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SCIENTIFIC INTELLIGENCE REPORT

LONG-RANGE SOVIET SCIENTIFIC CAPABILITIES, 1962-70

MONOGRAPH I

GEOPHYSICAL SCIENCES

OSI-SR/61-44
29 December 1961

CENTRAL INTELLIGENCE AGENCY
OFFICE OF SCIENTIFIC INTELLIGENCE

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Scientific Intelligence Report

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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.

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PREFACE

This Scientific Intelligence Report on the geophysical sciences and the related fields of astronomy and geodesy in the Soviet Union is the first of a series of monographs on long-range Soviet scientific capabilities during 1962–70. Soviet research on geophysics, astronomy, and geodesy contributes to the national missile and space programs and is of actual or potential value in a number of other activities of military, economic, or scientific significance. These activities include such applications as aids to undersea warfare, detection of nuclear explosions, improved methods of communications, discovery of additional mineral resources, development of improved methods of weather forecasting, and the possible achievement of weather and climatic control. The intelligence in this monograph emphasizes the trends in the principal areas of Soviet geophysical, astronomical, and geodetic research. Much of the scientific data on which this appraisal has been based resulted from the Soviet participation in the programs of the International Geophysical Year.

The information presented in this publication supersedes the intelligence in an earlier monograph on these fields for the period 1957–67. The subjects of the new series for 1962–70 follow: the geophysical sciences; metallurgy; physics; mathematics; chemistry; electronics; policy, organization, planning, and control of science and technology; scientific and technical manpower; the medical sciences; the control sciences; and the biological and agricultural sciences.

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LONG-RANGE SOVIET SCIENTIFIC CAPABILITIES, 1962–70

MONOGRAPH I

GEOPHYSICAL SCIENCES

CONCLUSIONS

1. Soviet research on the geophysical sciences in general is competently and progressively conducted and is well supported by a large segment of scientific manpower and an impressive number of facilities. The number of scientists working in geophysics and the related fields of astronomy and geodesy in the Soviet Union exceeds that in any other nation. Furthermore, the utilization of manpower has been effective in raising the levels of such work up to or near that of the leading countries of the world. Although research and development of Soviet geophysical sciences is progressive, this has come about as a result of an organized and very effective effort to exploit foreign work, particularly Western. Soviet research facilities are generally very good, and the number of observatories and institutes is rather large. The USSR now is capable of providing the small geophysical instruments and basic scientific support for which it once depended on Bloc countries.

2. The Soviet Union is handicapped in some areas of its geophysical sciences effort and in the areas of astronomy and geodesy where it has only a few world leaders and where the quality of its scientific manpower is generally lower than the quality of Western scientists. Although Soviet instruments and equipment in general are adequate, they are not up to Western standards; and the number of large, modern instruments is insufficient.

3. In the future, the Soviets will continue their intensive exploitation of foreign research in geophysics, astronomy, and geodesy. This effort—combined with the extensive Soviet programs to provide training, new institutes and observatories, and improved instruments and equipment—will produce effective results in the next 5 to 10 years, making the quality of Soviet scientific manpower equal to that of the West. The Soviets probably will step up the decentralization of their geophysical research facilities, with expansion taking place in the central and eastern regions of the Soviet Union. They will continue to place greatest emphasis on subfields that are significant primarily because of applications in communications, space, and military programs.

SUMMARY

The Academy of Sciences, USSR, is the leading organization for the planning and control of geophysical and astronomical research in the Soviet Union, but many ministries, chief directorates, and universities also participate. The Interdepartmental Geophysical Committee, which was formed in 1961 by the Academy to succeed the Interdepartmental Committee for the International Geophysical Year, seems destined to play a leading role in directing large domestic geophysical projects and cooperative international geophysical programs. The Astronomical Council of the Academy is the principal directing organization in astronomy and also appears to have an important part in coordinating scientific investigations of the upper atmosphere and space through its subordinate organization, the Interagency Commission for Interplanetary Communications. In geodesy, the Chief Directorate of Geodesy and Cartography and the Military Topographic Directorate of the Red Army General Staff function as the leading civilian and military organizations, respectively.

In general, Soviet facilities for geophysical research and for work in the related fields of astronomy and geodesy are adequate for conducting research in a wide range of problems. The number of observatories and research institutes has been increased, particularly in the outlying republics, but instruments and equipment, although adequate in general, are not up to Western standards in many instances.

In terms of manpower employed, the Soviet research programs in the geophysical sciences and in the related fields of astronomy and geodesy are the largest in the world. The Soviet Union leads in the number of scientific people employed, especially in astronomy, geodesy, oceanography, and seismology. In quality of scientific manpower, the Soviets lag slightly behind the leading Western nations in several of these areas. The utilization of manpower has been effective in helping the Soviets in building up overall geophysical capabilities but less effective in producing outstanding creative research than in the leading Western nations. Large training programs and improved facilities will provide opportunities for the USSR to advance the quality of its geophysical manpower in the next 5 to 10 years.

Objectives of Soviet research in geophysics and related fields are to advance basic scientific knowledge and to support the economic and military activities of the country. Specifically, some of the significant objectives include improvements in weather forecasting, in communications techniques, and in methods of exploitation of mineral resources; support to submarine, aviation, missile, and space programs; the utilization of polar and arid regions; and the development of methods of detecting nuclear explosions. Major Soviet scientific achievements have included detailed investigations of the ionosphere and extensive studies of magnetic fields, cosmic rays, and the earth's radiation belts by means of rockets and artificial satellites; photography of the reverse side of the moon; some outstanding theoretical work in astrophysics and radio astronomy; rapid progress on the completion of the geodetic framework of the USSR; and advances in the seismology and polar geophysics, particularly in ice research and forecasting. Present indications are that the emphasis on geophysical research related to communications, space, and missile programs will continue and that the Soviets will make significant advances in all areas of geophysics during the next 10 years.

The Soviet Union does not depend on the Satellites or Communist China for support in the geophysical sciences, but it takes advantage of the instrumentation capabilities of

some of the leading nations of the European Bloc. Weather and other geophysical data are exchanged and satellite tracking, which is encouraged in the Bloc countries, is very useful to the Soviet space program. Exploitation of non-Bloc, mostly Western, science and technology has been a major factor in Soviet progress in the geophysical sciences and closely related fields. This exploitation has been accomplished through use of open literature sources, international meetings, scientific exchanges, and other devices to obtain information. The purchase of Western instruments and equipment has also been very advantageous to the Soviets. Continued exploitation of all foreign resources in geophysics, according to their needs, can be expected of the Soviets.

DISCUSSION

ORGANIZATION, PLANNING, AND CONTROL

Overall Leadership

The leading organization for the planning, control, and execution of geophysical research in the Soviet Union is the Academy of Sciences, USSR, under the Council of Ministers. The Academy coordinates the work of other organizations and directs the activities of its numerous subordinate institutes, observatories, and laboratories through its departments, republic academies, and affiliates. The Departments of Physical-Mathematical Sciences and of Geological-Geographical Sciences are those most concerned with geophysical research.

In February 1961, the Presidium of the Academy of Sciences, USSR, formed an Interdepartmental Geophysical Committee, known by the abbreviated name of the Soviet Geophysical Committee, as successor to the former Interdepartmental Committee for the International Geophysical Year (IGY). According to Soviet reports, this new committee was entrusted with the task of coordinating all complex geophysical research in the USSR. The Committee was charged also with the organization and scientific application of IGY data, the publication of these data, and the regulation of the activity of the Soviet IGY data center (IGY World Data Center B). Other responsibilities of the Committee include acting as the National Committee of the USSR in relation to the International Union of Geodesy and Geophysics and IGY organizations. Under this reorganization, the former National Committee for Geodesy and Geophysics was discharged.

