research in higher educational institutions. At present, the USSR Academy has about 130 scientific institutions controlled by 8 substantive departments for: physico-mathematical sciences; chemical sciences; technical sciences; biological sciences; geological-geographical sciences; history; language and literature; and philosophy, economics, and law. The recently established ninth, or Siberian Department, controls activities in several scientific fields. Seventy percent of these institutions are currently located in Leningrad and Moscow, employing over 80 percent of the Academy's scientists. Steps are being taken to decentralize a greater proportion of the Academy's efforts as part of the economic reorganization. (See figure 1 for photograph of building of Academy of Sciences, USSR.)

2. All-union and union republic ministries, such as the Ministry of Agriculture and Ministry of Health, will be concerned with policy relating to scientific research under their jurisdiction. The State Committees for Defense Technology, Aviation Technology, Radio-Electronics, and Shipbuilding attached to the Council of Ministers, USSR, will probably re-

tain control over scientific research and development in their respective fields.

3. The State Planning Committee (GOSPLAN) will be concerned primarily with research in key non-defense industries and with making maximum use of science and technology. GOSPLAN will check plan fulfillment and maintain a high degree of indirect control over scientific research, including that directed by Regional Economic Councils. Many of the research organizations and enterprises are being transferred from abolished industrial and construction ministries to GOSPLAN or to Regional Economic Councils (SOVNARKHOZes).

4. Regional Economic Councils (SOVNARKHOZes) are responsible for providing direct research and technological assistance to industrial plants and for exploiting regional natural resources. A number of institutes of abolished ministries are being transferred to SOVNARKHOZes. Some institutes of republic academies of sciences are also being transferred to SOVNARKHOZes.

5. The new Scientific-Technical Committee of the USSR Council of Ministers will advise GOSPLAN chiefly as to the scientific and technical level at which the national economy can be planned. This committee, which includes representation from the Academy of Sciences, USSR, the Ministries, and GOSPLAN, is also responsible for policy on the application of new techniques in industry and the national scientific-technical information program.

6. The most competent and best equipped institutes in a given discipline will be designated as Head Research Institutes, whatever their subordination. They will coordinate research activities of appointed institutes on a nation-wide basis.

7. Institutions of Higher Education (VUZes) have been called on to increase the amount of their research and to provide greater support for regional research programs. These institutions include the 39 universities and an estimated 380 institutions offering technological, and some scientific, training. The lack of emphasis on research in VUZes was considered as a major gap in Soviet science.

The best Soviet equipment is concentrated in institutes related to defense and heavy industrial development. Although the average Soviet laboratory is less well equipped than the average American laboratory, there are many examples where their facilities are equal or superior to their U.S. counterparts, particularly in "prestige" institutes. Institutions engaged in research of a routine nature, however, will probably continue to face shortages of material and equipment at least during the next five years. (See photographs of Soviet equipment in figures 2, 3, and 4.)

SCIENTIFIC AND TECHNICAL INFORMATION

The USSR has the world's largest scientific and technical information center, the All-Union Institute of Scientific and Technical Information (VINITI). New Scientific-Technical Committees which exist in Union Republics and in some cases on the SOVNARKHOZ level are responsible for following domestic and foreign technological development and channeling information on them to appropriate research or industrial groups. Soviet scientists in important research centers now have access to almost all scientific developments reported in unclassified Soviet and foreign-language publications.

SOVIET BLOC RESEARCH COORDINATION

The current program of integrating Soviet Bloc scientific and technical research and development is still in the planning stage for the most part. The program is sufficiently comprehensive, however, that its development now poses a serious technological threat to the West. We expect an expanded effort to integrate Bloc work permitting full Soviet exploitation of these scientific resources.

SCIENTIFIC AND TECHNICAL MANPOWER IN THE USSR

The Soviet Union now possesses a large and highly motivated force of scientific and technical professional manpower which is growing in size and effectiveness. As of 1957, the Soviet Union had about 1,475,000 scientific and technical professionals as compared with about 1,330,000 in the United States, or

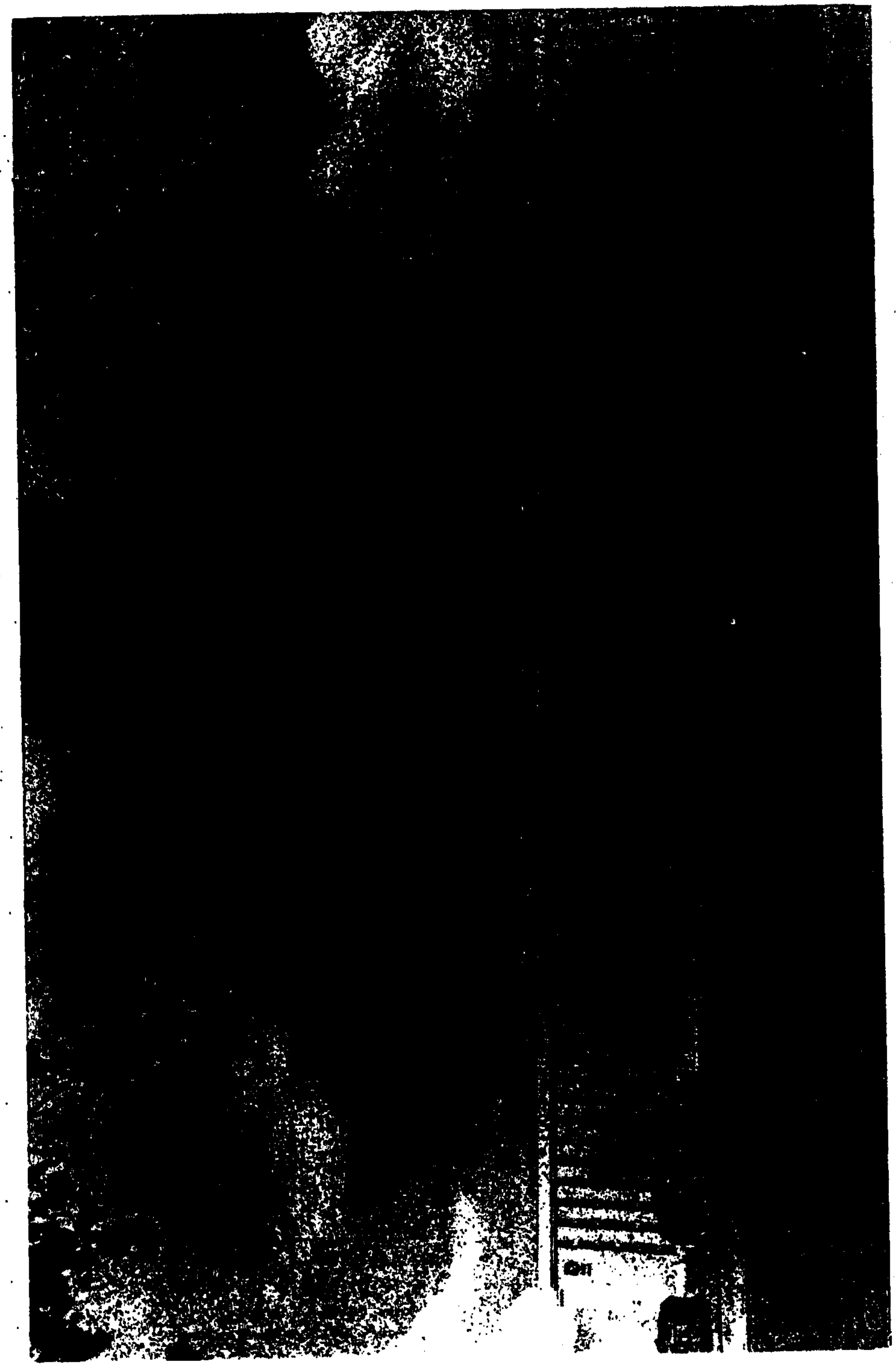

FIGURE 1. Academy of Sciences, USSR, in Moscow.

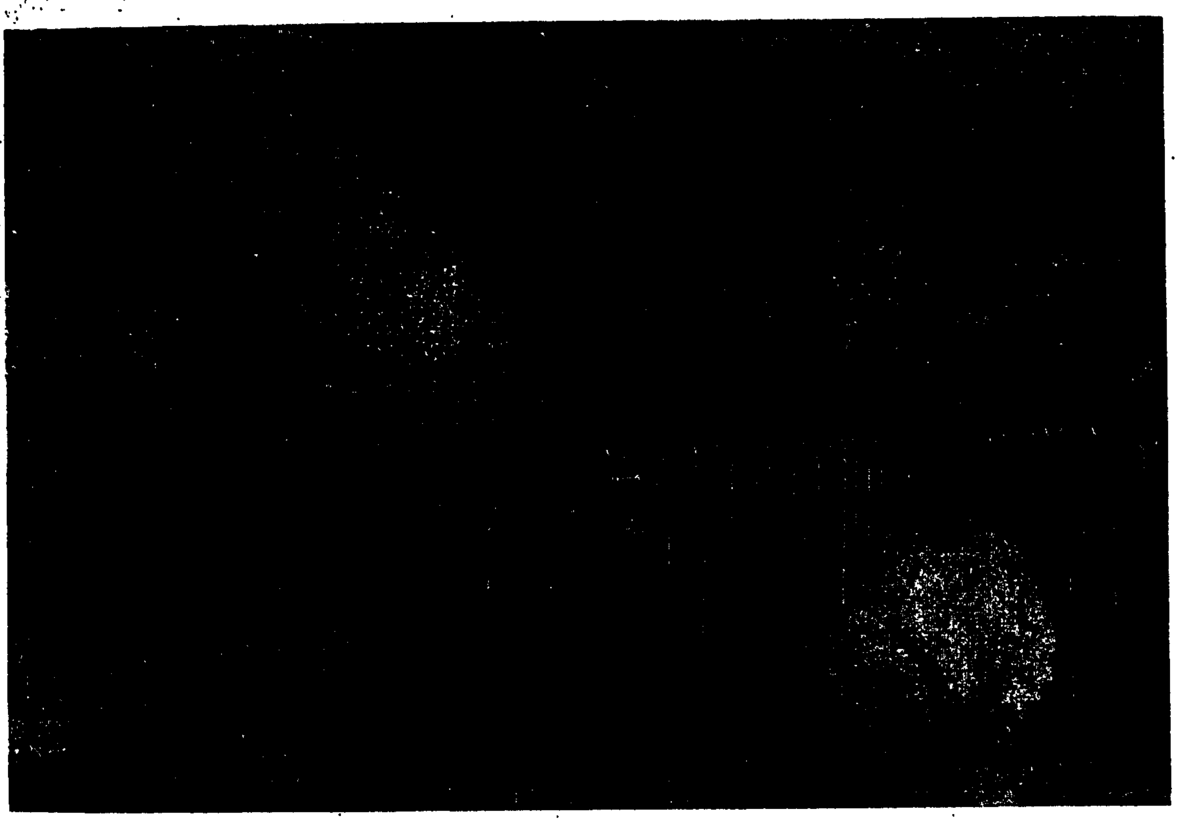

FIGURE 2. Apparatus for converting solar energy to electricity at Experimental Station of Krzhizhanovsky Institute, Tashkent.

