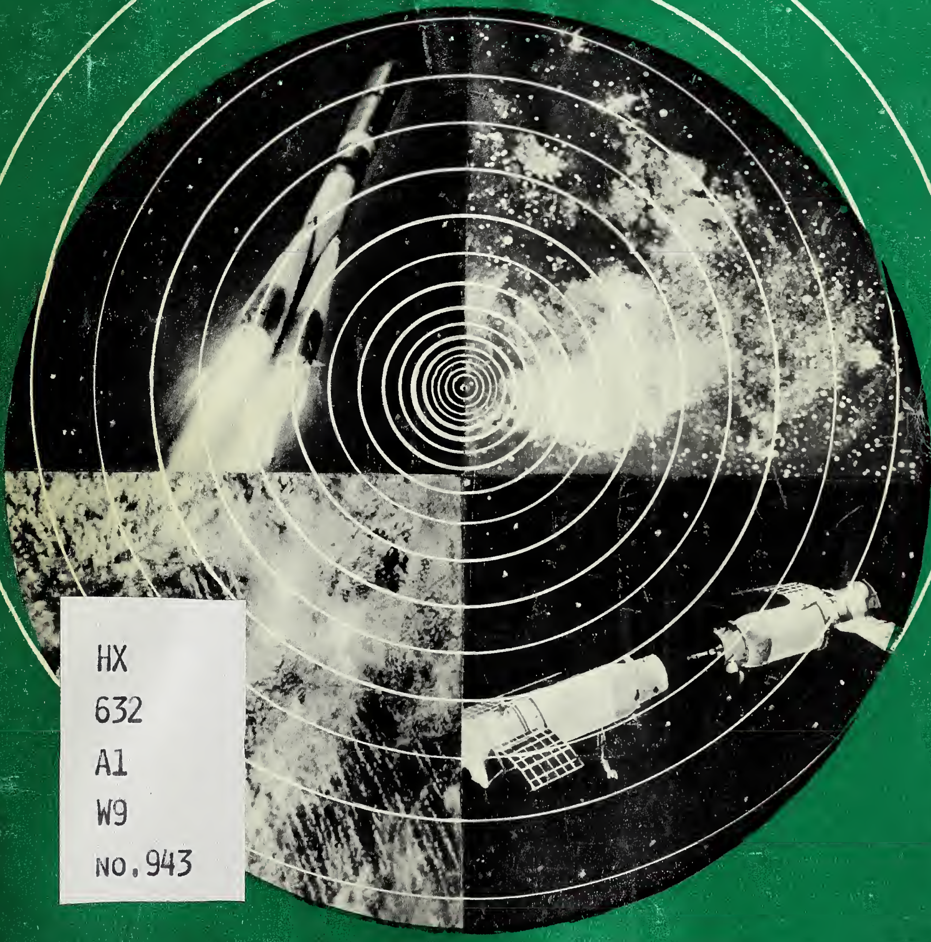
USSR probes space



NOVOSTI PRESS AGENCY,

MOSCOW,

U.S.S.R. 1968. 2/6

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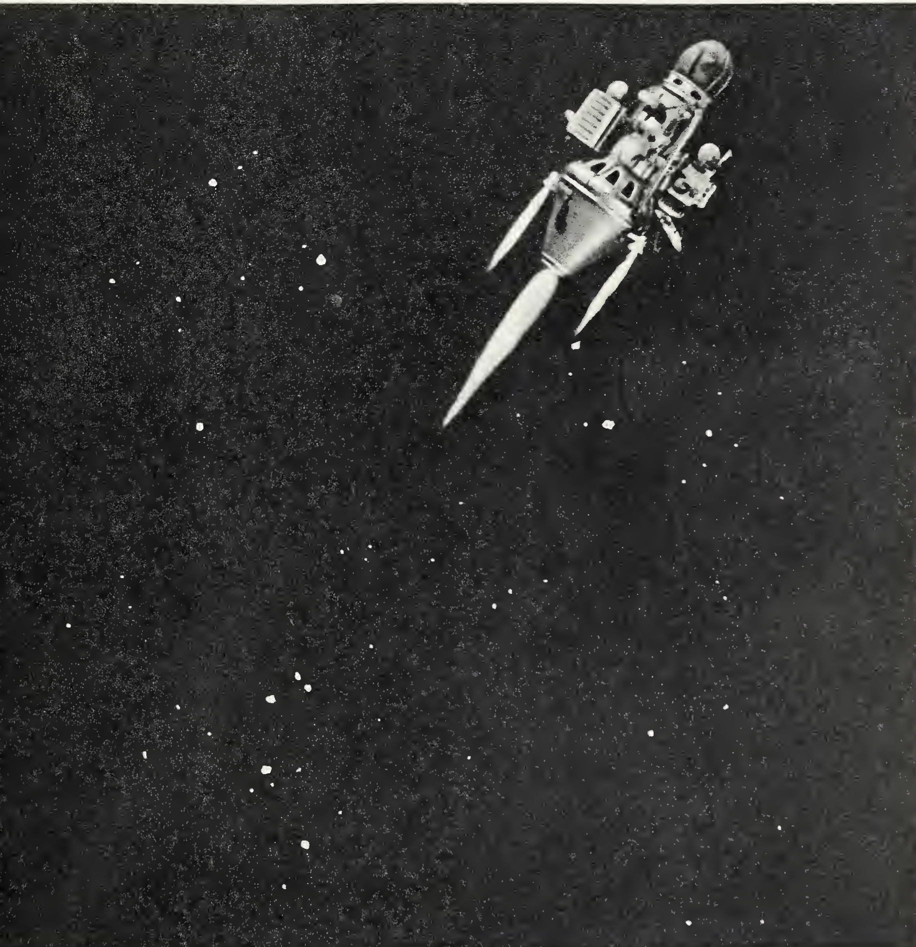


Beginning of the Space Era

On October 4, 1957 the Soviet Union launched the world's first artificial Earth satellite. This major achievement marked a turning point in the development of science and engineering.

For milleniums man's exploration of the Earth was confined to its surface and the lowest layer of the atmosphere. For information about the Universe, he had to be content with what could be gained with the assistance of astronomical instruments.

At present the astronomer has very fine equipment at his command. Despite the efficiency of such instruments as telescopes with a five-metre mirror, special tower solar telescopes, radio telescopes with a span of up to 76 metres and radio interferometres with antenna fields of several square kilometres, what they can do is still limited.

The turbulent atmosphere surrounding the globe makes it impossible to ensure large magnification in telescopes, while conditions in the ionosphere interfere with the working of radio telescopes. For these reasons astronomers have always dreamt of an observatory outside the atmosphere, of installing instruments on the Moon and the planets, for instance, and taking a look at the Earth "from the outside."

Physicists, chemists, geologists, biologists and physicians as well as astronomers, are interested in changing from indirect to direct methods of exploration, in making closer contact with the Universe, and consequently in taking research equipment outside the atmosphere, beyond the boundaries of the globe's magnetic field.

Direct methods of exploration of space can help physicists uncover the secrets of the so-called elementary particles, their structure and intricate interaction.

On the science of elementary particles is based the immense edifice of the science of nature. The experimental foundation of the science of elementary particles is the physics of high energy particles. There are two areas of investigation of high energy particles: first, the construction of powerful accelerators to increase enormously the velocity of the particles and communicate to them great energy with the help of magnetic fields; second, investigations connected with the study of cosmic rays which come to the Earth from the depth of the Universe. Nuclei of the atoms of hydrogen and helium and nuclei of heavier elements, which make up cosmic rays, are increased in Mother Nature's accelerators to stupendous velocities, resulting in the appearance of particles with an energy thousands of millions of times greater than that of the particles in terrestrial accelerators. In order to learn the nature of matter it is necessary to unravel the mysterious mechanism of space "accelerators" and use the particles they produce.

The accumulation of new experimental data will help man to understand the many intricate laws concerning the processes taking place in the Sun.

The Sun, apart from providing light and warmth, also produces the Roentgen ray, ultra-violet ray and corpuscular emissions, which do not penetrate to the Earth's surface, but greatly influence the density, temperature and chemical composition of the upper atmosphere, the state of the ionosphere and radio communication conditions, the variations of the magnetic field and radiation conditions in outer space. Connected with solar activity are such grandiose natural phenomena as the Auroras during which energy is produced in tremendous quantities.

So far biology and geology have been considered the most earth-bound of the sciences—their purpose being to investigate objects on the globe. But should living beings be discovered on Mars or Venus and study be undertaken of the origin and development of nonterrestrial biological forms, biology would assume much wider scope.

In geology, scientists would be able to study other planets, their structure, surface and what lies beneath it. This would help solve many problems connected with the exploration of our planet. Geology would become part of the all-embracing science of planetology.

One can say with confidence that space research provides conditions for a giant leap forward in the development of all the natural sciences.

On a more practical plane, the exploration of space is of immense importance for radio and TV communications, for weather forecasting, and navigation.

Balloons and flying machines made active and systematic study of the lower atmosphere possible. Radiosondes enabled researchers to probe the atmosphere up to an altitude of about 30 km. Some idea of the structure of the upper atmosphere was formed through observation of meteorites, the luminocity of the night sky, the Aurora, and the propagation of acoustic waves from superpowerful explosions. The lower atmosphere was also sounded with radio pulses of variable lengths. Extensive information on processes taking place in the atmosphere, the ionosphere and in the Sun was obtained with geophysical rockets.

Our knowledge of the pressure, density and temperature of the upper atmosphere has increased. Rockets have made it possible to study the ion composition and concentration of electrons at altitudes of several hundred kilometres and to investigate the ultraviolet part of the solar spectrum. Photographs have been obtained of the Earth's surface and cloud formations have been filmed from great altitudes. Rockets have made it possible to obtain information about the distribution of the brightness of the sky by day and by night, about the concentration and energy of micrometeorite particles, etc. However, all these observations have been restricted in time and space. Data on the state of the atmosphere from one point of the globe only, and registered for only a few minutes, is not satisfying to scientists. Besides, the results obtained are not always reliable or comprehensive enough.

Thus, for many branches of science

the sputnik met a vital need—investigations beyond the dense layers of the atmosphere at different latitudes and over lengthy periods.

The International Geophysical Year (IGY) programme, which began in July, 1957, was then under way. This was a stupendous scientific undertaking in which 64 countries, including the USSR and the USA, took part. It was these two countries that, aware of the vital need for and the importance of Earth satellite exploration in combination with ground observations, had actually proposed that a satellite be put into orbit under the IGY programme.

In developing the programme of space research with satellites Soviet scientists planned comprehensive experiments. There was the necessary scientific and technical basis for this, but there were also difficulties. These concerned above all the choice of measuring instruments and the ensuring of their operation during transmission of data to be received and processed on Earth. The object of investigation—space—was then still largely a mystery. The only information available was based on terrestrial observations and rocket probings. Investigations with Earth satellites might be unsuccessful because of incorrect assessment of the quantities measured. The sensitivity or measuring range of the instruments might prove inadequate. It was not known what temperature should be maintained in an orbiting satellite; it might get overheated, or the temperature might fall below the permissible level, causing the breakdown of the instrumentation.

Scientists were faced with the problem of developing satellite systems and on-board facilities that would operate for more than a single session—in other words, the prospects of space research had to be taken into account.

Selection of the sputnik's orbit and the general arrangement of instrumentation had to meet equally intricate and often conflicting demands.

In tackling these problems, each new step in the investigations had to be considered from every angle with a view to obtaining the maximum results from the experiment. These considerations subsequently determined the strict sequence of studies which characterized Soviet space research.

The Very First

One of the main purposes of launching the sputnik was to determine the parametres of the upper atmosphere. The spherical shape of the satellite was well-chosen for that. The sputnik moved in an elliptical orbit with an apogee of about 1,000 km. Its perigee lay in the upper atmosphere and gradually lowered owing to atmospheric resistance. By observing changes in the parametres of the sputnik's orbit it was possible to determine with sufficient accuracy the degree of its lag. From its mass, shape and size it was comparatively easy to compute the value of the drag and then to calculate the density of the upper layers of the atmosphere. A similar experiment was made by observing the braking of the sputnik's carrier rocket.

An equally important experiment was the investigation of the ionosphere. This was done by observing the propagation of radio waves emitted by the sputnik which had on board transmitters operating on 20.005 mc and 40.002 mc.

Since the distance between the satellite and the tracking stations altered, there was also a change in the quantity of ions between the satellite's transmitter and receiver on the ground. This produced a change in the nature of registered radio signals, helping to give an idea of the state of the ionosphere.

Besides, the radio signals of these frequencies propagate through the ionosphere in a curve rather than a straight line. Measurements of the difference in time between the satellite's optical and radio rising (and setting) made it possible to determine the curvilinear distortion of the radio beam and thereby the electron density in the path of this beam.

Investigation of the peculiarities of shortwave propagation in the ionosphere was of exceptional importance for ensuring reliable communication with space vehicles.

Radio signals transmitted by the first sputnik were used not only for sounding the ionosphere but also for sending to Earth measurements made by the instruments on board the sputnik. Temperature conditions inside the capsule were investigated, among other things.

The sensors which registered temperature fluctuation changed the frequency of telegraphic signals and the signals pauses ratio. The ground tracking stations registered all changes. Investigation of the temperature conditions in the capsule of the first sputnik was necessary for determining the optimal thermal conditions for the operation of the on-board instrumentation and for checking the efficiency of the thermoregulation system.

Without all this it would have been impossible to prepare for the next phase of space research—the biological experiment with a dog, or for the final and key task—manned space flight.

What Laika Had to Tell

By the time the first Earth satellite was launched researchers had carried out a whole series of medicobiological experiments with the help of high-altitude and geophysical rockets. They had accumulated sufficiently extensive information on living organisms' reaction to various factors under conditions closely resembling, those of a space flight, by launching rockets with test animals to altitudes of several hundred kilometres. Those experiments established the ability of living beings, i.e. dogs, to endure satisfactorily the great stresses during the take-off and landing. They also endured well the state of weightlessness during power-off flight. However, the duration of weightlessness in these flights was too short for the results obtained to be applied to the conditions of orbital flight.

November 3, 1957 saw the launching of the second Earth satellite with the dog Laika on board. That experiment yielded information on the physical condition of a living being during space flight over a period of a week.

During telemetry sessions Laika "gave an account" of her state. This account enabled scientists to determine conditions for the normal functioning of a living organism in outer space, which was of tremendous significance for future manned flights.

The physical experiments carried out with the second satellite were in some measure similar to those made with the first—determination of the atmospheric density by observing the drag, study of ionospheric characteristics by observing the propagation of radio waves, and registration of temperature changes inside the instrument container which, incidentally, was an exact replica of that on board the first satellite.

Instruments, registering the number of particles in cosmis rays, were also installed in the second satellite. One of the most important results obtained from the physical experiments with the second satellite was the discovery of the growing intensity of the flux of charged particles of high energy as the altitude of flight and the geomagnetic latitude of the point over which the satellite was passing at a given moment increased. Subsequently, it was found that this was due to the satellite entering the Polar regions of the outer zone of the radiation belt. That was the first indication of the existence of a zone of high-energy particles around the Earth.

Laboratory in Space

May 15, 1958 saw the launching of the third Soviet satellite. By its technical characteristics and the number of parameters it could measure, it was much superior to the first two satellites. It weighed 1,327 kg, of which 968 kg were taken up with the instrumentation and power supply. During its lifetime of about two years the satellite made more than 10,000 orbits around the Earth. The use of solar batteries as power supply made it possible to obtain scientific information over a long period of time.

Measurements of high-energy particles showed, for instance, that in all cases when the satellite entered the zone between 55° and 65° latitude, both North and South, there was a sharp increase in the braking roentgen radiation. It was observed that its intensity increased with altitude. This resulted from the bombardment of the satellite's shell by electrons having an energy of 100 kw which started as soon as the satellite entered the zone of intensive radiation. This zone soon came to be called the outer zone of the radiation belt.

The density of the upper atmosphere was determined this time by observation of the changes in the parameters of the satellite's orbit as a result of the drag, and by registration of the pressure with ionization and magnetic manometers.

The values of the density of the upper atmosphere obtained by means of the satellites proved to be much higher than the pre-calculated values. It should be stressed however that it was a period of maximum solar activity, when the atmosphere is heated and expands further into outer space. Indeed, subsequent investigations proved the cooling and "setting" of the atmosphere at other periods.

Investigation of the parameters of the ionosphere with the third satellite was carried out by varied methods: by observing the propagation of radio waves emitted by the satellite's powerful transmitter, and by means of instruments for direct measurement of the concentration of positive ions in the satellite's path. The composition of the positive ions was studied by means of a radiofrequency mass spectrometer.

The sputnik had a self-orienting magnetometer to measure the Earth's magnetic field at great altitudes; it registered the full intensity of the magnetic field. The magnetometer was also used to determine the orientation of the satellite, which was important for the interpretation of other measurements.

Satellite-borne instruments registered the intensity of primary cosmic rays, and experiments were made to determine the quantity of heavy nuclei in cosmic radiation.

Several sensors registered micrometeorite impacts. Because of the large number of experiments it carried out and their diverse nature, the third sputnik may be called a research station in space. This project enabled Soviet scientists to carry out investigations on all relevant points of the IGY programme which they had taken upon themselves.

In early 1958 American scientists began their programme of space research with Earth satellites. Because of difficulties in realizing the **Vanguard** project, specially planned for the IGY, a different satellite, **Explorer-1,** weighing just 5.6 kg (less the last stage) was launched first. The diminutive **Vanguard-1** was put into orbit somewhat later. It carried no instrumentation other than two radio transmitters, one of which was powered by solar batteries.

Because of the absence of sufficiently powerful rockets in the USA at that time, the first American satellites could carry only a small amount of equipment. Their flights were each in the nature of a specific physical experiment. **Explorer-7,** a satellite with a comprehensive research programme, was launched only in late 1959.

At the Source of Astronautics

It was in Russia that the first rocket-powered flying machine was designed. The inventor was Nikolai Kibalchich who in 1881 was sentenced to death for taking part in the attempted assassination of Tsar Alexander II. While in prison Kibalchich wrote scientific papers on a flying machine propelled by a gun powder rocket engine. Awaiting the day of his execution, the condemned man thought not of death, not of writing an appeal for mercy, but of his ideas which he had not been able to realize, of the benefit that the rocket could bring man. Kibalchich's papers were found, published and acclaimed only after the socialist revolution of October 1917.

In 1897 Professor Ivan Meshchersky of the St. Petersburg Polytechnical Institute evolved an equation for the motion of a variable mass, thereby making an important contribution to the fundamentals of rocketry.

The role of K. E. Tsiolkovsky, a brilliant Russian scientist and dreamer, in the development of astronautics is truly unique. His classical work, **Exploration of the Universe with Rocket-Propelled Instruments** was published in 1903. In it Tsiolkovsky formulated for the first time the fundamentals of the mechanics of rocket flight and the principles of designing rockets and liquid-fuel rocket engines. Tsiolkovsky was also the first to expound the idea of an electric rocket engine in which thrust is created by expulsion of charged particles. He pointed out the advantages of a nuclear rocket engine. But that was for the distant future. Meanwhile, the scientist suggested building liquid-fuel rockets using liquid oxygen, ozone and nitrogen pentoxide as oxidants, and liquid hydrogen, methane, benzene, gasoline, turpentine and some other substances as fuel. Tsiolkovsky conceived a number of constructive ideas which have been applied in modern rocketry: a pump system for fuel supply, rudders in the gas stream, cooling of the combustion chamber by fuel components, etc.

Tsiolkovsky considered that rockets should be used for the "exploration of the expanses of the Universe," and not for military purposes.

However, under the conditions of the pre-revolutionary Russia Tsiolkovsky's brilliant ideas found no support. There were neither sufficiently skilled personnel to implement his projects, nor the necessary technical facilities.