The new Soviet Geophysical Committee apparently will exert considerable influence in future Soviet geophysical research, particularly on large projects within the USSR and on cooperative international projects. The Bureau or Council of the Committee is headed by a president, V. V. Beloussov, three vice presidents, and nine members. The Committee has 13 sections: Geodesy, Seismology and Physics of the Earth's Interior, Meteorology and Physics of the Atmosphere, Geomagnetism and Earth Currents, Auroral, Ionosphere, Solar Activity, Cosmic Rays, Oceanography, Scientific Hydrology, Glaciology, Vulcanology, and Geochemistry. The Committee has a number of working commissions for special projects—for example, the Working Commission on the Upper Mantle, the Working Commission on the International Year of the Quiet Sun, and the Working Commission for Coordination of IGY Data Application. Each Commission consists of representatives from corresponding sections. In all, the Soviet Geophysical Committee has about 50 members.

Polar Geophysics *

In polar geophysics, the Academy of Sciences, USSR, cosponsors and provides scientific support to the Soviet Arctic and Antarctic programs through its departments and research institutes. The Academy probably controls the Soviet Antarctic program through a Working Commission for Antarctic Research under the Soviet Geophysical Committee. In cooperation with the Academy, the Chief Directorate of the Northern Sea Route (GUSMP), which is subordinate to the Ministry of the Marine Fleet, plans and executes the Arctic program and is the operational headquarters for the Antarctic projects. GUSMP organizes and staffs polar expeditions, provides logistic support and transportation, and maintains the principal research institute for polar studies—the Arctic and Antarctic Scientific Research Institute, Leningrad, with a branch in Moscow. The Chief Directorate of the Hydrometeorological Service (GUGMS), under the Council of Ministers, with its numerous meteorological and hydrological institutes and observatories, assists in planning and conducting Soviet polar geophysical investigations.

Meteorology and Hydrology

There are several organizations within the USSR which are involved in meteorological and hydrological research, but the most important are the Academy of Sciences, USSR, the Chief Directorate of the Hydrometeorological Service (GUGMS), and the Ministry of the Marine Fleet, all subordinate to the Council of Ministers. The GUGMS is responsible for maintaining the national meteorological and hydrological observational network as well as for providing operational forecasts to support the various economic and military activities. In addition, the GUGMS is actively engaged in meteorological and hydrological research through its institutes and observatories. The Chief Directorate of the Northern Sea Route, under the Ministry of the Marine Fleet, is responsible for weather forecasts for the northern regions of the country and conducts supporting research. In addition to these organizations, the Ministry of Defense maintains its own weather services and conducts some research. Within the Academy of Sciences, USSR, there are several commissions concerned with planning and coordinating meteorological research. These include the Commission on the Physics of the Atmosphere, the Coordination Council on Problems of Physics and Clouds and Precipitation, the Coordinating Working Group on Meteorology, and the Meteorological Commissions of the Geographical Society of the USSR.

Astronomy and Upper Atmosphere Research

Soviet astronomical research and most of the upper atmosphere research is organized under the Astronomical Council, which functions under the Department of Physical-Mathematical Sciences of the Academy of Sciences, USSR. The Astronomical Council consists of 20 to 30 members, including institute and observatory directors who are nominated by the Academy of Sciences. The Council accomplishes much of its work through its commissions, made up of scientists working in various specialized fields, and through committees appointed for special tasks. An important activity of the Astronomical Council in recent years has been its participation in the Soviet space program through the Interagency Commission Interplanetary Communications (ICIC), which is the Soviet organization for scientific space investigations and is organizationally subordinate to the Council. Like the Council, the ICIC appears to be primarily a planning and coordinating agency functioning through commissions and/or committees and having the authority to draw on the research and development resources of the entire country.

The Academy of Sciences, USSR, is the most important organization conducting astronomical and upper atmosphere research in the Soviet Union, but various other organizations maintain observatories and institutes that carry on astronomical research on a full-

* In following sections of this report, polar geophysics is not treated as a separate subject but is included, when pertinent, in discussions of substantive subfields of research, such as meteorology and oceanography.

or part-time basis. The most important of these other organizations are the republic academies, the affiliated academies, the universities, and various ministries. The Chief Directorate of the Hydrometeorological Service (GUGMS), functioning directly under the Council of Ministers of the USSR, is the other principal organization involved in upper atmosphere research. The GUGMS, with its own observatories and research institutes, plans and carries out investigations of the upper atmosphere by means of meteorological rockets and conventional ground equipment.

Geodesy

The Chief Directorate of Geodesy and Cartography (GUGK) of the Ministry of Geology and Conservation of Mineral Resources is the civilian organization charged with planning, administering, coordinating, and controlling geodesy in the USSR. The GUGK functions also as an educational, training, research, and production organization. To carry out its functions, the GUGK maintains a series of directorates and other subdivisions for administration and control, institutes for research and education, and aerial geodetic establishments for field work. The Military Topographic Directorate (VTU) of the Red Army General Staff functions in a similar role for the military but on a smaller scale, with some assistance from the Hydrographic Directorate of the Soviet Navy. In the Academy of Sciences, USSR, the Geodetic Section of the Committee on Geodesy and Geophysics, the Institute of the Physics of the Earth, and the Institute of Theoretical Astronomy engage in the following: studies of the size and shape of the earth; theoretical and instrumental research in gravimetry; and the establishment of gravity control points, international gravity ties and calibration lines. Soviet Time Service, determination of the absolute value of gravity, and other standards of length and measures are the responsibility of the Committee on Standards, Weights, and Measuring Devices under the Council of Ministers.

Geodetic work is also carried out by many other organizations for specific purposes such as prospecting, railroad construction, land development, and agriculture. The procedures and results of geodetic work for these specific purposes must be sent to and approved by the GUGK or the VTU for their use in geodetic research. Planning and implementation of geodetic research on both a long range and a current basis is performed by the GUGK, VTU, and the Academy of Sciences, USSR. The GUGK and VTU rigidly control geodetic data and programs through directives which provide a unified geodetic system concept and which regulate the availability of results from geodetic research programs.

Geomagnetism

There are approximately 10 institutions in the Soviet Union conducting important research in geomagnetism exclusive of geophysical prospecting and related mineral surveys. Most of the important basic research is at institutes under the Academy of Sciences, USSR. The Institute of Terrestrial Magnetism, Ionosphere, and Radiowave Propagation (IZMIRAN) under the Academy is the foremost institution for geomagnetic research in the USSR. As such, it directs or helps administer research at the Soviet geomagnetic observatories. Important geomagnetic work is also being conducted at institutes under the Council of Ministers, the Ministry of Geology and Conservation of Mineral Resources (MINGEO), the Ministry of River Fleets, the Ministry of Higher and Secondary Specialized Education (MVSSO), and the Academies of the Union Republics. The majority of MINGEO's geomagnetic work, however, is concentrated on economic pursuits.

Control of geomagnetic research at the subministerial level for the Academy of Sciences, USSR, is centered under the Department of Physical-Mathematical Sciences and the Siberian Department; the Committee on Standards, Weights, and Measuring Devices under the Council of Ministers; the Chief Directorate of the Northern Sea Route under the Ministry of River Fleets; and the Chief Directorate of Geodesy and Cartography under MINGEO.

Applied research in geomagnetism for marine and space navigation and control, for antisubmarine warfare, and for other civil

and military requirements is also conducted largely by these same institutions with advanced research and testing by organizations under the Ministry of Defense.

Earth current research is conducted principally at IZMIRAN and at the Institute of Physics of the Earth (IFZ), both under the Academy of Sciences, USSR. The earth current observations are more closely associated with IFZ, and IZMIRAN concentrates primarily on the use and effect of earth currents on communications.

By 1970, more of the widely developed and heavily financed aspects of applied geomagnetism and earth currents will have been moved from the Academy to the ministerial organizations.

Oceanography

Oceanographic research in the Soviet Union is conducted by nearly 100 institutes and laboratories of the Academy of Sciences, ministerial organizations, and universities. Most of the significant research, however, is, and probably will continue to be, accomplished at five leading institutes—the Institute of Oceanology, the Marine Hydrophysics Institute, the State Oceanographic Institute, the Arctic and Antarctic Scientific Research Institute, and the All-Union Scientific Research Institute for Marine Fisheries and Oceanography.

