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SCIENTIFIC INTELLIGENCE REPORT

THE SOVIET SPACE RESEARCH PROGRAM

MONOGRAPH XI

ASTRONOMICAL ASPECTS

CIA/SI 18-59

15 May 1959

CENTRAL INTELLIGENCE AGENCY

OFFICE OF SCIENTIFIC INTELLIGENCE

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Scientific Intelligence Report

THE SOVIET SPACE RESEARCH PROGRAM

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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 monograph, one of a special series on the Soviet space research program, presents intelligence on astronomy with emphasis on the present and future capabilities of Soviet astronomers to support the space research program.

As discussed herein, Soviet astronomy as a whole and its subfields are reviewed and evaluated separately. Further, the support given by European Bloc countries and Communist China to the Soviets is discussed briefly. For the benefit of nontechnical readers, an appendix presents a short general explanation of the relationship of astronomy to space research. The latest information utilized in this report is dated March 1959.

The complete series of 12 monographs on the Soviet space research program is listed below. Monographs II through XII are designed to support the conclusions found in Monograph I, which is an overall evaluation of significant Soviet space research capabilities. Monograph I will be published last.

Soviet Space Research Program:

MONOGRAPH	TITLE
I	Estimate 1959–74
II	Objectives
III	Organization, Planning, and Control
IV	Space Vehicles
V	Propulsion System
VI	Guidance and Control
VII	Telemetry, Communications, and Reconnaissance Instrumentation
VIII	Ground Support Facilities
IX	Space Medicine
X	Space Biology
XI	Astronomical Aspects
XII	Current Status of Progress

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THE SOVIET SPACE RESEARCH PROGRAM

MONOGRAPH XI
ASTRONOMICAL ASPECTS

SUMMARY AND CONCLUSIONS

The Soviets are in a position to give strong astronomical support to their space program, and they are taking steps to insure that their work in astronomy will meet future space requirements; they are also able to exploit the space program for the advancement of astronomy and related sciences, particularly physics and geophysics, and thereby derive many practical benefits.

In the Soviet Union, the Astronomical Council of the Academy of Sciences, USSR, plans, organizes, and supervises the astronomical research of a large and expanding network of observatories and institutes. Organizationally subordinate to the Astronomical Council is the Interagency Commission for Interplanetary Communications, composed of high-ranking Soviet scientific, technological, and military leaders. This commission is officially charged with the solution of problems of the national space research program, the first one of which was the launching of artificial earth satellites. Sputniks I, II, and III and other space research rockets are ample evidence that the Commission is carrying out its assigned task in a competent manner.

Soviet astronomy is being expanded rapidly. The training program has produced relatively large numbers of well qualified astronomers; but observatories are somewhat underequipped because of a lag in the construction of large and modern instruments. Steps are underway to overcome this situation, including plans for new equipment which, if successfully carried out, may result in facilities surpassing those of leading Western nations. The Soviets have already made significant advances in the development and production of image infrared and other types of photoelectric image converter tubes for astronomical use, as well as diffraction gratings, spectrographs, and coronographs. Soviet application of television techniques to optical astronomical observations appears to be another promising development, although not an original one.

The Soviets are very competent in practically all of the sub-fields of astronomy having direct significance to present and near-future space programs, including celestial mechanics, meteor and meteorite research, studies of the moon and planets, radio astronomy, solar physics, and solar-terrestrial relations. Soviet astronomers have achieved outstanding accomplishments in several other sub-fields—comet research, cosmogony, positional astronomy, stellar photometry, time research, and variable star studies—most of which are of potential significance to long-range space plans. The Soviets appear to be weakest in the area of stellar physics, a sub-field of little

direct significance to space research. They are handicapped somewhat by the lack of a permanent astronomical observatory in the Southern Hemisphere. Steps to remedy this situation may be expected.

The current progress and high potential of the USSR in celestial mechanics and radio astronomy are especially significant and could lead to future Soviet leadership in these fields. Recent Soviet emphasis upon research on the moon and planets points to a well coordinated program to furnish astronomical support to the national space program.

In the application of optical astronomical techniques to the tracking of satellites and other space vehicles, the Soviets are very competent. They have shown considerable resourcefulness in adapting their astronomical telescopes and aerial reconnaissance cameras to rocket and satellite tracking, but they lack a world-wide optical system comparable in quality and extent to the U.S. Baker-Nunn camera network. Recently the Soviets have ceased their efforts to purchase U.S. tracking cameras. There are indications that they are working on plans to produce improved instruments of this type. There is no evidence that they possess large versatile fully-steerable parabolic radio astronomical telescopes comparable to those of the West. Instead, the Soviets seem to be more dependent upon non-astronomical radio and radar tracking techniques. Satellite observations from foreign countries, including the United States, have been of considerable assistance to the Soviets.

Communist China and the European Bloc countries support the Soviet space program by satellite observations and some theoretical and technological work. Communist China is rapidly expanding its astronomical facilities. East Germany, Czechoslovakia, and Poland, in the order named, have the highest support capabilities in the Sino-Soviet Bloc at present.

DISCUSSION

REVIEW OF TOTAL SOVIET ASTRONOMICAL EFFORT AND CAPABILITIES TO SUPPORT THE SPACE PROGRAM

Background

From 1917 to the 1930's astronomy in the USSR was conducted on an uncoordinated basis. In the 1930's, a reorganization of scientific research took place, and planned educational programs were established. Foreign books were translated into Russian for use as texts, and shortly thereafter the Soviets were producing their own educational literature. Both World Wars caused great destruction of astronomical facilities. Within the past several years the Soviets have fully rebuilt the observatories destroyed in World War II and have inaugurated large effective astronomical training and research programs.

Administration of Soviet Astronomy

In the USSR, astronomical research is planned, organized, and supervised by the Astronomical Council of the Academy of Sciences, USSR. The Council, composed of leading scientists, appears to be a powerful body with the full backing of the Soviet government and with a large and expanding network of observatories and research institutes under its direction.[1 p.166-170] (See appendix B.)

Administration of the Soviet Space Research Program

The Astronomical Council, through its subordinate organization, the Interagency Commission for Interplanetary Communications (ICIC), apparently plays a leading role in the Soviet space program. The ICIC, formed in 1954 or earlier, is made up of outstanding scientists from the fields of astronomy, mathematics, physics, geophysics, and chemistry, as well as specialists from the fields of engineering, computers, automatics, communications, ordnance and rocket technology. (See appendix C.) The names of such members as Sedov, Kapitsa, Blagonravov, Pobedonostsev, and Masevich, if not known abroad previously, have become familiar to most persons interested in space activities.[8 p.7] There is a possibility that the ICIC wields such influence and power that it is practically independent of its parent organization, but the number of astronomers among its members probably results in close coordination of the rocket programs with the Astronomical Council. The military is well represented on the Commission.

The ICIC is charged officially with the solution of problems in astronautics. According to the statement announcing the formation of the ICIC, its first task was to organize the work of building a "laboratory in space" (a research satellite).[3 p.333-334] The first three Soviet Sputniks and other research rockets presented ample evidence that the Commission is carrying out its assigned task in a capable manner.

Magnitude of Soviet Astronomical Effort

The Soviet astronomy program is being expanded at an increasing rate by the government. Training programs have been enlarged and the number of applicants for advanced degrees in astronomy is increasing. In late 1958, the staffs of Soviet observatories were approximately five or six times as large as those of any other nation. The staff of Pulkovo Observatory, largest in the USSR, is estimated to number about 400 people, in contrast to the staff of some 50 to 60 persons at the largest U.S. observatory. Soviet observatories are overstaffed in relation to present instrumental research facilities. As a result, many of the young astronomers are working on routine rather than significant astronomical problems. Recent emphasis upon new equipment (see next section) indicates that the Soviets are taking steps to remedy the present situation.[2 p.2-3]

Since the 1930's over 5,000 Soviet papers and books on astronomy have been published. This number represents approximately 25 percent of the world total of astronomical publications. Soviet publications in astronomy have been appearing at an ever increasing rate since World War II.[2 p.3]

Significant Instrumental Developments and Plans

The Soviets have announced plans for two large new telescopes. One, a 102-inch reflector of 33-feet focal length, will be installed at the Crimean Astrophysical Observatory, near the village of Partizanskoye (about 20 miles southwest of Simferopol', 44°58'N, 34°05'E). According to Soviet reports the telescope, being made by the State Optical Institute, Leningrad, will be "one of the most precise instruments of our times." A tower as high as a 10-story building with a dome 66 feet in diameter is under construction to house the telescope.[4] Soviet plans call for the completion of the installation by the end of 1959.[5] The second large Soviet telescope, planned to be the largest in the world, is "in the early stages of consideration." In August 1958, surveys of possible sites were reportedly being started in several locations, including central Asia. Present plans call for a 236-inch (6-meters) instrument to be completed by 1973. Some reports have indicated that rather than use glass, the Soviets will use a stainless steel mirror, polished with chrome oxide and coated with aluminum.[5]

There is little doubt that not only science but national pride and propaganda interests are being served by the Soviet plans for large telescopes which, if successfully completed, will just exceed in size the famous 100- and 200-inch U.S. telescopes, the latter the largest in the world.

In the field of radio astronomy, the Soviets have grandiose plans also, including a proposed radiotelescope antenna 3,281 feet in diameter, consisting of a circular array of 400 tiltable elements, each 66 x 98 feet in size. The proposed antenna would be modeled after the much publicized Pulkovo radiotelescope, itself often reported erroneously as the largest in the world.[6 7]

Another Soviet claim concerning plans for the construction of the large-scale model of the present Pulkovo radiotelescope gives its proposed collecting area as 100,000 square meters (as contrasted to 240,000 square meters in other reports) for operation on 20-centimeters wavelength at a location in the Caucasus, probably at the branch Mountain Station of Pulkovo near Kislovodsk.[11] Just how seriously the Soviets are considering this antenna has not been determined. If completed, its size would be enormous, and it would represent a scientific and engineering achievement of considerable magnitude. Some alterations in the design of a Pulkovo-type antenna would permit satellite and space vehicle tracking. Such an arrangement might be more powerful but less versatile than the large fully steerable paraboloidal radiotelescopes available or planned in the West.

Foreign delegates to the 10th General Assembly of the International Astronomical Union (IAU), Moscow, 13–20 August 1958, noted that the Soviets had achieved a highly advanced development of photoelectric image converter tubes. These tubes, on small optical telescopes, were producing results comparable with the best obtainable in the United States with much larger instruments according to some reports. Some of the Soviet image tubes were obviously copies of Western developments, but the better tubes had a unique feature, a mica "window." These tubes had the advantage of simplicity and practically unlimited life. But they had the disadvantage of somewhat low resolution. The Soviets have displayed excellent photographs of the infrared night sky spectra obtained from spectrographs using special image tubes constructed by V. I. Krasovskiy.[8,9,10]

Other significant astronomical instrumental developments noted in the USSR in recent months include the production of high-quality diffraction gratings and spectrographs.[5,12,13] At the Main Astronomical Observatory, Pulkovo, the achromatic coronograph appeared to have advantages over Western instruments, and the application of television techniques reduced the exposure time required for photography with optical telescopes, the latter a promising but not an original Soviet development.[14,15,66]

Soviet emphasis on planned large and modern astronomical instruments reflects their present deficiency in this respect as compared with leading Western nations. In the past, the Soviets have had to depend upon Western data from large instruments, and they have concentrated upon theory rather than observational work. Lack of large and modern instruments has caused the USSR to lag in such fields as stellar spectroscopy, photometry, and the study of faint extra-galactic light. Their progress in astronomical instrumentation has been surprisingly rapid in the past year or so and promises to place them in a much stronger position within a few years.[10,17] (See also section on Astronomical and Satellite Tracking.)