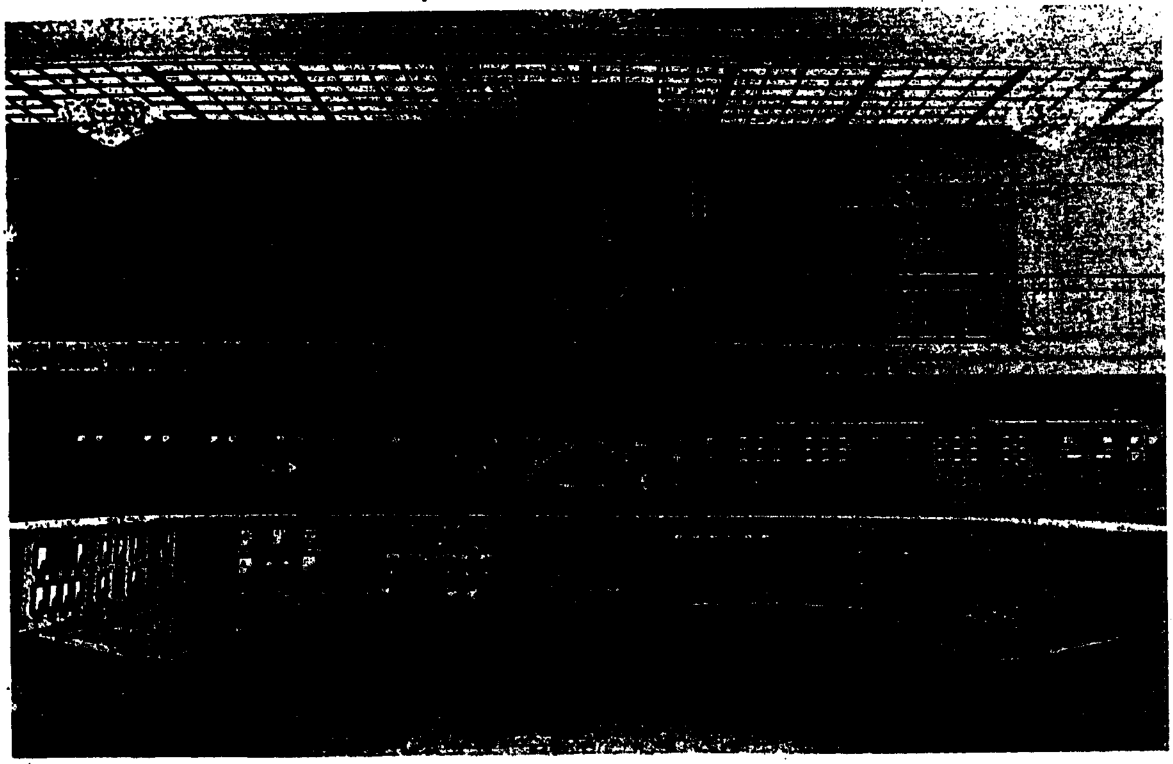

FIGURE 3. Control panel of the 10-Bev proton synchrotron, 1956.

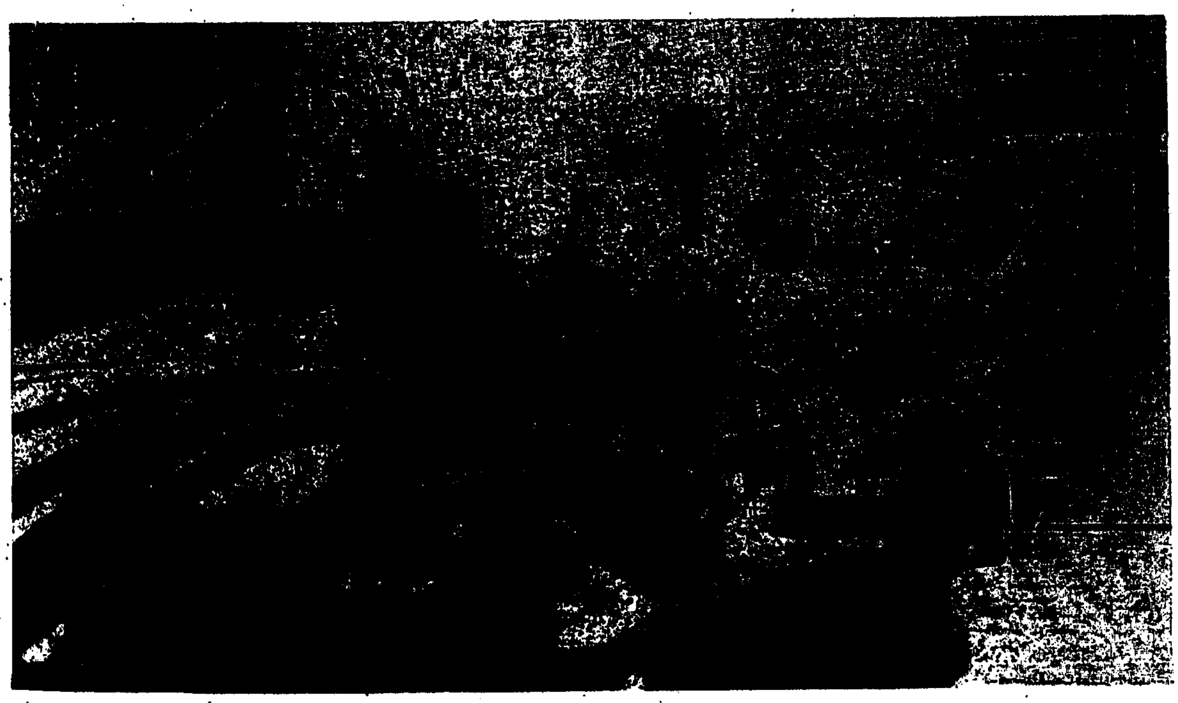

FIGURE 4. Vacuum centrifuge used in cancer research, 1954.

a force about 10 percent larger than its U.S. counterpart. The Soviet force includes about 30 percent more holders of advanced scientific and technical degrees, roughly of Ph.D. level, than does the U.S. force. The Soviet numerical superiority, however, is not uniformly reflected among the different fields and educational levels of science and technology. The following table presents a survey of the relative size of the various components of the Soviet and U.S. force.

The large Soviet groups of professional manpower in engineering, the health sciences, and the agricultural sciences include higher percentages of advanced personnel than do their U.S. counterparts. The smaller Soviet groups in the physical and biological sciences, on the other hand, include about the same percentage of personnel with advanced degrees as do their U.S. counterparts.

The Soviet force is growing at a net yearly rate of between 6 and 7 percent, while the U.S. force is increasing between 3 and 4 percent. By 1961, Soviet manpower will probably increase to 2,000,000, or about 25 percent larger than the estimated U.S. strength of about 1,600,000. The Soviets will have an even greater quantitative advantage in engineering and agricultural sciences, but their relative disadvantages in health sciences, physical sciences, and biological sciences will remain much as they are today. The patterns of difference between the two countries are expected to persist during the next ten years.

Standards of Soviet professional competence and education vary according to scientific or technical field and according to the period during which personnel were trained. For example, scientists and technicians graduated since the 1940's generally are much better trained than those graduated in the early years of the Soviet period. However, at present, most Soviet scientists and technicians generally have had comparatively few years of experience. We believe that the average Soviet scientist and technician, as yet, is less capable than his U.S. counterpart.

The Soviet educational system emphasizes science and technology at all levels. Higher education is extremely selective, and the curricula provide both fundamental science training and a "specialty" which tailors the student to the specific activity in which he will be employed. Changes are being effected in Soviet higher education to improve its quality further, to broaden it, and to make it even more responsive to anticipated state needs. In a few years, the number of experienced Soviet professionals will exceed the number of comparable U.S. professionals. In addition, the relative proportion of advanced degree holders in the Soviet force will increase. Improvements in facilities, planning, coordination, and direction of effort also foreshadow increased capability.

The conclusion is inescapable that the increase in numbers of Soviet scientists and technicians is being accompanied by an overall increase in quality. We believe, therefore,

RELATIVE STRENGTH OF SOVIET AND U.S. SCIENTIFIC AND TECHNICAL PROFESSIONAL MANPOWER — 1957

	Employed Professionals			Advanced Degrees		
Field	USSR	U.S.	Ratio	USSR	U.S.	Ratio
Engineering	780,700	480,000	1.6	26,900	5,700	4.7
Health Sciences	370,500	448,300	0.8	17,600	1,300	13.5
Agricultural Sciences	203,800	158,400	1.3	8,300	4,900	1.7
Physical Sciences *	100,500	168,400	0.6	18,100	32,300	0.6
Biological Sciences	20,300	73,100	0.3	7,600	16,900	0.4
All Fields	1,475,800	1,328,200	1.1	78,500	61,100	1.3

* Including Mathematics.

that the total professional capability of Soviet scientists and technicians, relative to that of U.S. scientists and technicians, will tend strongly to improve during the period of this estimate.

The increasing size and competence of the Soviet scientific and technological manpower pool, together with the associated growth of technical sophistication, productive facilities, and industrial capacity, are expanding the areas within which technological advances may be made and also increasing the probability of such advances.

SOVIET PRESENT AND FUTURE CAPABILITIES IN BASIC RESEARCH

Physics

The capabilities of the Soviet Union in critical areas of physics generally are excellent and are second only to those of the United States. There are about the same number of people carrying out the work as in the United States, but there appears to be a critical shortage of people in lower priority fields. The Soviets have demonstrated a high competence and are particularly outstanding in theoretical physics and high-energy nuclear physics, as well as in the theoretical aspects of solid state physics, of low temperature physics, and of optics and photography.

Although Soviet work in theoretical physics is excellent and comparable to that of the United States, it is considered somewhat lacking in originality. Soviet and U.S. scientists concentrate their efforts on the same subfields and will probably continue to do so.

Soviet research in high-energy nuclear physics, which is now technically competent but somewhat unoriginal, will progress rapidly and may become comparable to that of the United States by the end of the period of this estimate. The particle accelerators available for high-energy nuclear research are excellent in quality but are much fewer in number than those in the United States and are insufficient for the many Soviet physicists working in this field. The 10-Bev proton synchroton is currently the most powerful accelerator in operation in the world.* (See figure 5.) Several additional accelerators, including a 50-Bev machine, are currently in the design or construction stage and may begin operation during the period of this estimate.

The Soviets will maintain their current high capabilities in the theoretical aspects of solid state physics (crystallization and crystallography, alloys, phase transformation, diffusion, strain and deformation, and mechanical properties of crystals). They have been lagging considerably in the experimental and applied aspects of solid state physics. Progress in applied semiconductor work has been rapid, however, and it is expected that there will be steady improvement in the whole area of solid state physics, which should nearly eliminate this lag in 10 years.

Similarly, the Soviets will maintain their high capabilities in the theoretical aspects of low temperature physics and will improve in their currently lagging experimental phases. They have made several important discoveries and more can be expected.

In the experimental and applied aspects of optics and photography, the Soviet Union is generally lagging the United States although it has achieved several notable accomplishments, such as wide-angle lenses for photographic map making.

Computer work has been given increasing support and is now considered one of the 11 basic problems of Soviet science. The accomplishments to date may be considered of major importance although digital computer development has only reached the 1952 U.S. level and analog computer development, the 1955 U.S. level. A rapid increase in computer development is likely, and their capabilities in this field will probably be comparable to those of the United States by 1967. Photographs of the Soviet BESM digital computer and the URAL computer are shown in figures 6 and 7.

* In comparison, the highest energy proton synchrotron in operation in the United States is the 6.4-Bev bevatron at the University of California. The 3.2-Bev proton synchrotron, the cosmotron, is located at Brookhaven National Laboratory and is the accelerator with the next highest energy.

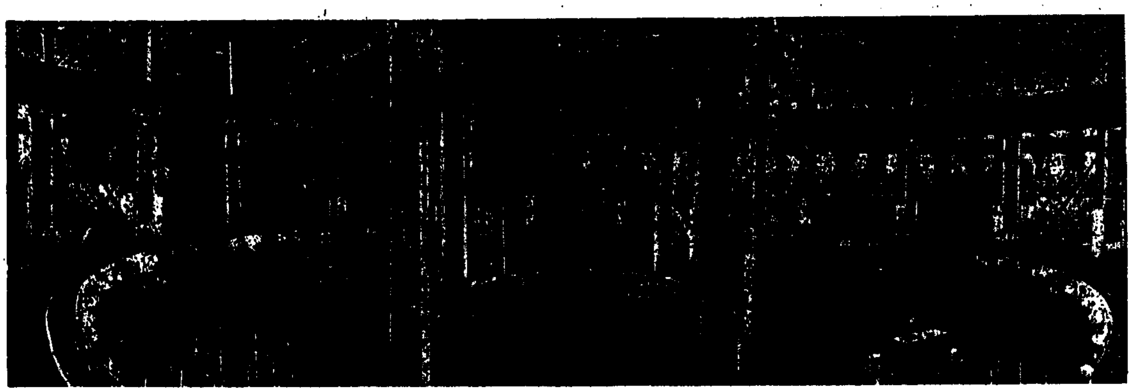

Figure 5. 10-Bev proton synchrotron at the Joint Nuclear Research Institute at Dubna, 1958.