Basic research is centralized mostly in the research institutes of the Academy of Sciences and the State universities in Moscow and Leningrad. Applied research is generally conducted by ministerial institutes and is undertaken to support the missions of the parent organizations. Overall planning and coordination of the national oceanographic research program, including the 5-year plans, is the responsibility of the Presidium of the Academy of Sciences through its Interdepartmental Oceanographic Commission. Actual control of oceanographic research apparently rests with the parent organizations, and the Academy of Sciences is limited to the control of its own institutes. The ministries and directorates controlling the research of the leading nonacademic institutes are the Chief Directorate of the Northern Sea Route under the Ministry of Marine Fleet; the Chief Directorate of the Hydrometeorological Service under the Council of Ministers; and the Chief Directorate for Scientific Research Institutes under Gosplan. The local Sovnarkhozes are believed to have some control over the regional oceanographic research institutes concerned with supporting the fishing industry, and the Hydrographic Directorate of the Soviet Navy under the Ministry of Defense cooperates with important oceanographic organizations in their collection programs.

Seismology

Seismological research in the Soviet Union is being conducted by approximately 30 institutions of the Academies of Sciences, the ministries, and the universities. In addition, there is a much larger number of institutions in seismological prospecting for minerals, mining studies, and other economic pursuits. Most of the significant research in seismology is being conducted by institutes under the Academy of Sciences, USSR. By far the most important of these is the Institute of Physics of the Earth (IFZ) in Moscow. Planning and control of Soviet seismology is exercised by the Council for Seismology under the Presidium of the Academy of Sciences, USSR, and the Department of Physical-Mathematical Sciences, the Department of Geological-Geographical Sciences, and the Siberian Department of the Academy. Other important institutes conducting seismological research under the Academy are the Mathematics Institute in Leningrad, the Institute of Geology and Geophysics at Novosibirsk, and the Sakhalin Complex Scientific Research Institute at Novo Aleksandrovsk. Of the Union Republic Academies, the most important is that of the Georgian SSR, with its Institutes of Geophysics. Of the universities, Moscow State University is conducting the most important seismological research. The ministry with the greatest interest in seismology is the Ministry of Geology and Conservation of Mineral Resources, USSR.

The IFZ, which at present conducts a large portion of the nation's noneconomic seismology, is active in both basic and applied seis-

mological research. IFZ operates the Seismological Service, which directly controls the bulk of the approximately 120 permanent and temporary stations for detecting and reporting earthquakes and explosions in the USSR, Antarctica, and elsewhere.

Through 1970, the IFZ is expected to continue as the most important Soviet seismological research organization, although its activities in applied research may be transferred to new or existing institutions outside the Academy. The rapid rise of basic seismological research in the Academy's new scientific cities at Novosibirsk and Irkutsk is not expected to challenge seriously IFZ's pre-eminence in Soviet seismology through 1970.

Geophysical Prospecting

Research related to the methods for geophysical prospecting is carried on at more than 50 facilities in the USSR. The more important of these facilities are in the structure of the Ministry of Geology and Conservation of Mineral Resources, the Academy of Sciences, USSR, and the Ministry of Higher and Secondary Specialized Education (MVSSO). In general, the Ministry of Geology and Conservation of Mineral Resources is concerned with applied research directly related to mineral exploration, such as the interpretation and analysis of anomolous fields and the design and construction of geophysical instruments. Field data are assembled by institutes of that ministry in research on subsurface geology for development of the mineral resources of local areas. Two leading institutes of that ministry are the All-Union Scientific Research Institute of Methods and Techniques of Prospecting (VITR) and the All-Union Scientific Research Institute of Geophysical Methods of Prospecting (VNIIGeofizika).

Institutes of the Academy of Sciences, USSR, are concerned chiefly with the basic fundamentals in terrestrial geophysics to understand better the elements of the natural environment reflected in geophysical exploration: the nature, composition, constitution, origin, and history of mineral deposits and the interrelationship, both individually and collectively, of those elements to the parameters measured by the various methods of geophysical prospecting. Research and development of geophysical instruments is also carried out by the Academy of Sciences, USSR. Institutes and laboratories of the departments of biological sciences, chemical sciences, geological-geographical sciences, and physical-mathematical sciences are the chief contributors to research on geophysical exploration in the Academy of Sciences, USSR. Emphasis at the institutes and universities of the MVSSO seems to be about equally divided between basic and applied research. Industrial ministries and chief directorates responsible for assigned geographical areas perform research on geophysical topics related to their specific goals and objectives. The economic portions of the planning and control of research on geophysical methods of prospecting are believed to be largely concentrated in the Ministry of Geology and Conservation of Mineral Resources. The more basic researches are probably planned, controlled, and coordinated by both that ministry and the Academy of Sciences, USSR. The recent trend toward concentrating basic research in the Academy of Sciences, USSR, is expected to continue through 1970. Substantial changes from the current status are not foreseen, however, because of flexibilities in defining basic research in geophysical prospecting.

EXTENT AND ADEQUACY OF PRESENT AND FUTURE RESEARCH FACILITIES

Meteorology and Hydrology

The meteorological network of observing stations is extensive and is adequate to support most aspects of the operational program. Nevertheless, a higher density, particularly of radiosonde observing stations, is desirable, and it is probable that the Soviets will expand the network during 1962–70.

In general, the meteorological and hydrological research institutes in the USSR are adequate to conduct significant research over a wide range of problems. The Soviets in recent years have been expanding the number

of these research institutes, especially the ones in the outlying republics, and this trend is expected to continue through 1970. They have also recently formed some institutes that work on specialized problems, such as cloud physics and weather control. Institutes of this type may also be increased during this period, but probably not as rapidly as the general research institutes.

Astronomy and Upper Atmosphere Research

In recent years the Soviet Union has expanded its facilities for astronomical and upper atmosphere research so that at present it has one of the largest networks of observatories and research institutes in the world devoted to such work. Three major astronomical observatories are currently under construction, others are planned, and a number of other observatories and stations are being expanded. The Soviets have also supplied new instruments and equipment to many of their older observatories.

The major deficiency of Soviet astronomy, which was a lack of large modern telescopes, has been overcome to some extent but still exists. The installation in 1960 of a 102-inch reflector at the Crimean Astrophysical Observatory provided the Soviets with the world's third largest optical telescope—the largest outside the United States. At about the same time the USSR approved plans for the largest optical telescope in the world, reportedly a 276-inch * reflector. The Soviets appear to be going ahead with site selection and other preparations for the huge new telescope, which will probably require about 10 years to construct and install. Such a telescope would add greatly to the research capabilities and prestige of the country.

The Soviets have been even more active in construction of radio-astronomical equipment. They now have in operation a relatively large number of radio-astronomical telescopes. A recently completed fully steerable 72-foot parabolic reflector of great precision and versatility is one of the finest of its type available. Other large radio telescopes planned or under construction are among the largest in the world, but no Soviet developments are known which are likely to overcome the Western superiority in this area.

These and other developments in the design and construction of auxiliary equipment indicate that the USSR has already overcome its past dependency on foreign countries for astronomical equipment and that it is rapidly emerging as a leading country in the extent and adequacy of its observational research facilities.

Geodesy

Soviet facilities for geodetic research are well organized both within a specific facility and as an integrated national effort. These facilities are adequate to carry out by classic methods research on the figure of the earth and to apply the results of this research to practical and scientific problems. The Soviets are expected to organize by 1970 the facilities for the better utilization of newer methods and techniques in geodesy. In addition, research facilities are exected to be enlarged, or new facilities are expected to be established in the central or eastern part of the USSR, possibly at Novosibirsk. The educational and training capability of Soviet geodetic facilities will continue to exceed current U.S. capability.