The USSR, Home of Astronautics

Since the early 20's the works of Soviet scientists have held the leading place in the theory of astronautics. Research in rocketry which put Tsiolkovsky's ideas into practice was started on May 15, 1929 with the setting up of the first experimental designing bureau at the Laboratory of Gas Dynamics (LGD) in Leningrad. That bureau was to develop electric and liquid-fuel jet engines. At the LGD for the first time the theory was proved by experiments that it was, in principle, possible to make use of an electric jet engine employing as propellants solid and liquid conductors exploded by electric current in a chamber with a nozzle. From 1930 to 1931 the staff of the same laboratory developed and built the Soviet Union's first liquid-fuel jet engines. Self-igniting fuel and chemical ignition were proposed. In 1933, official test stand trials were made of the experimental engines ORM-50 (with a thrust of 150 kg) and ORM-52 (with a thrust of 300 kg).

In 1931, the Central Group for the Study of Jet Propulsion (CGSJP) for rockets was formed under the guidance of F. Zander. This group also issued information on interplanetary flights.

Then CGSJP became an industrial enterprise, headed by Sergei Korolev. In 1933 the enterprise built and launched the first Soviet experimental rocket using liquid oxygen and solidified petrol as fuel. The same year saw the launching of another rocket—GSJP-10 fueled with liquid oxygen and alcohol. This rocket had a parachute, which brought it gently back to Earth. This principle of retrieving the rocket and its instruments proved so effective that it is now widely used for meteorological and geophysical rockets.

In 1934 the staffs of LGD and CGSJP were united to form the Research Institute of Jet Propulsion (RIJP) headed at first by Ivan Kleimenov, and then by Grigory Langemak. It was at that Institute that a group of Soviet rocketry specialists produced experimental ballistic and winged rockets and the engines for them.

The assault of Nazi Germany on the USSR interrupted the peaceful development of Soviet rocketry. Our designers and engineers were compelled to direct their efforts to the development of missiles for the country's defence.

After the war, work on the problems of non-military rocketry and astronautics was resumed. More experimental designing bureaus and research institutes were established. Beginning with the second half of the 40's the Soviet Union started exploring the upper layers of the atmosphere with rockets. Since 1951 rockets have also been used for meteorological observations. Rocket research continued on a grand scale during the IGY. Along with geophysical experiments rockets were also used for biological studies. Systems for landing animal passengers and instrumentation packs were developed. Rockets such as B-24 could lift a payload of 2,200 kg to an altitude of 212 km.

The B-5B type of geophysical rocket, which was also used for astrophysical and biological investigations, went up 512 km with a payload of 1,300 kg.

The study of near space carried out by the Soviet Union and the USA with rockets and satellites under the IGY programme provided the first and fairly general information about the parameters of the upper atmosphere and the physical processes taking place there. Thorough processing of the experimental material obtained by the first space scouts tremendously enlarged and in some cases substantially changed the theories and conceptions of the physical and chemical characteristics of the upper atmosphere.

However, these were only the first steps in unravelling the mysteries of the Universe. There remained many points that required checking and confirmation. The research carried out with the first three satellites came at the peak of the 11-year cycle of solar activity. In order to study the dependence of the parameters of the upper atmosphere and the interplanetary medium on solar activity and to gather material on the period of the ebb and minimum solar activity for further statistical processing, it was necessary to have systematic sputnik flights and carry on observation of spatial phenomena.

Moreover, after the successful solution of the initial problems, the need arose for conducting specialized comprehensive experiments in preparation for the solution of more complicated problems and the attainment of new stages in man's conquest of space.

Spaceships Probe the Unknown

Between May 15, 1960 and March, 1961 the Soviet Union launched five super-heavy orbiting spaceships. The main object of these flights was to develop on-board systems, to study the paths for a manned flight and to make further medicobiological investigations in preparation for this flight. Satellite spaceships were used in a number of physical experiments concerning the study of cosmis rays, the registration of cosmic radiation levels and investigation of the ultraviolet and roentgen radiation of the Sun. Scientists had to determine the actual radiation danger during manned space flight. Dosimetric instruments for measuring space radiation on board the ships showed that the capsule casing was adequate protection against radiation at the altitudes at which satellite spaceships fly.

An unexpected result from the measurements made by gas-discharge counters was the discovery of several areas of increased radiation in the Southern Hemisphere—over the South Atlantic (the Brazilian anomaly) and over the Indian Ocean (the Cape Town anomaly).

Research done on board satellite spaceships on ultraviolet and roentgen ray emissions was of great importance. Though the sun emits energy in a very broad range of wave lengths only a small part of the spectrum of this radiation reaches the observer on Earth. The whole band of ultrashortwave emission—ultraviolet rays, Roentgen and gamma rays for instance—are absorbed by the terrestrial atmosphere. At the same time the study of short wave emissions of the Sun are of considerable scientific and practical interest. The main radiation of the outer spheres of the Sun, still almost unexplored, is concentrated in this part of the spectrum. It is under the effect of shortwave radiation that the terrestrial ionosphere, determining the conditions of radio communication, is formed. These emissions have an influence on the molecular composition and density of the upper atmosphere, and consequently on the heat balance of the atmosphere's lower layers.

The information gained during the flights by spaceships was examined against data gleaned from terrestrial observations of the ionosphere, chromospheric flares and other phenomena connected with solar activity.

"Sentries of Science"

On March 16, 1962, the first of the **Kosmos** series of satellites went into orbit around the Earth. Soviet scientists started a new extended programme of investigation of the upper atmosphere and near-Earth space. By the 6th anniversary of the launching of the first satellite there were more than 200 sputniks of this series in orbit.

The data they provide helps the study of the radiation belts of the Earth, the magnetic fields and the shortwave emissions of the Sun. The instruments they carry record the concentration of charged particles in the ionosphere, a condition influencing the propagation of radio waves. Equally important is the data the sputniks supply on the distribution of cloud formations in the Earth's atmosphere.

The **Kosmos** sputniks also help solve many technical problems connected, among other things, with improving the design of space vehicles.

Orientation control, re-entry, landing in a pre-set area and life-support systems are worked out on them. Simultaneously, reliability of the protection for the spaceship from radiation is tested.

The designs of the **Kosmos** sputniks are as varied as the research they do. Depending on the purpose of the experiment they are powered by chemical or solar batteries. They can be orientated either with respect to the Sun or to the Earth. When it is necessary to retrieve the instrumentation container they are brought back to Earth by means of retrorockets and parachute systems.

Yet, the **Kosmos** sputniks have many common design features. They all have the same service systems, the same scheme for the control of on-board apparatus, power supply, etc. Many of the parts do not require new development each time and can be manufactured serially. Naturally, this helps considerably to reduce the costs of building sputniks and carrying out research.

Kosmos sputniks are launched from the many rocket ranges in the Soviet Union. The parameters of their orbits differ vastly both as to inclination and altitude in apogee and perigee. In cases when simultaneous measurements have to be made at different points of space with several sputniks, fitted with similar instrumentation, these are put into orbit by a single carrier rocket. Several types of two- three- and four-stage rockets of different capacities have been developed for this purpose. The first of the carrier rockets of the **Kosmos** series was a two-stage vehicle of the same name, which performed well from the very first launching on March 16, 1962.

During the past years we have certainly learned a lot from the satellites of the **Kosmos** series. Of great practical interest are the data received on the radiation of the inner and outer zones of the radiation belt. Lengthy measurements carried out with the **Kosmos** satellites made it possible to determine the intensity of radiation inside the satellites and in surrounding space. Investigations have been made of the dependence of this radiation on solar activity and geomagnetic disturbances. A detailed study was made of the distribution and intensity of charged particles in the areas of the South Atlantic and the Brazilian coast where magnetic field anomalies were observed.

Of great interest to geophysicists are the investigations of fluxes of low-energy electrons and ions known as "geoactive corpuscles," which may prove to be the source of energy of various processes taking place in the upper atmosphere. As a result of these investigations, the "softest" particles were discovered—electrons with energies of several score electron-volts. These electrons are formed during ionization of the upper atmosphere by the ultraviolet radiation of the Sun.

Earth satellites of the **Kosmos** series were used to continue the study of the ionosphere and of the conditions of radio wave propagation. This was done by ground-station recording of the radio signals from the on-board **Mayak** transmitters.

Study of the ionosphere was also carried out by means of various types of charged-particle traps. This led to the discovery of a substantial change in the vertical distribution of charged particles as compared to 1958, when the Sun was most active.

Under the programme for a world magnetic survey and on the basis of measurements with instruments of special design—proton magnetometers—experimental data were obtained on geomagnetic field intensity at altitudes of about 300 km. Several **Kosmos** satellites were equipped with instruments for studying the infrared and ultraviolet radiation reflected by the Earth. The results of these measurements are of great value for geophysics; they also furnish important data for developing meteorological satellites, improving orientation control systems, etc.

Until recently the existence of the so-called dust cloud (consisting of tiny particles) around the Earth was not questioned. In keeping with this assumption it was necessary to take into account, in designing spaceships, the danger of collision with meteorites especially during manned flights. The data giving rise to this assumption was obtained from direct measurements made with rockets, sputniks and space craft at various distances from the Earth. Most of these experiments were made with piezoelectric impact detectors. A drawback they all have is that internal noises resulting from temperature changes can be mistaken for impact with micrometeorites. In some of the **Kosmos** sputniks piezosensors were used, but special measures were taken to reduce the level of interference.

The new experiments revealed that the frequency of impacts with dust particles was a thousand times less than registered during earlier research.

Kosmos sputniks have also been used in investigating shortwave emissions of the Sun. These experiments were made at a time when the Sun had entered a new phase of increased activity. Their purpose was to accumulate material on the statistics of X-ray flares and the dynamics of their development. The results registered were also used to determine the temperature and electron concentration in the solar corona, the nature of X-ray flares and their connection with optical flares.

Kosmos sputniks were the first to be used for testing molecular generators--masers—under conditions of space flight. It is expected that with the help of these generators it will be possible experimentally to check some of the theses of the general theory of relativity.

Data on the aerodynamic braking of **Kosmos** satellites were used for calculating the distribution of atmospheric density and assessing its variations in the 170-300 km altitude range. Specifically, changes in the density of the upper atmosphere depending on solar activity were studied.

Four "Elektrons"

The most important scientific event in the study of near space with the early satellites was the discovery of the so-called radiation belts of the Earth. These proved to be a very intricate formation both as to nature and structure. The most contradictory opinions were expressed about the mechanism of their appearance and the composition of particles.

All these questions had to be checked experimentally. Since there were reasons to assume that the radiation belts were exclusively a dynamic formation, connected with other geophysical phenomena and solar activity, it was necessary to take integrated, synchronized measurements at different points in near space. This approach called for the development of a special system consisting of at least two sputniks placed simultaneously into vastly different orbits by one carrier-rocket. The Soviet Union had the superpowerful rockets necessary for this purpose. The first step was made on January 30, 1964, when a space system consisting of two probes, **Elektron-1** and **Elektron-2,** was launched. The separation of **Elektron-1** was carried out when the engine of the last stage of the carrier rocket was still working. Subsequently the second sputnik separated from the rocket.

The research programme carried out by the **Elektron** system envisaged a study of the low-energy and high-energy particles making up the radiation belts, the Earth's magnetic field, cosmic rays, the chemical composition of the gas medium in near-Earth space, the shortwave emissions of the Sun, cosmic radio emissions and micrometeors.

To continue the investigations begun on July 11, 1964, the **Elektron-3** and **Elektron-4** probes were put into orbit simultaneously. Their instrumentation was identical to that carried by **Elektron-1** and **Elektron-2,** and was intended for carrying out similar tasks.

The experiments showed that there is a close connection between the radiation belt and such geophysical phenomena as the Auroras, magnetic storms and deformation of the outer magnetosphere of the Earth. Apparently the main dynamic process in this complex of phenomena is the interaction of solar corpuscular fluxes with the geomagnetic field. In this connection the terms "inner" and "outer" radiation belts are at present of a purely conventional nature and are used mainly in the historical aspect, for it has been proved that this is a single complex formation existing in the magnetosphere of the Earth.

There are different ideas now about the composition of the radiation belts. Whereas initially it was considered that the "inner" belt consisted of protons with an energy of scores of megaelectronvolts and that the "outer" belt consisted of electrons with an energy of scores of kiloelectronvolts, research has shown that the entire sphere of radiation belts consists both of protons and electrons, and that the intensity of both changes depending on the distance from the Earth. The inner parts of the radiation belt are rather stable, and the fluxes of particles there do not alter substantially. The greater the distance from the Earth, the greater the variations of intensity which in a substantial measure depends on a geomagnetic latitude.

"Protons" in Orbit

About 50 years ago it was established that from the depths of the Universe there comes to Earth some very strong "radiation" which can penetrate even thick layers of lead. It was found that these so-called cosmic rays consisted of the protons of the nuclei of atoms of hydrogen and heavier elements, for instance, iron and nickel. The velocity of these rays approaches that of light.

Cosmic rays are of a remarkably stable nature—their intensity in different directions is absolutely the same and changes very little with the course of time.

Investigation of these rays, carried out by physicists in many countries, helped to establish the extremely multifarious nature of the elementary particles which make up the substance of the material world surrounding us; they also helped to lay the foundation of a new branch of science—the physics of elementary particles. As they study the interaction of high energy particles with matter scientists obtain information on their properties: mass, electrical charge, the forces acting between particles, and the distinguishing features of their structure.

Cosmic rays make a substantial contribution to the energy balance of the inter-stellar space and are among the most important component elements of the Universe. That is why the study of their origin and changes during movement in outer space is important also for astrophysics.

The appearance of sputniks and space rockets opened vast prospects for the study of cosmic rays. The composition of cosmic radiation observed by terrestrial stations is vastly different from that of primary rays. Before reaching the Earth this radiation changes substantially as a result of interaction with the nuclei of atoms in the atmosphere. The magnetic field also introduces tangible distortions. Even at altitudes of 25-30 km above sea level (such altitudes are reached by radiosondes) the composition of cosmic radiation cannot be considered as coinciding with the primary.

The mightiest of the accelerators, can produce particles with an energy of only several score Bev. And in cosmic rays there are particles with energies reaching 10^{10}—10^{11} Bev.

Added interest is given to research done with sputniks and rockets because the study of some phenomenon can be continued at any length, something which is impossible in terrestrial laboratories. What is particularly important is that now apparatus weighing scores of tons can be put into orbit around the Earth. With such heavy equipment it is possible to study high and superhigh energy particles and to measure the energy of each separate particle.

A vast amount of experimental material was provided by the three space probes of the **Proton** series. Thus, the number of superheavy nuclei registered by the instrumentation of **Proton** sputniks is several times greater than the figure obtained in all the preceding years of the study of cosmic rays. The energy spectrum and the content of cosmic rays was determined with a high rate of accuracy.

A new carrier rocket was developed for launching the **Proton** sputniks. The total capacity of the rocket's power units was more than 60 million hp, and its orbited payload 12.2 tons.

Man Penetrates Into Space

Successes in space exploration with artificial Earth satellites and spacecraft prepared the way for man's flight in space.

Superpowerful carrier rockets were developed, which could put a manned spaceship weighing over 4.5 tons into orbit around the Earth.

The problem of spaceship re-entry is complex both scientifically and technically. Its successful solution depends on a knowledge of the physics of the atmosphere, the laws of movement and heating of bodies at the great speeds reached during re-entry, of how to protect the surface of the ship from the vast heat fluxes appearing during braking in the atmosphere.

The Soviet Union had long before solved the problem of retrieving high-altitude rockets used to probe the atmosphere and to make biological experiments. Dummy models of the last stages of superpowerful rockets tested as far back as January, 1960 were adapted for passage through dense atmosphere. Manned flight through the upper atmosphere could be performed already then; only it would have been ballistic, not orbital flight. The idea of a manned ballistic flight was rejected in the USSR, since flight on a ballistic trajectory is not the same as space flight and contributes nothing towards the solution of the major problems of preparing the first manned space flight.

Pre-Start Preparations

Life-supoprt, attitude-control, re-entry and landing systems were worked out and tested on satellite spaceships with animal passengers. Retrievable spacecraft enabled scientists to make comparative studies of the animals' condition before and after flight and draw conclusions as to how a space journey affects living organisms.

The experiments with the 4th and 5th spaceships were what one may call a dress rehearsal for manned space flight. These ships were put in an orbit which had been selected for a space vehicle to be piloted by man, and the duration of their flight was the same.

Thousands of Soviet citizens, people of different ages and occupations, volunteered to make a flight into space. It is generally known that during space flight man is subjected to the action of specific forces—acceleration, weigthlessness, vibration, etc.—and to considerable nervous and emotional strain. Meanwhile, the astronaut must pilot the ship, maintain fitness for work and keep a cool head in difficult situations. All this meant that the space pilot must have perfect health, excellent psychological qualities and a high level of general and technical training.

As a result of clinical and physiological screening of a great number of volunteers, a team was selected, which began a programme of intense training on specially designed stands and training installations simulating on the ground and in airplane flight the conditions of space flight.

During plane flights investigations were made of the reactions of each of the astronaut trainees to weigthlessness and to transition from weightlessness to increased G-forces.

A special training programme was designed to give the astronauts the necessary information on the basic theoretical questions associated with the tasks of the coming flight.

Yuri Gagarin was selected from the astronaut team to make the world's first manned space flight.

Around the Globe in 108 Minutes

The spaceship **Vostok** piloted by Gagarin was launched on April 12, 1961, from the Baikonour Cosmodrome situated at 47° North, 65° East. The total duration of flight was 108 min, the maximum height of the orbit being 327 km. Vostok landed near the village of Smelovka, Ternovka District, Saratov Region.

The rocket which put the ship into a circumterrestrial orbit consisted of three stages and had a total length of 38 m and a maximum diameter (in the stabiliser belt) of 10.3 m. The first stage had four lateral sections—19 m long and up to 3 m in diameter. The second stage was the central section of the rocket. This section was 28 m long and up to 2.95 m in diameter. The third stage was 10 m long and had a diameter of 2.58 m. The rocket's six engines with a capacity of 200 million hp developed the aggregate maximum thrust of 600 tons. The weight of the ship (including the weight of the pilot) was 4,725 kg.

Mention should be made of the efficiency of the rocket engines used to launch the **Vostok** spaceship, which were distinguished by their exceptionally high mean thrust (economy of performance). Thus, the mean thrust of the RD-107 engine in vacuum is almost 30 seconds greater than the mean thrust of the American engine H-1 (this is an engine of the same class also using oxygen-paraffin fuel) which since 1966 has been used for the first stage of the **Saturn-1B** rocket.

The re-entry system of the **Vostok** was based on its braking in orbit due to a small impulse developed by the engines. The ship had an orientation and control system which helped it to manoeuvre in flight and ensure the right direction of the braking impulse before descent. The trajectory of descent was selected so that the pilot could successfully stand the stress during the ship's entry into dense layers of the atmosphere. From the moment of the switching on of the engines right up to the moment of landing the ship covered about 8,000 km. The descent lasted about 30 minutes. When the capsule reached the pre-set altitude, the parachute system came into operation.

Even if the re-entry system failed, the altitude of the orbit of the ship guaranteed its landing, due to aerodynamic braking, in the upper layers of the atmosphere, not more than 10 days after the launching.

The thorough preparation of the **Vostok** spaceship as well as the prelaunching tests ensured the complete success of man's first flight in space. This flight by Yuri Gagarin proved that man can normally stand the conditions of space travel: the launching into orbit, orbital flight and the state of weightlessness, and return to Earth. The assumptions of the scientists were confirmed that man could fully retain his working capacity in conditions of weightlessness.

The flight provided highly valuable information on the operation of the on-board systems and equipment. The reliability of the carrier rocket and the efficiency of the ship's design were fully confirmed.

Chain of Exploits

The success of Gagarin's flight made it possible to start immediate preparations for the next space flight, which was to be much longer. The flight was made by Herman Titov in **Vostok-2** launched on August 6, 1961.