Overall Capabilities to Support the Space Program

In an assessment of the capability of the Soviet Union in astronomy, the fact that astronomy cannot be distinctly separated from some other sciences, such as mathematics, physics, and geophysics, must be considered. Furthermore, astronomy is dependent upon the technology of other areas of research, such as instrumentation and computation. In such a situation, cooperation or coordination of the work in different specialities is of great importance; here, the Soviets seem particularly well organized.

The Soviets have started to place more emphasis on the quantity and quality of instruments and equipment. In fact, their progress within the past few years has been outstanding, even though based in large part on copying and improving upon Western instruments and exploiting Western scientific literature. It is believed that the effect of improved instrumentation and the impact of many young, competent enthusiastic astronomers will place the USSR on a par with leading Western nations within the next 5 to 10 years.[2 p.3] Conceivably, the Soviets could forge ahead thereafter.

Recent events have demonstrated that Soviet astronomy is adequate to fill the current practical needs of the USSR; and the Soviets are known to be taking steps to insure that their work in astronomy will meet future requirements. It is apparent that the Soviets are in a position to give strong astronomical support to their high-priority space program, and that they can exploit the space program for the advancement of astronomy and related sciences, particularly physics and geophysics.[2 p.4]

SPACE SIGNIFICANCE OF SOVIET CAPABILITIES IN ASTRONOMY BY SUBFIELDS

Celestial Mechanics

The nature of celestial mechanics makes knowledge of the field a very valuable asset to a country engaged in an astronautics pro gram. Knowledge of the laws of motion of a vehicle in orbit are necessary for tying in scientific measurements to points in space, forecasting the vehicles' position, planning the operation of scientific equipment, determining the lifetime of the vehicle, and for certain geophysical problems, such as revealing and accurately defining anomalies in the earth's gravitational field and determining density distribution in the atmosphere.

The quality of research on celestial mechanics in the USSR is good and is considered equal to the quality of work in the United States; nevertheless, the USSR has more people of demonstrated ability working in the field and therefore has a greater potential for advances. The Soviets have been placing emphasis on celestial mechanics since the 1930's.[2 p.5 68]

In their Institute of Theoretical Astronomy, Leningrad, the Soviets have the world's largest institute devoted almost exclusively to celestial mechanics research. The institute has a permanent staff of from 80 to 100 professional and technical people.[2 p.6]

In addition to applying and refining classical theory, the Soviets have devoted considerable effort to the comparatively new fields of stability, variable mass, and capture, as well as to new developments in the qualitative methods used in connection with the restricted three-body problems. This emphasis on new fields and methods may develop a Soviet lead in some important modern branches of celestial mechanics.[2 p.6]

Soviet work in celestial mechanics indicates a close connection between that activity and the space flight plans of the USSR. For example, the Soviets worked intensively from 1953 to 1955 in a systematic investigation to find satisfactory solutions for the fundamental problems in the theory of flight to the moon. Furthermore, an article published in November 1957 by V. A. Egorov* of the Steklov Mathematics Institute, Moscow, entitled "Some Questions on the Dynamics of Flight to the Moon" disclosed that more than 600 trajectories were calculated by means of electronic computers in order to find solutions to the problems (i) of the form and classification of unpowered trajectories, (ii) of the possibility of periodic circumflight of the moon and the earth, and (iii) of hitting the moon. The paper also dealt with the important question of the effect of the dispersion of initial data on the realization of impact or circumflight.[20 21] Egorov's work, as well as other Soviet unpublished celestial mechanics research, probably was utilized in the launching of Lunik on 2 January 1959. Lunik, of course, was not a complete success as a lunar probe but continued on to become the first probable artificial planet in orbit around the sun. Soviet celestial mechanics experts, by their work on Sputniks I, II, and III and Lunik, have demonstrated that they have the ability to apply in a very practical way their theoretical knowledge in support of the national space program.

*Also transliterated as Yegorov.

Comets

Comets, large units of the solar system, generally move in very elongated elliptical orbits. Comet heads, or nuclei, probably consist of solid parts, but the tails are made up of very small particles, probably gaseous. Possibly the most significant aspect of the study of comets is to obtain an understanding of the physical processes involved in their formation and existence that may prove to be of importance to basic physics. Due to the vastness of space, the avoidance of comets is not a serious problem in space flight but the problem should receive some consideration.

The Soviets clearly lead the world in observational and theoretical work on comets. The number, extent, and quality of Soviet publications on this subject greatly exceed those of other countries.[2 p.11] The only phase of the study in which they lag is in spectroscopic work. Leading Soviet workers in the field are S. K. Vsekhsviatskiy, S. M. Poloskov, B. Yu. Levin, A. D. Dubiago, O. V. Orlov, and B. A. Vorontsov-Vel'iaminov.

Cosmogony

Cosmogony, the study of the origin of the universe, and its companion field, cosmology, the study of the character of the universe as an orderly system, probably have little connection with astronautics in its present state. A knowledge of the character of the universe beyond the solar system may be useful to future space explorers, however, and an understanding of the processes involved in the origin of the universe, particularly those involved in stellar evolution, could result in advances in physics and thus, indirectly, in astronautics.

The Soviets have made solid contributions to the total progress of cosmology, principally through the efforts of V. A. Ambertsumian and his followers in the field of stellar associations and the alleged observational proof by Fesenkov and Rozhkovskiy of the formation of stars out of diffuse nebulosity. There seems to be no question that the Soviet cosmogonists have put forward a well-substantiated theory, remarkable in its documentation and thorough development. It differs from theories of Western cosmogonists in having a substantial observational basis which is constantly being enlarged by systematic efforts. The whole structure of Ambartsumian's theory was developed on the basis of Western data, but recently a large observational program aimed at confirmation of the theory was initiated at the Crimean Astrophysical Observatory. Although Ambartsumian's work has not been fully accepted by Western astronomers, it has elevated him to a position of high esteem in the profession.[1 p.41-44] [2 p.11]

Meteors and Meteorites

The number, location, and size of meteors in space are of prime concern to the operations of space vehicles. Both the United States and the USSR have included instrumentation in their artificial earth satellites to measure the frequency and energy of impacting meteor particles. Meteors enter the earth's atmosphere with cosmic velocities and produce various phenomena, particularly meteor trails, from which can be derived information relating to the upper atmosphere and space. Of special interest is the similarity between formulas describing the motion of rockets and meteors. Theoretical work on the motion of a body of diminishing mass is applicable to both meteors and rockets. Foundations of this theory were developed by the Russian mathematician Mescherskiy in the early 1900's.[1 p.38] Meteor and meteorite studies may be connected with the recoverable capsule or the ICBM reentry problem. At present, meteorites are the only cosmic substances which can be studied by laboratory methods, therefore they offer a means of studying the chemical content, radioactivity, and magnetic qualities of other natural bodies in space.

The Soviets appear to be very active and competent in the fields of meteors and meteorites and have produced a large body of literature. Some of their work is not published openly because of its connection or possible application to significant upper atmosphere and communications research or rockets and missile developments. According to a former Soviet astronomer who remained in Germany after World War II, his studies of meteors were classified secret as early as 1939.[1 p.38]

Only recently have the Soviets identified programs within the USSR that are concerned with the investigation of meteors by modern techniques, such as meteor cameras and radar. It appears that the Soviets have made considerable progress in the development of equipment, one example being a very promising meteor camera which may be of importance in the photographic observation of artificial earth satellites. This device is described in the Soviet *Astronomicheskiy Zhurnal* (Astronomical Journal), Volume 35, 1958.[36] A recently translated 1952 Soviet article reports the development of a highly sensitive meteor detection device which has been operating since 1948. The author claims good correlation between photographic, radar, and visual detection of the passage of a meteor with a short-period, small-amplitude pulse variation of the vertical component of the earth's magnetic field, the latter indicated by the meteor detection device which consists of a large induction loop, approximately 3,281 feet in diameter, and a highly sensitive fluxmeter. A subsequent Harvard College Observatory experiment failed to verify this correlation.[65]

Soviet studies of meteorites that have fallen in territory under the control of the USSR have impressed Western observers as being extremely careful and detailed. Expeditions organized by the Soviet Academy of Sciences have been very impressive and expensive. For instance, the Academy undertook four separate expeditions between 1947 and 1950 to the site of the Sikhote-Aline meteorite which fell on 12 February 1947. Results of work on the vast project were being published as late as 1954. The information uncovered in this thorough study is similar to that needed for the recovery of an ICBM or space vehicle.[27]

The leading Soviet workers in the fields of meteors and meteorites appear to be V. G. Fesenkov, I. S. Astapovich, B. Yu. Levin, Ye. L. Krinov, V. V. Fedynskiy, and K. P. Stanyukovich.[1 p.76-87, 26, 28] Soviet International Geophysical Year observations of meteors were concentrated at Kharkov in the Ukraine, Kazan on the Volga, Tomsk in Siberia, and Stalinabad in Central Asia.[29] The Soviets have publicized their "meteor patrol," (meteor photographing camera) at Stalinabad Astronomical Observatory. The Institute of Physics and Geophysics of the Academy of Sciences of the Turkmen SSR, Ashkhabad, is another leader in meteor studies while the Institute of Astrophysics, Alma Ata, has recently engaged in meteorite searches.[30, 31]

Moon and Planets

Studies of the moon and planets dealing with their motions, the physical characteristics of their surfaces, and their internal structures are of considerable importance in space research and will be of increasing interest as capabilities are approached for manned lunar or interplanetary expeditions. Knowledge of the atmospheres of the planets is equally important. While many facts about the moon and planets have been deduced by scientists in the past, it is probable that observations from artificial satellites and space probe missiles will increase human knowledge considerably before landings are attempted by manned space vehicles. These observations will utilize astronomical and reconnaissance techniques, such as TV systems which telemeter data back to earth. The Moon, Mars, and Venus, our nearest large neighbors in the solar system, appear to be the most logical targets for early visitation; but less is known about Venus, the nearest planet, than Mercury. This has resulted from the dense atmosphere of Venus and other factors.