Geomagnetism

The Soviet Union has a large network of approximately 30 geomagnetic observatories, about 20 of which also conduct earth current, or geoelectrical, observations. These stations are well distributed over the country, as well as outside the USSR at stations in Antarctica and on Spitzbergen. The number of Soviet geomagnetic and earth current stations is greater than that of any other country, and there are indications that the USSR has a broad basic research program with numerous military applications. Most of the earth current stations are combined with geomagnetic observatories located near the periphery of the USSR. The Soviets conduct their marine magnetic survey measurements, not from aircraft as is done in the West, but from the non-

* Some sources report this figure as 236 inches.

magnetic research schooner *Zarya*, which is stressing measurements of the earth's magnetic field and correlating them with other geophysical data observed at sea.

By 1970, the Soviet geomagnetic and earth current station network will further numerically outweigh similar Western networks, but the overall quality of the research work and instruments will still fall short of the best Western work.

Oceanography

Soviet shore-based and shipboard facilities are comparable to those of other leading countries. Most of the significant research institutes are concentrated in the Moscow and Leningrad areas with subordinate research stations located on the coasts. There is a recognized need to disperse these institutes, and the need seems greatest in the Far East. New facilities that have been acquired recently have been located in Kaliningrad and apparently Vladivostok and Sevastopol, rather than in the Moscow-Leningrad areas. Whether or not the leading institutes remain in the large cities, new buildings will have to be acquired to accommodate their large staffs resulting from the recently expanded national research program. The Institute of Oceanology definitely expects a new building soon and the other institutes will probably receive additional buildings by the late 1960's.

The floating research facilities—the oceanographic fleet—have already undergone an expansion program and now rank as the largest and most modern in the world. The fleet now has an estimated strength of approximately 150 ships with a combined capability to collect data from any oceanic area in the world. The ships range in size from small coastal types to deep-sea research ships of several thousand tons displacement. As many as 10 new ships may be under construction for the fleet. Though the total number of ships probably need not be increased, there is need for some older ships to be replaced and for all the leading institutes to have large modern ships assigned to them for their staffs. Therefore, new research ship construction can be expected to be continued at least at its present level through 1970. By the mid-1960's the USSR also should have a small fleet of underwater research vehicles, including several submarines and a bathyscaph.

Seismology

Soviet seismological research facilities are considered adequate for both the present and future needs of a leading nation in that field. The USSR has more than quintupled the size of its network of seismological stations since World War II. As a result, the USSR has one of the largest and most modern seismological networks in the world. Most of the seismic facilities are equipped with modern seismographs capable of recording near as well as distant earthquakes.

IFZ, which specializes in seismology and related research, is the largest institution of its kind in the world. Over 100 employees of IFZ have made contributions to the seismological literature. Of the approximately 16 departments and laboratories in IFZ, all but 4 conduct research involving seismology. In general, the top ranking Soviet seismologists are associated with IFZ either in Moscow or in the institute's field facilities.

By 1970, Soviet seismological facilities will have expanded still further under the impetus of the Soviet desire to be second to none in science. This desire will be reinforced by the continuing needs for improved explosion detection and earthquake prediction capabilities.

Geophysical Prospecting

The number and diversification of present Soviet geophysical research facilities meet the requirements to conduct research in all the disciplines of geophysics which contribute to advance in geophysical prospecting. These facilities are organized to perform basic research and to put into practice the latest developments in geophysical methods of prospecting. Different disciplines are emphasized at various facilities, but the organizational structure of these facilities is such that contributions from the various disciplines can be

unified into a coherent approach to geophysical exploration problems. Present Soviet research facilities engaged in basic and applied research in geophysical prospecting have contributed in large measure to the current Soviet strengths in mineral resources. Barring anomalous changes in the world situation, only normal growth rate of those facilities is foreseen through 1970. Strengthening of the research capabilities of facilities in the central and eastern regions of the USSR is to be expected.

QUALITY, QUANTITY, AND EFFECTIVE UTILIZATION OF MANPOWER

The Soviet Union has larger numbers of workers in geophysics, geodesy, and astronomy than any other nation. On the other hand, the quality of Soviet scientific manpower in these areas is somewhat lower than in the leading Western nations, being approximately equal in some fields and poorer in others. Utilization of manpower in the geophysical sciences by the USSR appears to have been somewhat less effective than in the West. In general, Soviet achievements have been more in terms of quantity of manpower than in terms of quality, and the Soviet Union has not generally achieved positions of world leadership in as many geophysical fields as have the Western countries. The Soviets have been more effective in using their scientists to exploit the work of other nations, thereby bringing Soviet general capabilities up to the level of other leading nations in many areas. In the following sections, Soviet scientific manpower in specific areas of geophysics and closely related fields is discussed.

Meteorology and Hydrology

There are many meteorologists and hydrologists in the USSR who spend at least part of their time in research. A few of these personnel are considered to be outstanding, and many are capable of conducting significant research, given the proper guidance and leadership. Although the Soviets may have a larger total number of scientists engaged in research, the number with high capabilities probably is about equal to or slightly less than the number of U.S. meteorologists and hydrologists with similar capabilities.

In general, the meteorological and hydrological manpower in the USSR is used effectively to meet the national objectives. The Soviets often bring together scientists from many institutes to attack particular research problems; this is probably the most effective means to attack some problems, especially in cases where extensive special instrumentation is necessary.

Astronomy and Upper Atmosphere Research

Soviet employment of manpower in the field of astronomy is probably larger than that of any other nation. In the related field of upper atmosphere research, the Soviet scientific force is relatively smaller. Although the Soviets have a number of well-qualified scientists in these areas, they have relatively few scientists who can be classified as very outstanding or as world leaders. Below the top echelons, Soviet scientific manpower also appears to be generally lower in quality than in the leading Western nations in these fields, although the present Soviet training program probably will improve this situation. The Soviet Union has utilized its best scientists very effectively in work not directly involving creative research, such as in following Western developments and writing textbooks. Soviet utilization of lower quality scientists appears not to have been very effective. In many cases, observatories and institutes have many personnel working on routine or trivial tasks. Soviet astronomers and upper atmosphere scientists are strongest in the theoretical aspects, although increased interest has been noted in experimental work as better facilities and special opportunities, such as rockets and space vehicles, are provided.

Geodesy

The USSR is placing more-than-average emphasis on the subject of geodesy. This emphasis is manifested in the unusually large number of personnel at all levels of geodesy, including geodetic training. Notwithstanding this emphasis, there is little difference between the quality of geodetic work in the

USSR and in leading Western nations, a situation expected to continue through 1970. The Soviets possess a quantitative advantage over the U.S. in the number of geodetic personnel, both in total numbers and in number of personnel per unit of area. They are expected to attempt to utilize their manpower advantage to introduce new geodetic techniques more rapidly than in the West, thereby accomplishing the stated objectives of their geodetic program—to strengthen their military, economic, and scientific posture. According to Soviet statements, their current 7-year plan, ending in 1965, will require about 3,120 professional persons and 7,350 technicians in topography and geodesy. It is estimated that by 1970 the USSR will have 1,300 professional geodesists (1,000 diploma graduates, 225 candidates, 75 doctorates) and 3,800 geodetic technicians.

Geomagnetism

In general, Soviet geomagnetologists have been followers rather than leaders in their field. Soviet research in earth currents, however, probably provides the exception. Quantitatively, Soviet scientists and technicians working in geomagnetism are 7 to 8 times more numerous than the approximately 100 U.S. scientists in that field. In earth currents, the Soviet numerical superiority is even more pronounced.

In geomagnetism and earth currents research, the Soviets have about 100 competent, first-class scientists who are their main bulwark against mediocrity in the field. The most glaring shortcoming in Soviet geomagnetism is the virtual lack of really outstanding men with international reputations. The Soviet magnetologists are predominantly data handlers who are intensively and extensively studying the earth's magnetic field. They are also engaged in research and development, but these efforts appear to lack the originality of Western work.