The design and equipment of **Vostok-2** were similar to those of its predecessor. The distinguishing feature of Titov's flight was that it lasted longer (17 orbits) and that a greater volume of research work was carried out under the flight programme. Among other things, Titov made meteorological and geophysical observations. He was the first to use a motion picture camera in space. His film provided meteorologists with valuable material for the study of cloud fields and for assessing the possibilities of making meteorological investigations with Earth satellites.

Since Titov's flight was to be a lengthy one, special measures were taken to protect him from radiation exposure. Before the launching and during the entire flight an extensive network of astronomical observatories made regular observations of the Sun, employing a number of methods for accurate forecasting of increases in solar activity and the occurrence of flares. Balloon probes were also launched systematically in different parts of the Soviet Union, particularly in the Arctic latitudes, for directly registering the intensity of cosmic radiation in the stratosphere and higher. The information obtained by these methods was immediately processed and communicated to the staff in charge of the flight. This information was taken into consideration when determining the day of the flight and its mission.

"Handshake" in Space

The next step in the exploration of space came with the launching, on August 11, 1962, of **Vostok-3** piloted by Andrian Nikolayev, and of **Vostok-4,** orbited the next day, piloted by Pavel Popovich.

The distinguishing feature of this flight was that **Vostok-4** was put practically in the same orbit as **Vostok-3**. The distance between the two ships at the moment **Vostok-4** was put into orbit was only 6.5 km. This demonstrated the exceptional accuracy of the carrier rocket's control system as well as the high automation standards of the launching complex and satellite tracking means.

The volume of investigations performed by the astronauts was much greater than on preceding flights. In the course of the flight various physiological functions of the astronauts were registered. Experiments were made in "floating" during which the pilots remained for a long time suspended in the cabin so as to check the reaction of the vestibular organs to a state of weightlessness and to see how pilots could orient themselves.

The spaceship carried a great many biological test objects which were used for studying the effects of cosmic radiation.

The flight of **Vostok-3** and **Vostok-4** demonstrated the solution of several serious problems: putting two spaceships into close orbits with very high precision; the establishment of two-way communication in space, providing conditions for a prolonged flight. The experiment also showed that an astronaut retained his ability to work for a long period in a state of weightlessness, that it was possible to make a comparative analysis of the reactions of two astronauts during such a flight, and to achieve the practically simultaneous landing of spaceships in a preset area.

A Woman Space Pilot

The year 1963 saw one more twin flight performed by Valery Bykovsky in **Vostok-5** and Valentina Tereshkova in **Vostok-6.** To this day Valentina Tereshkova remains the world's only woman astronaut. The mission of that twin flight was to continue study of the effect of space flight on the human body and the capacity for working. The first space flight by a woman provided data for ascertaining the reactions of a woman's organism to the specific conditions involved.

As a result of this experiment the conclusion was drawn that space flight did not involve conditions unendurable for a trained man or woman.

Bykovsky remained in a state of weightlessness for five days, and although his record was broken later, it can be said that it was actually this flight that proved the possibility of a person remaining in space for a lengthy period. It was found that on the 4th or 5th day of weightlessness one's physiological functions became adapted to the new conditions. Further development of compensatory phenomena should lead to stable adaptation of the body to conditions of weightlessness. However, there remains the danger of pathological phenomena during flights of much greater duration. This problem still calls for thorough study.

During the flight an extensive programme of experiments, observations and filming was carried out.

Space Trio

The opportunities of carrying out research during space flight increased greatly when Soviet scientists developed a multi-seater spaceship. The crew that made a flight in it consisted of Vladimir Komarov, commander; Boris Yegorov, a doctor; and Konstantin Feoktistov, a scientist.

The flight of the three-seater **Voskhod** marked the beginning of space expeditions including scientists in the crew.

The presence of a scientist and a doctor on board the ship helped to expand substantially the programme of research, to make various astronomical, geophysical and medical observations.

Voskhod was put into a higher orbit than **Vostok** had been. The astronauts did not wear spacesuits. To ensure greater safety in landing **Voskhod** was fitted with two retro-engines.

Walk in Space

The flight of **Voskhod-2,** the second multi-seater, marked another qualitatively new stage in space exploration. It was during this flight that Alexei

Leonov took a walk in space, the world's first experiment of this kind. He left the spaceship cabin through a special air lock and for 12 minutes remained in airless space, protected only by his spacesuit equipped with an autonomous life-support system. Leonov's walk in space ranks on a par with such stages in space research as the launching of the first satellite and the pioneer flight of Yuri Gagarin.

To carry out the diverse operations involved in space research a person must be able to work in conditions of outer space while outside the ship. This is necessary, for instance, when astronauts have to go from one spaceship to another or to repair spacecraft in flight, etc.

Belyayev and Leonov's flight showed that an astronaut wearing a special spacesuit with an autonomous life-support system could leave the ship, move freely in outer space and work there.

Another distinguishing feature of this flight was the use of manual controls during the spaceship's descent, an operation which was brilliantly performed by first pilot Pavel Belyayev.

Lives Lost in the Name of Human Progress

The road into space is unexplored, and it is hard in such a vast undertaking to avoid casualties. Any scouting is dangerous, but scouting in space is doubly so.

On April 23, 1967, the new spaceship **Soyuz-1,** piloted by Vladimir Komarov, was put into orbit in the Soviet Union.

During the test flight, which lasted more than 24 hours, Komarov, completed the programme of the ship's systems workout and made the scientific experiments planned.

When completing this flight, astronaut Komarov had covered the most difficult section of descent and braking of orbiting velocity, and was at a low altitude from the Earth when the parachute system failed. This led to the death of the astronaut.

An incongruous accident robbed Soviet astronauts of Yuri Gagarin who died during an ordinary training flight.

The death of these courageous astronauts was a great loss to all mankind. Humanity will always cherish the memory of the glorious sons of the Soviet Union. Their heroism and fearlessness will never be forgotten.

On the Road to the Stars

The exploration of outer space is unthinkable without the docking of spaceships in orbit. To put one kilogram of payload into orbit around the Earth calls for about 50 kg of the initial weight of the carrier rocket. That is why spacecraft of great weight and long life should be assembled in orbit from parts delivered from the Earth by comparatively low-powered carrier rockets. Docking will also be necessary for deliveries of fuel, food and for the replacement of crews on a "coasting" orbital station.

Spaceships can be docked entirely automatically or with man's participation, which naturally provides an easier solution of this problem.

Research into the development of the necessary devices and mechanisms for automatic docking in orbit was done in the Soviet Union. To test the soundness of the scientific ideas and design solutions the experimental sputniks *Kosmos-186* and *Kosmos-188* were built.

Kosmos-186—"the active" sputnik—was put into a circumterrestrial orbit before *Kosmos-188*. In a three-day flight the sputnik's on-board systems were checked, along with the engines, and the correct fulfilment of various manoeuvres; corrections of the orbit were also carried out. Then, on October 30, 1967, *Kosmos-188* was launched at a carefully precalculated time. At the moment of its insertion into orbit the distance between the sputniks was 24 km. The homing systems of both sputniks conducted reciprocal search and measured the parameters of their respective movement. On the basis of these data, on-board electronic systems worked out commands for the orientation of the sputniks with respect to each other, and their orientation and movement control systems automatically carried out the necessary manoeuvres in space. When the distance between the sputniks was not more than several hundred metres, further approach was carried out by means of a system of special low-thrust engines. The sputniks kept approaching until their coupling devices linked mechanically. The docking operation over, both satellites flew for 3.5 hours as a single complex. Then, following a command from Earth, the sputniks uncoupled automatically. April 15, 1968, saw the second automatic linking in orbit of the satellites *Kosmos-213* and *Kosmos-212*.

The satellites were in linked flight for three hours 50 minutes carrying out a research programme as a single research complex. Then they were unlinked and put into different orbits to continue the flight programme. Five days later, having completed the programme of experimental investigations, *Kosmos-212* and *Kosmos-213* were returned to a preset area of the Soviet Union, following a command from Earth.

Rocket Flies to the Moon

As space research developed man acquired a realistic opportunity to begin the study, by direct methods, of other celestial bodies and especially the Moon. Such investigations have immense importance. In origin and development the Moon apparently has much in common with the Earth. At the same time its surface layers are not subject to the effects of atmosphere, as on the Earth. A comparative study of the two will therefore provide a key to understanding the development of the Moon and of our planet. The results obtained will be an important contribution to the treasury of human knowledge.

The use of space vehicles in the study of the Moon began soon after the launching of the first artificial Earth satellite.

On January 2, 1959, the Soviet automatic probe *Luna-1,* weighing 361.3 kg was boosted to escape velocity for the first time. After 34 hours of flight it passed the Moon at a distance of 5,000-6,000 km and entered an orbit of an artificial satellite of the Sun thus becoming its new planet.

September 12, 1959 saw the launching of the *Luna-2* probe. At 00 hours 02 minutes (Moscow time) on September 14, 1959 this probe weighing 390 kg landed on the Moon near the Crater of Archimedes. It delivered a steel sphere and a pennant with the Soviet national emblem. Their safe landing was ensured by the probe's design despite the impact (the velocity of collision with the Moon was three km per sec).

The on-board magnetometers made magnetic measurements down to a height of 55 km above the lunar surface. It was found that the Moon has no magnetic field (the permissible error of the magnetometer was 60 gammas). It was also established that the Moon has no radiation belts, this result being in keeping with the preceding finding.

A certain increase in the concentration of ionized particles was registered in the vicinity of the Moon as compared to the interplanetary medium. That is, it can be said that there is an extremely rarefied ionosphere around the Moon.

Twenty days later the third automatic probe—*Luna-3* was launched. Its purpose was to fly around the Moon, photograph the far side which is invisible from Earth and transmit the pictures back to Earth. The probe had an automatic system to orient it in space with respect to the Sun and the Moon. It also carried photo and television equipment with automatic film processing.

During the first session the entire illumined area of the lunar surface was photographed, although this afforded less details of the physical features than can be obtained with side illumination.

The photographs were sent back to Earth in a way similar to that used in the transmission of motion pictures by TV stations. The signals received were registered on film, magnetic tape, electrochemical paper and on special electron-ray tubes with long image retentivity.

The photographs obtained made a major contribution to science.

Reportage From the Ocean of Storms

The next stage in the exploration of the Moon was the soft landing of a vehicle on its surface.

The first three probes of the *Luna* series were launched directly from the ground by a continuous boosting of velocity to the necessary value, followed by coasting flight to the target. Moonward flight with a soft landing at the end required a more complex launching: the probe was first to be put into an Earth satellite orbit, and from this orbit it was to be fired at a set time with subsequent boosting of speed until it reached escape velocity: then, as it approached the Moon, correction of the trajectory was to be made; and finally, deceleration must be carried out by means of a retrorocket to ensure a soft landing. In preparation for this five automatic probes were launched to the Moon in 1965. These helped to develop the trajectory radio control systems, on-board apparatus, the astro-orientation system and the autonomous control instruments. The necessary research was completed, and finally on January 31, 1966, the *Luna-9* probe weighing 1,583 kg was launched.

On February 3 it made the world's first soft landing on the Moon's surface, on the eastern part of the Ocean of Storms, between the craters of Galileo and Cavalieri. For the next three days, the probe which weighed 100 kg transmitted to Earth pictures of the lunar surface and various telemetery data.

The site chosen for the landing was on the illuminated part of the lunar surface near the morning terminator to ensure the most favourable conditions for photography. Since the lunar surface was photographed when the Sun was at different heights over the lunar horizon the length of the shadows from the uneven features of the relief varied. From the photographs it was possible to determine the shapes of depression and promontories.

The panoramas transmitted gave extensive material for the study of the morphological and geological features of the landing place. There the surface is, on the whole, of a "pocked" cellular nature. The potholes or "craters" are small round pits with sometimes a barely discernable ridge. There are large numbers of stones mainly near the edges of the craters.

Clearly seen on the panoramas are about 20 linear structures 20-30 cm long. Also seen are mixed, intermediary details without characteristic aspect or form. Stereoscopic analysis of the panoramas resulted in a physical map of the area.

The information transmitted by *Luna-9* proved very valuable in determining the radiation conditions on the lunar surface.

On December 24, 1966, the Soviet probe **Luna-13** made a soft landing on the Moon, also in the Ocean of Storms.

The main task of this probe was to transmit to Earth pictures of one more section of lunar relief. The study of the physicochemical properties of the lunar surface directly at the landing place was carried out with a penetrometer, a dynamograph and a radiation density meter. The radiation conditions were assessed by gas discharge counters. All this instrumentation had previously been calibrated on Earth ground of "lunar" type. This made it possible to make a comparative assessment of the results of measurements. It transpired that the density of the surface layer of the Moon was about 0.8 gram cu. cm, i. e.. much less than terrestrial ground and the average density of the Moon. The indentor of the penetrometer went 45 mm into the lunar soil. This value means that there was a loose granular surface with a volumetric weight of less than 1 gr/cu. cm. The duration and value of the acceleration impulse, registered during the landing of the probe by the dynamograph, confirm that the afore-mentioned measurements were correct. The data on the gas discharge counters coincide with the results, obtained by similar instruments in the *Luna-9* probe.

Satellite of a Satellite

On April 3, 1966, the *Luna-10* probe was put into a lunar orbit. This experiment marked a new stage in the exploration of the Moon and near-Moon space.

The flight of *Luna-10* began in the same way as other 'luniks'. The rocket which was launched on March 31, 1966, put *Luna-10* first into an orbit around the Earth satellite altitudes of 250 km (in apogee) and 200 km (in perigee). Then the rocket's speed increased to 10.87 km per sec. and the vehicle changed over to a trajectory of flight to the Moon. However, at that time the trajectory of the flight was aimed not at some definite point of the surface of the Moon, but at a point 1,000 km from it. The artificial Moon satellite weighing 245 kg separated from the orbiting system after the rocket liquid-fuel jet engine was switched on twice—for trajectory correction and for braking during entry into a near-Moon orbit. The angle of inclination of the satellite orbit to the plane of the lunar equator was 71°54′, and the satellite's maximum and minimal altitude over the lunar surface was 1,017 and 350 km respectively.

Luna-10 was fitted out with instruments for investigations of near-Moon space.

During the very first days of its flight in a lunar orbit the probe registered a weak, homogeneous and very regular magnetic field.

The data obtained with charged particle traps made it possible to reach some conclusions concerning the length of the tail of the Earth's magnetosphere, fluxes of solar plasma in near-Moon space and the upper border of the concentration of charged particles in the ionosphere of the Moon. The study of the nature of radio signals when the satellite went behind the Moon and then emerged again showed that the Moon had no noticeable gas medium. Lateral gas discharge counters had determined very accurately the intensity of cosmic rays at various distances from the Moon and of low energy particles in the area of the tail of the Earth's magnetosphere. The measurements of Roentgen ray, infra-red ray and gamma ray emissions and of the surface layers of the Moon told scientists that the total intensity of the emissions was on the whole comparable to the intensity of radiation over the rock of the Earth crust only somewhat greater.

Observations of the changes of the parameters of the movement of *Luna-10* made it possible to assess the heterogeneous nature of the Moon's gravitational field. It appears that the anomalies thereof are not great.

Luna-11 and *Luna-12* continued the investigation of the meteorite and radiation conditions in near-Moon space, of infra-red ray and gamma ray emissions of the lunar surface, of the magnetic field of the Moon, of the solar plasma and gravitational field.

Luna-12 furnished a series of photographs of the lunar surface taken at distances ranging from 100 to 340 km.

A New Page in the History of Science

Economy of fuel is a problem of particular importance in interplanetary flight. In this connection great prospects for space vehicles in conditions of lengthy flight are offered by electrojet plasma engines. They were first tested as attitude control units of the orientation system during the flight of the *Zond-2* probe.

July 18, 1965 saw the launching of *Zond-3*. The main objects of its flight were to test the on-board systems in conditions of lengthy space flight and to carry out investigations in outer space.

Information was transmitted to Earth concerning the interplanetary magnetic field, cosmic rays, interplanetary plasma, cosmic long-wave radio emission, and micrometeorite particles. *Zond-3* photographed the still unregistered portion of the Moon's far side. Photographing was done at a distance of 9,220-11,570 km. Thirty-three hours after its launching **Zond-3** had photographed practically all the regions not covered by **Luna-3** in 1959. Within 68 min 25 pictures were taken. The photo and television equipment provided transmission to Earth of high-quality pictures with plentiful details, since each frame consisted of 1,100 lines with 860 elements per line. (For comparison it should be noted that when *Mariner-4* transmitted photographs of Mars each frame consisted of 200 lines with 200 elements per line, while the *Ranger* pictures of the Moon consisted of 800 lines with 800 elements per line.)

Scientists now have photographs of practically the entire lunar surface. Out of the total of 19 million square kilometres of the far side of the Moon's surface only about 1.5 million square kilometres remain unphotographed.

Surface features of that side discovered in 1959 have been confirmed. A continental distribution of ground with vast depressions and an abundance of craters of different sizes are typical of the far side. Formations which are not found on the visible side have been discovered—numerous chains of small craters extending for hundreds of kilometres, and sea-like formations known as thallassoids. Whereas on the visible hemisphere about 40 per cent of the surface consists of plains, called seas, these constitute only 10 per cent of the surface on the far side.

A schematic map of the eastern section of the far side of the Moon was made and work was done to compile a map of the entire lunar surface.

Rockets Fly Through Galaxy

The year 1961 saw the beginning of flights to the planets of the solar system.

Venera-1, the first interplanetary probe, was put into a trajectory, passing near the planet Venus, on February 12, 1961. In November 1962 the Soviet probe *Mars-1* was launched in the direction of Mars.

At present rockets flights to other planets can be carried out only at a certain time, depending on the position of the planets. This suitable time comes at intervals of 19 months, for flights to Venus, and 25 months, for flights to Mars.

A flight to Venus takes about four months, and to Mars—six or seven months. Before reaching these planets a space vehicle covers hundreds of millions of kilometres. The development of rocket systems, of navigation and long range space communications are difficult problems that must be solved to achieve this. An equally serious problem is that of launching an interplanetary probe from aboard a superheavy artificial earth satellite. Though basic solutions have been found to these problems, persistent work will have to be done for some years before such flights can be made.

Radio communication failed with *Venera-1* on February 27, 1961 making it impossible to perform the necessary corrections of the trajectory. The probe passed near Venus and entered an orbit around the Sun.

Mars-1 supplied a substantial amount of information about the state of outer space up to a distance of somewhere around 106 million km.

Venera-2, weighing 963 kg, was launched on November 12, 1965. After the probe went into its interplanetary trajectory its orbit was so close to that pre-set that it was decided not to do any correcting with the liquid fuel engine. The probe passed Venus on February 27, 1966, at a distance of 24,000 km.

There were 26 communication sessions with *Venera-2*.

Soviet Pennant on Venus

The *Venera-3* probe was launched towards Venus on November 16, 1965. The flight programme envisaged planting on the surface of the planet a spherical apparatus, 900 mm in diameter, provided with an insulation coating to protect it from overheating during braking in the atmosphere of Venus.

On December 26, 1965, when *Venera-3* was at a distance of 12,900,000 km from the Earth, the necessary correction of the flight was carried out.

Three and a half months later, on March 1, 1966, at 09 hours 56 minutes (Moscow time) the probe reached Venus and planted on its surface a pennant with the Soviet Union's national emblem. Thus Venus was the second celestial body, after the Moon, on which a man-made space vehicle was landed.

During the 63 communication sessions with *Venera-3* telemetric information on the operation of the station's systems was transmitted to Earth, trajectory measurements were taken and the necessary radio commands were sent; the readings of the on-board instrumentation were likewise transmitted.

On October 18, 1967 *Venera-4* entered the atmosphere of Venus, and took the first ever direct measurements of the physico-chemical parameters of the atmosphere there and then smoothly descended on the planet's surface. The probe weighing 1,106 kg, consisted of an orbital compartment and an instrument pack weighing 383 kg.