In spite of the fact that the Soviets have paid much attention to the physics of the moon and planets, the major discoveries in this area in recent years have been made by the West, mainly by the United States. Most Soviet activity has been expended in studying the surface features of the moon and planets. Soviet concentration on this work can be explained by the fact that such studies do not require elaborate equipment and good results can be obtained with small telescopes.[2 p.10]

There are indications that the Soviets stepped up their research on the moon and planets recently. Professor Mikhailov, Chairman of the Astronomical Council of the Academy of Sciences USSR, in reviewing Soviet astronomical work during 1958, said on 21 January 1959 that Soviet scientists are successfully carrying out "great" research into the problems of the moon and Mars. He indicated that interesting results have been obtained with the aid of spectrophotometric observations with the 50-inch reflector of the Crimean Astrophysical Observatory. Mikhailov said that in 1958, Pulkovo and Abastumani Observatories for the first time in the Soviet Union used thermoelectric methods to measure the temperature of the narrow zones of the lunar surface and that measurement of the polarization of the light of the moon is now being carried out. Other progress mentioned includes the fact that Kharkov Observatory has begun six-color photography of Mars and the discovery by Nikolai Kozyrev of volcanic activity on the moon.[32] Kozyrev's reported discovery, if verified, will add considerably to the Soviet Union's reputation in astronomy.

Systematic photographic observations of the moon were reportedly started at Pulkovo in 1956, the stated objective being the study of irregularities in the earth's rotation. The result of this study may be useful in the solution of various problems related to astronautics. For several years a group of Soviet astronomers and biologists under G. A. Tikhov at the Astrobotanical Laboratory, Alma Ata, has been actively studying the problem of life on other planets, principally Mars. Reportedly, since January 1958, this group has been working on the problems of supporting human beings in sputniks.[2 p.10 51]

All of these activities point to a well coordinated program to furnish astronomical support to the Soviet space program. There is little doubt that the Soviet rocket "Lunik," launched on 2 January 1959, was intended to impact on the Moon or to come closer* than it did, considering advance statements by Soviet newspapers** and astronautical experts,*** the significance of the name Lunik,**** the scientific experiments planned, and the metal sphere on board which was composed of specially designed and marked segments intended to break apart upon impact and leave evidence of the first rocket to strike the moon.[33] The Soviets were clever enough to change the name of the rocket and to cease their emphasis on its lunar research mission after it became apparent that the desirable proximity to or impact on the moon had not been achieved.

Positional Astronomy, Navigational Astronomy, and Time Research

The subfields of positional astronomy, navigational astronomy, and time are considered together because of their many interrelations and their close connections to geodesy and space navigation. The accurate measurement or calculation of time is necessary in both positional and navigational astronomy. All three are important in space flight, since the location of the launching or take-off point, the orbit, the destination, the position of natural bodies in space, and the time factors must be known to a high degree of accuracy.

The Soviets are very strong in positional astronomy, which consists of the study of the motions of the earth's poles, variations of latitude and deviations of the vertical, as a result of a long tradition of work in the field and the fact that their instrumentation is quite adequate for the purpose. The USSR has a network of at least seven stations for the study of the variations of the pole. Some large programs are under way in Soviet positional astronomy; one of these, the preparation of a catalogue of faint stars, may be of importance in the future. The Soviets are handicapped in this work by their inability to observe the southern stars, and some steps toward the establishment of a permanent Soviet observatory in the southern hemisphere may be expected.[2 p.13] Leading Soviet workers in positional astronomy include A. N. Deutsch, D. K. Kulikov, M. S. Zverev, and E. Ya. Bugoslavakaya.[1 p.66]

The Soviets have published several books since 1957 on the fundamentals of the theory and practice of applying astronomical means to navigation for determining position and direction by celestial means. Among the subjects discussed have been the future of astronomy in interplanetary voyages, guided missiles, and rockets.[35] Some of the leading figures in navigational astronomy appear to be Colonel M. V. Zakharov, A. P. Belobrov, N. Ya. Kondrat'ev, A. B. Marinbakh, R. V. Kunitskiy, and S. V. Gromov.[1 p.67]

Soviet work on the subject of time has been much more extensive, perhaps, than that of the entire Western world but the time system of the Soviet Union is probably less accurate than that of the United States and the United Kingdom. The Soviets have a network of time stations (12 in the USSR alone, plus some in the Bloc countries, as contrasted with 2 in the United States). The ultimate significance of this extensive network will be dependent upon correlations yet to be established between the variable rate of rotation of the earth and its possible connection with geophysical, astronomical, and geodetic phenomena. The Soviets have indicated that they plan to use artificial earth satellites to verify the theory of relativity; this program may shed some light on the nature of time itself. There is some activity in the construction of quartz and atomic clocks, and the Soviets claim that their instrumentation is at least as good as that of the West.[2 p.13] N. N

*The rocket reportedly missed the moon by at least two moon radii. It would have been desirable to approach within one moon radius—1,080 miles for scientific purposes.[34]

**For example, the Young Communist League paper *Moskovskiy Komsolets* and the Soviet Navy's Newspaper *Sovietskiy Flot* of 5 December 1958.[34]

***Dr. Yuri Pobedonostsev, Soviet satellite expert, stated that on 5 December 1958 a Soviet Moon shot was ready.[34]

****"Lunik" is a coined word, a play upon the word "sputnik," apparently meaning a little moon or a moon satellite.

Pavlov and M. S. Zverev appear to be among the leaders in the time research.[1 p.69]

Radio Astronomy

Radio astronomy is a relatively new scientific field having its origin in the United States and involving the cooperative effects of astronomers and radio engineers. Prior to 1955 the Soviets utilized only Western data in their published radio astronomical papers and even denied that they had radiotelescopes although there is evidence now that such instruments were in operation in the USSR at an earlier date.[22]

There are numerous groups of Soviet radio astronomers, most of them very active and very eager to surpass Western efforts. The number of people in the USSR working on radio astronomy is believed to be much greater than in the United States, perhaps in the ratio of 4 to 1. The development of Soviet radio astronomy has been in terms of work with large fixed or semi-steerable telescopes, rather than with fully steerable parabolic mirrors or "dishes," such as are often used in the West. The Soviets have at least 25 radio astronomical installations.[2 p.8] (See appendix B.)

The largest Soviet equipment at present is the new interference telescope at the Byurakan Astrophysical Observatory, near Yerevan, at the foot of Mount Aragats. The antennas of the radiotelescope are "parabolic cylinders" with a total receptive area of nearly 48,438 square feet. The Soviets claim that soon they will increase this to 107,639 square feet. The radiotelescope is to be used for "research into the nature of radiation, the distribution in space of weak, discreet sources of cosmic radiation, and general radiation of the sun in the metric range of radio waves."[23 24]

The second largest Soviet radiotelescope is the much publicized Pulkovo installation, consisting of an array of 90 reflecting plates about 5 x 10 feet each. At present there is probably no antenna in the world that can compete with this instrument for making 3- and 10-centimeter wavelength measurements of small sources of radio emission on the disk of the sun.[6 7 11] Members of the Pulkovo (Main Astronomical Observatory, Leningrad) group are outstanding in their speciality, and the intensity of their drive is great, according to Western astronomers who have visited the observatory. The Soviets have a large number and a wide variety of other antennas; and they have plans for a much larger radiotelescope than any now known to exist or to be planned in the world. (See "Significant Instrumental Developments and Plans.")[11 24]

In the field of antenna design and instrumentation for radiotelescopes, the Soviets at present appear to be behind the United States and the remainder of the West, particularly in the design and construction of the very versatile, large, fully steerable parabolic reflectors on astronomical mounts. The Soviets at present have no known radio astronomical telescopes comparable to the great 250-foot fully steerable dish of the University of Manchester at Jodrell Bank, U.K., nor to the 300-foot dish planned by the U.S. Air Force, both instruments with excellent satellite tracking capabilities.[11]

In the field of theoretical radio astronomy, the Soviets are extremely competent. I. S. Shklovskiy and V. L. Ginsburg were the pioneers in bold and often correct speculations as to the origin and nature of radio waves from our galaxy and beyond. Their creativity is of the highest order.[11]

Much of the radio astronomical research of the USSR could have direct application to space travel by furnishing information on the environment through which space vehicles must travel and the celestial bodies which may eventually be visited or which must be avoided. Radio astronomical techniques also appear most promising for space communications and are useful in satellite tracking. The potential physical discoveries of radio astronomy may also play an important part in space exploration. Soviet studies of high-velocity shock waves in supernovae and other sources of cosmic radio emissions, also studies of interstellar polarization of light, are connected with the synchrotron phenomena and magnetohydrodynamics which, in turn, are closely connected with the problem of controlled nuclear reactions. These Soviet studies could assist in the development of a means of propulsion to fit the needs of space travel, that is, a means which minimizes the masses necessary in space vehicles.

Solar Physics and Solar-Terrestrial Relationships

Studies of solar physics and solar-terrestrial relationships comprise one of the most rapidly developing sections of astronomy in the Soviet Union. The Soviets are studying all aspects of these areas, from the theory of solar processes to the effects of the sun upon the earth and its atmosphere. Soviet effort in these areas is expanding in terms of both number of workers and amount of equipment. In the period 1955 to 1957, the Soviets published more than 300 papers on solar physics. Many of these were trivial, but nevertheless the numbers point to considerable emphasis upon the study of the sun.[3 p.4]

The USSR has good solar theoreticians. The main deficiency has been in the area of instrumentation. Even here, Soviet instrumentation is good and is improving both in quality and in quantity. The Soviet Sun Service, a network of observatories systematically studying the sun according to a regular program, is well organized but the quality of its equipment is generally below U.S. standards. One advantage held by the USSR in solar work is its great extent in longitude allowing Soviet astronomers to follow the sun during the major part of a 24-hour period (taking into account cooperation by Bloc countries).[3 p.4]

At the 10th General Assembly of the International Astronomical Union, Moscow, August 1958, probably the most outstanding new result in the field of solar astronomy presented at the meeting was A. B. Severnyy's studies of solar magnetic fields. His new techniques of mapping fields in active areas has shown that a marked reduction in the field, and therefore, presumably, in the electric current, takes place during a solar flare. The results are in accord with independent, though less extensive surveys made by a Western scientist.[18] Severnyy is director of the Crimean Astrophysical Observatory, about 20 miles from Simferopol, which has an advanced solar observatory and probably the only productive magnetograph in the USSR at the present time, though others are under construction. Foreign observers have evaluated the solar work at Crimea and at the Sternberg Institute, especially in those areas leading to the physical understanding of solar and associated problems in gas dynamics, plasma physics, and other disciplines as being on a par with the work at leading Western centers. The Soviet work has been judged outstanding in terms of the fertility of the minds of the people working in the field in producing new ideas and results.[18 19] (See also section on Radio Astronomy.)

Soviet work in solar physics is of considerable significance from the space flight point of view, since much can be learned regarding solar radiation and the effect of the sun upon the environment in which space vehicles will operate throughout the solar system. Solar studies also may result in fundamental physical discoveries and in increased knowledge of the geophysical processes of the upper atmosphere.

Stellar and Interstellar Astronomy

As in some other astronomical fields, little of direct application to present and near-future astronautics is to be expected from Soviet activities in stellar and interstellar astronomy. The most promising potential benefits to future space flight activities appear to be increased information on the dynamics and physics of the stars and interstellar matter. Increased knowledge of the internal physics of the stars, in particular, may lead to advances in nuclear physics or developments of a similar fundamental character such as the discovery of new sources of energy which may have widespread benefits, including those to space flight.