Oceanography

The Soviet Union has more scientists and technicians engaged in oceanographic research than any other country in the world. There are estimated to be more than 500 Soviets engaged in oceanographic research, exclusive of marine biology. The professional qualifications of these Soviets are not generally comparable to the personnel of leading Western countries, particularly those of the senior scientists. Owing to the recent influx of personnel into oceanography, there is a need for more qualified senior scientists. Such leaders appear to be emerging, and by the mid-1960's a cadre of internationally recognized oceanographers should exist. Furthermore, the experience being gained from processing the oceanographic data collected during and since the International Geophysical Year is expected to result in improved professional qualifications of Soviet oceanographers.

The existing manpower seems to be effectively used to meet national oceanographic requirements. Instead of a large, independent military effort, the USSR apparently incorporates its military research into the programs of its nonmilitary organizations, thereby meeting civilian and military needs more effectively with the existing manpower. The assignment of specific missions to the leading institutes also tends to reduce duplication of effort and to insure more effective use of the Soviet oceanographic manpower.

Seismology

The Soviet Union has more trained seismologists and seismological technicians than any other nation in the world. Over 1,200 Soviets contributed to the seismological literature in recent years. Of the 1,200, there are about 50 well-established seismological authors who have made 10 or more contributions, and there are about 750 who have made only a single contribution. This suggests that the large majority are young and relatively inexperienced personnel. The 1,200 may include as many as 200 or 300 individuals whose main contribution to the seismological literature has been in mineral prospecting and other economic fields.

The existing manpower is believed to be effectively used to meet basic and applied

Soviet seismological requirements of both a civil and a military nature.

Recent trends indicate that, by 1970, approximately 2,000 Soviet scientists and technicians will be employed in the field of seismology.

Geophysical Prospecting

The competency of the leading Soviet scientists engaged in basic geophysical research that can be related to prospecting is comparable to that of the U.S. leaders in this area. This is also believed to be the case in the applied aspects of research, with the probable exception of prospecting instruments and automatic data processing equipment. In this equipment, the Soviets have not yet reached the level of sophistication found in the leading Western nations, although the Soviet instruments and equipment are probably adequate for the present needs of the USSR. It is estimated that the Soviet Union has 25,000 to 30,000 people in terrestrial geophysics and geology. Utilization of a large part of that manpower for geophysical prospecting seems to have been successful, as indicated by the apparent strength of the USSR in proven mineral resources. The level of difficulty of locating mineral deposits in the USSR is not expected to increase substantially by 1970. Therefore, the number of Soviet personnel engaged in prospecting—including field, office, and research personnel—is expected to continue to increase at normal rates through 1970.

OBJECTIVES, MAJOR ACHIEVEMENTS, TRENDS, AND FUTURE CAPABILITIES IN BASIC RESEARCH

Meteorology and Hydrology

The major ultimate objectives of meteorological research are to acquire some degree of control over the weather and to obtain a high degree of accuracy in forecasting the weather. To reach these objectives, almost all meteorological research is conducted to achieve a better understanding of the physical processes that occur in the atmosphere. Until these processes are understood completely, it will not be possible to produce perfect weather forecasts or to control the weather to any great extent.

The geographical location of the USSR has been responsible for a very large research program in polar meteorology and hydrology. Since the beginning of the IGY, this research has included the Antarctic as well as the Arctic regions. Because of this large program and their many years of experience, the Soviets are among the world leaders in this type of research. It is expected that they will continue their efforts in polar meteorological and hydrological research and that the quality of this research will remain high through 1970.

Another research area receiving much emphasis in the USSR is cloud physics and weather modification. At the present time, Soviet research in this field is somewhat inferior to that of leading Western countries. A proposed All-Union Cloud Year in 1962 is an indication of the extent of the future Soviet effort, and the Soviets can be expected to make significant original contributions in this field before the end of this estimate.

Soviet theoretical work in numerical weather prediction has been quite competent, but the Soviets seem to have neglected some of the problems that are associated with applying numerical forecasts on an operational basis. This neglect has been due to the Soviets having only limited time available to them on general-purpose digital computers. This situation has now been remedied with the formation of the Joint Meteorological Computing Center of the Academy of Sciences, USSR, and the Chief Directorate of Hydrometeorological Service. This joint center has the full-time use of a suitable computer, and thus Soviet research in numerical weather prediction during the next 10 years will become much more significant. Nevertheless, it is not probable that the quality of this Soviet research will surpass that of leading Western nations through 1970.

The USSR has conducted high-quality research in many other subfields of meteorology, such as turbulence, radiation, and diffusion.

Large efforts in these fields are likely to be continued through 1970 because greater knowledge in these fields is necessary for improved forecasting, and the fields are closely related to some military problems, such as biological and chemical warfare. Hydrological research is also well developed in the USSR, and strong efforts will be continued through 1970 to support projects, such as the development of virgin lands.

The Soviets have lagged behind the United States in launching weather satellites for collecting meteorological data. There are indications however, that they will become active in this field in the near future.

Astronomy and Upper Atmosphere Research

The principal objectives of Soviet astronomical and upper atmosphere programs are to support the national space program, to improve communications, and to advance basic scientific knowledge. Soviet sounding rockets and space vehicles have been instrumented to determine the environment in which space craft will operate. The sample measurements obtained probably have been used in planning subsequent space programs, in designing later space vehicles, and in solving problems in communications and re-entry. By studies of the sun and stars, the Soviets also hope to obtain scientific information that will lead to a better understanding of solar-terrestrial relationships, new sources of energy, and other practical benefits not specifically foreseeable at this time.

The major achievement of Soviet astronomy in recent years has been the expansion and improvement of observational research facilities in both the optical and radio astronomical areas. At the same time, Soviet capabilities in optical and radio instrumentation have been improved so that the USSR no longer depends on foreign suppliers for instruments and equipment needed in astronomical and upper atmosphere research work. This improvement, with the large training program, has placed the Soviet Union in a position from which significant scientific advances can be made.

Actual major scientific achievements by the Soviets have included the work of Viktor A. Ambartsumian in theoretical astrophysics, which has been recognized as outstanding throughout the world. Ambartsumian's principal accomplishments have been two. One was the formulation in the 1940's of a theory regarding the origin and evolution of stars and galactic structures and their relations to interstellar gas and dust. This theory is known as the theory of stellar associations. The other accomplishment was his work on interstellar light scattering and absorption.

In the field of theoretical radio astronomy, I. S. Shklovskiy and V. L. Ginsburg have been pioneers in work on the origin and nature of radio waves from our galaxy and beyond. In 1953, Shklovskiy made an outstanding contribution with his hypothesis of the synchrotron effect as an explanation for the polarized light from the Crab Nebula.

The more recent work of A. B. Severnyy on studies of solar magnetic fields has been recognized as outstanding. This work is considered important because of the role that solar magnetic fields play in generating corpuscular and electromagnetic solar radiation, in triggering geomagnetic storms, and in influencing ionospheric conditions. Some other notable solar research by the Soviets includes the discovery by Severnyy, and J. V. Kazachesvskaya of an extra emission of energy from chromospheric outbursts; G. M. Nikol'skiy's findings on the shape and structure of the corona; V. V. Vitkevich's studies on the super corona; P. Ye. Kolpakov's approach to the problem of solar ejection of charged particles; and Shklovskiy's ideas on the equilibrium state of the solar corona.

In lunar research, the successful photography of the far side of the moon from Lunik III was a spectacular achievement that has added considerably to Soviet prestige, as did the attempt to detect a magnetic field of the moon by means of Lunik II. Although the investigation of the magnetic field was made with a relatively crude magnetometer, it is the only one yet made relating to the lunar magnetic field; and the Soviet report that no lunar

magnetic field was found has been generally accepted by the scientific community.