Here are the main results of the work of *Venera-4*. The data received earlier through radio astronomical observations, about the high temperature of the lower layers of the planet's atmosphere were verified and confirmed. Most important are the measurements of the atmosphere's chemical composition. It was assumed formerly that there was a large amount of carbon dioxide in the upper layers of the atmosphere of Venus. *Venera-4* proved that there was also carbon dioxide in big concentrations in the lower layers of the atmosphere, with oxygen and water vapour making up only 1.5 per cent.

As for nitrogen, it comprises less than seven per cent, perhaps only 2.5 per cent, of that part of the atmosphere.

Atmospheric pressure is approximately 20 times greater than on Earth, at sea level.

The apparatus installed in the probe's orbital compartment was used to make extensive investigations during the entire flight as well as in Venus's near space.

The measurements taken confirmed data collected during earlier experiments with other interplanetary probes, in heliocentric orbit. Some new results were also obtained. It was discovered, for instance, that the intensity of solar cosmic rays has increased hundreds of times, since 1964-65. This is connected with the general growth of solar activity.

Observations of particles of cosmic rays of high energy showed that Venus has no radiation belt of the kind that surround the Earth, nor has it any noticeable magnetic field.

Space Serves Man

The development of rocketry made it possible to use satellites not only for research but also for various practical purposes important for the national economy. One of these is the employment of satellites for communications. *Molnia-1*, the first communications satellite was launched in the Soviet Union on April 23, 1965.

An elliptical orbit with an apogee of 40,000 km was chosen for it. True, a stationary orbit passing at an altitude of about 36,000 km over the Earth, in the plane of the equator, is more feasible for communications satellites. A satellite placed in such an orbit, so to speak, hangs suspended over one and the same point of the globe. Ground antennas can be directed towards it permanently and thus ensure round-the-clock communications. For the Soviet Union such an orbit is not the most advantageous, as it does not ensure communications for areas lying north of 70° North. Though the *Molnia-1* orbit does not "function" permanently, it can "cover" any area of the USSR. *Molnia-1* rotates so as to serve the same area at the same time every day. A power unit ensures the exact adjustment of the rotation period.

Subsequently several more satellites of the *Molnia* series were put in orbit.

Initially communications were maintained only between two points—Moscow and Vladivostok. Then a network of receiving stations, called *Orbita*, was built in remote parts of the Soviet Union—in Siberia, the Soviet Far East, the Far North and Soviet Central Asia. And now Central TV programmes, relayed via *Molnia-1* sputnik, are watched by more than 20 million people living in these areas.

The *Orbita* network is designed in the following way. A superpowerful ground transmitter installed in the Moscow area sends regular signals of the programmes of the Central TV System to *Molnia-1*. On the satellite these radio signals are amplified and sent back to Earth. The *Orbita* receiving stations situated many thousand kilometres from Moscow catch the signals, amplify them and transmit them by wires to local TV centres. TV centres remote from the receiving station are linked with the *Orbita* by a small one-way radio relay line. The final link in the chain—the TV centre—transmits the Moscow programme received via the space bridge.

The *Orbita* station network is one way in which Soviet space research directly benefits man.

The Soviet Union is paying great attention to meteorological observations from sputniks and to setting up a global meteorological system. Experimental research has been carried out using a number of satellites of the *Kosmos* series. A meteorological research complex was installed, for instance, in *Kosmos-122*. This was one of the first satellites to obtain data on the distribution of clouds, the snow and ice cap, temperature of the Earth's surface and the upper limit of the clouds. The information was used for weather forecasting.

On Feb. 28 and April 27, 1967, *Kosmos-144* and *Kosmos-156* were put into orbit. This was the first time that an experimental meteorological system of two satellites functioning simultaneously began operation. The orbits were so selected as to enable observation of weather over every area of the globe with a time interval of six hours. The complex also includes ground centres for control, reception, processing and transmission of information collected by the Hydro-Meteorological Service of the

USSR and of other countries. The processing of the information is completely automated with the exception of deciphering photographs of clouds.

This experimental meteorological system will be improved with time. For a complete panorama of global weather it will apparently be necessary to have in orbit at least four or five sputniks functioning simultaneously. Possibly there will be a combination of low flying sputniks with those moving in very high orbit.

TV pictures of the Earth have already been taken from the high orbital sputnik *Molnia-1*. Special apparatus with changeable lenses was used ensuring coverage of all the visible part of the globe at all altitudes of flight. The pictures showed the distribution of large-scale cloud systems determining the nature of the weather over a vast area.

Further development of space meteorology calls for more information from sputniks. It is necessary to have data on the vertical distribution of temperature, concentration of humidity and some other parameters of the atmosphere. It is also necessary to determine the quantitative features of the cloud of canopy—the altitude of its frontiers, temperature and volumetric structure. Most interesting in this respect was an experiment made with *Kosmos-149*. Unlike the ordinary meteorological sputnik whose programme of actinometric measurements is mainly aimed at determining the complete "outgoing" radiation of the Earth, in this case it was planned to measure radiation in spectrum sections. Such measurements provide very accurate information on the composition of the atmosphere and on the cloud canopy. This is indispensable for reliable weather forecasting.

Facts, Conclusions, Problems

It is a little over ten years since the first experiment which opened for mankind the road into space was carried out. During these years sputniks and interplanetary probes provided information which astronomy had failed to give in 1,000 years. Thanks to successes in rocketry, space researchers gained unprecedented opportunities for making observations. Sputnik orbits are becoming ever more varied, and the research apparatus installed in them can be delivered to new, formerly inaccessible areas of outer space. Measurements are taken simultaneously with several vehicles which can change the altitude and inclination of their orbits. Superpowerful carrier rockets can take extremely heavy research apparatus into space.

The theory of information has helped in a new way to improve the efficiency and reliability of space communications. The application of the principles of this theory to building systems to transmit measurements, coupled with advances in the development of radionics and instrument-making, made it possible to send back an immense amount of information over hundreds of millions of kilometres.

Quantum electronics is confidently gaining ground in space communications. Molecular generators in apparatus installed on interplanetary probes can be used for the emmission of electromagnetic waves in the nature of pencil beams and for control and transmission of telemetric information over very great distances from Earth.

Last but not least, man's space flights and his walk in space have provided new opportunities for space research. A skilled observer can at will select the most interesting objects for investigations. Man's participation can help solve problems of the kind which automatic devices cannot tackle—from the analysis of the data obtained and rearrangement of observation programmes to the finest adjustment of the on-board instrumentation.

At the same time, despite the great scope of space exploration, there has been felt, particularly over the past few years, a need to raise quality of experiments and make integrated experiments with a subsequent thorough analysis.

Not yet completed is the study of the numerous mechanisms of interaction of corpuscular fluxes from the Earth's magnetosphere and atmosphere. Most present-day information on the invasion into the Earth's atmosphere of fluxes of solar corpuscles and on the accompanying disturbances of our planet's magnetic field are still being obtained not with rockets and sputniks, but through observations from Earth.

Sputniks and rockets have not been sufficiently used for the study of Auroras even though this vast geophysical phenomenon provides a vivid manifestation of the behavior of plasma in a magnetic field, and this on a scale which cannot be produced in laboratory conditions.

The study of the Sun's corpuscular emissions is especially important today to ensure safety from radiation during manned flights and to determine the surface doses when the outer elements of space vehicles are exposed. Large doses of exposure can produce irreversible changes in the paints and coatings of ships, dimness of lenses, intensive luminosity of surfaces, including, specifically, optical elements, and breakdowns in the operation of semiconductor instruments.

Still unclear is how cosmic rays are generated, the mechanism of acceleration of particles to tremendous energies and the processes responsible for the propagation of high and superhigh energy particles in the Galaxy. The solution of these problems is connected, first of all, with precision measurement of energy spectra, the chemical and isotope composition of cosmic rays, both of low and superhigh energies.

The proton-nuclear component of primary cosmic rays (the main one as to intensity and energy carried) has been subject to most comprehensive study. Even so, there is still a number of questions that remain unclear to this day. Quite interesting, for instance, is the search for fast antiprotons which should form among other particles during the interaction of cosmic ray protons with interstellar matter. The development, in the past few years, of superconductive magnets now makes it possible to produce a magnetic analyser for carrying out the aforementioned experiment on board a sputnik. Such an instrument will, apart from deviding particles as to their charge (protons and antiprotons, electrons and positrons), obtain impulse spectra of particles, make analyses of mass and solve other problems connected with the composition of cosmic rays.

The simultaneous registration of the general component of cosmic rays and of its individual features (various groups of nuclei) can provide additional opportunities for a more detailed study of conditions in interplanetary (and sometimes in interstellar) space and of the processes leading to the acceleration of charged particles in the Sun and to the emission of corpuscular fluxes. The best information on the composition of primary cosmic rays can be supplied by instruments installed either on a long-living remote artificial earth satellite, whose orbit goes through the poles, or on the Moon where there is no magnetic field, and study of energy spectra of cosmic rays, beginning with those of the lowest energy, can be made.

It has been established that there is intense circulation in the upper atmosphere and consequently processes stimulating it. Apparently these are winds blowing in various directions. Yet, the picture of global circulation, of its structure with vertically ascending and descending streams still remains unclear, though such details are very important for very many geophysical processes.

In view of the changes in the structural parameters of the terrestrial atmosphere, depending on solar activity, season, time of the day, etc., it is necessary to have systematic launchings of geophysical rockets and sputniks designed specially for the study of the atmosphere. A most important problem of further exploration of the ionosphere is the continuation of experiments at great distances from the Earth in order to get an idea of the altitude relations of the values measured. In doing so several methods of measuring should be used in the same space object. Such integrated experiments will make it possible to compare by various methods the results obtained.

The Roentgen emissions of the Quiet Sun have been studied on the whole, both experimentally and theoretically. It now remains only to accumulate further material and ascertain certain questions. However the Roentgen radiation of the Sun during flares is still a mystery in many respects. In this case it is necessary to have a development of the general theory of flares and the use of finer methods of exploration with sputniks and rockets.

It is generally known that the possibility of astronauts being exposed to radiation is mainly connected with the radiation appearing during large chromospheric flares. This phenomenon discovered during the latest cycle of solar activity has not been studied extensively. Unfortunately at present it is impossible to recommend means to protect astronauts from the effects of cosmic rays. To do this it is necessary to make a detailed study of energy and charge spectra of the corpuscular emissions generated during solar flares. The knowledge of the spectrum will make it possible to determine more accurately the permissible doses to which astronauts may be exposed and to develop protective means.

Very important (for long-range forecasting) is the clarification of the connection between the nature of corpuscular emissions of flares presenting radiation danger and various heliophysical features observed at periods preceding flares.

To solve these problems a wide range of experiments with artificial earth satellites in combination with terrestrial observations must be carried out.

The Soviet Union for Peace and Cooperation in Space

In 1967 most of the countries of the world signed a treaty covering the main principles to be observed in exploring and using outer space. The aim of the treaty is to promote extensive international cooperation in the conquest of outer space.

The Soviet Union regards its progress in space research as an achievement of all mankind. The Soviet Union's cooperation with other countries takes a great variety of forms—bilateral and multilateral agreements on joint research, international conferences of scientists, exchanges of scientific publications and work in international organizations.

Initially international cooperation in space research was limited to exchanges of the data obtained and results of experiments made. The prevailing trend now is for scientists and specialists from different countries to work jointly in the conquest of space.

Cooperation of this nature exists among socialist countries. Soviet scientists have bonds of close friendship with the scientists of Bulgaria, Hungary, the GDR, Cuba, Mongolia, Poland, Rumania, Czechoslovakia and other socialist countries.

The main areas in which cooperation is developing are the study of physical properties of outer space, space meteorology, space communications, space biology and medicine.

The joint work of scientists from the socialist countries in space physics, through ground observations, began as far back as the end of 1957, when the first artificial earth satellite was launched. The experience accumulated in visual and photographic observations of sputniks made it possible to change over, after 1962, to multilateral cooperation.

Thus, implementation of more complicated research programmes requiring the collective effort of observers in many countries became feasible. Besides scientists of the socialist countries, those of Holland, Greece, Italy, the UAR, Finland, the FRG, Sweden and other states are participating in some of these programmes.

Through joint effort of a number of countries synchronic photographic observations have been made for geodetic purposes, as well as tracking of low-flying satellites for the study of transitory changes in the density of the atmosphere.

The international bulletin *Observations of Artificial Earth Satellites* carries reports on the most interesting research work. The researchers taking part in the collective effort gather annually at scientific conferences held in different countries.

In 1965 and 1967, schools for observers of artificial Earth satellites were organized on Soviet territory, and at these young specialists were trained under the guidance of prominent Soviet scientists.

Cooperation between the socialist countries which is developing successfully in the study of the physical properties of outer space will enable researchers in these countries to carry out, in the next few years, some important scientific experiments, with Soviet sputniks and rockets, directly in space.

A Soviet-French agreement on cooperation in the study and conquest of outer space for peaceful purposes, signed in Moscow in June 1966, was an important step in the establishment of all-European scientific and technical cooperation.

At present Soviet and French colleagues are discussing the possibilities of expanding joint work in the study of outer space physics. Active preparations are being made for a Soviet-French experiment. The satellite, which French scientists are building, is designed for investigation of the magnetosphere of the globe and near-Earth space, and will be placed in a circumterrestrial orbit by a Soviet carrier rocket.

For several years Soviet and French physicists have been engaged in a joint study of electromagnetic phenomena in magnetically conjugate points of the Earth. Soviet scientists have worked on Kerguelen Island in the Indian Ocean, and their French colleagues—in the village of Sogra, Arkhangelsk Region.

The developing Afro-Asian states are now also contributing to international cooperation in the exploration of space. This cooperation opens for them the road into space though as yet their ability to carry out independent space research is limited.

At the beginning of 1968, at a gala ceremony attended by many foreign guests, an international rocket range was opened in the southern part of India in the area of the geomagnetic equator.

The Soviet Union which together with other countries took an active part in the construction of the range presented valuable scientific equipment to India.

Scientists from some countries, including the Soviet Union, use this range for studying the physical properties of the upper atmosphere at low latitudes.

Stations for the observation of artifiicial Earth satellites have been set up, with Soviet aid, in the UAR and Mali. Working side by side with Soviet specialists, the scientists of those countries gain the experience which will enable them to carry out their own research.

An important area of the Soviet Union's cooperation with other countries is space meteorology.

The vast information coming from the Soviet meteorological sputniks is quickly transmitted to Soviet and foreign meteorological establishments, via special communication channels.

Soviet meteorological rockets with instrumentation developed by French scientists were launched from Heis Island (Franz Josef Land), while French specialists made observations from an Il-18 laboratory plane. This experiment, planned to study the temperature of the upper atmosphere, was successful.

World meteorological centres have been set up in Moscow and Washington, D.C., under an agreement concluded between the USSR Academy of Sciences and the US National Aeronautics and Space Administration. A direct communication channel for the transmission of conventional meteorological information and that received from the satellite links these centres opened in 1964, via the Moscow-Warsaw-Berlin-Frankfurt am Main-London-Washington line. This channel is used for round-the-clock transmission of the most important information on the weather by sending photographs, facsimiles and telegraph signals.

It is considered necessary, in the interests of the further development of economic, commercial and cultural relations, to establish an international communications system using satellites. This system is to be built on the principles of complete equality and mutual benefit. It should ensure telephone and telegraph communications, the transmission of TV programmes and other information.

Any country that desired to should be able to join.

Experimental colour TV transmissions between Moscow and Paris via the Soviet satellite *Molnia-1* began in November, 1965.

One of the first Soviet-American experiments in space communications was the establishment of communication via the US satellite *Echo-2*. In the spring of 1964 that satellite was used for 34 communications sessions between Jodrell Bank in Great Britain and the Gorky University Observatory in Zimenki, the USSR.

With man's penetration into outer space two new sciences have appeared—space biology and space medicine. Space techniques have equipped biologists with new means of tackling outstanding issues, while at the same time confronting them with fresh problems.

Notable successes in space medicine and biology have been achieved in late years by scientists in a number of countries. However, there are still many problems whose solution demands international cooperation. Of considerable interest is the agreement between Soviet and American scientists on the joint publication of a book in Russian and English on the major achievements and prospects of space biology and medicine.

Soviet scientists take an active part in international congresses and symposiums devoted to space research problems.

Annual astronautical congresses have been held regularly since 1950. They provide extensive opportunities for exchange of the results of research in a great variety of fields relating to astronautics. The International Astronautical Federation, uniting astronautical and rocketry societies of more than 40 countries, organizes congresses attended by up to a thousand scientists from different countries. The USSR Academy of Sciences is a member of the Federation, and Soviet Academician Leonid Sedov has been President of the Federation for two terms running.

Another scientific organization, set up specially for coordinating the efforts of researchers in different countries in the exploration of space, is the Committee on Space Research (COSPAR). It was formed in 1958 by the International Council of Scientific Associations for the purpose of continuing the cooperation in the study of the upper layers of the atmosphere and outer space which had developed during the IGY (1957-58). COSPAR unites leading research establishments of more than 30 countries as well 10 international scientific associations engaged in space research.

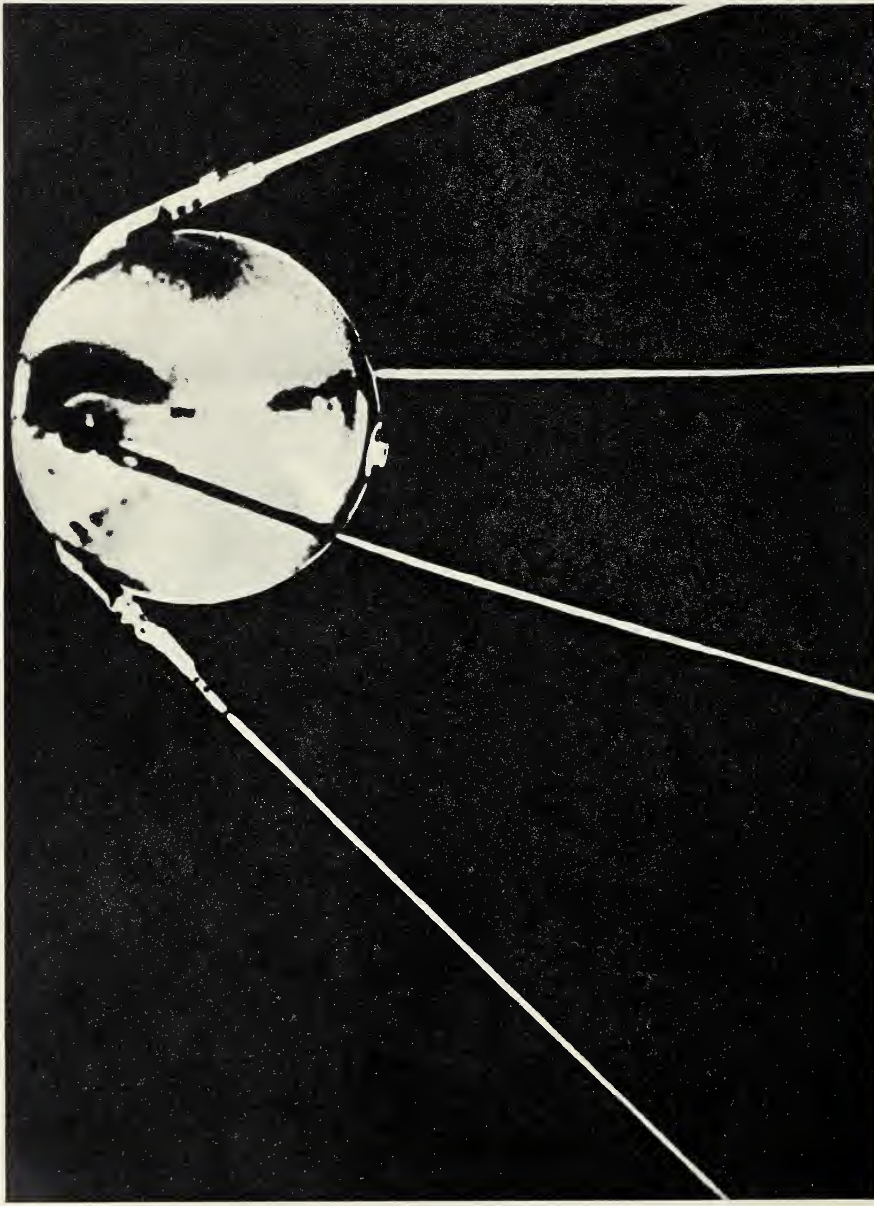
Six permanent groups made up of prominent scientists from different countries have been formed for carrying out the work of coordination of the efforts of GOSPAR members.