FOR OFFICIAL USE ONLY

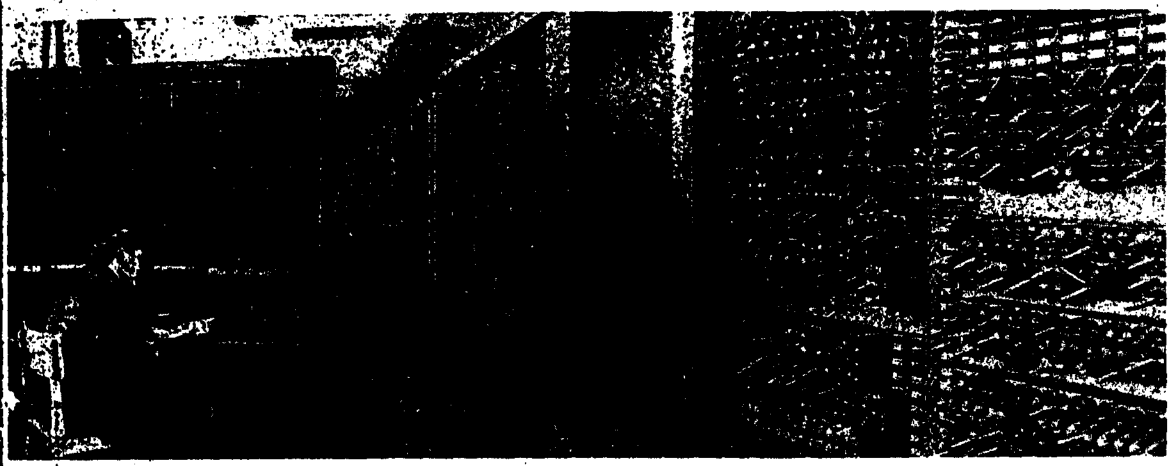

FIGURE 6. Soviet BESM high-speed digital computer.

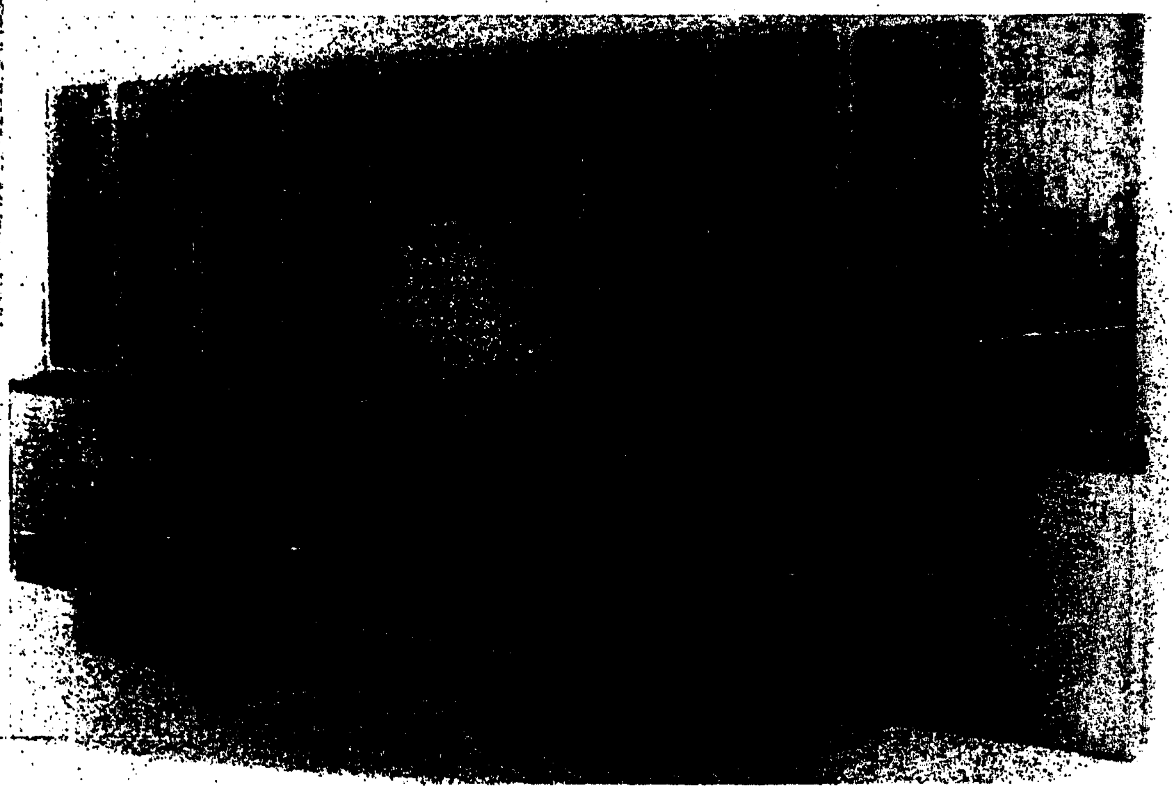

FIGURE 7. Soviet URAL digital computer.

Mathematics

The Soviet Union has an exceptionally high capability in both pure and applied mathematics with their major strengths being in the excellent mathematical training of scientists and engineers and the appreciable number of highly competent theoretical mathematicians capable of supporting Soviet science on a broad front. Soviet mathematicians are currently working on essentially the same problems as Western mathematicians. With their continuing emphasis on training and their demonstrated effective utilization of mathematicians, Soviet strengths in this area should continue and even improve during the next ten years.

Soviet engineers receive significantly more mathematical training than their Western counterparts. About 500 hours of classroom study are given in mathematics during training regardless of the engineering specialty. Mathematical methods for solving problems are emphasized more than the current empirical methods commonly used in the West. Applied mathematics is used increasingly to support basic industrial and military problems of a technological nature. There is a significant Soviet capability in the now technologically important fields of non-linear mechanics and non-linear differential equations. There is no evidence that priority scientific or technical research and development is suffering from a lack of mathematical support, and increased utilization of mathematics and high-speed digital computers for solving engineering problems in the development of weapon systems of increasing complexity and automaticity appears very likely during the next ten years. High-speed calculation facilities are now available for high priority problems but, for most purposes, the Soviets have relied on desk calculators, analogue computers, punch card computers, and Western and Soviet calculated tables of functions. There is a program now underway for introducing high-speed digital computers into scientific institutes, universities, and laboratories; by 1967, the general research and development community should have access to them.

Geophysical Science

The Soviet Union is one of the leading nations of the world in both quantity and quality of work in the geophysical sciences. It is the world leader in polar geophysics and is approximately equal to the United States in geology, geomagnetism, geodesy, gravimetry, seismology, meteorology, hydrology, and upper atmosphere research. It probably lags slightly in oceanography in general. The USSR is outstanding in the subfields of polar oceanography, polar meteorology, permafrost science, geochemistry, seismic theory and instrumentation, research on seismic waves by means of explosions, theoretical geodesy, applied gravimetric technology, and upper atmosphere research by means of rockets and artificial earth satellites. It lags somewhat in geophysical instrumentation, in practical application of engineering geology and soil mechanics, and in the application of computers in weather forecasting.

As a result of its large IGY program and its probable continued emphasis on geophysical research, the Soviet Union can be expected to advance its generally high capabilities in all fields of geophysics during the period of this estimate. It will improve its capabilities in polar geophysics and its ability to conduct cold weather operations by a continuation of much of its current intensive polar geophysical research program and will probably surpass the United States in economic geology during the period of this estimate. Rocket and artificial earth satellite investigations will be improved and expanded and probably will result in significant advances in knowledge of the upper atmosphere and solar-terrestrial relationships and will lead to ventures into outer space research.

In general, the Soviets have numerous and adequate facilities for research in all of the geophysical sciences, although some shortages of equipment exist, and Soviet instruments often lack some of the refinements of similar Western types. These deficiencies are likely to be overcome within the period of this estimate.

Soviet polar research improves their capabilities for cold weather operations and IGY activities provide them with a possible basis for making territorial claims in Antarctica. Furthermore, Soviet geodetic work may improve their capabilities for positioning accuracy required for launching of missiles to distant targets, and upper atmosphere research may assist them in the design and operation of missiles and aircraft as well as improving communications techniques. Advances have been made in all of the geophysical sciences, but the greatest single recent achievement of Soviet science and technology has probably been the use of artificial earth satellites for upper atmosphere and space research.

Significant factors in specific subfields include the following:

Polar Geophysics — Facilities for polar geophysical research are outstanding and are being expanded. The Soviets use diversified expeditionary techniques for collecting valuable geophysical data on a year-round basis in all areas of the Arctic.

The Soviets are taking full advantage of the IGY program to collect data for an assessment of the economic and strategic potential of Antarctica. They intend to continue their efforts in Antarctica after the IGY. Intensive exploration and continued maintenance of scientific stations could provide some basis for future territorial claims. (See figure 8.)

Geology — Geological facilities are adequate for continued progress. Increased emphasis on strategic mineral development is noticeable. The USSR probably will be more advanced than the United States in economic and engineering geology by 1967, and facilities for permafrost science and geochemistry will probably remain superior to those of the United States. The Soviets have completed major geological mapping programs and have developed new mineral forecasting maps.

Geomagnetism — Soviet facilities for research in geomagnetism are comparable to those of other leading nations and probably will remain so during the next decade. Their work is aimed at both scientific advancement and practical application in such things a the improvement of communications, militar detection devices, and probably the develop ment of a geomagnetic guidance system fo cruise-type guided missiles. In addition t measurements of the earth's magnetic fiel by land stations and observatories, the So viets also are making measurements at se aboard the *Zarya*, the only nonmagnetic re search ship in the world,* and from Sputni III. The emphasis on geomagnetic observa tions will be significantly increased, especiall in high altitude research. (See figure 9.)

Geodesy and Gravimetry — Research facili ties are extensive and appear adequate. Th Soviet geodetic net is one of the largest of th world's principal horizontal control net Work is in progress to extend the net an complete the integration of the geodetic net of the European Satellites. The Soviets ar expected to attempt a resolution of the diffe ences between their own and the recently ad justed European Datum West of the Iron Cu tain and to make a connection with the Nort American Datum across the Bering Strai This would provide them with improved ge detic positioning accuracy required for th launching of missiles to all parts of Europ and to U.S. targets.

Seismology — Facilities are very impressiv and adequate for both present and futur needs. The network of seismological station has quadrupled in size since World War I Despite considerable effort, however, the So viets have not made any significant advanc in earthquake prediction. They will probab maintain their already high capabilities i basic and applied seismological researc especially in detection of natural and artifici disturbances.

Oceanography — Present oceanographic r search facilities are comparable to those o other leading nations, and the ambitious So viet program for oceanographic research du

* A similar U.S. vessel, the *Carnagie*, was de stroyed by explosion and fire in 1926 and was nev replaced. While the United States continues t make measurements of the geomagnetic field usi magnetometers towed behind ships, emphasis h been increased on making airborne geomagnet surveys over both land and sea.

ıings as
military
develop-
ıtem for
ition to
tic field
the So-
s at sea
netic re-
Sputnik
observa-
specially
ıre 9.)

ch facili-
te. The
st of the
ol nets.
net and
etic nets
viets are
ne differ-
ently ad-
ron Cur-
he North
g Strait.
wed geo-
for the
f Europe

npressive
d future
l stations
War II.
, the So-
advances
probably
ilities in
research,
artificial

aphic re-
those of
ltious So-
arch dur-

, was de-
was never
ntinues to
field using
phasis has
omagnetic

FIGURE 8. North Pole Scientific Station 6 on drifting ice floe, 1956.