In upper atmosphere research, the Soviets have conducted detailed investigations of the structure, composition, and dynamics of the ionosphere by means of vertical probes and artificial earth satellites. They have obtained electron densities up to and above the F region maximum from rocket soundings and above 300 kilometers by observation of radio signals from Sputnik I and III. Their observations disclosed about four times as many electrons above the F region maximum as below; they also disclosed that the predominant ion from 250 to 950 kilometers is positive atomic oxygen.

The Soviets have obtained density measurements of the upper atmosphere from drag measurements of satellite motion and from direct measurements made with instrumenation on Sputnik III. Using small rockets launched from both ground and shipboard sites they have also conducted an extensive program of meteorological type soundings in the lower portion of the upper atmosphere. This effort has provided atmospheric data at middle-European, Arctic, and Antarctic locations showing seasonal as well as geographic variations.

By means of earth satellites and space vehicles, principally by instruments on Sputnik III and Lunik I, the Soviets have obtained measurements of the earth's magnetic field. A marked dip in the field was observed in the region of the radiation belt, indicating the existence of a ring current that had been postulated earlier by Western scientists. Sputnik III measurements indicated that the East Siberian magnetic anomaly is deep seated. Although of importance, the Soviet magnetic measurements were made with relatively crude instruments. Therefore the quality and reliability of the Soviet results are inferior to those obtained by the United States with improved instruments in Vanguard III and Explorer X.

The USSR has made intensive studies of cosmic rays, particularly primary cosmic rays, and radiation belts using instrumented rockets, satellites, and space probes. The USSR has in progress a large cosmic ray balloon observational program. Although Soviet claims of the discovery of the now well-known Van Allen belts are not well founded, the Soviet work did verify and extend the U.S. investigations. In general the Soviet upper atmosphere cosmic ray research has been extensive and competent.

In auroral and airglow research, the Soviets have conducted a considerable amount of work of high quality in their specialty, the infrared region of the spectrum. In addition, their all-sky camera, developed for the IGY, is of good, sound design and is capable of producing excellent auroral observations. Much effort has gone into the measurement of temperature determined from the OH (oxygen-hydrogen) rotational levels in the infrared. Recent papers published by the Soviets also indicate that their airglow research in the ultraviolet portion of the spectrum has been more extensive than previously supposed.

Because earlier emphasis was strongly on theoretical work, present Soviet trends to increase observational and experimental research on astronomy and the upper atmosphere are likely to continue and will probably result in a well-balanced research effort. Increased use of rockets and space vehicles for both astronomical and upper atmosphere investigation, which are indicated for the future, may result in de-emphasis of some ground-based observations, but these observations will continue in most subfields because of the need to support space programs. From all indications Soviet capabilities in astronomy and upper atmosphere research will improve and become approximately equal to those of the leading Western nations by the end of 1970.

Geodesy

The rapidity with which the geodetic framework of the USSR is being accomplished is a major achievement of Soviet geodesy. In this field, the Soviets have reached a high and competent level as a result of their increased emphasis on basic and applied research in recent years. Soviet geodetic capabilities are likely to continue to improve through 1970,

remaining approximately equal to those of leading Western nations. The objective of Soviet geodetic research is increased knowledge of earth physics and the size and shape of the earth, such knowledge to be used for scientific and military purposes and for the space program.

The current Soviet 7-year plan in geodesy places first priority on the completion of the astrogeodetic net in the form of polygons, a task scheduled for completion by 1965. The completion of a state level net of unspecified order is also scheduled by 1965 as well as repeated leveling for research on the vertical and horizontal motion of the earth's crust. To attain its geodetic objectives more rapidly, the Soviet Union is expected to attempt to accelerate the development and use of newer techniques and equipment, such as the following: electronic and light interference distance measurement; earth satellite vehicles for geodetic purposes; computing machines; and land, sea, and air measurements of the value of gravity. A further shift of geodetic operations to Central Asia, East Siberia, the area north of the Arctic Circle, and the Kazakh Republic is foreseen in the Soviet plans to direct up to 80 percent of all capital outlays of the Chief Directorate of Geodesy toward the eastern regions of the USSR.

Geomagnetism

In geomagnetism, the Soviets are active in the subjects of the earth's main field, secular changes, transient variations, magnetic instruments, and earth currents to accomplish what seems to be their principal objective—to measure and describe the earth's magnetic field and its changes in time and space. In the applied aspects of those subjects, Soviet capability, on the average, is comparable to that of the leading Western nations. In more theoretical researches of geomagnetism, the Soviet Union has not yet demonstrated a competency comparable to that of the West. Up to the present, the West has made the basic fundamental contributions to geomagnetism. The USSR has mainly applied the results of theory developed in the West to conditions within the Soviet Union. Soviet world magnetic charts for 1955 seem to be excellent charts for the elements given and were prepared by use of established techniques. In rock magnetism, the Soviets have assembled and analyzed much data on most aspects of transient magnetic variations. The effort of the Soviet Union in the study and measurement of earth currents is very large compared with the rest of the world. In this field, the Soviets have made significant contributions and are pressing for world leadership. Average competence and considerable interest have been shown by the Soviets in space studies of the geomagnetic field in the high atmosphere and beyond along with the motions of charged particles in a magnetic field. Soviet instruments for routine surveying of the earth's magnetic field and observatory instruments for monitoring the earth's field are adequate. The Soviets have developed nuclear resonance and proton precession magnetometers and have demonstrated a capability in the basic physics necessary to develop the newer alkali vapor (rubidium vapor and metastable helium) magnetometers.

The Soviet geomagnetic program is expected to continue emphasizing the charting of the earth's field and its variations. More emphasis is foreseen in basic research for better understanding of the relationships between the earth's magnetic field and phenomena in the higher atmosphere. The Soviets are expected to develop by 1965 instruments for more precise measurements of the magnetic field of bodies in space and for antisubmarine warfare systems involving the detection and identification of small magnetic anomalies.

Oceanography

Although the USSR has made considerable progress in recent years toward its objective of becoming a world leader in oceanography, the level of its oceanographic research is not generally as advanced as that of leading Western countries. A mass of data has been accumulated by the large-scale Soviet collection activities begun during the International Geophysical Year, and research problems have been assigned to various institutes for its

analysis. As a result of this analytical program, Soviet research should improve and may be on a par with that of other leading countries by the late 1960's.

The present effort is oriented toward applied research in support to military and economic requirements. The collection of basic oceanographic data that are useful for the exploitation and development of fisheries for the development of polar regions, and for support of submarine and antisubmarine operations continues to be emphasized. The polar and deep-sea oceanographic activities, which are largely collection efforts, are the strongest areas in the program. Soviet activities in the arctic region related to the development of the Northern Sea Route during the past quarter century have achieved a position of world leadership in arctic oceanography which probably will be unsurpassed by any other country during the period of this estimate. Work in other areas of oceanographic research generally is not commensurate with the collection oriented efforts. High-quality research has been conducted in marine geology. The suggested use of oceanic deeps for radioactive waste disposal areas by Western scientists and the complex geological-geophysical study of Far Eastern seas bordering upon the USSR has influenced the level of this research. Chemical oceanographic research has been routine. In physical and dynamic oceanography, the Soviets are outstanding only in ice research and forecasting. Efforts are being made to develop methods for predicting the thermal structure of the oceans, and results should be achieved within the next decade. The work in underwater sound is of high quality in the theoretical aspects, but apparently there is a deficiency of underwater sound data obtained from strategic oceanic areas for determining or predicting sonar ranging conditions in the areas. This deficiency is recognized, and an extensive effort is expected to be directed at collecting such data at least through the middle of the 1960's.

Neither the theoretical nor experimental work on ocean currents, tides, and waves has been outstanding. Soviet work on oceanographic instrumentation is competent but generally has followed the Western development of devices which the Soviets have modified or adapted as needed. As in the other areas of oceanographic research, however, significant contributions in instrumentation should result during the next decade, increasing throughout the period as Soviet capabilities improve.