Stellar physics has been the weakest area in Soviet astronomy, primarily as a result of the lack of the great telescopes required for such studies. The situation is likely to be changed appreciably in the near future, considering the present Soviet radio astronomical, image-tube, and large optical telescope programs. The USSR has several able theoreticians whose attention is concentrated on those matters, but their contributions up to th present time have been for the most part based on Western, and primarily U.S., data.[2 p.11]

In subfields not requiring large instruments, the Soviets have risen to a place of leadership in recent years. Thus, the USSR has become preeminent in stellar photometry and is the center for variable-star study, publishing more on variable stars than the rest of the world combined. Leading theoretical workers in the interpretation of stellar variability are B. V. Kukarkin, P. P. Parenago, and B. A. Vorontsov-Vel'iaminov.[1 p.45]

Other leading Soviet astronomers in the field of stellar physics include V. V. Sobolev and V. A. Ambartsumian, the latter probably the most outstanding.[1 p.46] Among the competent workers in interstellar astronomy are V. I. Krasovskiy, V. G. Fesenkov, P. P. Dobronravin, S. A. Kaplin, and G. A. Shain.[1 p.160-162]

Astronomical and Satellite Tracking

The Soviets have made rapid progress in astronomical optics in the past few years. Typical of the statements made by Western scientists, who attended the Tenth General Assembly of the International Astronomical Union held in Moscow in August 1958, is the following, "The Soviet cameras used in astronomical research struck me as being extremely elaborate and of a much more highly complicated mechanical and optical nature than I would have considered them capable of developing on the basis of my previous trip and knowledge. They have become very sophisticated in this field in a surprisingly short time."[37] The Soviet exhibit at the Brussels World Fair in 1958 showed a very impressive collection of optical glass. Although one Soviet astronomer admitted that these glasses were exhibition pieces not readily obtained in the USSR, they clearly demonstrated Soviet capability to produce high quality optical glass whenever they so desire.[5]

In the USSR, so-called visual (Moonwatch) observations of artificial earth satellites were organized by the Astronomical Council of the Academy of Sciences, USSR. The Soviet program, under Mrs. Alla G. Masevich, is very similar to the U.S. Moonwatch program organized for the International Geophysical Year. The Soviets claim that about 3,000 students, instructors, and others—mostly at universities—participate in the program at about 70 stations. Each station is equipped with 30 small telescopes (Soviet Model AT-1*). These telescopes, somewhat like the U.S. Moonwatch instruments, are 6-power, 50-millimeter aperture, and have a field of vision of nearly 11 degrees. Time signals are broadcast or telephoned to the stations, but there is a program to equip them with contact chronometers, systematically checked by radio, and to designate the instant of passage on magnetic recorders.

The visual observations were designed to record within 0.5° to 1.0° and from 0.5 to 1 second the position of a satellite. In the experience of the Soviets, the error in determining the position of the satellite often is less than 1° and the time error at the best stations is 0.2 to 0.3 second but is generally around 0.5 second.[38 39]

The purpose of the visual observations is to make an approximate determination of a satellite's orbit. Positions obtained from visual observations are very useful in the calculation of ephemerides. Visual observations are communicated by telegraph to the Research Institute of Terrestrial Magnetism, Ionosphere, and Radiowave Propagation (NIZMIR), near Moscow, where calculations are made for the Soviet ephemeris service.[70]

Most photographic observations of the early satellites were made with very simple cameras. Mrs. Masevich exhibited pictures of a simple tracking camera which appeared to be worth about $250.00. In precision these cameras compare with visual observations. The Soviets have concluded, however, that when the satellites are sufficiently bright, these cameras are more reliable than visual observations.

In March 1958, 24 stations for photographic observations of satellites were organized. Later, this number was increased to at least 27. The stations were located mainly at astronomical observatories and at some visual stations equipped with time service. These photographic stations were equipped with wide-

*The Soviets distributed many of these especially designed telescopes to Bloc countries for artificial earth satellite observations.

angle air survey (aerial reconnaissance) cameras of 10-centimeter aperture, 25-centimeter focal length, and about 30° field. The Soviets had found that by modifying the shutters of powerful air survey cameras they could be used for photographing satellites brighter than the third stellar magnitude. The action of the air survey camera shutters is recorded on a chronograph. These instruments make it possible to determine the position of satellites with an accuracy of about 6 minutes of arc; but, under favorable conditions, greater precision is attained. The Soviet observational network, including visual and photographic stations, enables the USSR to give ephemerides data on the passage of a satellite with a claimed accuracy of 1° or 2°.[38 39 70]

The Soviets have reported the use or trial of various other photographic equipment in satellite tracking work, including meteor patrol cameras.

The work of the visual and photo camera networks makes it possible for them to utilize some of the existing long-focus, small visual field telescopes of the astronomical observatories which give greater positioning accuracy. Apparently the installation affording the most precise optical measurements of satellite coordinates is at the Alma Ata mountain observatory of the Astrophysics Institute of the Academy of Sciences, Kazakh SSR, where an attachment to the 50-centimeter Maksutov meniscus telescope* has been installed specifically for satellite observations.

With good ephemerides, this camera reportedly gives an accuracy of 1 minute of arc and 0.05 second of time. A Tass broadcast of 18 July 1958 stated that 20,000 negatives of the path of Soviet satellites and their carrier rockets had been obtained up to that date at Alma Ata.[38 39 40 43 71]

The present apparent limit of Soviet photographic equipment is the tracking of satellites of about third magnitude, which is not enough to record U.S. satellites, sometimes only of eighth magnitude; also Soviet optical tracking facilities do not appear to meet optimum geodetic requirements for accuracy. The Soviets have indicated that their future satellites may be provided with artificial light sources as tracking aids.[70 73 71]

The Soviet open literature has disclosed that one of their leading telescope designers, D. D. Maksutov, has worked out the optics for a "high-illumination power camera with a wide field of view, specially designed for determining the coordinates of satellites." Apparently they believe this planned satellite tracking camera will be superior to the U.S. Baker-Nunn cameras, for they have not recently renewed their attempts to purchase one of these U.S. instruments.[42 43 71]

Since the overall utility and accuracy of an optical tracking system depends upon several complex factors, it is difficult to evaluate absolute progress of the USSR in this area of technology. At present the USSR apparently has no optical tracking network as good or as extensive as the Baker-Nunn camera network of the United States, but advances in this area, especially in instrumentation, are to be expected in the near future.

The Soviets have been greatly assisted in their orbital determinations by observations from stations throughout the world, including those from the United States and other Western countries. A visitor to the Institute for Theoretical Astronomy, in August 1958, found that Soviet scientists had at their disposal some 200 observations a day from which they selected the best 10 to 20 for use in computations. The selections were made on the basis of such considerations as where the observations were made and by whom. "Moonwatch" and preliminary photographic observations were usually used in these orbital determinations.[41]

Although the Soviets have published on the observation of artificial earth satellite radio signals with direction-finding equipment by radio amateurs using conventional communications receivers,[49 50] little has been found on the use of radio astronomical or radar astronomical equipment for satellite tracking.* [46 47 48] The Soviets have several large

*This camera has a reflector 70 x 125 centimeters. Its plate is 10 x 10 centimeters and corresponds to a field of view of 5° by 5°. One degree corresponds to 20 millimeters on the plate.

*At the Conference on Problems of Cosmology, Moscow, March 1955, the Soviets described their radar designed for observation of meteors. The set, not technically outstanding, has a pulse duration of 80 microseconds, a range up to 300 miles, and a frequency range of 10–15–20 mcs.[47]

radio astronomical telescopes which might be converted to tracking purposes, but most of these are of the limited- or non-steerable type, and all appear to be used only for scientific research. The largest known fully-steerable radioastronomical parabolic reflector in the USSR is a dish about 30 feet in diameter. The Soviets are known to be competent in radio-telescope design techniques, but generally they have not specialized in the more versatile types most useful for tracking purposes. In the West, the parabolic reflectors developed by radio astronomers are larger than those used in missile tracking; but there is no evidence that the same holds true in the USSR.[44] (See Radio Astronomy section.)

The Soviets have spoken of "automated radar" installations for the precise determination of the elements of the early part of the orbit of their Lunik, or cosmic, rocket, launched on 2 January 1959. They have mentioned "highly sensitive" receivers and "special aerials with a large effective surface" which insured reliable measurements of the trajectory of the cosmic rocket up to a distance of some 270,000 nautical miles. While the receiving equipment may have been similar to that used in radioastronomy, the Soviets did not mention radio astronomical techniques.[45] Soviet scientists have indicated that Lunik carried a special device which transmitted periodically to the earth, allowing the absolute position of the rocket in space to be computed by a combination of radio and radar techniques.[45] Mrs. Masevich and other Soviet scientists have claimed that the positions so obtained were more accurate than those from conventional radio direction-finding and even telescopic tracking, so that these other observations were not used in orbit computations of Sputnik III and Lunik, although radio direction-finding was used as a standby.[89]

It appears that the Soviets depend largely upon especially designed electronic tracking systems and upon their missile-tracking radar and long-range radio direction-finding equipment rather than upon regular radio astronomical equipment for electronic tracking of rockets and satellites.[89, 72] (See Monographs VI and VII for additional information on Soviet artificial earth satellite and space probe electronics.)

CAPABILITIES OF COMMUNIST CHINA AND THE EUROPEAN BLOC COUNTRIES TO GIVE ASTRONOMICAL SUPPORT TO SOVIET SPACE RESEARCH

Communist China

The Communist Chinese are considered capable of rendering some support to the Soviet space effort, mostly by cooperating in the observation of research rockets and satellites, but with some other observational and theoretical work of minor importance. Their increasingly active astronomical programs and their plans for enlarged facilities indicate a growing capability of more significance in the future.

Although Soviet assistance has been invaluable in the current astronomical progress of Communist China, the Chinese in return have furnished observations of Soviet sputniks and have cooperated with the Soviet Union in astronomical and radio astronomical expeditions on the Chinese mainland.[52]

Communist China has several competent astronomers, most of them trained in the West. For example, Dr. Chang Yu-che, Director of the Purple Mountain Observatory, Nanking, largest observatory on the Chinese mainland, studied at Yerkes Observatory from 1936 to 1939 and again in 1946 and 1947.[52]

Present Communist Chinese astronomical work includes photographic observations of comets and asteroids at Purple Mountain; time service at Zi-Ka-Wei Observatory in Shanghai, which is equipped with a complete set of quartz clocks and photoelectric transit instruments; and cooperative work on the Faint Star Catalogue, by Zo-Se Observatory, near Shanghai. A new latitude station, equipped with a 180-millimeter zenith telescope has been established near Tientsin, and a chromospheric telescope to make routine observations of the sun in monochromatic light has recently been set up in the suburbs of Peiping. Three new radio telescopes for solar radiation research on 2 and 3.2 centimeters and 3 meters reportedly were completed late in 1958.[52]

A more ambitious project is the establishment of Peiping Observatory. Its equipment, reportedly under construction, includes a reflecting telescope of 79 inch aperture, a 600/900 millimeter Schmidt camera, and a twin astrograph of 400-millimeter aperture.