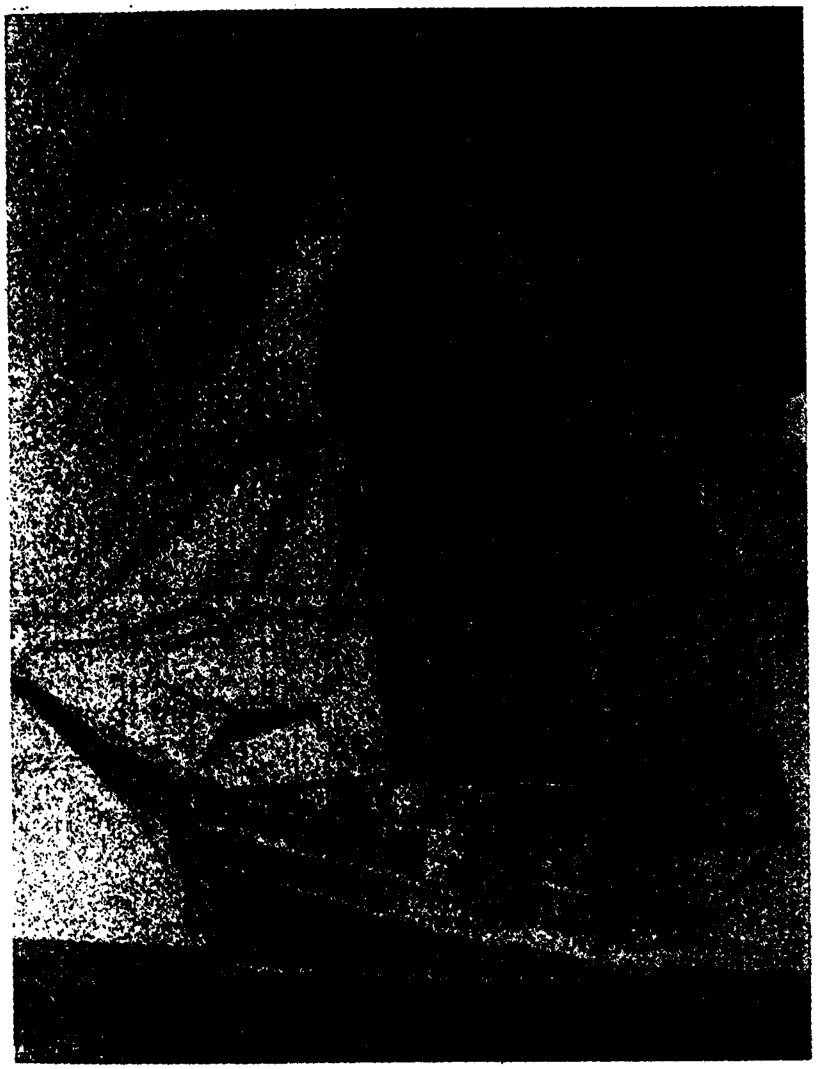

FIGURE 9. The Soviet schooner *Zarya,* at present the only non-magnetic ocean-going research vessel.

ing the IGY indicates that expansions of efforts and facilities are being planned. About 100 Soviet establishments conduct research in marine sciences. The present trend toward data collection from much wider areas is likely to continue as is the high quality work in submarine geology and ice research. Soviet work on oceanographic instrumentation is competent. Chemical oceanography is routine. The capability to progress and interpret data is expected to greatly increase as a result of the IGY oceanography program. (See figures 10 and 11.)

Meteorology and Hydrology — Research facilities are adequate. Large networks of meteorological and hydrological stations exist throughout the USSR with a great complex of research institutes, observatories, laboratories, and schools. Soviet work in weather and hydrological forecasting and climatology is competent. They are increasing their emphasis on numerical weather forecasting using high-speed computers. While nothing new has been contributed in cloud physics and weather control, they will continue efforts in these fields because of important economic and military implications. Work in micrometeorology will probably continue to be of high quality. Polar meteorological work is considered outstanding.

Upper Atmosphere Research — The launching of a satellite on 4 October 1957 and another a month later began a new era in upper atmosphere and outer space research. Rocket and satellite investigations include live animal experiments, as well as IGY work on upper atmosphere conditions. These studies will increase their basic scientific knowledge in biology, aeromedicine, physics, astrophysics, and geophysics. A large number of research institutes and observatories are now engaged in this work and facilities are being expanded. Present deficiencies in equipment will probably be overcome during the next several years. A photograph of a Soviet upper atmosphere rocket is shown in figure 12.

Chemistry

The Soviet Union has made few original contributions to chemistry in recent years, and is definitely behind the United States in the magnitude and level of the research effort. The consistently high quality of Soviet research in a few fields and the marked progress in others of priority importance, however, indicate that the level of Soviet research in all important fields of chemistry and chemical engineering will be close to that of the United States in ten years.

Organic Chemistry — Basic research in several fields of organic chemistry is excellent. It generally lags that of the United States by 3 to 5 years but should more closely parallel U.S. research by the end of the period of this estimate. Organophosphorus research is quite advanced. The capability in this field is probably greater than that of the United States and, from a military standpoint, the USSR may lead the United States by 5 years. Macromolecular chemistry is noticeably behind in certain areas while in others it is approaching that of the United States in quality, quantity, and numbers of scientists. Definite capabilities exist in the development of new high heat resistant polymers. Synthetic fiber research lags, and although past research in synthetic rubber has been excellent, there has been no significant advances in rubber chemistry within the last 5 years. The Soviet capability in plastics is expected to improve and probably will reach the same level as that of the United States within the next 10 years.

During the period of this estimate, Soviet research and development in ion exchange resins as applied to nuclear energy fields will probably reach a par with that of the United States, but work on other aspects of ion exchange technology, directed toward the consumer market, will proceed slowly.

Soviet research in fiberglass is comparable to that of the West; but production technology on fiberglass materials is definitely lower than that of the West, and without external assistance, it will probably remain so for at least the next two to five years.

Pharmaceutical research will be given increased emphasis to correct the present relatively poor standard of Soviet medicinal preparations. The USSR will probably lead other countries in a few areas of research, but it is highly doubtful that Soviet capabilities will approach the present high position of the United States in pharmaceutical research for many years.

Physical Chemistry — Research in combustion and chemical kinetics is on a par with that of the West and can be depended on to solve problems of military significance. Soviet chemists introduced the theory of chain reactions which has advanced the world understanding of detonation, flame propagation, and combustion.

Progress in radiation and tracer chemistry has been extremely rapid and has successfully supported a significant nuclear energy program. Tracer techniques now play important roles in medicine, agriculture, geology, and other sciences. These techniques are especially advanced in chemical engineering and metallurgy.

Electrochemical research is predominantly theoretical in the USSR; and, although a few Soviet electrochemists are competent experimentalists, little unique research meriting world recognition is expected.

Catalysis research is generally comparable with that of the West and has a great potential for significant advances. The commercial manufacture of synthetic rubber was made possible by the significant accomplishment of S. V. Lebedev who synthesized butadiene from ethanol. Intensified efforts are expected in the field of deposited catalysts such as platinum on charcoal.

Soviet use of spectroscopy is increasing and while there is now a lag in a few fields, such as high resolution spectroscopy, we expect Soviet research will equal that of the United States by the end of the period of this estimate. High precision gratings are now available for increased high resolution spectroscopy efforts.

Chemical Engineering — The USSR is considerably behind the United States in chemical engineering research and development. Well-trained chemical engineers are becoming increasingly available, however, which should help to progessively narrow this gap and approach near equality with the United States by 1967. The production of new materials now in the laboratory stage and the development of a chemical industry comparable to that of the United States will depend on the Soviet expected increase in trained manpower to apply the concept of unit operations, which is already well understood by the Soviets.

Propellants and Explosives — Soviet liquid propellant research is primarily directed toward the development of materials and combinations that are reliable and logistically available in the USSR. Exotic fuels with high energy content are under development and this work could parallel U.S. efforts. For example, the Soviets have been engaged, since at least 1949, in a boron fuel program. Soviet research is capable of developing such high-energy fuels, although firm predictions of specific accomplishments are not possible. We believe that boron fuels are being developed for and will be used in air-breathing engines and rocket engines during the period of this estimate.

Research in solid propellants through 1967 could equal that of the United States in all aspects, including fabrication, if sufficiently high priorities are imposed.

The USSR is on a par with the United States in applied and fundamental explosives research and will probably remain so for the next ten years. No major achievements in explosives are expected during this time.

Petroleum Technology — Fundamental research in refining, synthetic fuels, and petrochemicals is excellent, but Western technology in these fields is usually adopted. Many of their organic and physical chemistry research studies are on petroleum and its derivatives. Conventional methods of exploration are now emphasized; they already have developed a superior turbine drill for oil well drilling. Work on lubricants and additives is sound and they have the capability for synthesis of new lubricants for use in high temperature engines. Petroleum technology will generally advance but will remain significantly behind the United States through 1967.

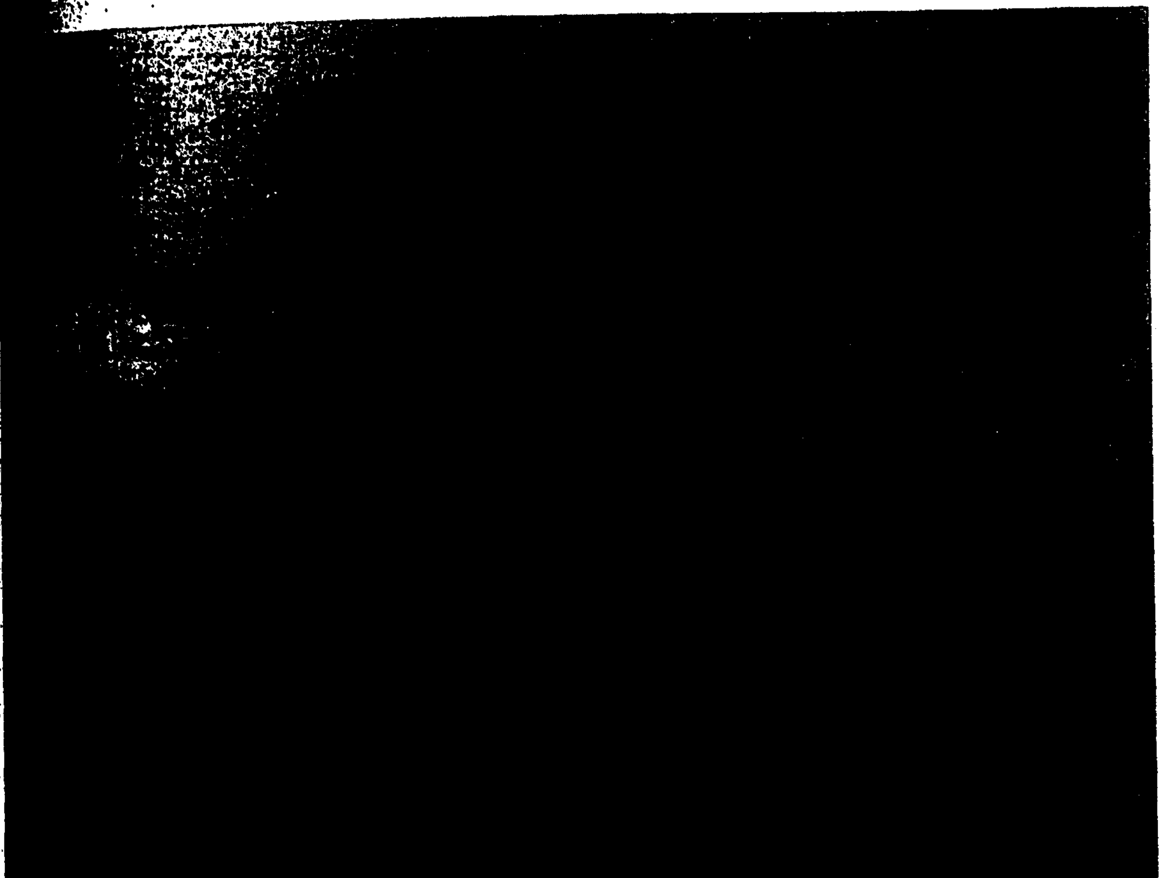

Figure 10. Soviet oceanographic research vessel, *Vityaz*.

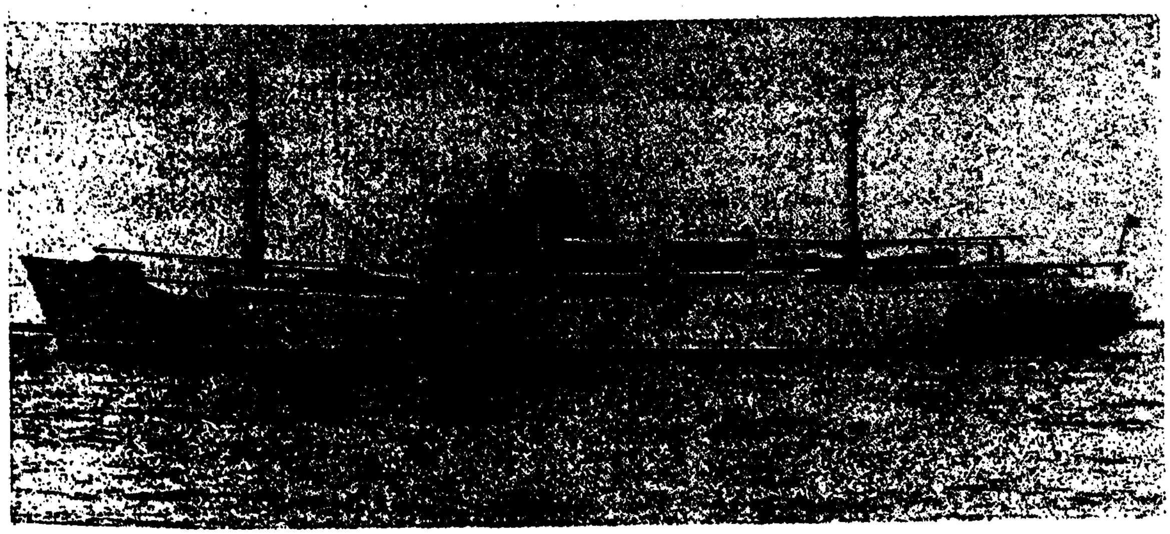

Figure 11. Soviet oceanographic research vessel, *Mikhail Lomonosov*.