Seismology

The Soviet Union has been one of the world leaders in seismology for several years. The recent Soviet politically inspired reports of the alleged simplicity of the seismological detection of explosions and their differentiation from earthquakes have indicated considerable Soviet capability in seismology. Although Western seismologists doubt the complete scientific honesty of the Soviet claims in seismological detection, Western views of Soviet competence in the overall field of seismology have been raised. Basic seismological research that can support the Soviet seismological detection capability is found in virtually every aspect of earthquake seismology, theoretical and laboratory investigations, instrumental work, and explosion seismology. The Soviets have placed high priority on the development of an adequate technique of earthquake prediction to warn the public of the location, intensity, and occurrence of damaging earthquakes. Their inability to accomplish this has led the Soviets, who have numerous severe earthquake areas within their borders, to expand work on tsunamis earthquake mechanisms, interpretation of seismograms, seismicity studies, seismic regionalization, and earthquake-resistant construction in an effort to minimize earthquake losses. Research on all of these areas will continue through 1970, but major achievements will probably be rare. By 1970, the Soviets are expected to have a capability to differentiate reliably between large explosions and earthquakes by seismic means; but reliable and adequate techniques of earthquake forecasting will not be so easily attained.

Geophysical Prospecting

The Soviet objective of attaining maximum independence for supplies of mineral resources and the diversity in the types and occurrence of mineral deposits in the vast territory of the USSR have motivated development of Soviet capabilities in all methods of geophysical prospecting. Their research on seismic, magnetic, gravimetric, geoelectric, and radioactive exploration techniques has achieved for them a position among the world leaders. In the USSR, as in the United States, the seismological prospecting method receives the most emphasis and the Soviets have a good grasp of all the elements needed in seismic exploration. They were among the early developers of aeromagnetic surveying. They now possess a good knowledge of the earth's magnetic field and are conducting research on rock magnetism to interpret better the anomalies found in magnetic fields.

Geoelectric methods of prospecting, including airborne surveys, are emphasized more in the USSR than in the United States. Research is being stressed on methods using alternating and natural electrical currents for prospecting at greater depths below the earth's surface. In gravimetry considerable attention is given to theoretical studies of the anomalies created by models of various geometric configurations and interpretation of geological structures. Laboratory work on the radioactive constituents of rocks and minerals and development of better equipment for aerial surveys of radioactivity are being studied to improve Soviet work in this method of prospecting. Seismology is expected to continue as the major area of Soviet research in geophysical prospecting. Gravimetric, magnetic, and the other methods are expected to receive emphasis in about the same ratio as in the past. Greater emphasis is foreseen on research for better equipment and better interpretation of data.

SATELLITE AND CHINESE COMMUNIST SUPPORT IN BASIC RESEARCH

Meteorology and Hydrology

The USSR has access to all meteorological and hydrological data collected by the Sino-Soviet Bloc countries. In addition, research conducted by these countries is available through the scientific literature and through inter-Bloc scientific conferences. On the other hand, the research conducted by the East-European countries and by Communist China is not outstanding, and the support given to Soviet research is therefore minimal.

Astronomy and Upper Atmosphere Research

Communist China's capabilities in astronomy and upper atmosphere research are currently relatively low, although a beginning has been made by improving facilities and training personnel to fill the large deficiencies in scientific manpower in these areas. In the next 10 to 15 years the Chinese Communists will have made progress but will still be much below the USSR in overall capabilities in astronomical and upper atmosphere research. Therefore, they will be incapable of giving significant support to the Soviets except possibly in a few subfields.

The larger of the European Bloc countries—East Germany, Czechoslovakia, Poland, Hungary, and Rumania—have relatively large astronomical programs, for countries of their size, and have active but smaller programs for upper atmosphere research. Research in these countries is generally competent but is hampered by a lack of funds and, in most cases, by personnel shortages. Some improvements in facilities have been achieved in recent years and much enthusiasm has been displayed, particularly in areas related to space research. Several small programs for rocket sounding are being planned.

In the area of instrumentation, East Germany and some of the other countries have supported the Soviet effort with optical and electronic instruments. Currently East Germany is constructing at least one major (2-meter) optical telescope for the USSR and has built for its own use a large (36-meter) radio astronomical reflecting parabolic dish, a major research instrument. Both East Germany and Hungary have designed and constructed ionospheric research equipment for the USSR.

As a whole, the European Bloc countries are capable of rendering support to the USSR in some specialized areas of instrumentation and in some subfields of research, but their assistance is currently not very significant, because the Soviets in recent years have been able to improve significantly their own capabilities. In observational work, particularly in space vehicle tracking, all of the Bloc countries are supporting the Soviet space program, and their efforts are likely to continue with improved facilities in the future.

Geodesy

For more precise solutions, research problems in geodesy require geodetic data that are worldwide in extent. The proximity of the European Satellite nations and especially the mountainous terrain of Communist China could have considerable effect on the basic and applied aspects of Soviet research in geodesy. The Soviet Union is well aware of the worldwide character of geodesy and in 1952 requested that the European Satellite nations commence work to convert and integrate their geodetic systems with that of the USSR. The situation with respect to Communist China is not clear, but the Soviet Union is expected to request support to connect the geodetic systems of the two nations, if this task has not already been done. The Soviet Union would then have a continuous land network covering 180° in longitude and about 80° in latitude along with data necessary in their research program. Through 1970, support of more direct nature in the form of distance, angle, and gravity measuring instruments is expected to be supported by convenience rather than by necessity. Support to the Soviet Union will probably increase in observing earth satellites for geodetic purposes.

Geomagnetism

With the exception of East Germany, the Soviet Union receives practically no technical support or help in geomagnetism and earth currents research. The East Germans have supplied to the Soviets several specific results of applied and basic research in instruments, which have been significant. Aside from providing data and cooperation in data collection programs, the other Sino-Soviet Bloc countries have provided little or nothing of importance. In reality, the flow of support has been in the other direction, for none of the other countries can match the overall Soviet capability in geomagnetism and earth currents.

Oceanography

The Soviet Union provides more support than it receives from the Satellite countries and Communist China, all of which have low capabilities in oceanography. East Germany furnishes a limited amount of instrumentation, but its contribution has diminished and is expected to continue to diminish because of the establishment of domestic Soviet instrument production facilities. All the countries with coastlines are believed to be acquiring local oceanographic knowledge that may be of military value. Other contributions by the coastine countries to Soviet oceanography appear to be limited to joint surveys and participation in Soviet scientific expeditions. These countries will probably best serve the Soviet Union during the next decade by continuing to concentrate on their local areas, thereby allowing the Soviet Union to concentrate on its local waters and deep-sea research.

Seismology

The Soviet Union does by far the most significant seismological research among the Communist countries and, therefore, furnishes considerable support to Communist China and the East European Bloc countries. The amount of seismological support received in return is negligible. Of the Satellites, East Germany, Czechoslovakia, Hungary, and Poland come the nearest to being self sufficient in seismology. On the other hand, Communist Chinese seismology is advancing the most rapidly, chiefly because it contains earthquake areas that are seismically active.

By 1970, the capabilities in all of the Communist countries will have advanced, but the support aspect by the USSR is expected to remain relatively stable.

Geophysical Prospecting

Little or no support to the USSR in geophysical prospecting research is expected to come from the Chinese Communists through 1970. Support of a minor nature, especially in instruments, can come from the European Satellites, particularly East Germany.

SOVIET EXPLOITATION OF NON-BLOC SCIENCE AND TECHNOLOGY

Exploitation of non-Bloc, mainly Western, science and technology has been a major factor in Soviet progress in the geophysical sciences and closely related fields for a number of years. This exploitation has consisted largely of the use of open literature to obtain information on foreign developments. The Soviet program for exploitation of the foreign open literature is extremely well developed. The magnitude and quality of the effort extended by the USSR to keep its scientists abreast of current developments is probably unsurpassed anywhere in the world. The most important instrument of this effort is the *Referativnyi Zhurnal* (Reference Journal), a series of abstracting publications published by the All-Union Institute of Scientific and Technical Information. These journals carry excellent and often detailed syntheses of the research, including the geophysical, astronomical, and geodetic research of the Sino-Soviet Bloc as well as of the Free World nations. The effectiveness of this program has been demonstrated by the knowledge of Western research displayed by Soviet geophysicists at international meetings and in their other contacts with foreign scientists.