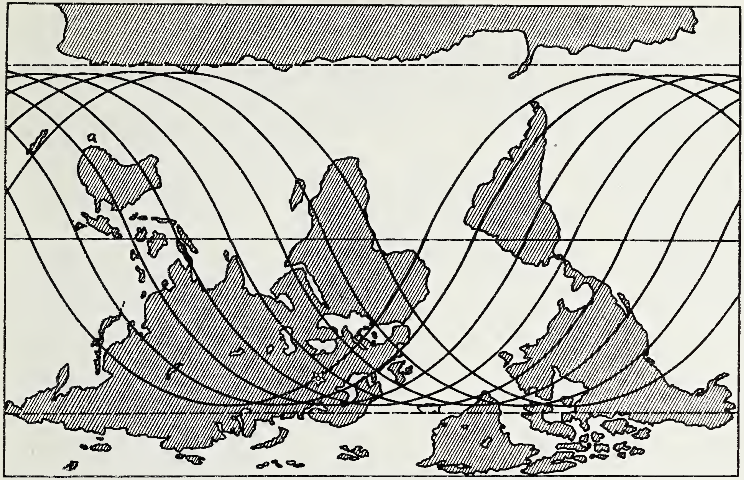
Scientists throughout the world have acclaimed COSPAR's international symposiums on space research, since they provide an opportunity for summing up the results of space research done in different countries, comparing objectively the results obtained and mapping out plans for joint experiments.

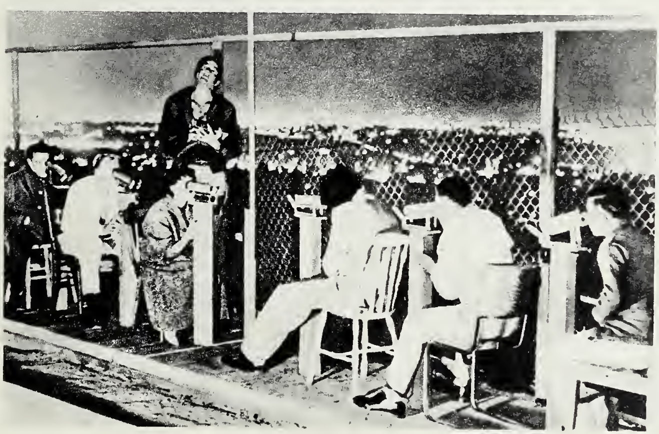
The Soviet Union invariably avails itself of the opportunities provided by congresses and symposiums organized by COSPAR and the Astronautical Federation to make the results of its space research accessible to the greatest possible number of countries. Scores of papers dealing with the latest developments in space exploration are read by Soviet scientists at each of these gatherings.

The thoroughness and scope of scientific exploration and the practical use of outer space grows steadily, as does the number of states directly participating in space research. Hence it is imperative that outer space should be turned into an arena of peace and international cooperation.

ILLUSTRATIONS



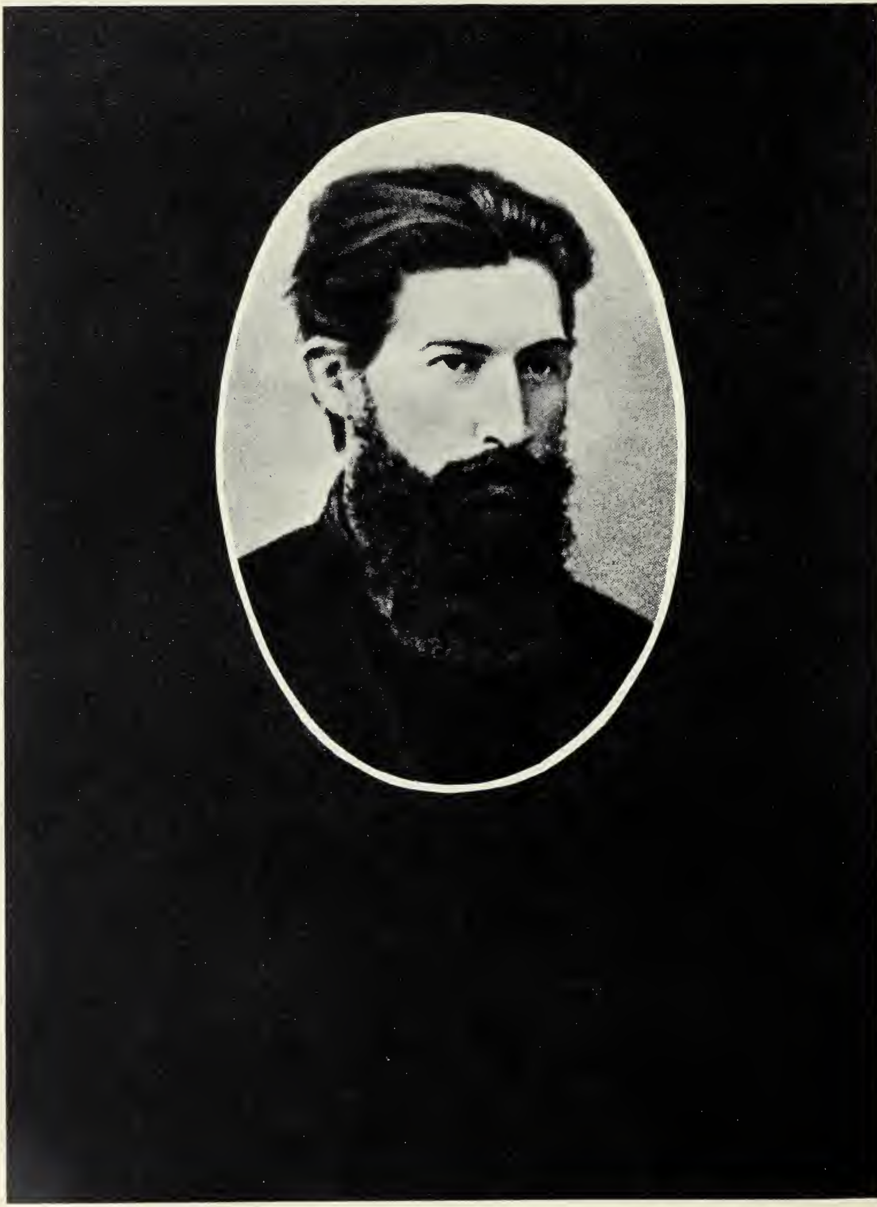


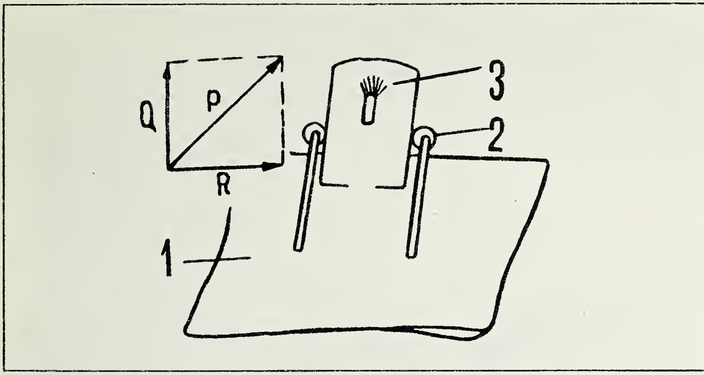


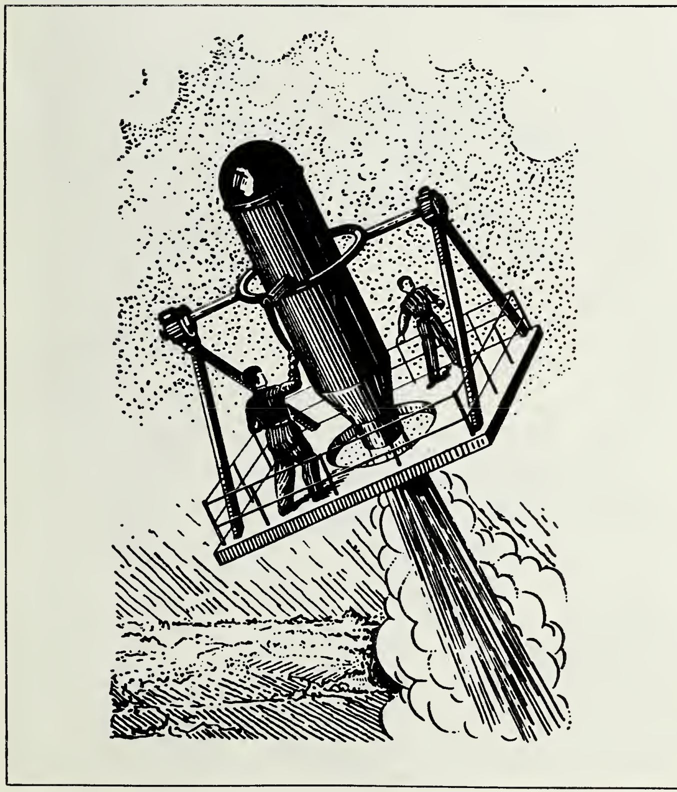
The first ever artificial Earth satellite launched by the Soviet Union on October 4, 1957

The path traversed by the first man-made satellite after 24 hours of flight

Members of an amateur astronomer circle in California tracking the first Earth satellite

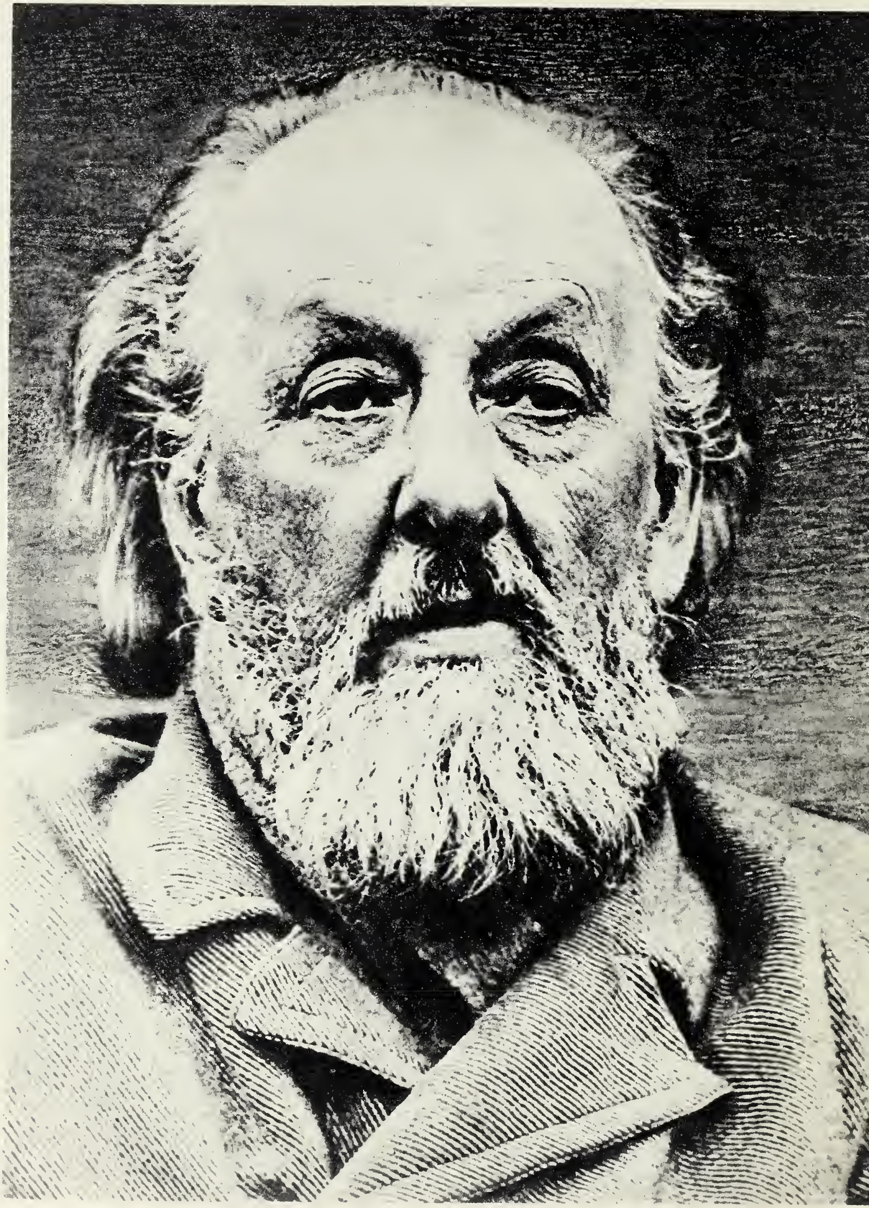


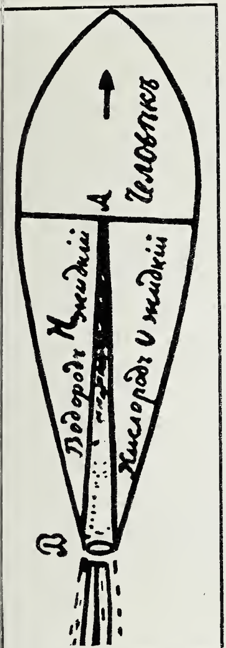




Nikolai Kibalchich

Air vehicle by N. I. Kibalchich



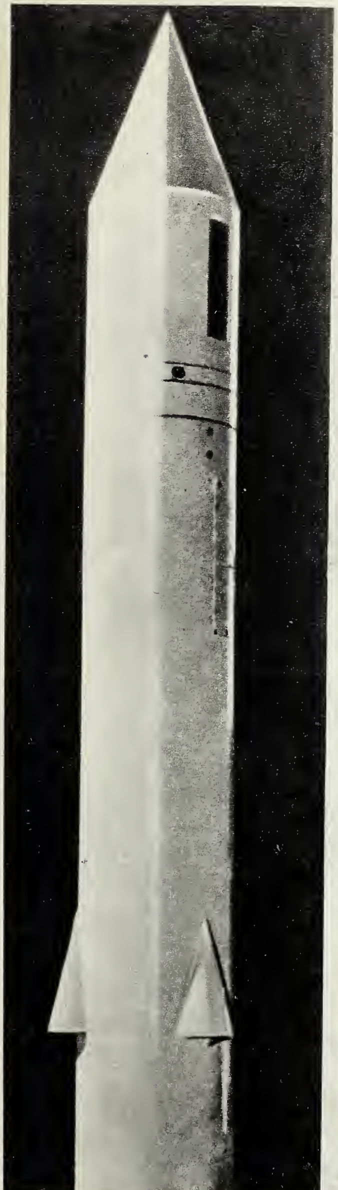


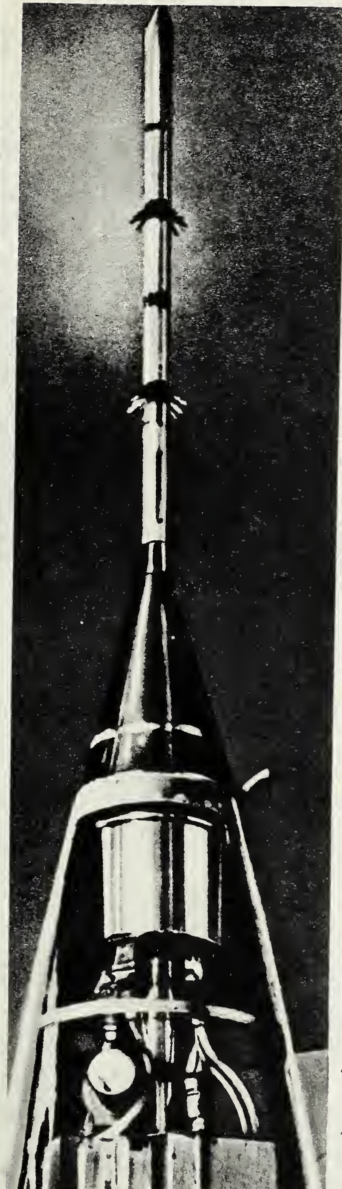
"If life is so varied on the Earth where conditions are relatively uniform, it must be infinitely varied in outer space where any conditions are possible," wrote K. E. Tsiolkovsky, the great Russian scientist, pioneer of rocket engineering, astronautics and the theory of interplanetary travel

Jet device by K. Tsiolkovsky

Monument to Tsiolkovsky in Kaluga where he worked for years


ГИРД-Х





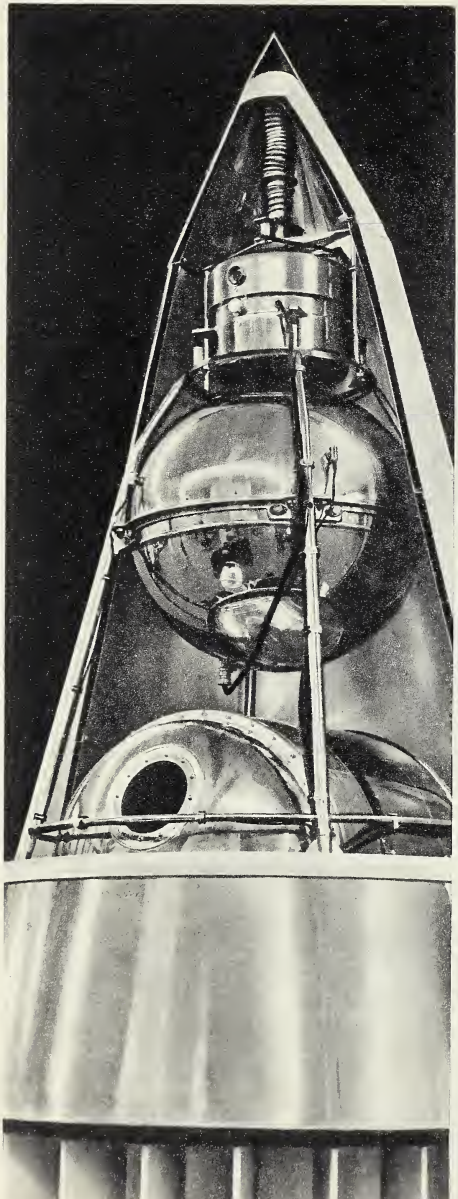
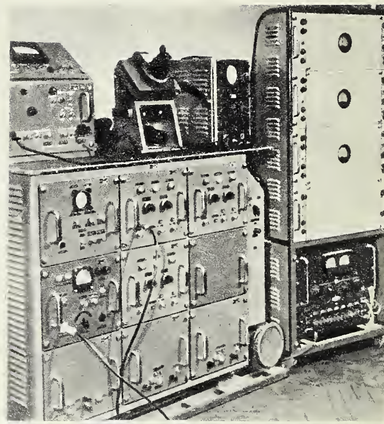
One of the first soviet liquid-fuel rockets (1933)