C01057748

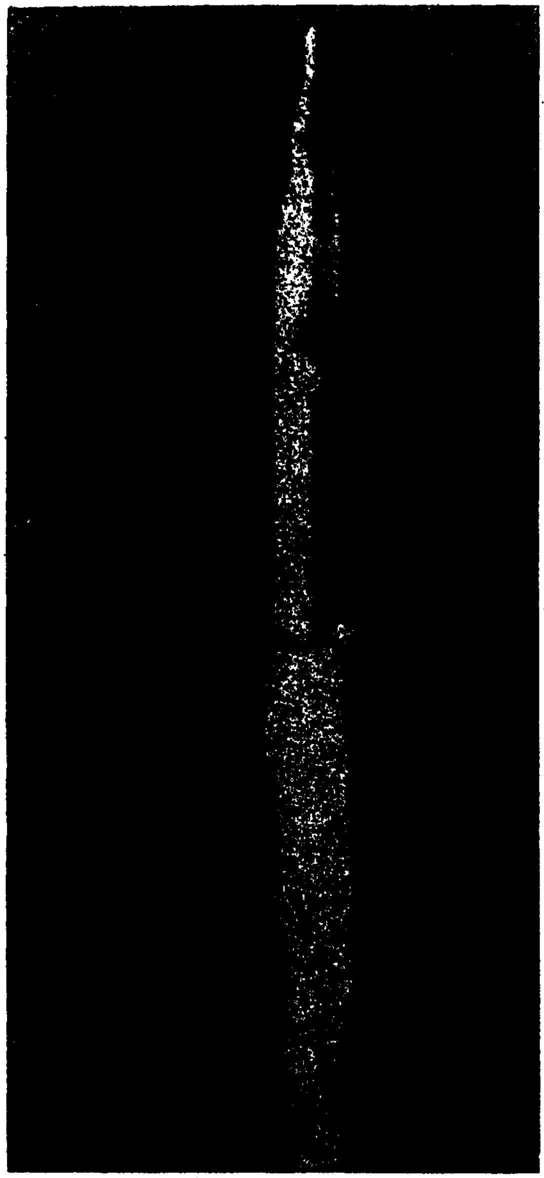

FIGURE 12. Soviet geophysical rocket which reached an altitude of 294 miles on 21 February 1958.

Metallurgy

Metallurgical research is effectively organized by the Soviet government to meet expanding industrial and military requirements. The USSR is behind the West in certain fields of research; but, in most important areas of fundamental and applied work, Soviet metallurgists have exhibited originality and good research ability. Also, the variety of research in progress is extensive. While the Soviets will probably continue their present extensive program of monitoring, evaluating, and adopting Western metallurgical knowledge and technological developments, native Soviet metallurgical research may be expected to make increasingly important contributions. Research facilities are adequate to meet most present Soviet needs and the quality of metallurgical research equipment is improving steadily. (See figure 13.) They will continue to have fewer laboratories than the United States through 1967, but they will probably equal qualitatively U.S. facilities in equipment and staff research personnel.

Research is directed toward advancing Soviet capabilities in metal extraction, processing, and fabrication, as well as improving capabilities in alloy development. An active interest in conserving scarce alloying elements, such as nickel, is evidenced in their research.

Steel Technology — The capabilities of the USSR in steel technology are high and should compare favorably with those of the United States throughout the period of this estimate. The Soviet steel industry is now the second largest in the world and has adopted new steel making technology on a broad scale.

Physical Metallurgy — Work toward developing high temperature alloys has been creditable and fundamental research on interatomic bonding has almost no counterpart in the West. It is difficult, however, to estimate what accomplishments of strategic importance may be made in these fields in 10 years.

Aluminum and Magnesium — Soviet scientists have devoted less attention to research on the metals, aluminum and magnesium, than have U.S. scientists and most Soviet light alloys are similar to, if not duplications of, Western compositions.

Titanium — Research and development on titanium metal and its alloys are not advanced. The current trend of closely following Western progress in titanium technology will probably continue.

Extractive Metallurgy — Soviet research efforts in nonferrous extractive and process metallurgy were relatively neglected until recent years. Research capabilities will increase and approximate those of the United States by 1967.

Nuclear Metallurgy — The Soviets have abundant supplies of uranium metal, extensive national laboratory organizations for exploiting the physical metallurgy of both uranium and plutonium, and a highly competent corps of research metallurgists. They have concentrated the efforts of about 100 scientists on research on plutonium and plutonium alloys — an impressive number in a specialized area of metallurgy. Soviet plutonium metallurgists currently maintain a position closely competitive to their counterparts in the United States; and, unless there is a decreased effort in the Soviet Union, there exists the likelihood that the USSR will begin to advance beyond the West in plutonium metallurgy during the last part of the period of this estimate.

The Soviets have used beryllium and zirconium in reactor design. They appear to be concentrating on zirconium alloys and on high temperature alloys, probably suitable for nuclear power reactors operating at very high temperatures. Their research on materials suitable for reactor construction is of good quality by Western standards. In the area of fused salts, they have become very adept and have been building up to this position of eminence in research for many years. This high capability should permit a number of Soviet applications highly favorable both to production of extremely pure metals and to increased efficiency of nuclear power reactors.

Ferromagnetic and Semiconductor Materials — Research and development on the newer magnetic materials, including ferrites and powdered and cast materials, appear to be on a par with Western efforts. Supporting metallurgical research on semiconductor materials is of high quality and will probably be closely equivalent to Western work during the next decade.

Electronics

The Soviet Union presently is one of the two or three leading nations in both quantity and quality of electronics research and development. Its research effort is capable of supporting developments of importance to the national defense of the Soviet Union, discovering significant new approaches to strategic problems, as well as following Western developments.

Soviet leaders have placed the highest priority on the development of militarily important equipment and instrumentation for other scientific investigations.

The Soviets stress the theoretical aspects of electronics in an attempt to provide a unified, coherent, and useful theoretical description of phenomena from which developmental information can be readily obtained. In general, this stress may have hindered past developments in some areas; but, as in the case of materials research, it has provided Soviet scientists with a breadth of understanding not normally achieved by U.S. scientists.

With the present high priority accorded electronics research and development, it is highly probable that the Soviet Union will maintain its present world leadership in several phases of theoretical electronics and its growing capability in applied electronics during the period of this estimate.

Propagation of Radio Waves — Soviet work in the theory of radio wave propagation has been outstanding, and their capability in this field is on a par with that of the West. V. A. Fok, of the Leningrad State University, probably has produced the world's outstanding theoretical work of the past 20 years on radio wave propagation. The Fok theory was a significant achievement in that it solved the basic propagation equations in a form relatively easy to calculate. The Soviets achieved significant success in using the Fok theory in the description of diffraction and reflection processes. This work is directly applicable to aircraft and missile detection and the problem of antenna placement on flying objects. The Soviets also probably solved the problem of communications with missiles and satellites before this was accomplished in the United States.

Soviet investigations of the ionosphere for its effect on long haul high frequency communications has been extensive and of high quality. Their research on the use of the ionosphere for long-distance transmission of VHF communications (scatter links), however, appears to be lagging by 2 or 3 years.

Radio Astronomy — Soviet radio astronomers are generally competent and have made rapid advances. They take full advantage of Western results, and the USSR now ranks closely behind the leading Western nations in this field. The Soviet Union has a progressive research program and is expected to equal the leading nations by the end of the period of this estimate. Technological advances expected during this period would be useful for long-range surveillance of airplanes and missiles and improved navigational and communications capabilities. While the Soviets are well aware of the military and economic applications of this work, they are equally interested in increased knowledge of the universe. (See figures 14 and 15.)

Communications Theory — Soviet investigations of modern communication theory have been extensive and are generally of high quality. Their theoretical descriptions of noise phenomena are the best in the world. They are familiar with the principles governing the detection of signals in noise, which are presently being considered for early warning systems in the United States. In other areas such as coding theory and equipment designed on the basis of theoretical results, there is insufficient information to allow comparison. While the Soviets were late in their apprecia tion of information theory and may be somewhat behind the United States in engineering applications, Soviet mathematicians are world leaders in developing a solid foundatio

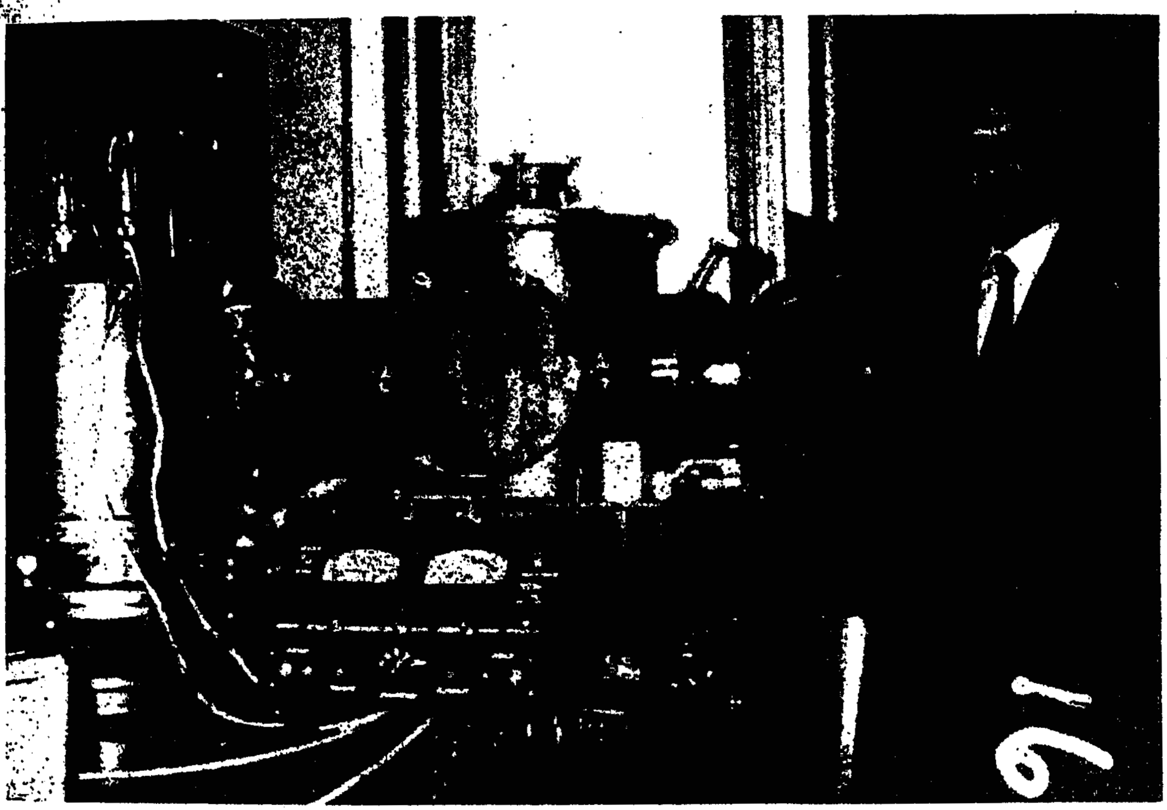

FIGURE 13. Vacuum furnace in A. A. Baikov Research Institute for Ferrous Metallurgy, Moscow, 1957.

FIGURE 14. Soviet radiotelescope being constructed near Byurakan Astrophysical Observatory, Armenian SSR. The reflecting surface will be about 48,000 square feet, 1958.