Attendance at international scientific meetings, official scientific exchanges, private visits and tours of foreign scientific installations, and clandestine means have also been used by the Soviets to obtain information of this type. The Soviets have also profited significantly through participation in international scientific programs, such as the International Geophysical Year (1957–58), the International Geophysical Cooperation (1959), and subsequent geophysical cooperative efforts that still are continuing. Through these programs, the Soviet Union has acquired and is continuing to acquire masses of foreign data to supplement its own. Generally, in these international exchanges, the Soviet Union receives much more information than it gives to countries of the Free World.

Purchase of foreign instruments and equipment has been one of the more effective means by which the Soviets have improved their facilities and overall capabilities in geophysics. Although the Soviet Union has made considerable progress in recent years in building up its capabilities in geophysics and related sciences and is no longer as dependent upon the exploitation of Western research as it once was, the profitable exploitation program probably will be continued with little or no diminution for the next 10 or 15 years.

TABLE

OUTSTANDING SOVIET INSTITUTES FOR GEOPHYSICS RESEARCH

Academy of Sciences, USSR

Abastumani Astrophysical Observatory, Mt. Kanobili, near Akhaltsikhe

Crimean Astrophysical Observatory, Partizanskoye

Institute of Acoustics, Moscow

Institute of Applied Geophysics, Moscow

Institute of Astrophysics, Alma Ata

Institute of Geochemistry and Analytical Chemistry imeni V. I. Vernadskiy, Moscow

Institute of Geography, Moscow

Institute of Geology, Moscow

Institute of Geology, Ore Deposits, Petrography, Mineralogy, and Geochemistry, Moscow

Institute of Marine Hydrophysics, Moscow

Institute of Mineralogy and Geochemistry imeni M. N. Lomonosov, Moscow

Institute of Oceanology, Moscow

Institute of Permafrost Studies imeni V. A. Obruchev, Moscow

Institute of Physics imeni P. N. Lebedev, Moscow

Institute of Physics of the Atmosphere, Moscow

Institute of Physics of the Earth, Moscow

Institute of Terrestrial Magnetism, Ionosphere, and Radiowave Propagation, near Moscow (branch in Leningrad)

Main Astronomical Observatory, Pulkovo

Chief Directorate of the Hydrometeorological Service (GUGMS)

Far East Scientific Research Institute of Hydrometeorology, Vladivostok

Institute of Central Forecasting, Moscow

Kazakh Scientific Research Institute of Hydrometeorology, Alma Ata

Leningrad Institute of Hydrometeorology

Main Geophysical Observatory imeni A. I. Voyeykov, near Leningrad

Scientific Research Institute of Aeroclimatology, Moscow

Scientific Research Institute of Hydrometeorological Instrument Construction, Moscow

State Hydrological Institute, Moscow

State Oceanographic Institute, Moscow

Tashkent Geophysical Observatory, Tashkent

Chief Directorate of the Northern Sea Route (GUSMP), Ministry of Marine Fleet

Arctic Scientific Research Institute, Leningrad (with branch in Moscow)

Ministry of Geology and Mineral Conservation

All-Union Scientific Research Institute of Geology, Leningrad

All-Union Scientific Research Institute of Geophysical Prospecting, Leningrad

Central Scientific Research Institute of Geodesy, Aerial Photography, and Cartography, Moscow

Scientific Research Institute of Arctic Geology, Leningrad

Ministry of Higher Education

Leningrad State University

Moscow State University

State Planning Committee (Gosplan)

All-Union Scientific Research Institute of Marine Fisheries and Oceanography, Moscow

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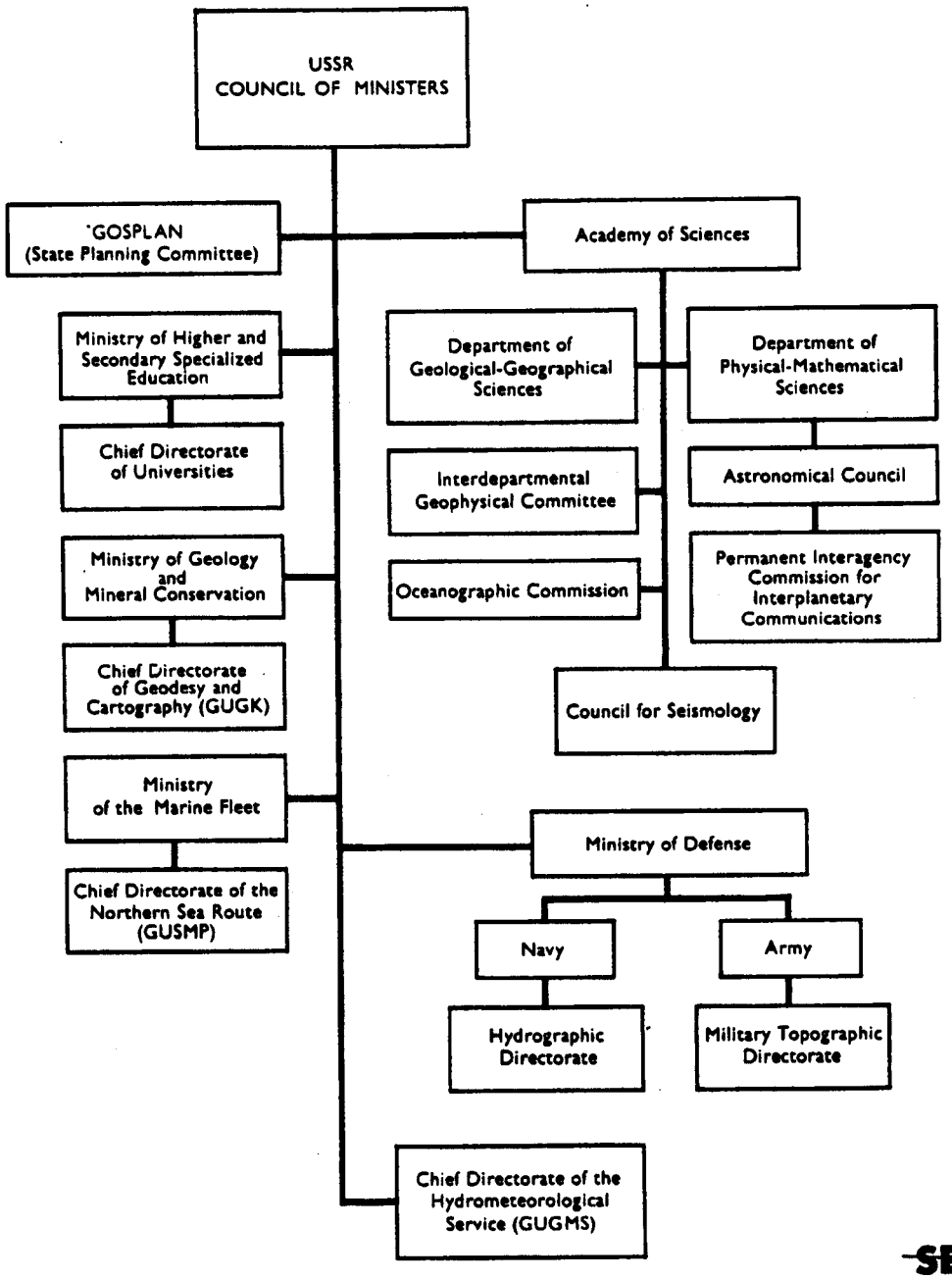
PRINCIPAL SOVIET ORGANIZATIONS CONTROLLING RESEARCH IN THE GEOPHYSICAL SCIENCES



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