The year 1962 has been set as the target date for completion of the observatory, which will work principally in stellar spectroscopy and photometry, according to plans. Other items under consideration are a high altitude observatory on the Tibetan Plateau for solar observations and an observatory in the south for general purposes.[52]

There have been persistent rumors that Communist China may launch a satellite in the near future. Kuo Mo-jo, President of the Academy of Sciences, reportedly said in May 1958, "Chinese scientists are seriously studying the Soviet Union's most advanced science and technology so that China may launch her own Sputnik in the nearest future."[53] Communist China, using its own resources, undoubtedly is far from being able to launch a satellite, but the Soviets might consider staging such an event from Communist China to boost the prestige of their ally.[54]

The European Bloc

With a number of highly qualified astronomers, a long tradition of research in the field, and several well-known observatories, the nations of the Bloc, especially such countries as East Germany, Czechoslovakia, and Poland, are in a position to render support, both practical and theoretical, to the Soviet space program; and the Soviets have taken advantage of Bloc astronomical work.

East Germany—The Heinrich Hertz Institute in East Berlin claims Europe's second largest (108 foot) steerable paraboloidal radio telescope, the dish for which was completed about September 1958.[55] The East Germans are well known for their solar, ionospheric, and radio wave propagation research and technology, all of importance to astronautics.

The Soviets maintain close contact with, and have learned much from East German technology. For instance, in January 1958, several specialists from the USSR visited the Development Office for Astronomical Instruments in the Carl Zeiss Company, Jena, to study the plans for the 2-meter mirror now being produced there. The mirror, scheduled for completion in 1959, will be installed in the observatory in Sonneborg/Thieringen.[63] East German industry also has developed and produced for the Soviets various electronics items of value in space research.[64]

Czechoslovakia—Czechoslovakia has made considerable progress in meteor and solar research including the development of a meteor-tracking radar antenna and devices to facilitate observation of the sun. Czechoslovakian atmospheric optics work has been judged as outstanding.[56 57 58 59]

Poland—Poland has 6 astronomical observatories and at least 2 radio astronomical telescopes. The country pursues an active astronomical research program and, of late, has exhibited a considerable amount of interest in astronautics, having begun the firing of small experimental rockets during the summer of 1958.[60] At the Warsaw Astronomical Observatory a small but active group of scientists is being developed through the study of interstellar polarization, particularly from the standpoint of magnetohydrodynamics.[61]

Other Bloc Countries—A survey of astronomical activities in other Bloc countries indicates that their capabilities are lower than those of East Germany, Czechoslovakia, and Poland to give astronomical support to the Soviet space effort, but practically all of the Bloc countries can and have contributed to the Soviet artificial earth satellite observation program.[62]

APPENDIX A

THE RELATION OF ASTRONOMY TO SPACE RESEARCH

Astronomy is receiving increased attention throughout the world as a result of the adoption of huge space programs by the Soviet Union and the United States. Successes by both countries in orbiting artificial earth satellites, attempts at launching lunar probes, and related astronautical ventures have emphasized the fact that space exploration is now possible and will become more feasible in the near future.

The ancient science occupies a unique position in the new space age. Astronautical activities are dependent upon astronomy for basic support. At the same time, the development of astronautics should bring about significant advances in astronomy and related sciences.

Observational data collected by astronomers over the past several hundred years furnish information on the environment to be encountered by space vehicles. Where observations are lacking, astronomical theories assist by supplying estimates of the most probable conditions to be encountered. Celestial mechanics furnishes the basis for calculating the orbits and predicting the motion and position of artificial earth satellites, lunar probes, and other space vehicles. Similarly, methods of celestial navigation are invaluable in space exploitation. Radio astronomical techniques undoubtedly will play an important part in space communications.* Radar astronomy will furnish precise measurements of distances from the earth or from space vehicles to celestial bodies. Finally, telescopes and other conventional optical instruments, whether mounted on the earth or on space vehicles, will continue to furnish extremely important information for all types of space activities.

The earth's atmosphere, while shutting out incoming radiations harmful to life, at the same time presents a severe handicap to astronomers and even interferes with visual observations of celestial bodies.* From an observatory in space, it will be possible to study the extremely significant infrared radiation, far ultraviolet light, X-rays, gamma rays, and their celestial sources, including the sun and other stars. Studies of solar disturbances and the resulting emanations from the sun's surface may make it possible to understand them and to predict their effects upon long-range communications, the weather, and other geophysical phenomena. Other studies which will be facilitated include (1) the processes of superhot and exploding stars; (2) the composition of the atmospheres of planets; (3) details of the surfaces of other planets, which may offer evidence concerning the possibility of life there; (4) the precise shape of the earth and its internal composition; (5) the great dust and gas clouds of the Milky Way, where stars have their origin; (6) the origin of the universe; (7) the origin, composition, and effects of cosmic radiation; (8) the origin, nature, and extent of magnetic and gravitational fields; (9) albedo measurements; (10) geodetic computations; and (11) physical experiments under the near perfect vacuum, low tempera-

*On 12 October 1958, radio signals were transmitted from Cape Canaveral, Florida to the NASA/Air Force Pioneer space probe vehicle which in turn relayed the signals to the 250-foot radio telescope of the University of Manchester, Jodrell Bank, UK.** This significant experiment promises to pave the way for the use of space vehicles to relay information to and from widely separated points on the earth. It also emphasizes the importance of the radio telescope in the reception of radio signals from space.

*The atmosphere has long been one of the most serious—and apparently insuperable—obstacles to astronomical research. Its distorting influence sets a limit to usable telescopic power, and, what is perhaps even more important, it blocks out almost all of the ultra-violet rays from space. Installing observatories on the tops of mountains goes only a short way to solving the first problem, and does not begin to deal with the second. The only complete answer is to use instruments above the earth's atmosphere.**

ture conditions of space. Advances in many of these fields may, in turn, facilitate space travel.

The scientific potentialities of space research are so great that any attempt to make a preliminary summary of them is likely to be inadequate. Nevertheless, the eventual discovery of new sources of energy, the development of new methods of propulsion in space, and the advancement of nuclear physics through astronomical studies in space are possibilities not overlooked by the USSR. The creation of the hydrogen bomb was initiated in close connection with an analysis of the method by which energy is generated in the sun and stars. The theory used in guiding the development of the bomb was the same as that derived from astrophysical studies.[1 p.xi]

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APPENDIX B

PRINCIPAL SOVIET INSTITUTES AND OBSERVATORIES ENGAGED IN ASTRONOMICAL RESEARCH

NAME	ALTERNATE NAME	SUBORDINATE TO:	LOCATION (APPROXIMATE)	KNOWN EQUIPMENT O=Optical R=Radio Astronomical		REFERENCES
Abastumani Astrophysical Observatory (AAO)	Astronomical Observatory	AS,* Georgian SSR	Mt. Kanobali, near Abastumani (41°50'N.; 58°22'E.)	O	R	1; 87; 91
All-Union Scientific Research Institute of Metrology (Time Laboratory)	....	Central Bureau of the Unified Time Service (TsNIBYeSV), Office of Measures and Measuring Equipment. (PMIP), Commission on Standards, Moscow	Leningrad	O		1
Alma-Ata Coronal Station	....	Institute of Astrophysics, Alma-Ata, AS, Kazakh SSR	Zailiyskiy Alatau Mts., About 27 kms. from Alma-Ata	O		85
Ashkhabad Astrophysical Laboratory	Turkmen Astrophysical Observatory	Institute of Physics & Geophysics, AS, Turkmen SSR	Ashkhabad, Turkmen SSR (37°58'N.; 58°22'E.)	O	R	1; 22; 28; 91
Astronomical Observatory	....	Moscow Institute of Engineering in Geodesy, Aerial Survey, and Cartography (MIIGAiK)	Moscow	O		1
Azerbaydzhan Astronomical Observatory	Astronomical Observatory	AS, Azerbaydzhan SSR	Near Baku, Azerbaydzhan SSR	O		1
Biurakan (Byurakan) Astrophysical Observatory	Astrophysical Observatory	AS, Armenian SSR	Near Biurakan on Mt. Aragats (40°20'N.; 44°18'E.)	O	R	1; 22

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Astrophysical Observatory	...servatory		(40°20'N.; 44°18'E.)			
Central Scientific Research Institute of Geodesy, Aerial Surveying, & Cartography (TsNIIGAiK)	....	Ministry of Internal Affairs	Moscow	O	R	1
Crimean Astrophysical Observatory imeni G. A. Shayn (KrAO)	Crimean Observatory	Department of Physico-Mathematical Sci., AS, USSR	Partizanskoye ...... (44°44'N.; 34°01'E.)	O	R	1; 22; 28
Astrobotanical Laboratory	Inst. of Astrobotany	Astrobotanical Sector, AS, Kazakh SSR	Alma-Ata, Kazakh SSR	O		1
Engel'gardt Astronomical Observatory (AOE)	Astronomical Observatory imeni Engel'gardt	Kazan' State University	Laurent'yevo, Tatar ASSR (55°50'N.; 48°45'E.)	O	R	1; 22; 28; 91
Institute of Astrophysics	Alma-Ata Inst. of Astrophysics; Kazakh Inst. of Astrophysics	AS, Kazakh SSR	Alma-Ata, Kazakh SSR	O		1; 28; 88; 91
Institute of Physics of the Atmosphere	Academy of Sciences Inst. of Physics of the Atmosphere	AS, USSR	Moscow	O	R	92
Inst. of Theoretical Astronomy (ITA)	....	AS, USSR	Leningrad	O		1
Irkutsk Astronomical Observatory (IAO)	Astronomical Observatory	Irkutsk State Univ., Irkutsk	Irkutsk, RSFSR	O		1; 94
Kazan Astronomical Observatory (KazAO)	Astronomical Observatory	Kazan State University	Kazan, Tatar, ASSR	O		1
Khar'kov Astronomical Observatory (KhAO)	Astronomical Observatory	Khar'kov State University imeni A. M. Gorkiy	Khar'kov, Ukrainian SSR	O		1
Kiev Astronomical Observatory (KAO)	Astronomical Observatory	Kiev State University imeni T. G. Shevchenko	Kiev, Ukrainian SSR .	O		1

*AS=Academy of Sciences.