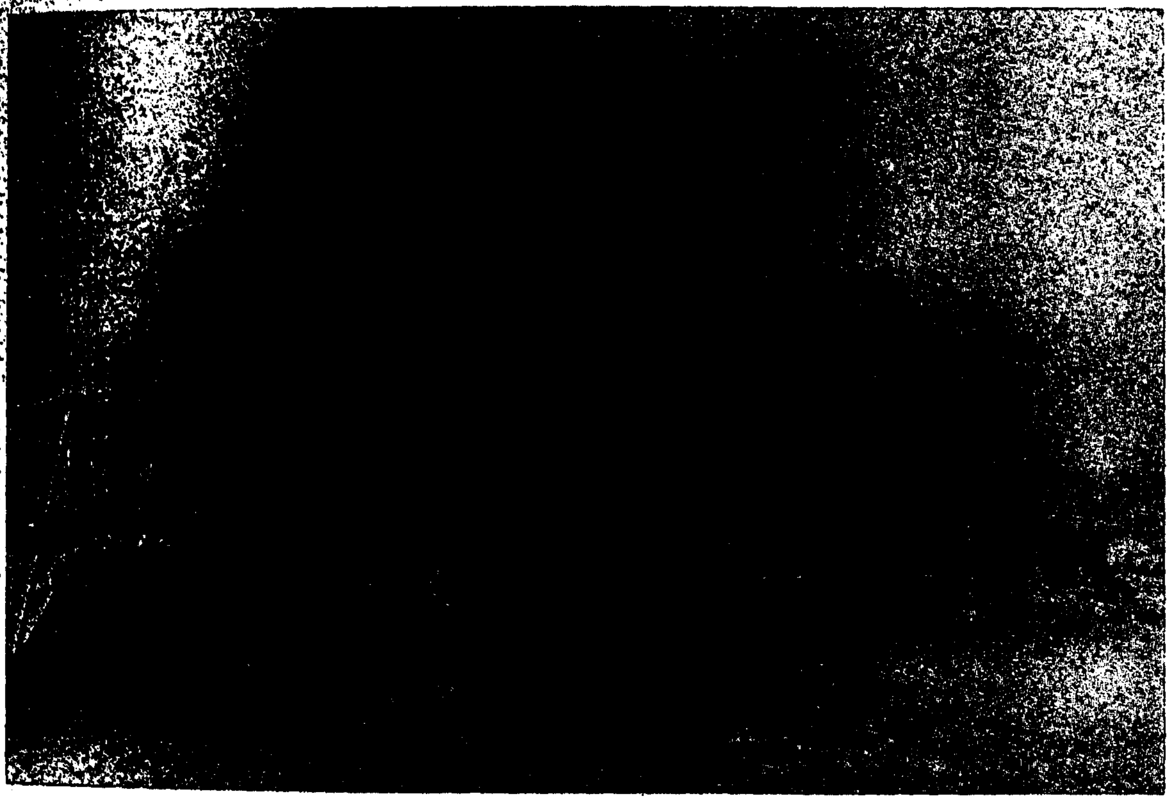

FIGURE 15. Radiotelescope at Pulkovo Observatory, January 1957.

of the theory. The USSR adopted a high priority for developments in communication theory in 1955. Because of the outstanding caliber of the Soviet scientists working in this field, the Soviet Union will probably be on a par with the United States within 2 or 3 years.

Automatic Control Theory — The theory of automatic controls was given new impetus in the USSR with the expansion of Soviet industry about 1950; and, at the present time, extensive investigations are conducted in the field. Most phases of their work appear to be on a par with the West in quality and ahead of the West in quantity. Their work in non-linear control theory is outstanding and has outranked the West for many years. The USSR has more scientists of high calibre working in the field of control theory than has the United States and is expected to continue to be among the world leaders during the period of this estimate.

Materials and Components — Soviet investigations of materials of value to electronics have been more intensive than those of the United States, giving them a broader base for the development of new components of strategic importance. The fundamental research ability of the USSR is very high, particularly in those areas applicable to priority components developments.

The Soviet Union has produced electron tubes similar to most of those developed in the West. The outstanding Soviet success has been the traveling wave-tube, in which they are about 2 years ahead of the United States. Such a tube was already in use in a Soviet missile guidance system by 1953, when similar U.S. tubes were still under development.

Soviet theoretical work on transistors appears to be on a par with that of the West, although they are generally slightly behind in production technology.

Current Soviet research on thermoelectric effect (the conversion of heat directly into electrical energy and vice versa) and materials exhibiting this effect is currently more advanced than that in any other country. The Soviets are on the threshold of making technological advances in this field that would have far reaching military and economic application. Some devices have already been developed for uses such as electric power sources and refrigerators.

Soviet components for high altitude and high temperature use have been developed. The USSR presently lags the United States in printed circuitry and miniaturization by about 1 year. Because of the very high priority, the Soviet effort will probably parallel the U.S. effort in this area by 1960 and possibly surpass the United States in the development of highly reliable, miniaturized components by 1967.

Medical Sciences

The Academy of Medical Sciences, USSR, continues to control tightly all Soviet medical research. Most priority research and the better equipped facilities are in the Moscow and Leningrad areas. The expected improvement in facilities and equipment in these and outlying areas should allow for a considerable broadening of effort within the next 10 years.

In many high priority areas of medicine, leading Soviet medical scientists are equal in competence to those of the West. The present lack of sufficient top research manpower to investigate adequately all areas of medical economic importance is being overcome. The Soviets are currently producing twice as many physicians as the United States. The individual Soviet physician is now considered only slightly less competent than his U.S. counterpart. Soviet emphasis is on quantity because the primary medical problems in the USSR are related to public health and preventive medicine.

Space Medicine — Soviet research on space medicine is extensive and is estimated to lead that of the United States in certain respects. The Soviets are believed to have conducted sufficient research, so they can now overcome all aeromedical obstacles connected with orbiting a human for a period of hours or days. Much fundamental physiological data is being obtained from animals exposed to space conditions. The Soviets will probably lead the study of acceleration effects and have already drawn special attention to transverse accelerations by their launching and orbiting of the Sputnik II dog, Laika. (See figures 16 and 17.) They claim that a 10 to 12 fold acceleration overload is fully permissible for man. A self-contained pressure cabin apparently has already been developed. (See figure 18.) The most outstanding feature of Soviet work is the preconditioning of space animals. In the weightless state, the animals are oriented by sight or touch without vestibular orientation. Through 1967, it is expected that the USSR will modify animal and human responses so that space travelers may adapt themselves to temporary or extended intolerable conditions, such as might occur during launching, orbital flight, and reentry.

Nuclear Medicine — Soviet research on the use of radioisotopes for diagnosis and therapy is approximately 3 to 5 years behind that of the West. The USSR is giving more emphasis than is the West on the effect of local and general irradiation on the central nervous system. Although the USSR will continue to lag slightly behind the United States in the general use of radioisotopes by 1967, it is expected that the USSR will lead the United States in radiobiological research on the nervous system and possibly also lead in the effects of cosmic radiation on organisms.

The Soviets are somewhat lax in the application of rigid radiation health standards in their nuclear energy research and operations. Although they will continue to subscribe to low maximum radiation exposure at international meetings, they will probably not let rigid health standards hinder their nuclear energy activities. (See figure 19.) Radiation equipment in some of the major research institutes appears modern and adequate. (See figure 20.)

Infectious Disease Research and Development — Almost all medical microbiological research and development is concentrated on infectious diseases which cause large labor losses. Basic research is relatively small and generally inferior to U.S. and other Western work upon which the Soviets greatly depend. Infectious disease studies of special human BW significance follow the U.S. pattern but lack the complexity, engineering, and concentration associated with U.S. BW efforts. For the future, increased emphasis will be placed on viral and rickettsial research and the development of broad-spectrum vaccines. They will continue to emphasize the defensive aspects of human BW but also will maintain research and development in support of an offensive human BW program. The development of live vaccines will continue for the next 5 to 10 years but, by 1967, the major emphasis will shift to development of purified and/or adaptation of Western vaccines.

Control of Human Behavior — The study of organic factors underlying human behavior is receiving maximum Soviet effort. They will continue to be on a par with Western nations in the overall field of neurophysiology and will maintain superiority in the study of conditioning and "functional" neuropathology. Advances in sensory physiology and psychology are being made predominantly in the USSR, and they have established approaches to the organic aspects of behavior analysis and control that are not fully appreciated in the West. We expect the Soviets to study further subauditory stimulation on perception for its value for training the population or for disseminating propaganda. They will continue to incorporate unconditioning and reconditioning techniques in their psychological warfare program.

Civil Defense — The Civil Defense program is extensively organized and manned, and everyone above 16 years of age receives 2[illegible] hours of instruction. We expect that the Soviet Union will continue its regimented training of the civilian population in the management of mass casualties. The production of drugs, biologicals, and equipment for civil defense purposes will lag that of the United States for the next 5 years but should approach U.S. levels by 1967. By this time, [illegible] moderate civil defense stockpiling program will have been completed in the USSR.

Effective therapy for radiation injury will probably remain an unsolved problem, both in the United States and the USSR. By 196[illegible] the Soviets probably will have developed im[illegible]

ern but
concen-
ts. For
placed
the de-
. They
sive as-
naintain
t of an
develop-
for the
e major
purified
s.

study of
havior is
hey will
nations
ogy and
of con-
thology.
psychol-
in the
proaches
analysis
ciated in
to study
percep-
pulation
They will
ing and
ychologi-

program
ned, and
ceives 22
t the So-
ed train-
manage-
uction of
civil de-
e United
ould ap-
s time, a
program
SR.

jury will
, both in
By 1967,
oped im-

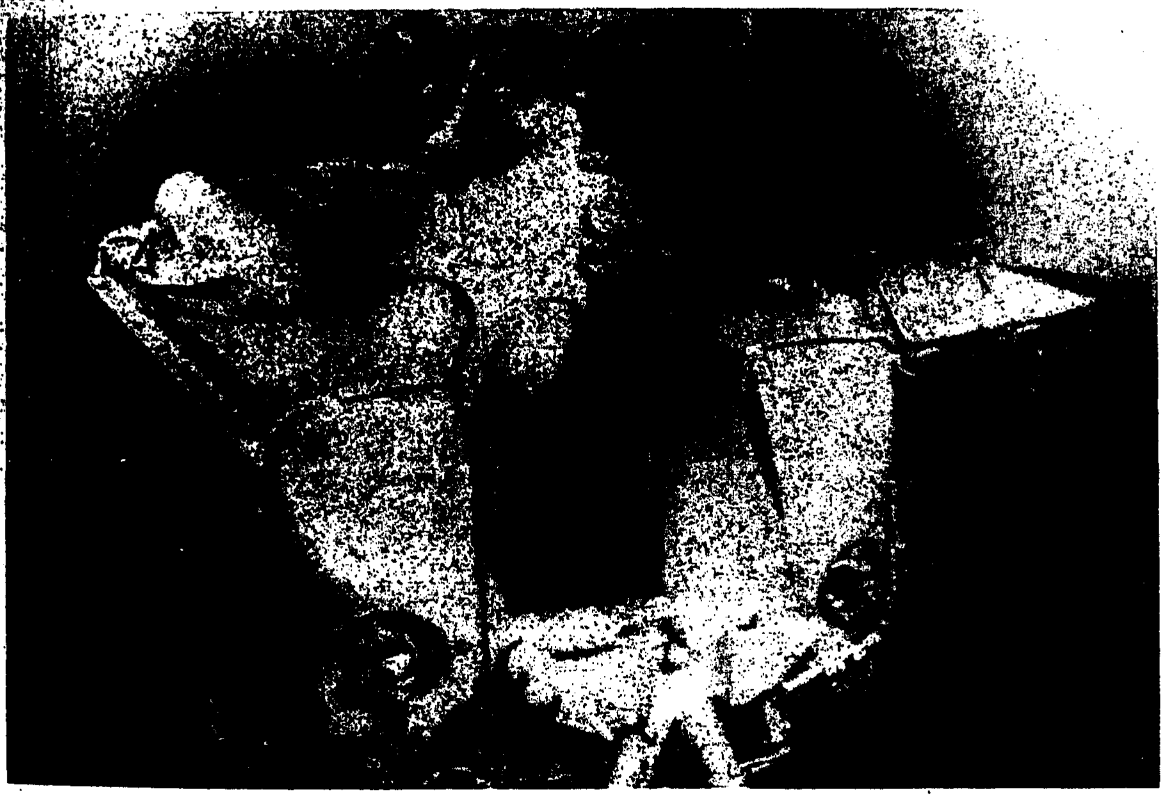

FIGURE 16. The dog, Laika, in cabin of Sputnik II.

FIGURE 17. Chamber used to hold dog in test flight preparatory to launching Sputnik II.