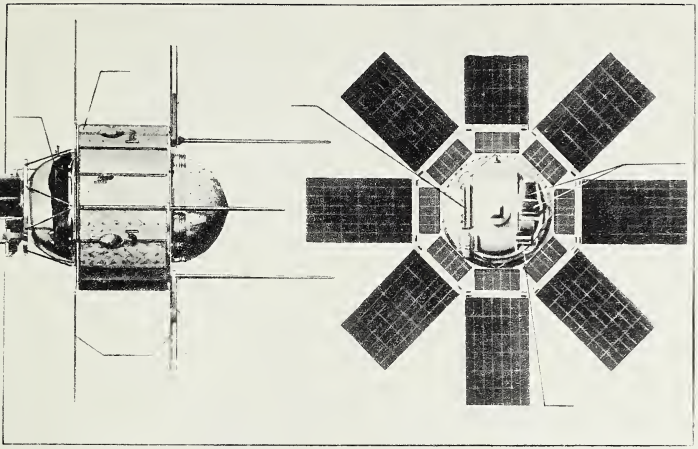
Fuelling the rocket with liquid oxygen

A team of rocket designers with their brain child. Extreme left (standing), is Head Designer—Sergei Korolev

A rocket spectrograph for solar research

Head of standard weather rocket

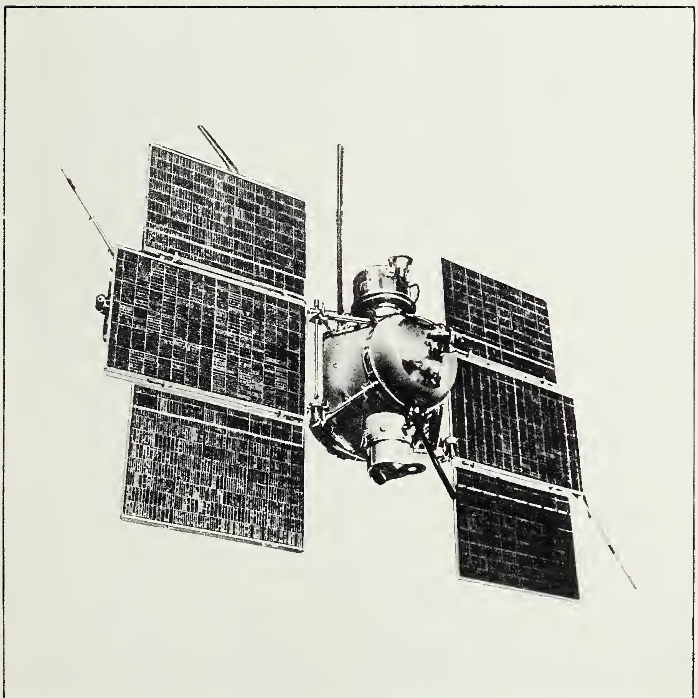



Second Earth satellite. The photo shows part of the protective nose cone jettisonable when the satellite is put into orbit. Below the spring is an instrument for investigating short-wave solar radiation; lower still is a container with radio transmitters and a pressurized cabin for test animals

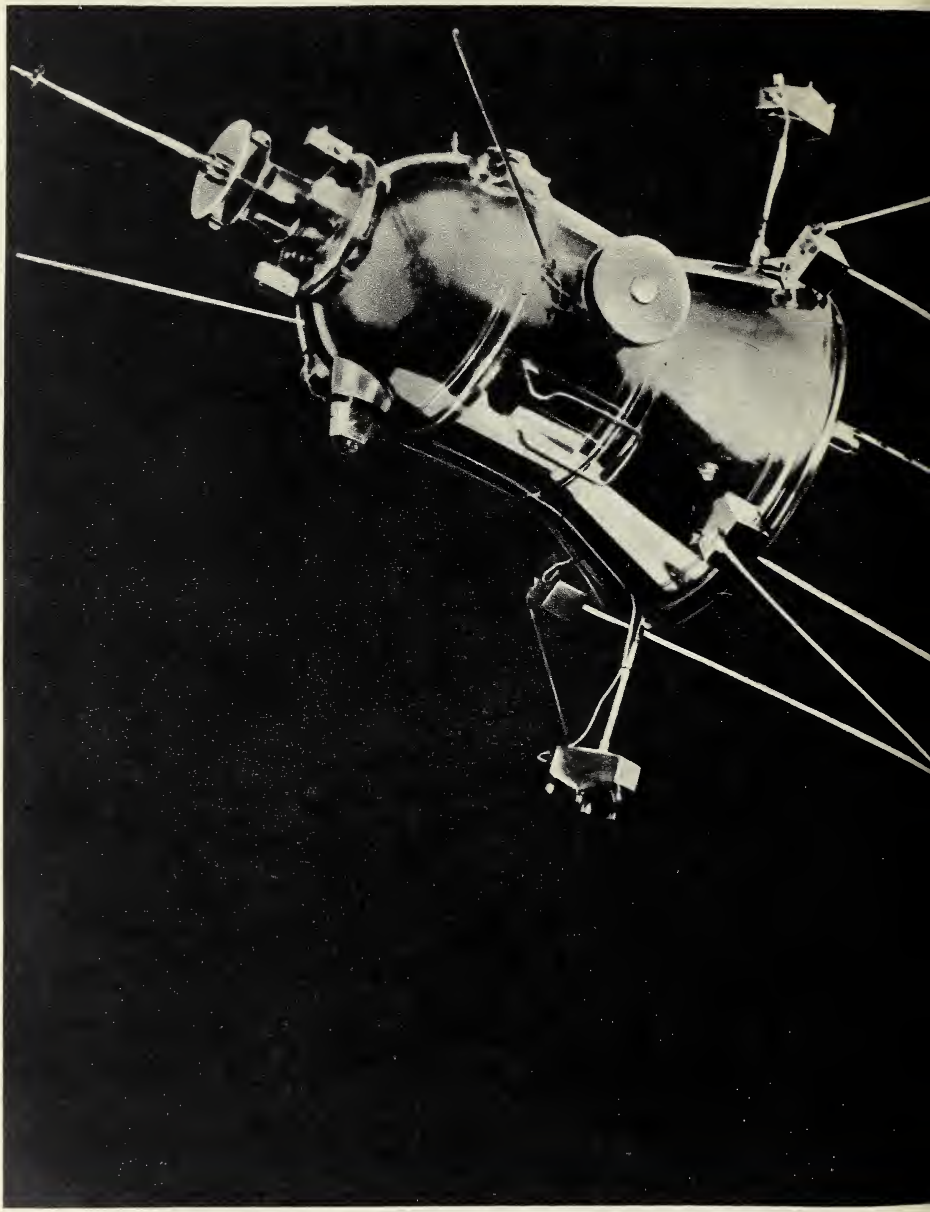
Ground facilities to pick up signals from the sattelite

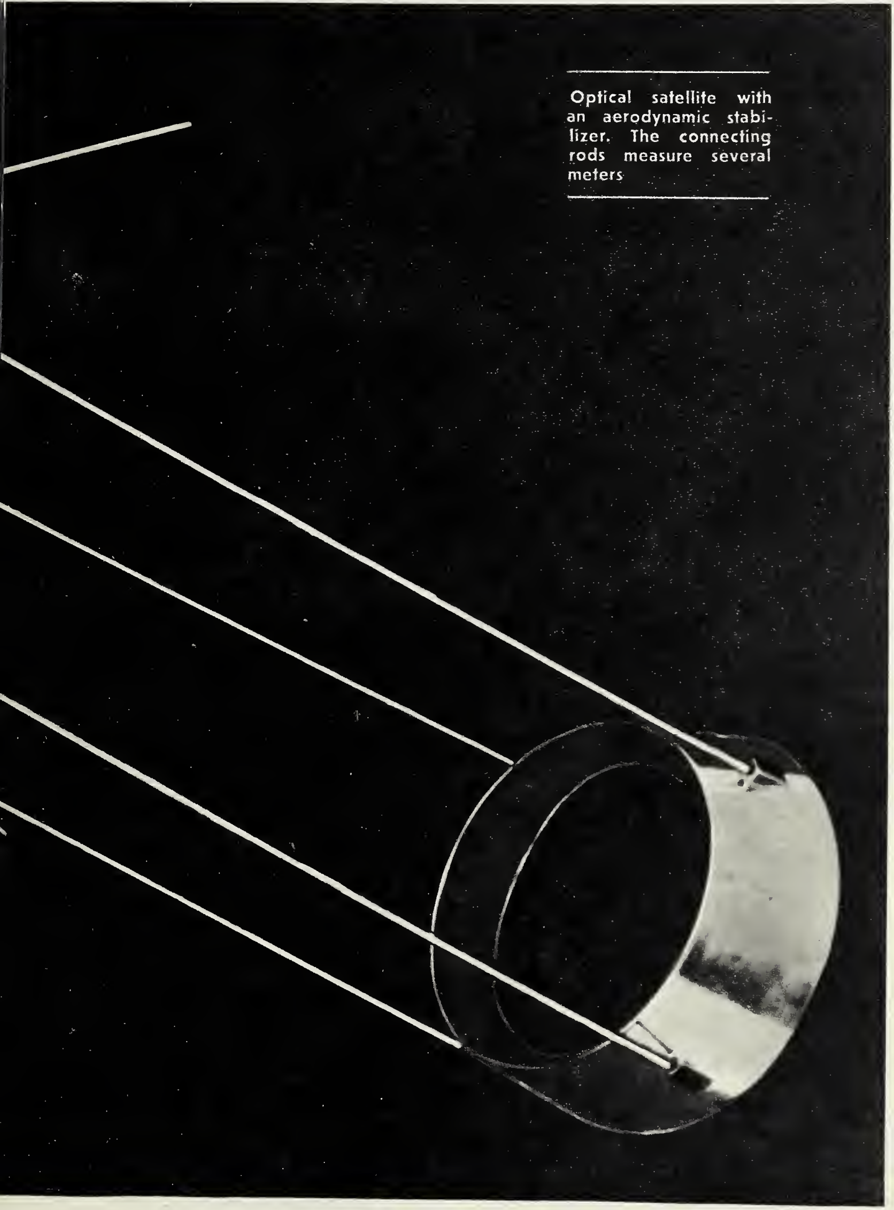
Laika aboard the satellite



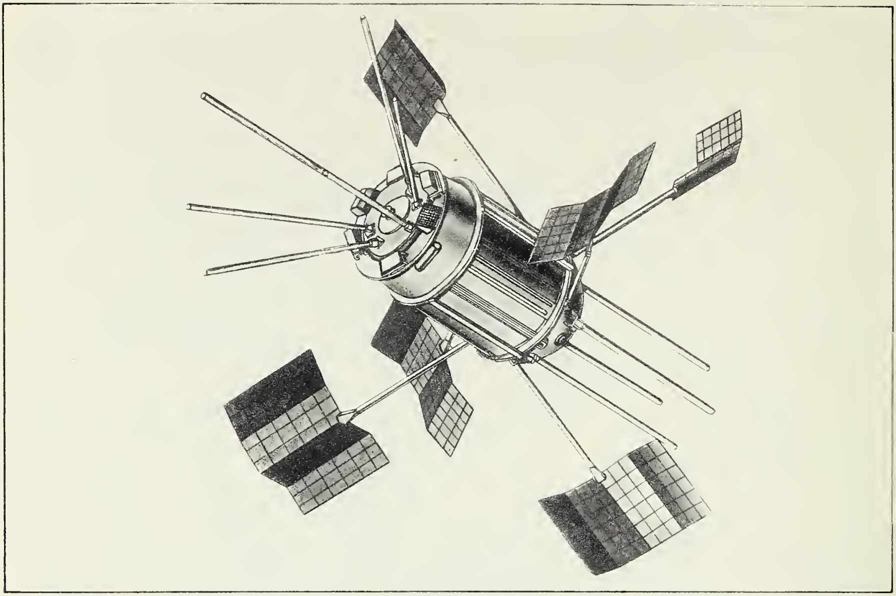
Satellite of the Kosmos series designed to investigate short-wave solar radiation

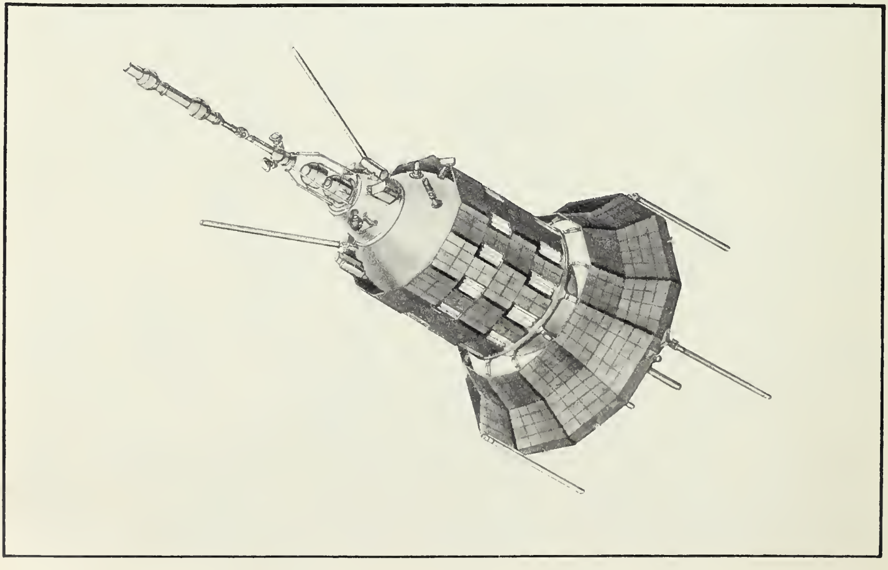
Kosmos probe to test flywheel attitude control system

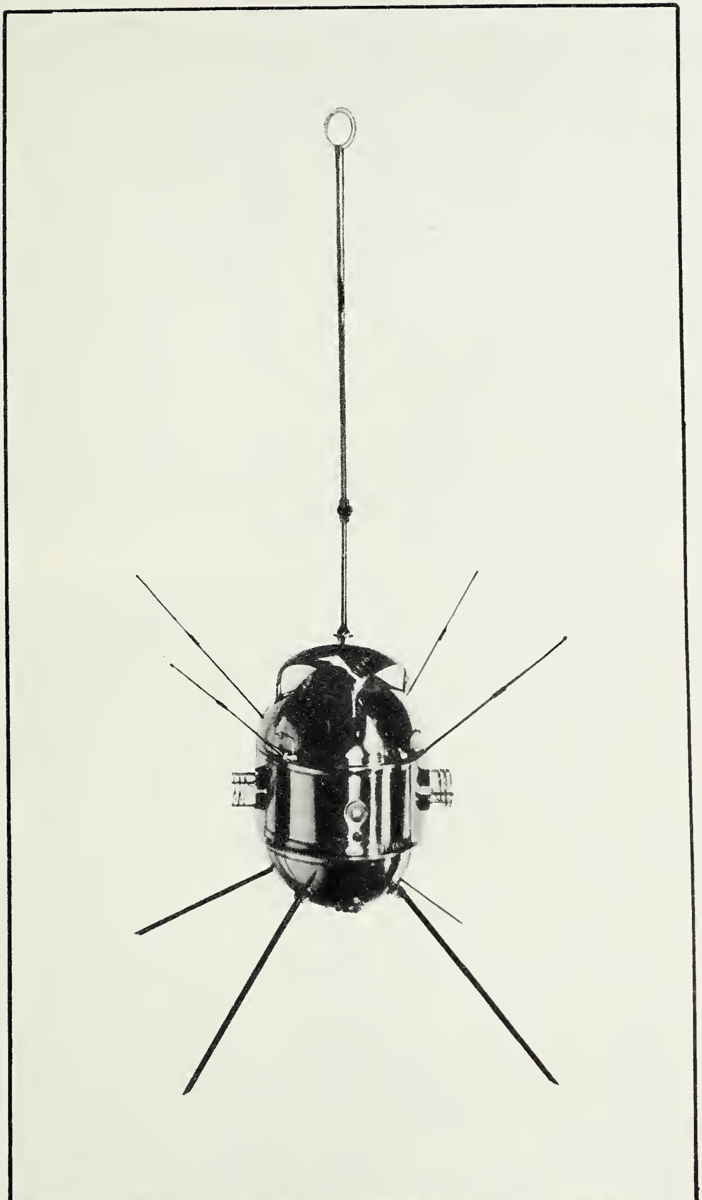




Optical satellite with an aerodynamic stabilizer. The connecting rods measure several meters

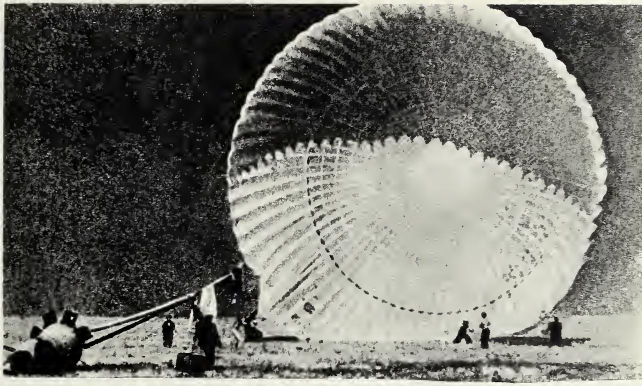






Electron **probes**

A Kosmos **fitted out with proton magnetometres**



Kozyavka about to make a journey in a rocket

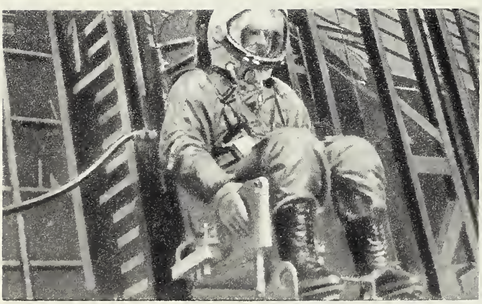
Testing equipment for high altitude flying

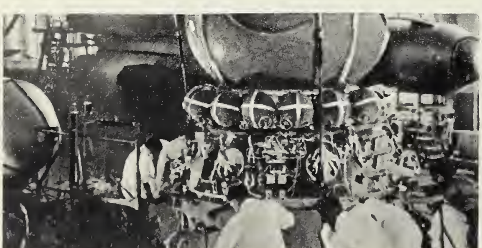
Landing of capsule with test animals

In a pressure chamber

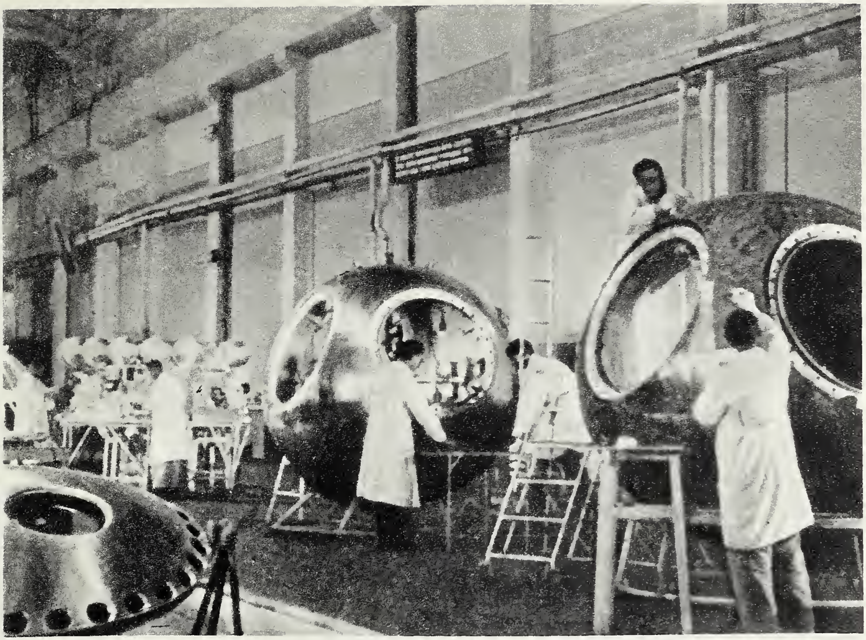
While in the pressure chamber a trainee's physical condition is constantly monitored