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Appendix B (Continued)

NAME	ALTERNATE NAME	SUBORDINATE TO:	LOCATION (APPROXIMATE)	KNOWN EQUIPMENT O=Optical R=Radio Astronomical		REFERENCES
Kitab International Latitude Station (KMShS)	Kitab Latitude Station	AS, Uzbek SSR, Tashkent	Kitab, Uzbek SSR . . .	O		1
Leningrad Astronomical Observatory (AOLGU)	Astronomical Observatory	Leningrad State University	Leningrad . . . . (59°57'N.; 30°18'E.)	O		1; 28; 91
L'vov Astronomical Observatory (LAO)	Astronomical Observatory	L'vov State University	L'vov, Ukrainian SSR	O		1
Main Astronomical Observatory (GAO)	Pulkovo Observatory; Central Astronomical Observatory	AS, USSR	Pulkovo, near Leningrad (59°46'N.; 30°20'E.)	O	R	1; 22; 28
Main Astronomical Observatory	. . . .	AS, Ukrainian Kiev . .	Goloseevo, Ukrainian SSR (59°46'N.; 30°20'E.)	O		1
Main Geophysical Observatory	Central Geophysical Observatory; Voyekovo Observatory	Main Administration of the Hydrometeorological Service USSR (GUGMS)	Voyekovo, near Leningrad	O		1
Mayaki Astrophysical Observatory	Astrophysical Observatory	Odessa Astronomical Observatory, Odessa State University	Mayaki, Belyayevskiy Rayon, Ukrainian SSR	O	R	95
Military Air-Engineering Academy imeni Zhukovskiy (VVIA)	Zhukovskiy Academy	Ministry of Defense . .	Moscow	O		1
Military Engineering Academy	. . . .	Ministry of Defense . .	Leningrad	O		1
Mountain Astronomical Station (GOGOA)	Kislovodsk Coronal Station; Kislovodsk Mountain Station	Main Astronomical Observatory, Pulkovo, AS, USSR	26 km. from Kislovodsk (43°55'N.; 42°43'E.)	O		1; 22; 28

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	Station					
Mountain Astrophysical Observatory	......	Institute of Astrophysics, Alma Ata, AS, Kazakh SSR	14 km. S. of Alma-Ata (43°11'N.; 76°58'E.)	O	R	28; 88; 91
Murmansk Station	......	Institute of Physics of the Atmosphere, AS, USSR, Moscow	Murmansk	O	R	92
Nikolayev Division (NOGAO)	......	Main Astronomical Observatory, Pulkovo, AS, USSR	120 km. NW. Odessa, Ukrainian SSR	O		1; 22; 28
Novomoskovsk Station .	Gor'kiy State University Station	Gor'kiy Physical-Technical Institute, Gor'kiy State University	Novomoskovsk, Ukrainian SSR		R	1
Odessa Astronomical Observatory (OAO)	Astronomical Observatory	Odessa State University imeni Machnikov	Odessa, Ukrainian SSR	O	R	1; 95
Physics Institute imeni P. N. Lebedev (FIAN)	Lebedev Physics Institute	AS, USSR, Moscow	Moscow	O	R	1; 22; 86
Poltava Gravimetric Observatory (PGO)	Poltava Observatory	......	Pavlenko, near Poltava, Ukrainian SSR	O		1
Radio Astronomy Station	......	Physics Institute imeni P. N. Lebedev, Moscow, AS, USSR	100 km. from Moscow between Kariva and Serapkov		R	22; 86
Radio Astronomy Station	Crimean Radio Astronomy Station	Physics Institute imeni P. N. Lebedev, Moscow, AS, USSR	Simeiz, Crimea ...... (44°24'N.; 34°00'E.)		R	22; 86
Riga Astronomical Observatory	Astronomical Observatory	AS, Latvian SSR, Riga	Riga, Latvian SSR ...	O	R	1; 22
Riga Astronomical Observatory	Astronomical Observatory	Latvian State University, Riga	Riga, Latvian SSR ...	O		1
Roshena Station	......	Institute of Physics of the Atmosphere, AS, SSR, Moscow	Roshena, near Leningrad	O	R	92

*AS=Academy of Sciences.

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Appendix B (Continued)

NAME	ALTERNATE NAME	SUBORDINATE TO:	LOCATION (APPROXIMATE)	KNOWN EQUIPMENT O=Optical	R=Radio Astronomical	REFERENCES
Rostov Astronomical Observatory	Rostov-on-Don Astronomical Observatory	Rostov State University, Rostov-on-Don, RSFSR	Rostov-on-Don, RSFSR	O		1
Scientific-Research Institute for Terrestrial Magnetism, Ionosphere, and Radiowave Propagation (NIZMIR)	Krasnaya Pakhra Institute	Ministry of Communications	Krasnaya Pakhra, near Moscow	O	R	1; 22
Scientific-Research Institute of Military-Topographic Service (NIIVTS)	....	Ministry of Defense ..	Moscow	O		1
Scientific-Research Institute of the Red Army (NIISKA)	Moscow Military Communications Institute	Ministry of Defense ..	25 km. NNE. Moscow .	O	R	1
Scientific-Research Radiophysics Institute	Gor'kiy Physical-Technical Institute; Zimenka Radio Astronomical Station	Gor'kiy State University imeni Lobachevskiy	400 km. W. Moscow ..		R	1; 87; 89
Simeis Department ...	Simeis Observatory	Crimean Astrophysical Observatory, Partizanskaya, AS, USSR	Simeiz, Crimea ...... (44°24′N.; 34°00′E.)	O	R	1; 22; 28
Stalinabad Astronomical Observatory (SAO)	....	AS, Tadzhik SSR	Stalinabad, Tadzhik SSR (38°34′N.; 68°47′E.)	O	R	1; 22; 28; 91
State Astronomical Institute imeni P. K. Shternberg (GAISH)	Shternberg State Astronomical Institute	Moscow State University imeni M. V. Lomonosov	Lenin Hill, near Moscow (55°45′N.; 37°34′E.)	O	R	1

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State Optical Institute (GOI)	....	Ministry of Defense Industry	Leningrad	O		1; 28
Sun Service Station ..	....	Far East Affiliate, Siberian Branch, AS, USSR	Ussuri, Primorskiy Kray (45°28'N.; 133°28'E.)		R	93
Tartu Astronomical Observatory	Estonian Astronomical Observatory	Estonian AS	Tartu, Estonian SSR .	O		1
Tashkent Astronomical Observatory (TAO)	Astronomical Observatory	AS, Uzbek SSR	Tashkent, Uzbek SSR	O		1
Time Laboratory	....	All-Union Scientific Research Institute of Metrology (VNIIM), Central Bureau of the Unified Time Service, Commission of Standards	Leningrad	O		1
Tomsk Astronomical Observatory	Astronomical Observatory	Tomsk State University	Tomsk, RSFSR	O		1
Vil'nus Astronomical Observatory	Lithuanian Astronomical Observatory	Vil'nus State University, Lithuanian SSR	Vil'nus, Lithuanian SSR	O		1
Vinograd Station	....	Institute of Physics of the Atmosphere, Moscow AS, USSR	Vinogradovo, 45 km. SE. Moscow (55°25'N.; 38°35'E.)	O		92

*AS=Academy of Sciences.

APPENDIX C

THE INTERAGENCY COMMISSION FOR INTERPLANETARY COMMUNICATIONS, USSR

NAME	FIELDS	AFFILIATION
AMBARTSUMIAN, Viktor A.	Astronomy; Astrophysics	Astronomical Observatory, Yerevan State University.
BARABASHEV, Nikolay P.	Astronomy; Mathematics	Astronomical Observatory, Yerevan State University.
BLAGONRAVOV, Anatoliy A.	Mechanical Engineering (Design of automatic weapons; Rockets)	Institute of Machine Studies.
BOGOLYUBOV, Nikolay N.	Mathematics; Physics	Joint Institute for Nuclear Research; Steklov Mathematics Institute.
BOLKHOVITINOV, Viktor F.	Aeronautical engineering (jet propulsion)	Military Air Academy.
DUBOSHIN, G. N.	Astronomy (Celestial Mechanics)	Shternberg Astronomical Institute, Moscow State University.
FLOROV, Yu. A.	Engineer	Central Institute of Aviation Engine Building.
FRANK-KAMENETSKIY, D. A.	Astrophysics; Physical Chemistry (Combustion kinetics)	Institute of Chemical Physics; University of Leningrad.
GINZBURG, Vitaliy L.	Radio Astronomy; Physics, Geophysics	Lebedev Physics Institute.
KARPENKO, Anatoliy G. (Scientific Secretary)	...	...
KAPITSA, Petr L.	Physics (Low-temperature physics)	Vavilov Institute of Physical Problems.
KHAYKIN, Semen E.	Astronomy; Radio Astronomy; Physics; Electrical Engineering	Main Astronomical Observatory, Pulkovo.
KUKARKIN, Boris V.	Astronomy	Shternberg Astronomical Institute, Moscow State University.
LAVRENTEV, Mikhail A.	Mathematics	Steklov Mathematics Institute; Moscow State University.
LEBEDEV, Sergey A.	Engineer (Computers)	Institute of Precision Mechanics and Computer Techniques.
LEVIN, Boris Yu.	Astronomy; Geophysics (Meteorics)	Geophysics Institute, Academy of Sciences.
LIDOV, M. L.*	Mathematics	Moscow State University.
MARKOV, A. V.	Astronomy; Physics (Lunar Studies)	Main Astronomical Observatory, Pulkovo.

MASEVICH, Alla G.	Astronomy (Stellar evolution)	Shternberg State Astronomical Institute, Moscow State University.
OKHOTSIMSKIY, D. Ye.	Aerodynamics (Rocket propulsion)	...
PARENAGO, Pavel P.	Astronomy; Astrophysics	Shternberg State Astronomical Institute, Moscow State University.
PETROV, Boris N.	Physics (Electromagnetics)	Institute of Automatics and Telemechanics.
PETROV, Georgiy I. (Vice-Chairman)	Aeronautical Engineering (Aerohydrodynamics)	Moscow State University.
POBEDONOSTSEV, Yuriy A.	Aerodynamics (Missiles)	Moscow State University.
POKROVSKIY, Georgiy I.	Physics; Engineering	Zhukovskiy Military Air Engineering Academy.
SEDOV, Leonid I. (Chairman)	Hydromechanics; Aerodynamics; Mathematics	Moscow State University.
STANYUKOVICH, Kirill P.	Mathematics; Geophysics; Astronomy (Meteorites)	Moscow Higher Technical School imeni Bauman.
TIKHONRAVOV, Mikhail K.	Engineer (Rocket design)	Academy of Artillery Sciences.
TRAPEZNIKOV, Vadim A.	Engineering (Instrumentation)	Institute of Automatics and Telemechanics.
VANICHEV, Aleksandr P.	Physics (Combustion kinetics)	Academy of Sciences USSR.

*An article in *Nauka i Zhittya*, no. 12, Dec 56, p 8–11 describes Lidov as a "scientific associate" of the Commission.