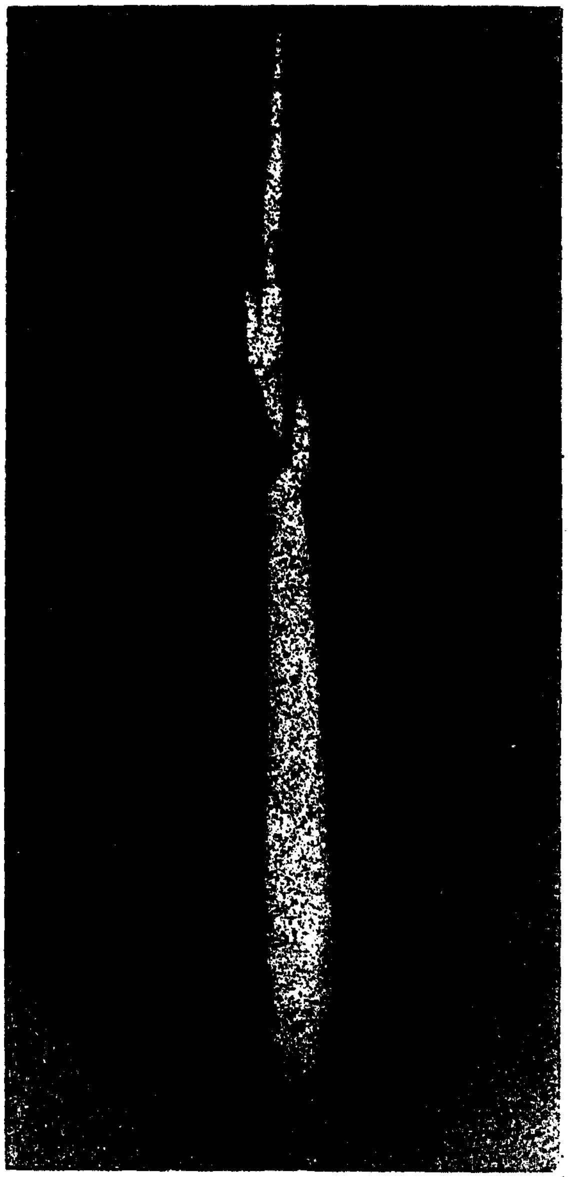

FIGURE 18. Soviet geophysical rocket with projecting instrument containers. This rocket reportedly carried dog to height of 212 kilometers, 1958.

C01057748

FIGURE 19. Clothing worn while handling radioactive material at Moscow Physical Institute, 1956.

FIGURE 20. Automatic x-ray machine at Molotov Research Institute of Roentgenology and Radiology, 1955.

proved shelters, personal equipment, and drugs for the treatment of CW casualties caused by conventional war gases and G- and agents. Their total CW defensive capability, however, will probably not equal that of the United States. In general, the USSR and the United States will probably be on a par in accomplishments in the field of whole blood, plasmas, and plasma extenders. The distribution and utilization of these products are closely controlled by the military in the USSR, and they would be readily available for medical defense in time of war. The United States will probably retain a clear lead in research, development, and application of antibiotics.

Polar Medical Research — We believe that the capabilities of the Soviet Union in polar medicine are equal to those of the United States. The Soviets are highly knowledgeable about the essential medical principles concerned with cold adaptation and, by 1967, they will be able to control human factors in polar operations through the application of known bioengineering principles. The Soviet rapid rewarming technique and the use of "super" diathermy for therapy of cold injury are unusual and not used in the United States. U.S. medical scientists also oppose the Soviet preventive practice of cold "conditioning."

Nutrition — Soviet nutritional research greatly lags and is similar to Western work of more than a decade ago. The Soviets will probably remain behind the West in the military and therapeutic applications of advanced nutritional principles. They will probably continue to depend on Western advances.

Basic Protein Research — Soviet accomplishments in the field of basic protein chemistry are less noteworthy than those of Western scientists. Some unique investigations, however, have considerable significance and could lead to major advances, such as the development of highly toxic substances and the formation of "wide spectrum" antigens and antibodies. Soviet basic research on the origin of life is centered in the field of protein chemistry and particularly enzymology. Western scientists are only slightly more advanced than the Soviets in this field, and a major advance may occur from either group by 1967.

Veterinary Sciences

Veterinary research capabilities and resources have advanced and expanded considerably since World War II. More veterinarians are believed to be engaged in research activity at the present time in the USSR than in the United States, and the rates of growth of Soviet veterinary manpower are greater than in the United States. Although the average Soviet veterinarian has a lower competency than his Western counterpart, some researchers are equal to the best in the world.

Research — Basic research is given less emphasis than are applied and developmental investigations. Interest in basic research has been hampered by political support of scientifically unsound concepts. In the past few years, however, there has been a trend toward more conventional research. The Soviets are becoming less dogmatic in applying the principles of Pavlov in research. At present, major emphasis is being put on improved field application of research findings.

A reasonably good capability exists in research on infectious livestock diseases, disinfection, and parasitology. Veterinary virology is progressing more rapidly than many other disciplines because most of the economically important diseases are of viral etiology. Soviet research has equaled and at times excelled U.S. efforts in fields of veterinary science, such as helminthology; entomology, and other subfields of parasitology; physiology; toxicology; and some areas of epizootiology. Soviet veterinary research in immunology, microbiology, and pathology has reached acceptable levels of proficiency but generally is inferior to that of the United States. The apparent research lag behind the United States is deceptive. The excellent results achieved in the reduction of some of the most serious livestock infectious diseases tend to offset any critical underestimation of Soviet veterinary capabilities. (See figures 21 and 22.)

We believe that Soviet veterinary research capabilities will increase considerably during the next 10 years. The long-existing discrepancy between veterinary research and practical application will diminish but will continue for the foreseeable future. Some of the best achievements can be expected in the field of virology, which will stress an increasing number of fundamental investigations. Soviet efforts to develop large-scale tissue culture methods for virus propagation will probably increase significantly.

Disease Control — An important trend has been the approach to problems of livestock disease through control rather than eradication. The relatively high prevalence of serious diseases, such as foot and mouth disease, hog cholera, and brucellosis, has rendered eradication economically infeasible. Soviet diagnostic capability is considered inferior to that of the United States, because laboratory services and adequate diagnostic agents are not as readily available. By 1967, there may be a shift in the direction of Soviet veterinary medicine from control of major epizootic infections to ultimate eradication. Increased emphasis will be given to control of noninfectious and chronic diseases of livestock. (See figure 23.)

Biologicals — Major emphasis has been placed on the development of live, dry vaccines and improved diagnostic agents. Shortages of veterinary products for field use will continue to exist. No biological products for veterinary use can be considered superior to U.S. products. Sound U.S. and Western accomplishments are being incorporated more rapidly into Soviet veterinary and livestock programs. More effective and refined immunizing, diagnostic, and therapeutic agents will probably be available by 1967. Therapeutic agents with viricidal properties will occupy a prominent part of future veterinary research activity.

Military Implications — The continued expansion of veterinary research resources and scope of interests will give the USSR a formidable scientific capability to support antilivestock biological warfare efforts. The present Soviet potential in this regard is already strong and facilities for mass-production of veterinary biologicals could be readily converted to production of antianimal agents. Veterinary services will probably be expanded to provide greater auxiliary medical and research support for the Soviet civil defense system.

Biological and Agricultural Sciences

The Soviets have demonstrated a fair competence in certain priority areas of biological and agricultural research. In general, however, Soviet capabilities in basic biology and agricultural sciences are low. Theoretical biology in the Soviet Union has been especially weak during the past two decades because of ideological restrictions. Since 1953, however, there has been greater freedom in scientific thought and a resurgence of sound principles. Greater official support to these fields has also been noted and is expected to increase considerably. Nevertheless, theoretical progress will be slow since Michurinism, which characterizes Soviet ideological philosophy in biological and agricultural sciences, continues to be the official scientific position in the USSR. Lysenko, the chief proponent of Michurinism, was removed from the position of President of the All-Union Academy of Agricultural Sciences in 1955 but has recently received some political support and still holds several important positions.

Biological Sciences Research — Biological research has received lower priority than physical sciences research in the USSR. Ideological restrictions and lack of recognition of Western advances have set back their progress by many years and it may take a decade or two to again approach Western standards.

Genetics, which vitally affects both biology and agriculture, deteriorated during the period 1948–53 from a high-ranking science in the USSR to a pseudo-scientific field based on the old theory of inheritance of acquired characteristics which was largely discarded in the West 30 years ago. Since 1953, however, the competent geneticists remaining in the USSR have been returned to research positions and are significantly influencing research trends. Although initially the

Figure 21. Electron microscope at the All-Union Institute of Experimental Veterinary Medicine, 1953.

Figure 22. Ultracentrifuge at the All-Union Institute of Experimental Veterinary Medicine, 1953.

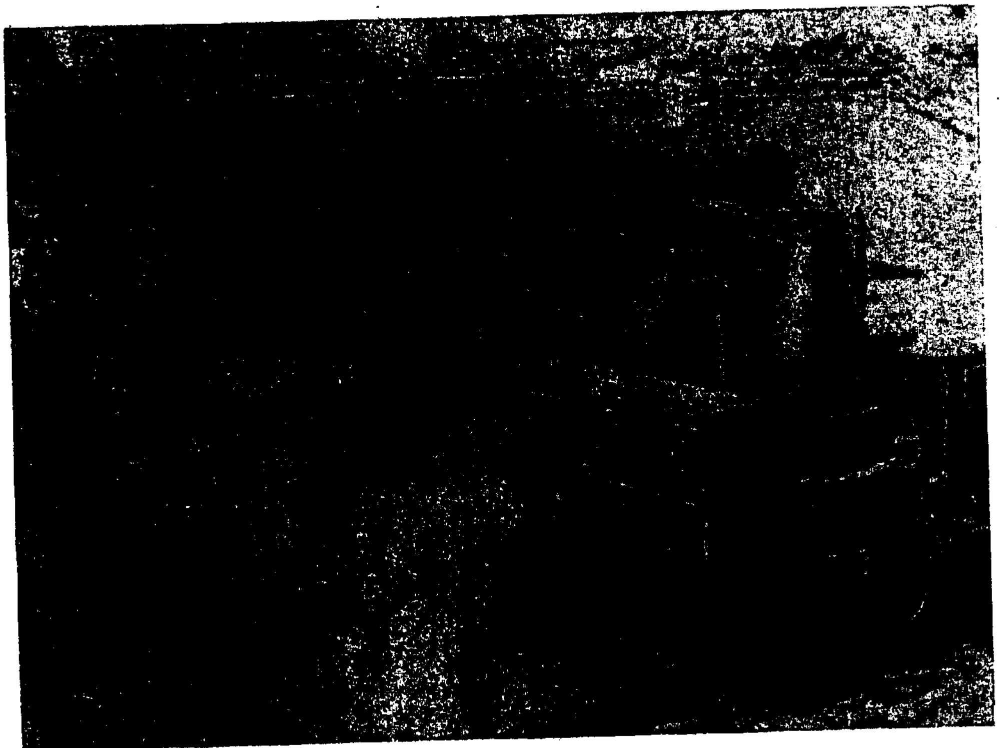

Figure 23. Machine for disinfecting livestock premises and exterminating blood-sucking insects, 1953.

scientists confined most of their activities to surveying Western genetic findings, they are now conducting research which is similar to that of the West in approach. Work on the effects of radiation on microorganisms is receiving considerable attention although it lags the United States by about 1 or 2 years. Soviet capabilities in genetics will be increased appreciably and will probably approach the United States in some subfields. However, the USSR is not expected to overtake the United States during the next 10 years.

Interest in astrobiological research is apparently gaining momentum in the USSR. The Academy of Sciences, USSR, has recently adopted an extensive research plan for studying life on other planets, and at least two institutes are now supporting this work. A special institute of cosmic biology has been suggested and may be formed at any time.

Industrial Fermentation — Soviet industrial fermentation techniques are less advanced than those of Western Europe and the United States. Research and technology on production of yeast and fungi for feed supplements is also inferior to that of the United States. Production of ethyl alcohol from non-food materials is receiving increased emphasis but has not reached the level of technological excellence achieved in the United States a decade ago. The USSR is 10 to 15 years behind the United States and Great Britain in biosynthesis of vitamins. Research and technology on industrial enzyme production is inadequate and of low quality; their research and technological capabilities in producing organic acids by fermentation lag greatly those of the United States. This lag may be narrowed somewhat but is not likely to disappear during the next 10 years.