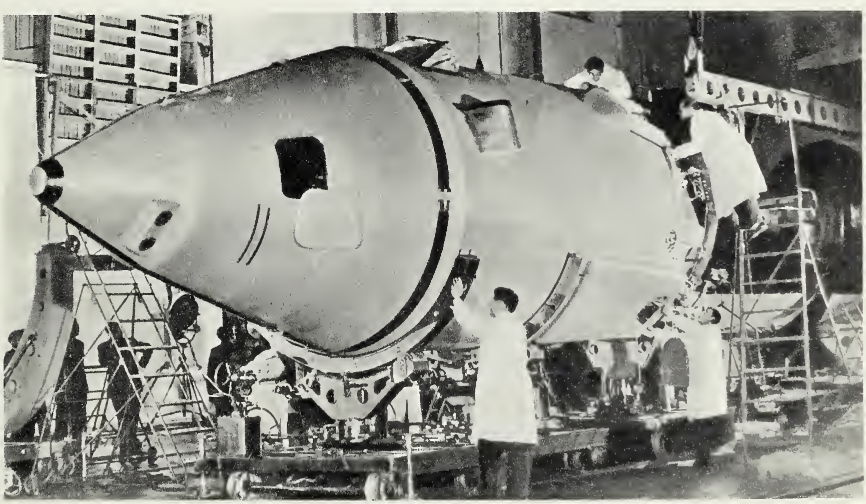
Astronaut's training

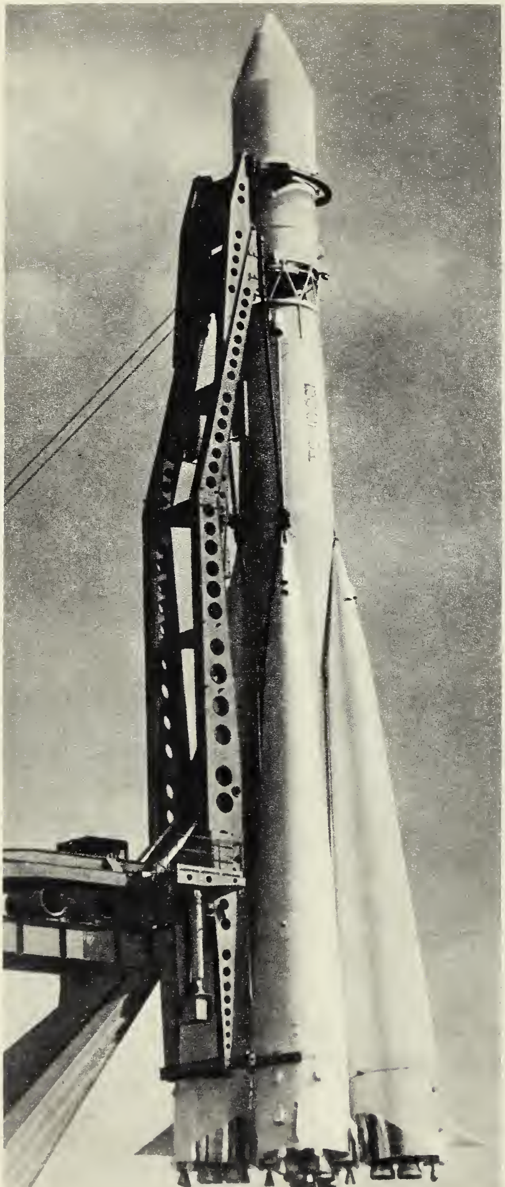


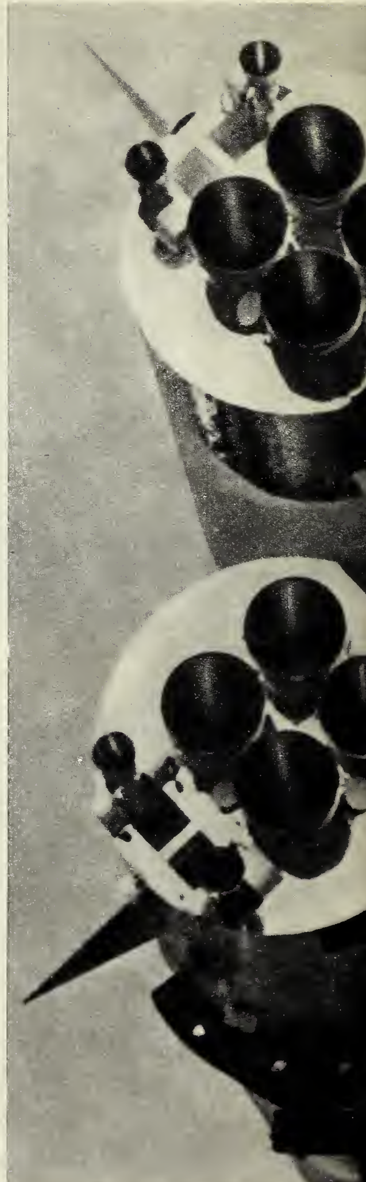


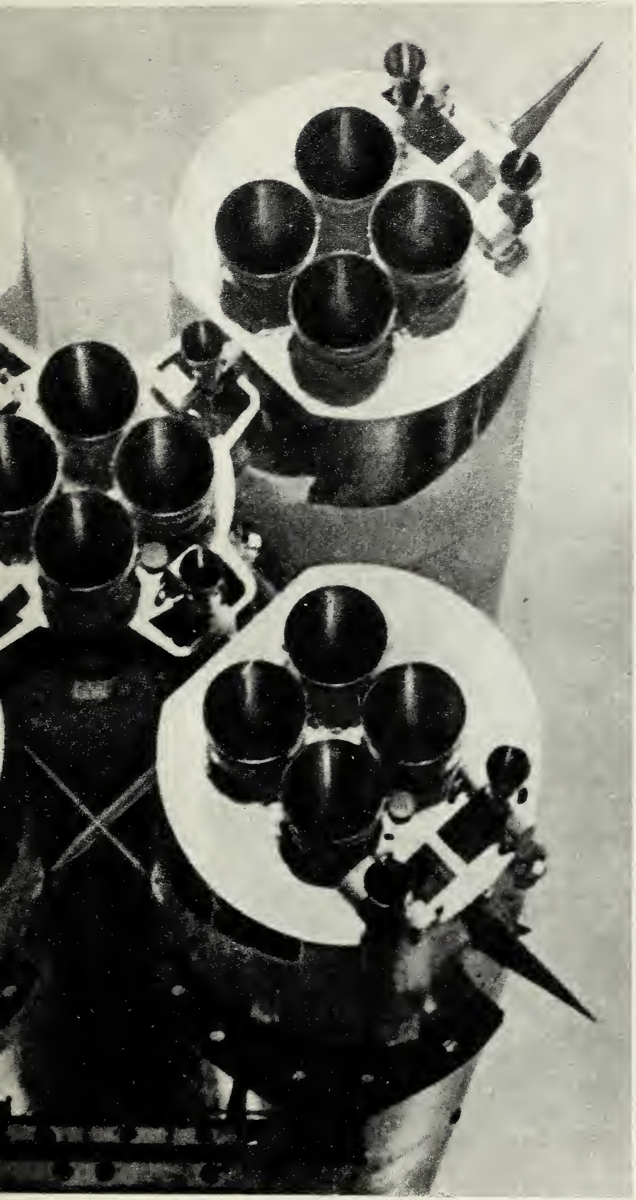
Space ships' assembly



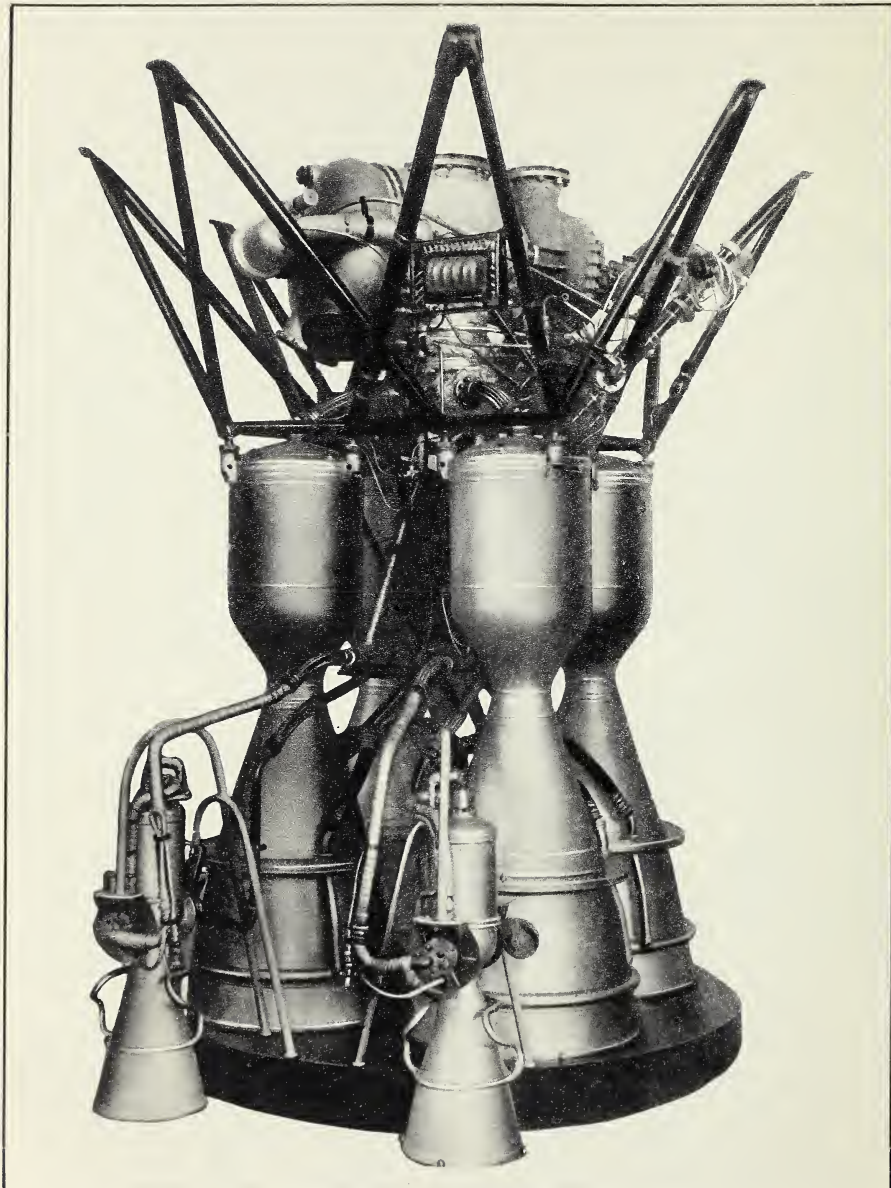


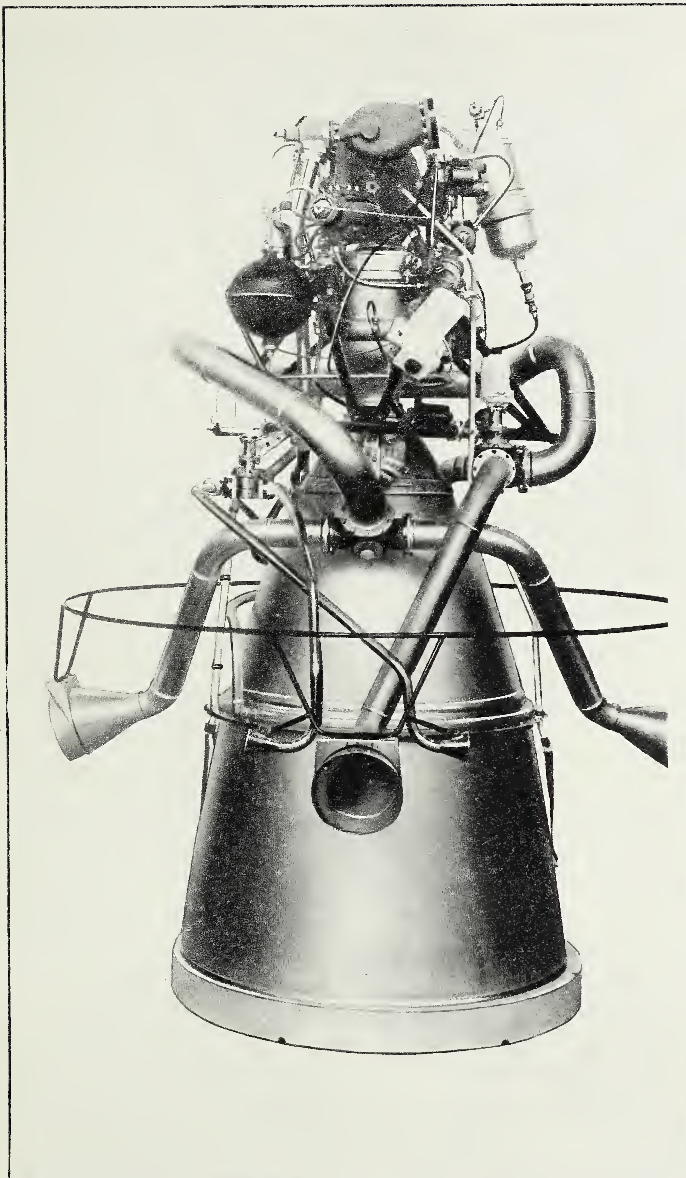






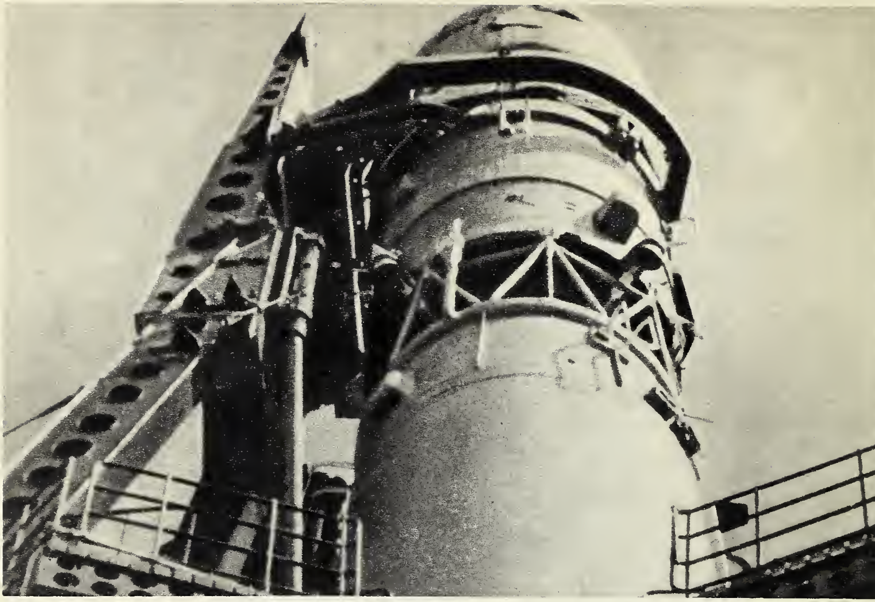
Vostok carrier-rocket

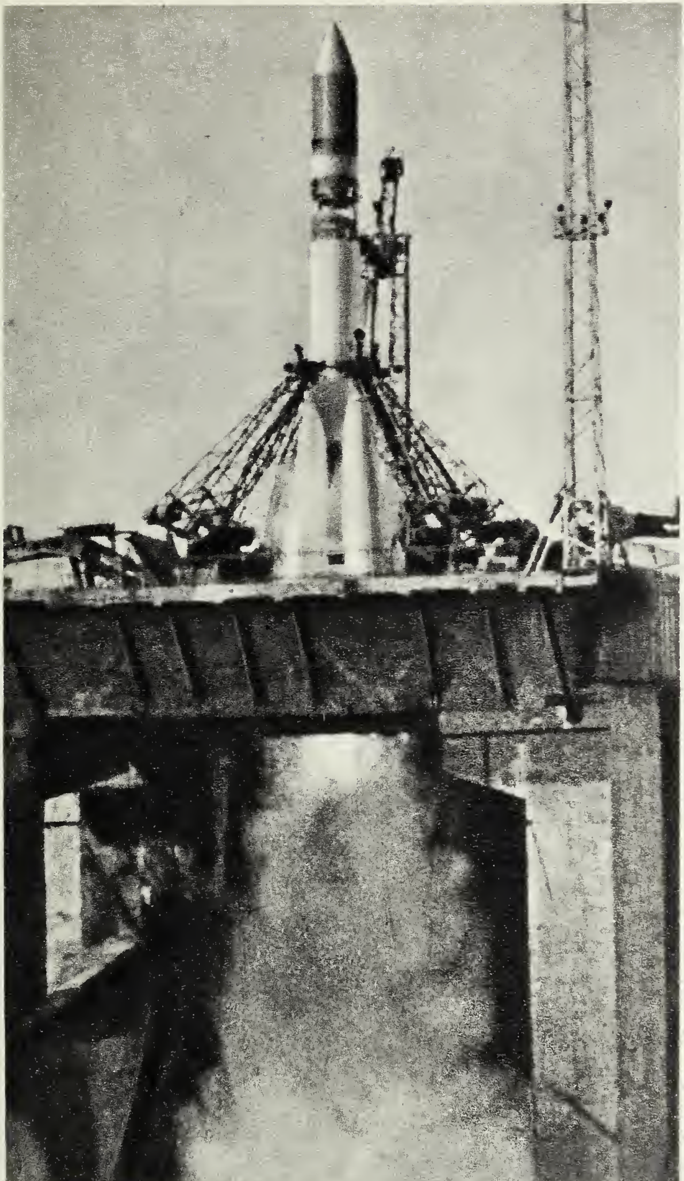




The RD-107 engine which powered one stage of the Vostok **carrier-rocket**

Engine of the Kosmos **carrier-rocket**



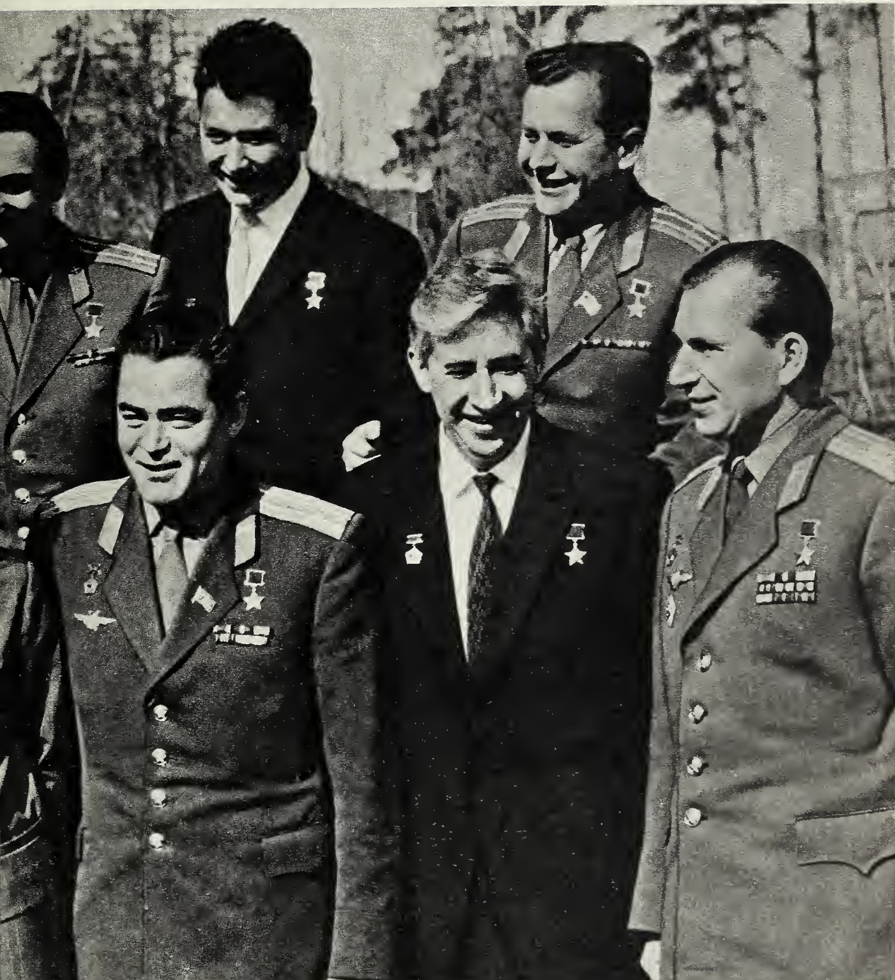


Countdown and take-off
Academician Sergei Korolev at the command post