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PICTORIAL SUPPLEMENT

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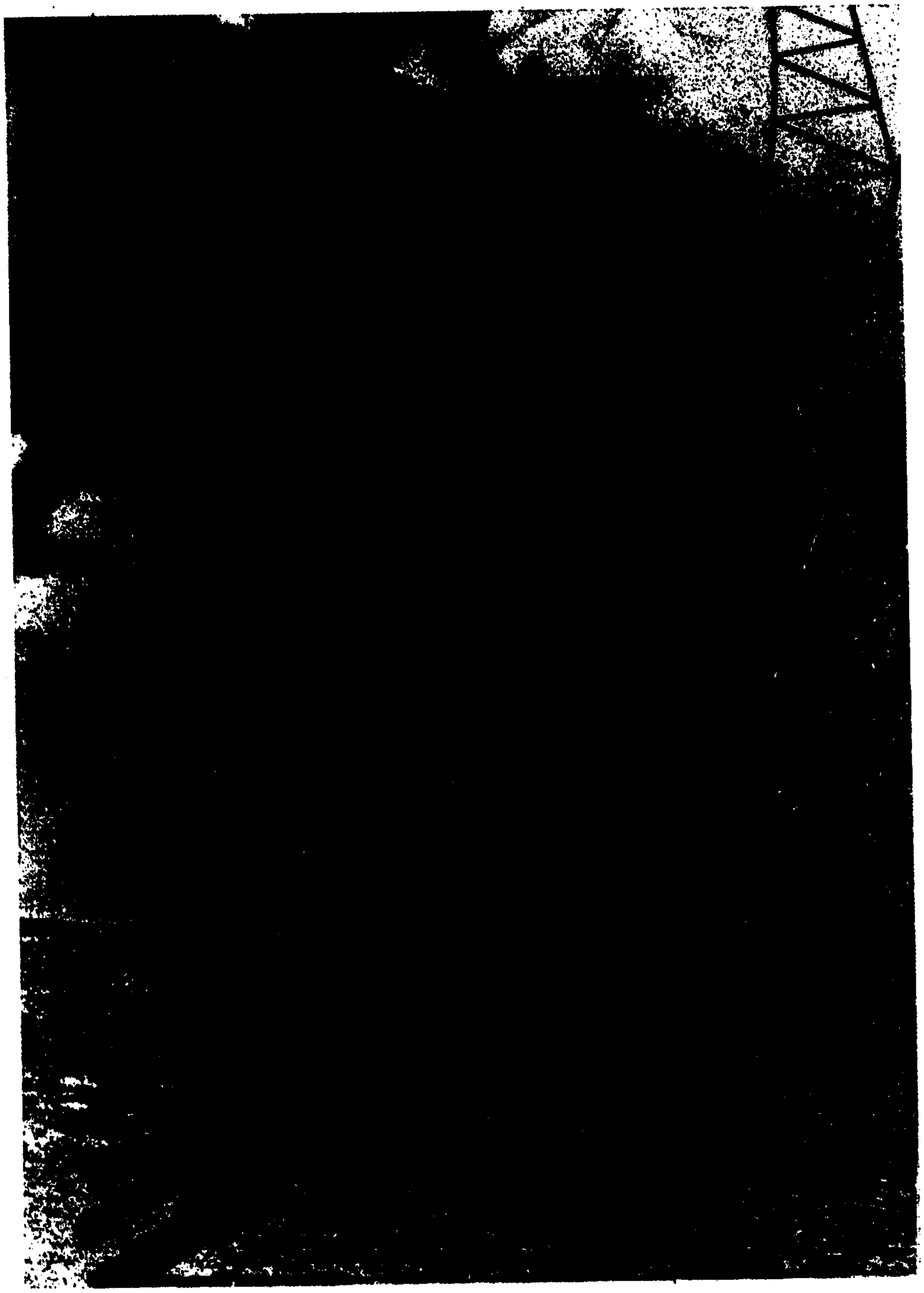

Figure 1. A partial view of the largest Soviet radiotelescope, Byurakan Astrophysical Observatory (40°20'N., 44°16'E.). September 1958.

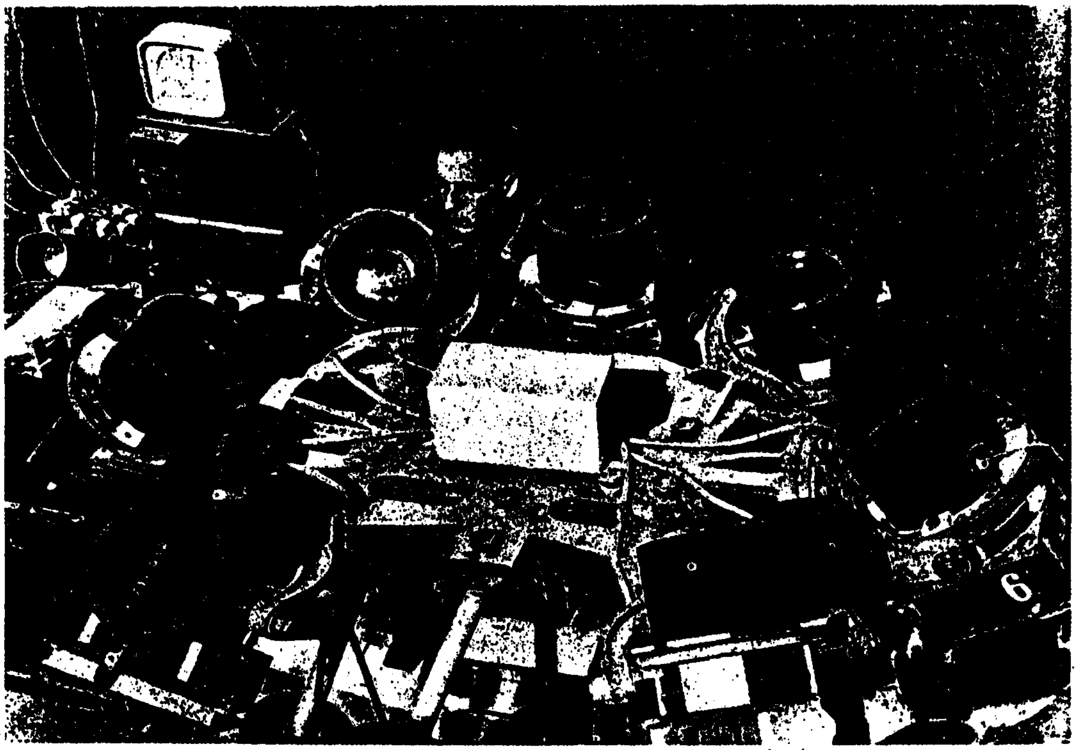

Figure 2. Soviet meteor patrol camera apparatus, Stalinbad Observatory (38°30'N., 68°45'E.).

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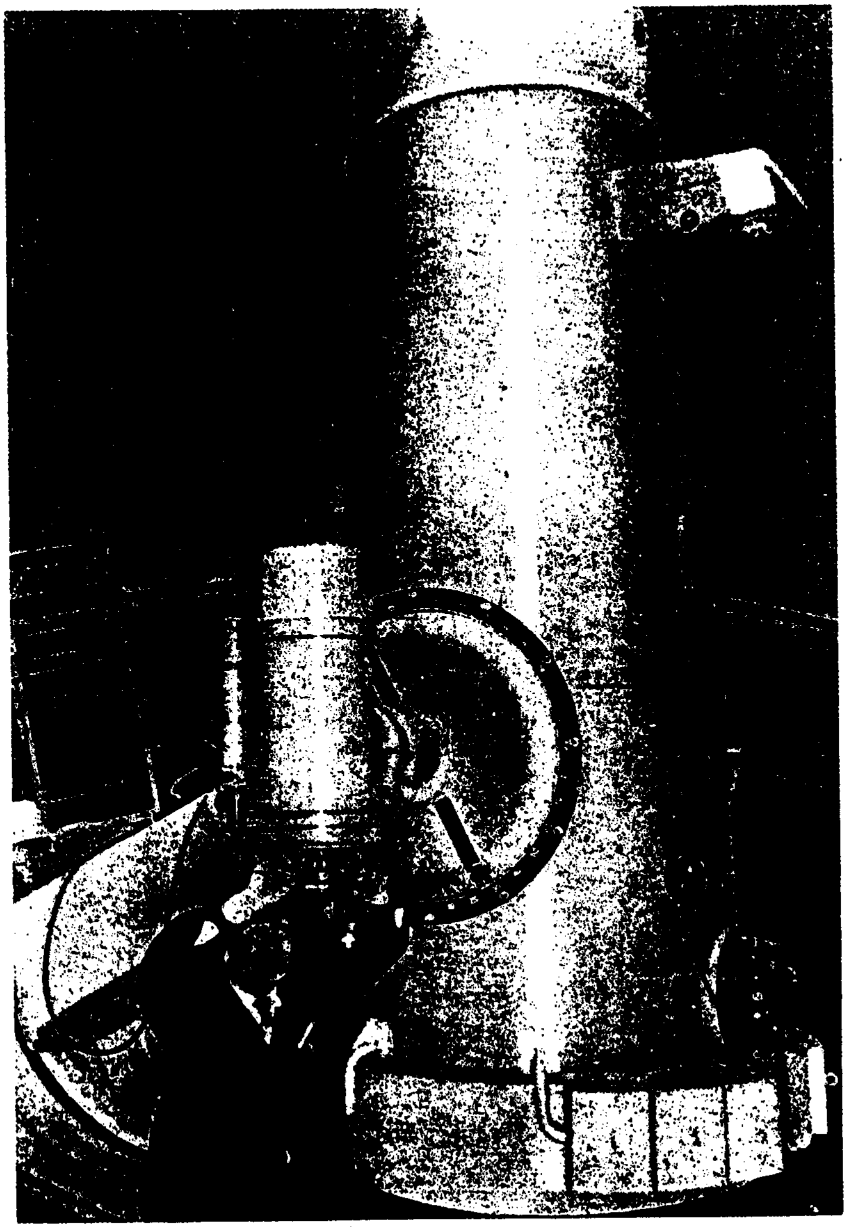

Figure 3. A 70-cm (28-in.) Meniscus telescope, Abastumani Astrophysical Observatory (41°43'N., 42°50'E.). This telescope is reported to be a direct copy made from plans from a Schmidt telescope which the Soviets obtained from the California Institute of Technology in 1948; however, it has a different optical design and re-engineered controls.

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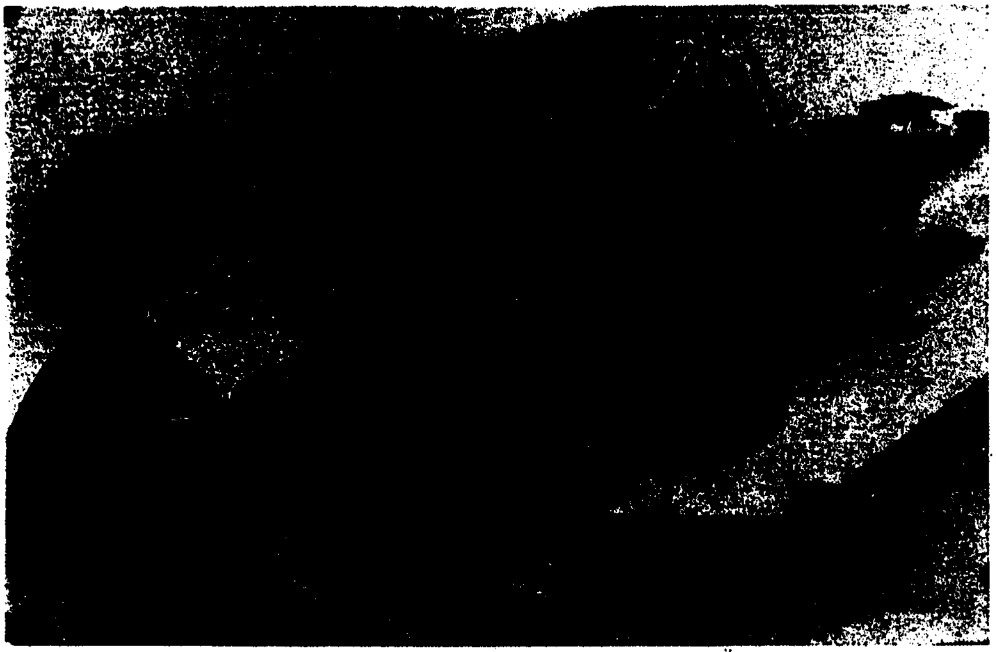

Figure 4. Chromospheric-photospheric telescope, Institute of Terrestrial Magnetism, the Ionosphere and Radio Wave Propagation (NIZMIR), 30 miles south of Moscow. October 1957.