Research and Technology Affecting Agriculture — An ever increasing capability in agriculture research is expected, but, even so, marked improvement in Soviet agriculture can be effected without a major research effort. Agricultural practices are expected to improve considerably. During the period of this estimate, significant increases in crop yield will probably result from progress in pesticide development, pest and disease forecasting, in producing disease-free seed stock, and in developing resistant plant varieties. (See figure 24.)

We also expect more rapid progress in plant breeding work. The Soviets will almost certainly develop some new and better adapted varieties of hybrid corn during the next 10 years. Significant increases in average per-acre yield of several major crops will be achieved. Such achievements will contribute substantially to increasing the output of crops by 1967.

Significant advances in plant physiology and soil science are probable within the estimate period.

The USSR has lagged the United States in many fields of livestock research and production. Significant, but gradual, improvement in the Soviet livestock situation is expected. Khrushchev's statement on equaling American per capita production by 1961, however, is believed to be overoptimistic.

In view of expanded application of research and technology to the solution of marine harvesting problems, we believe the total contribution of marine food sources to the Soviet diet of protein will increase substantially between 1957 and 1967.

The technological level of the Soviet food processing industry is below that of the United States, although some progress will occur by 1967 through development and utilization of modern techniques.

Soviet engineering technology in agriculture lags that of the United States. Significant improvement in agricultural engineering research and technology are expected during the period of this estimate.

Soviet attempts to improve Arctic production will not be very important to agriculture. Their research and development on agricultural problems of semiarid regions, however, are expected to continue to improve agriculture production in such areas.

SATELLITE AND CHINESE COMMUNIST SUPPORT IN BASIC RESEARCH *

Soviet Bloc research coordination is summarized in a previous section of this report and is fully discussed [redacted]. As previously noted, we expect the USSR to expand its effort to integrate Bloc research to permit the maximum utilization of scientific resources. The USSR can expect these areas to provide from considerable support to no support, depending on the country and the scientific field. Even in those areas where there is little capability, the additive and synergic effect of inter-Bloc cooperative efforts cannot be ignored. Each of the European Satellites and Communist China have a research organization which is almost a duplicate of the Soviet model. Competition is keen and the drive to emulate Soviet scientific accomplishments will probably result in more rapid progress than could otherwise be expected. A summary of each country's support to the Soviet effort is given in the following paragraphs.

Albania

Albania provides practically no scientific support and can be discounted for the purpose of this estimate.

Bulgaria

In Bulgaria, pure research has been neglected for the production of essentials. There are a few highly qualified scientists in Bulgaria and an increasing number of young, though poorly trained, scientists, which should raise the country's capabilities somewhat. While the climate is improving for pure research, there are inadequate resources to enable important contributions to scientific research and development. Bulgaria trails all European Satellite countries except Albania and possibly Rumania in medicine and allied sciences. Bulgaria does have a slight capability in mining, chemical, pharmaceutical, and electronic research directed mainly at applied aspects in support of the economy. Their capabilities in physics and mathematics are extremely low. Efforts in geophysical fields are modest, and although their capabilities are low, they are improving. In the overall, we do not believe it likely that Bulgaria will make any important scientific contribution to the total Bloc effort in the near future. Moreover, we expect Bulgaria to remain dependent on the USSR and to be a net drain, scientifically, for at least several more years.

[redacted]

Czechoslovakia

Although, until the end of World War II, industry relied heavily on foreign research and development, the Czechoslovaks have made a number of outstanding contributions to science. Some progress has been made since World War II and the present priority is on applied research.

There is little research and development in physics, although some work is done in solid state physics. Czechoslovakia is second only to East Germany in Satellite computer capability. Czechoslovakian mathematical research capabilities are very low.

Work in the geophysical sciences is expanding although still well behind that of the leading Western nations. The country produces geophysical instruments and conducts a limited amount of basic geophysical research. Capable theoretical research on numerical weather prediction has been evident.

Although chemical research capabilities are generally low because of the lack of chemists, equipment, and reagents, Czechoslovakia is making contributions to Soviet Bloc organic chemistry research and is also making substantial contributions in macromolecular research. While Czechoslovakia is not as advanced in plastics as East Germany, Czech scientists are doing basic research in most fields of plastics with emphasis on synthetic fibers. Czechoslovakia and East Germany provide most of the Satellite support in research and development of ion exchange resins.

FIGURE 24. Cooling cabinets to test hardiness of plants at the Artificial Climate Station, Ostakino, 1957.

Czechoslovakian metallurgical research is of good caliber, and although small in amount, it is progressing and has provided some support to the USSR in specific subfields.

Electronics research and development is becoming increasingly original and some of the products observed have been of high quality. Czechoslovakia provides electronics support to the USSR comparable to that provided by East Germany. It contributes to the Soviet IGY program with its radiotelescopes and meteor-tracking radar, as well as in other fields.

Czechoslovakia has not shown much originality in the medical sciences. Public health and industrial medicine are emphasized. This country does furnish the USSR with many instruments and materials for medical research. It has some capability in microbiology and in aviation medicine and has a sound pharmaceutical industry. A high capability in veterinary medicine also exists.

There are a few highly qualified biological and agricultural research scientists in Czechoslovakia. Microbiological research is generally of high quality. Research related to industrial fermentation and production of biologicals is of excellent quality.

East Germany

The East German technological effort has achieved considerable success with their emphasis on applied research. Despite the defection of many of their scientists, there are still some competent theoretical scientists available to support the Soviet effort. The highlights of their capabilities are discussed below.

The GDR has contributed significantly to the Soviet effort in optics and photography, particularly by their facilities at VEB Carl Zeiss Jena and VEB Filmfabrik Agfa A. G. Wolfen. In view of increasing Soviet capabilities in these fields, however, East German support will tend to decrease in importance to the USSR.

A good capability in solid state physics exists and some contributions can be expected.

East German work in geophysics is considered important to the USSR; East German scientists have developed new and highly complex geophysical instruments. They also provide theoretical and applied support in geophysics including geodesy. Surveying of the Baltic Sea by East Germany has continued since 1952.

East Germany still has many competent chemical research scientists. They have made some contributions in organic chemistry research, and the quality of their work in this area is considered superior to that of the Soviets. They are also making very substantial contributions in macromolecular research. The plastics research program is probably further advanced than that of the Soviet Union in certain areas. East Germany and Czechoslovakia provide most of the Satellite support in research and development of ion exchange resins. The GDR also has an outstanding capability in catalytic research.

Most of the Satellite support in synthetic fuels will probably come from East Germany; it has the experience and the facilities. A document and specialist exchange agreement between the USSR and East Germany in metallurgy and chemistry was made in June 1957, but this program probably will be of limited scientific value to the USSR.

The Soviet Union fully exploited East German capabilities in electronics; until recently, the USSR had many German electronics personnel in their own laboratories. The GDR still furnishes the USSR with much equipment. This country also is capable of providing support to the Soviet effort in radio astronomy.

East Germany furnishes the USSR with many instruments and materials for medical research and contributes in the fields of nuclear medicine, pharmacology, and biochemistry. It also has a high capability in veterinary medicine.

There are a few highly qualified biological and agricultural research scientists in East Germany but their contribution to Soviet research appears to be of minor significance. Microbiological research is generally of good quality; research related to industrial fermentation and production of biologicals is of high quality.

Hungary

Hungarian scientific capabilities are believed to have been greatly impaired by the 1956 revolt. Even before the revolt, Hungary was far behind the West and trailed East Germany and Poland in science and engineering. Nevertheless, science has received considerable financial support; the emphasis has been in applied fields in an effort to accelerate industrial development.

Physics and mathematics research is limited; little capability for research in optics and photography exists. Some capability in cosmic ray physics and solid state physics is noted.

Geophysical research has generally lagged and has greatly declined from its eminence of 40 years ago. A fair capability still exists in some geophysical fields, such as gravimetry and seismology.

Chemical and metallurgical research is usually directed toward specific problems; little basic work is conducted. Hungary has made some contributions in macromolecular research. This country also has a small but high caliber group of scientists working in the field of plastics. Outstanding contributions in the field of catalysis are probable within the estimate period.

Hungary has been contributing little significant fundamental knowledge to metallurgical science, although the Hungarians are capable of adapting foreign developments to their needs.

There have been no significant Hungarian advances in electronics. Most of their efforts have been in the development of military items; their electronic tubes and components are of good quality.

Hungary has a fair number of capable medical scientists, but they have shown little sign of contributing significantly to basic medical knowledge. Their aeromedical research program is extremely small. Hungary does have considerable competence in biochemistry, particularly in enzymology and protein studies, and in pharmacology. A high capability in veterinary medicine also exists.

Since the Hungarian uprising, many of the more competent agricultural and biological scientists have fled to the West, which limits the research capabilities of the country in these fields. The country, however, still has a capability for offensive clandestine biological warfare.

Poland

Since World War II, Poland has ranked somewhat below East Germany and Czechoslovakia in its capability to contribute to the Soviet Bloc scientific effort. The country has a high scientific potential but has not recovered fully from the extensive losses of World War II. The greatest concentration of effort appears to be in chemistry, geophysics, and medicine.

There are a number of competent physicists, but there is still a lack of facilities and equipment. Their mathematical capability is quite high and they can support the Soviet effort in electronic computers. Contributions in solid state physics also can be expected.

Much work appears in progress in the subfields of geophysics, although such work is mostly routine operation rather than research. Research facilities have been expanding for several years, however, and, with the anticipated improvement in instrumentation, good results can be expected during the period of the estimate.

Chemical research is advancing, although most of the effort is directly related to economic requirements. Poland has made some contribution to Soviet Bloc organic chemistry research. Substantial contributions in macromolecular research also are being made. Research of value in solid propellant materials may come from a few individual workers who are active in the field.

Little basic research is done in the field of electronics. Any effort in the immediate future will probably be of an applied nature. Poland appears to be the foremost Satellite country in development and production of radar equipment.

In the medical sciences, Poland possibly may contribute to the fields of hematology, physiology, and biochemistry. In these fields, they are probably ahead of the other Satellites. Some Polish microbiologists are of good calibre, but the lack of equipment and Western literature will limit their possible contribution in the immediate future.

Poland ranks close to East Germany in agricultural research potential but like East Germany will contribute very little to the Soviet effort.

Rumania

The quality of Rumania's scientific effort was at a low level in late 1953. Significant research results were not expected to emerge from the recently established institutes. Most of the research was of an applied nature — efforts mainly were the borrowing of foreign technology.

While there have been no recent surveys of scientific activities in Rumania, it appears that this country has a limited scientific capability which could be utilized by the Soviets in the fields of chemistry, mathematics, and medicine.

Very little success has been achieved in electronics research and development. There has been a serious lack of competent researchers and laboratory equipment.

The organizational structure of research has been patterned in the Soviet style which would facilitate cooperation with the USSR.

Communist China

Despite considerable emphasis on science and technology in Communist China, the great proportion of China's efforts are directed toward industrialization, developing resources, and improving public health. Communist China is still a net importer of scientific information and technological know-how in almost all scientific fields. Great efforts are directed toward building up scientific facilities and increasing the number of scientific personnel.* The amount of significant research works, however, continues to be small.

We foresee no significant contributions to the Soviet effort in important fields of physics, and there is only a moderate capability in mathematics.

The Chinese Communists are continuing to make rapid progress in the geophysical sciences. A large and fairly efficient meteorological service has been established. They are cooperating with the Soviets in establishing a network of artificial earth satellite tracking and monitoring stations in China. Other geophysical support includes routine geomagnetic, seismic, and meteorological observations. Increasingly significant contributions are expected within the next 5 to 10 years.

The country is still a net importer of chemical and metallurgical technology.

In electronics, there is an insufficient number of trained scientific and technical personnel to achieve research and development results of any economic or military significance. The country is rapidly building up an electronics production capability, but the USSR renders considerably more support to basic electronics research in Communist China than it receives.

Communist China is in no position, at present, to contribute to Soviet basic medical research since problems of public health in China are still occupying first priority. Basic medical research will probably receive greater support within about 5 years.

No substantial contribution in biological and agricultural research is expected during the period of this estimate.

* A new university of science and technology, with an initial enrollment of 1,600 students, was opened in Peking on 21 September 1958. There are 13 departments which cover advanced fields of nuclear physics, engineering, chemistry, and electronics.