Figure 5. Cophasal antenna for solar research; recording instrument at right. Institute of Terrestrial Magnetism, the Ionosphere, and Radio Wave Propagation (NIZMIR), 30 miles south of Moscow. October 1957.

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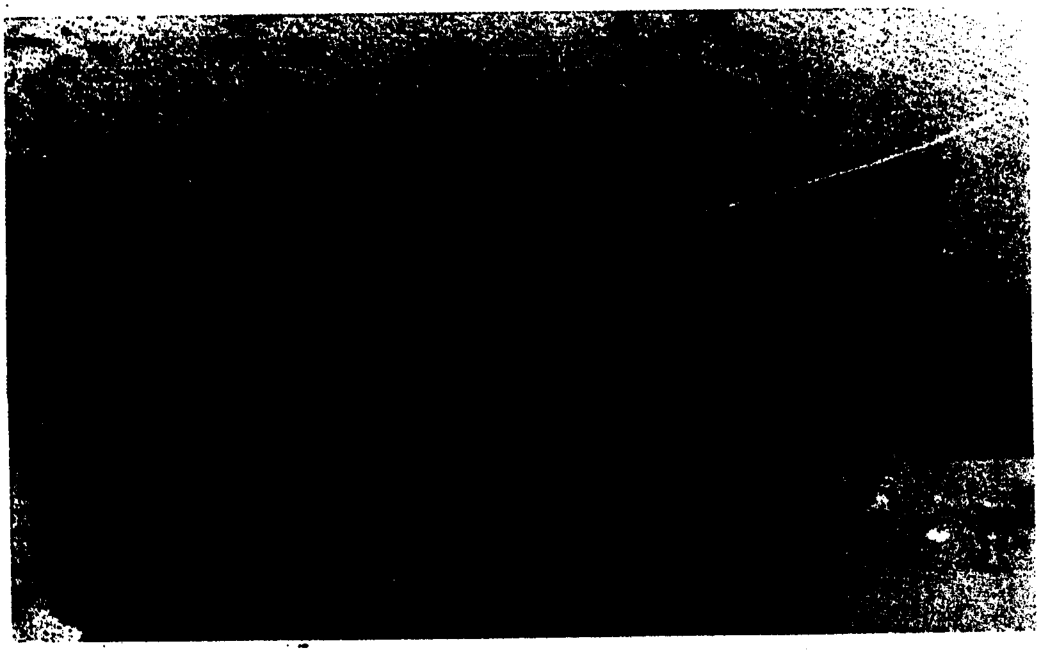

Figure 6. Prism spectrograph for astro-botanical research, used to study dark spots on Planet Mars, 1954.

Figure 7. Second largest Soviet radio telescope, Main Astronomical Observatory, Pulkovo (59°45'N., 30°23'E.), December 1957.

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Figure 8. Steerable Microwave antennas, Pulkovo (59°45'N., 30°23'E.), August 1958.

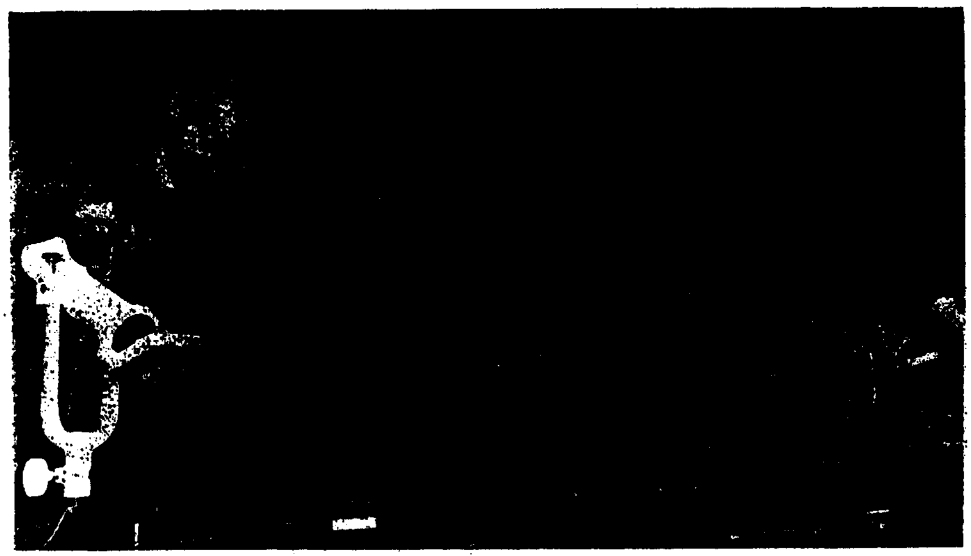

Figure 9. Soviet visual (Moonwatch) station for observing artificial earth satellites at Lomonosov Pedagogical Institute, Arkhangel. (64°34'N., 40°32'E.).

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Figure 10. Ukrainian satellite tracking team. Staff members of Central Astronomical Observatory, Ukrainian Academy of Sciences, preparing to observe artificial earth satellite using AT–I telescopes, October 1957.

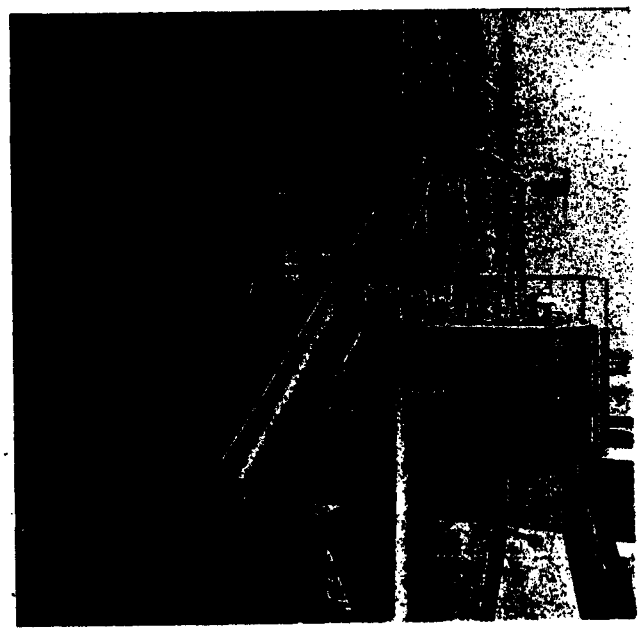

Figure 11. Transit instrument at Main Astronomical Observatory, Pulkovo (59°45′N., 30°23′E.), built at Munich in 1839.

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Figure 12. A 1-meter stainless steel mirror at Main Astronomical Observatory, Pulkovo (59°45'N., 30°23'E.), September 1958.

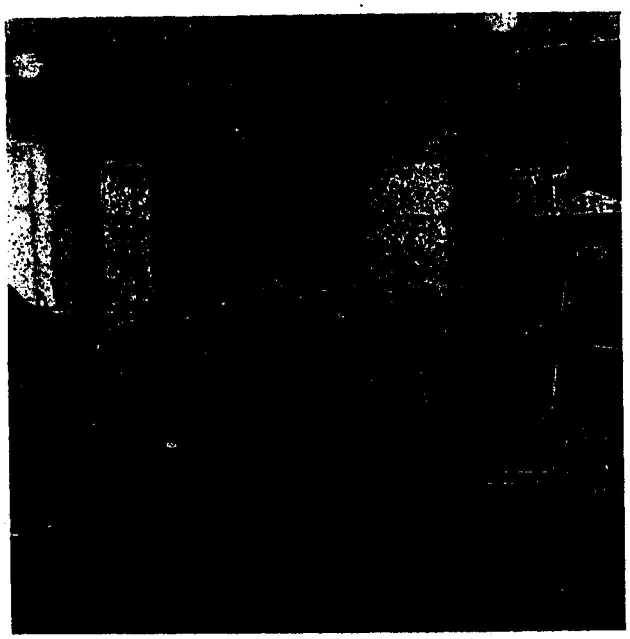

Figure 13. Machine shop, Main Astronomical Observatory, Pulkovo (59°45'N., 30°23'E.), September 1958.

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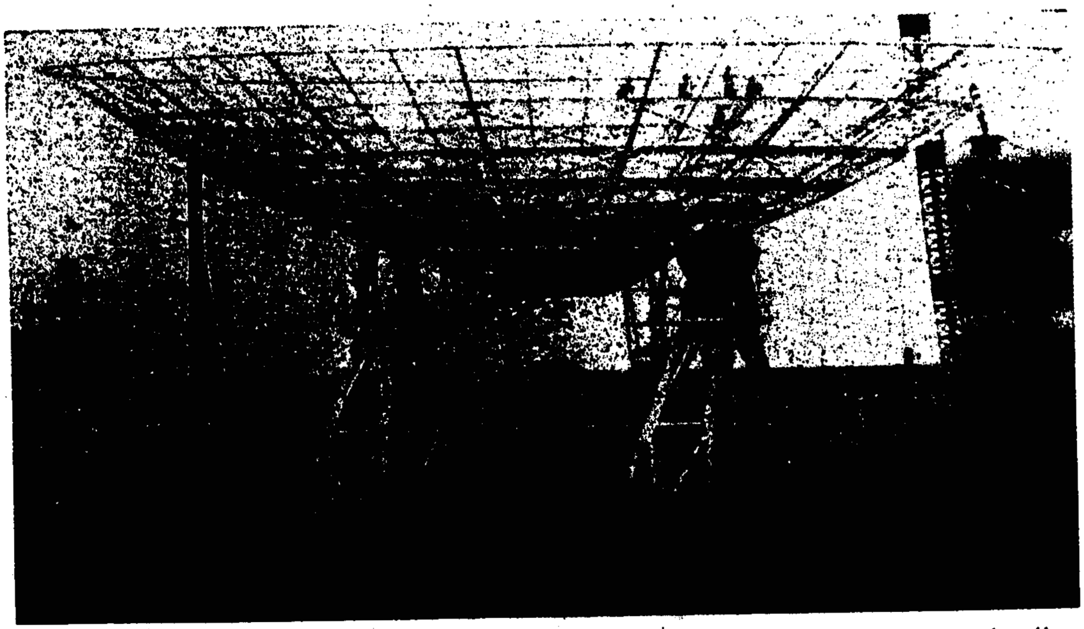

Figure 14. The East German 36-meter steerable paraboloidal radio telescope under construction in November 1957.