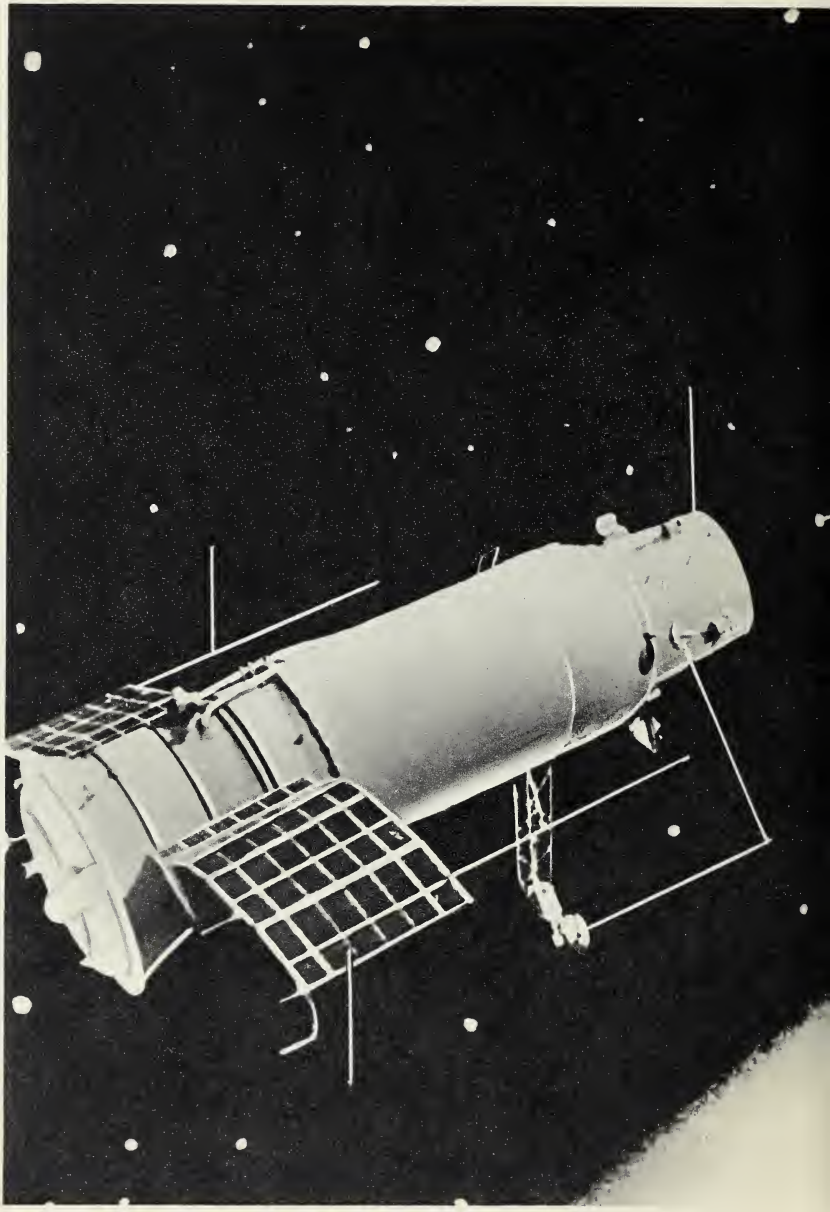
Superlong space communication centre

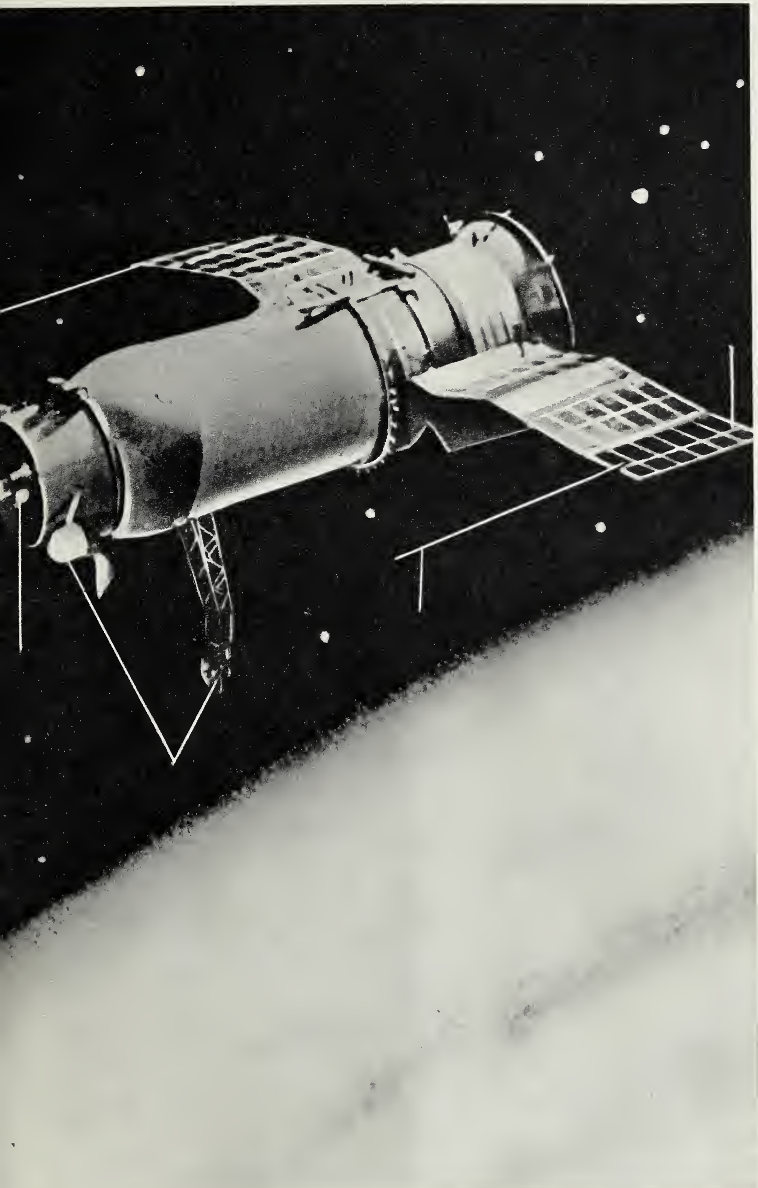
The walk in space

Back from outer space

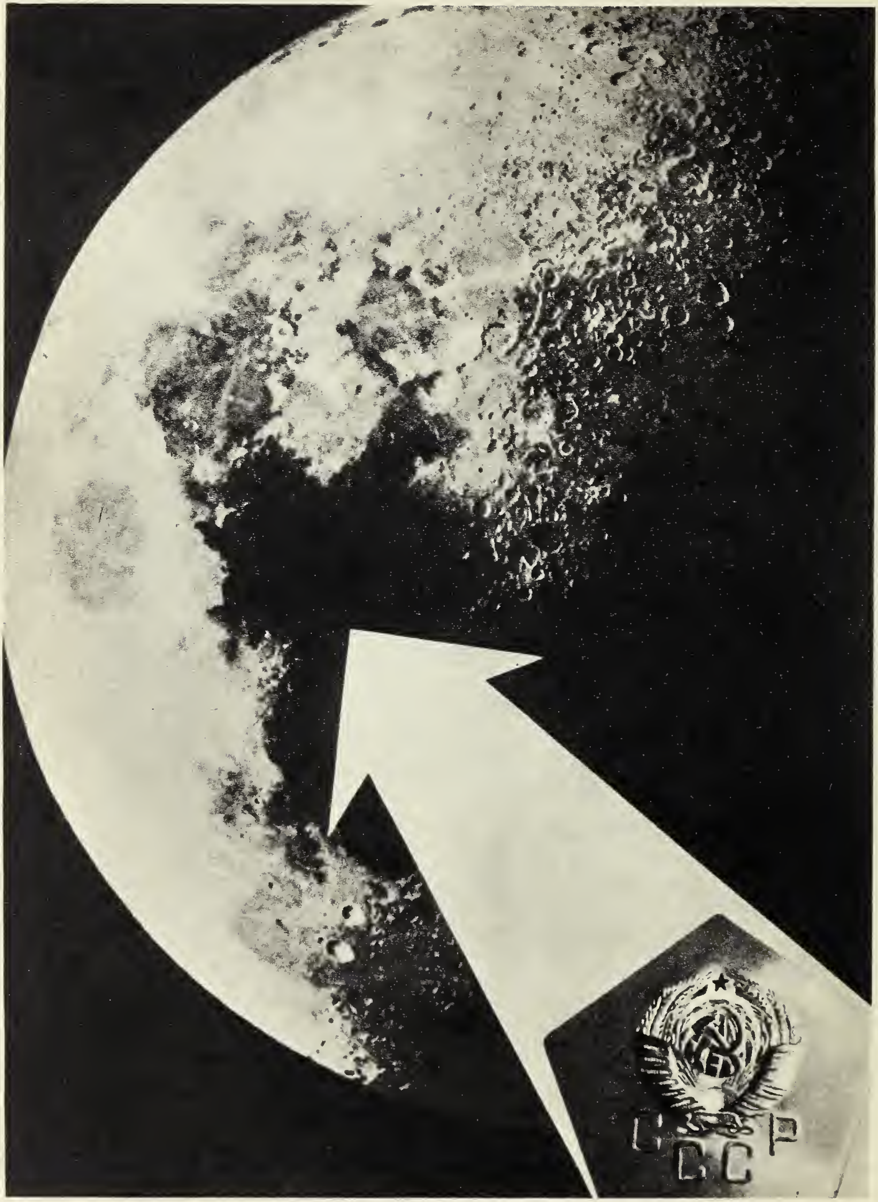


Soviet astronauts





Automatic docking of spaceships in orbit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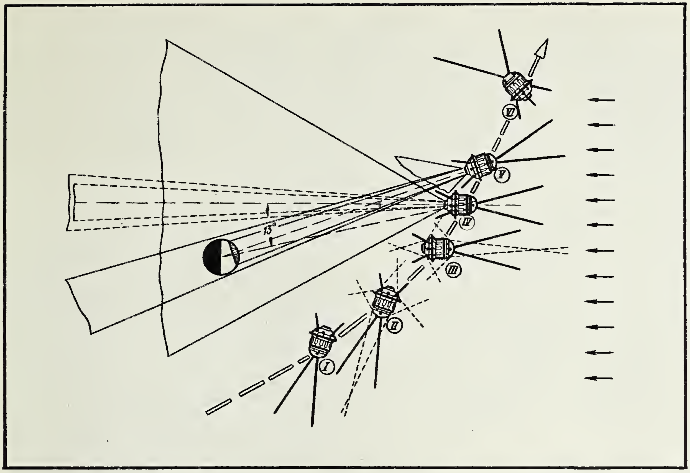
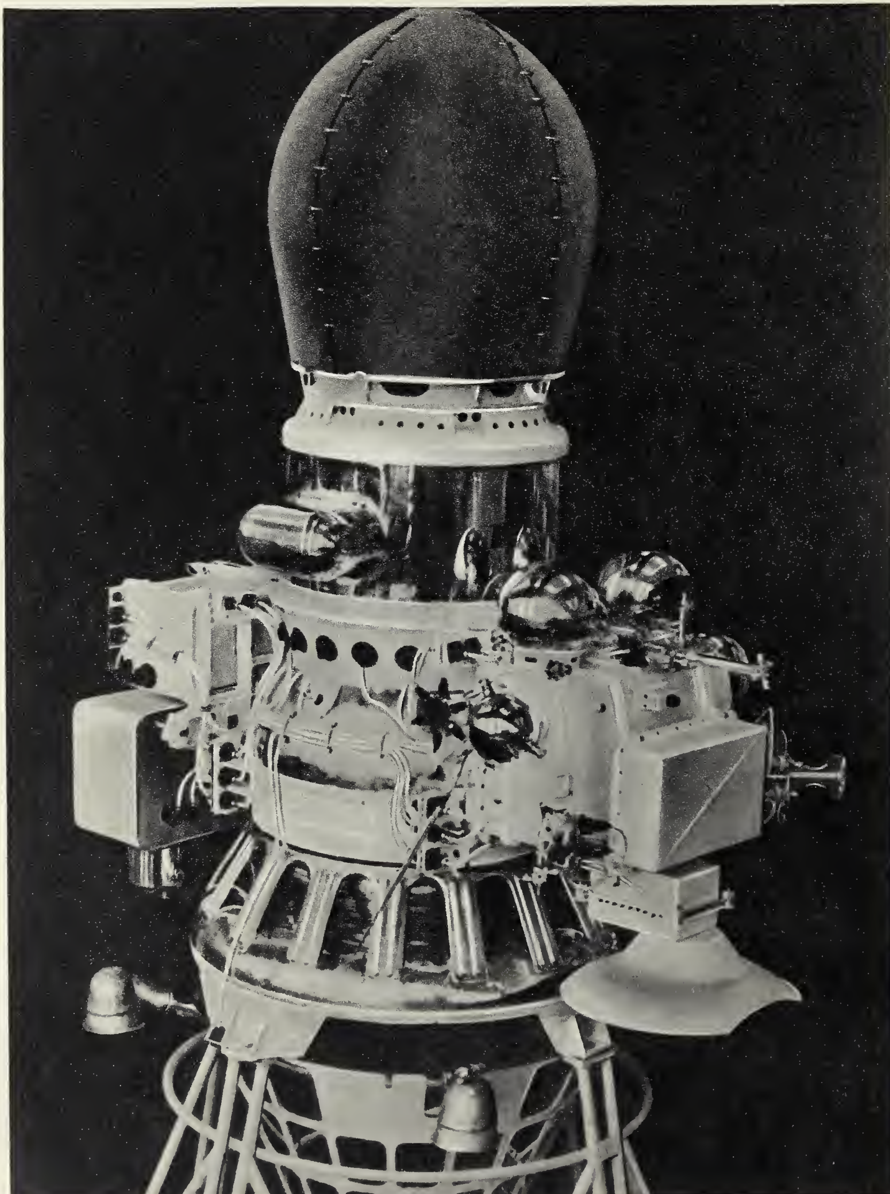
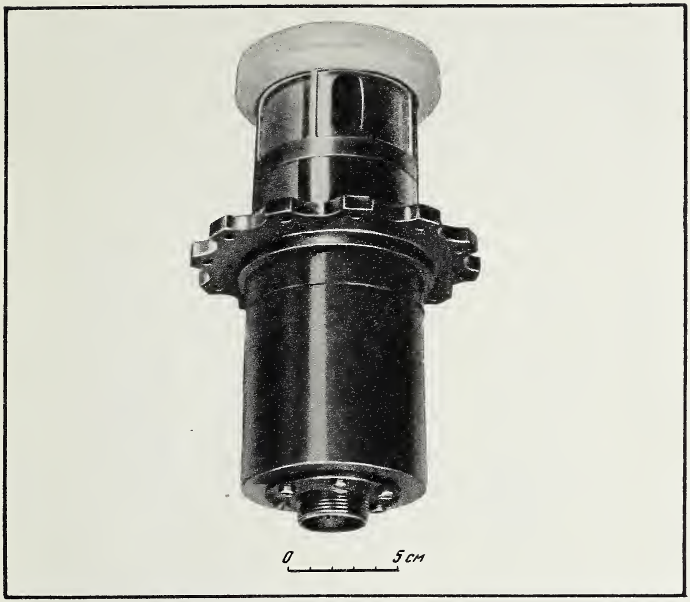
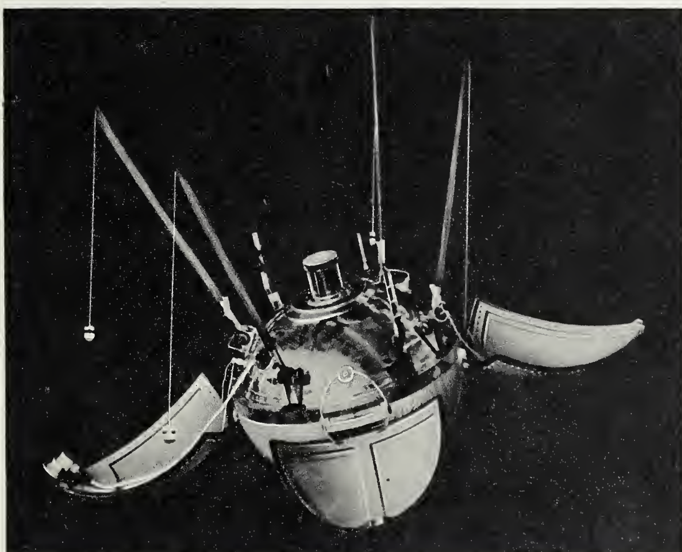


To the Moon!

The Luna-3 probe Moon oriented probe. The arrows show the direction of the Sun rays



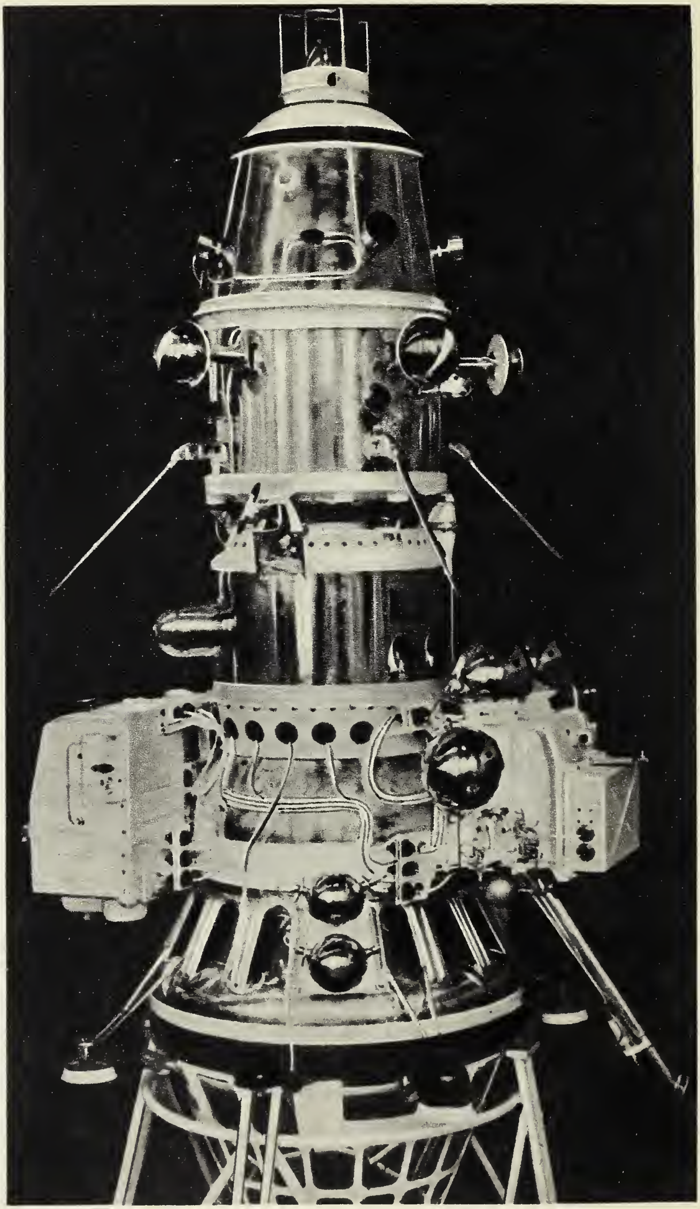




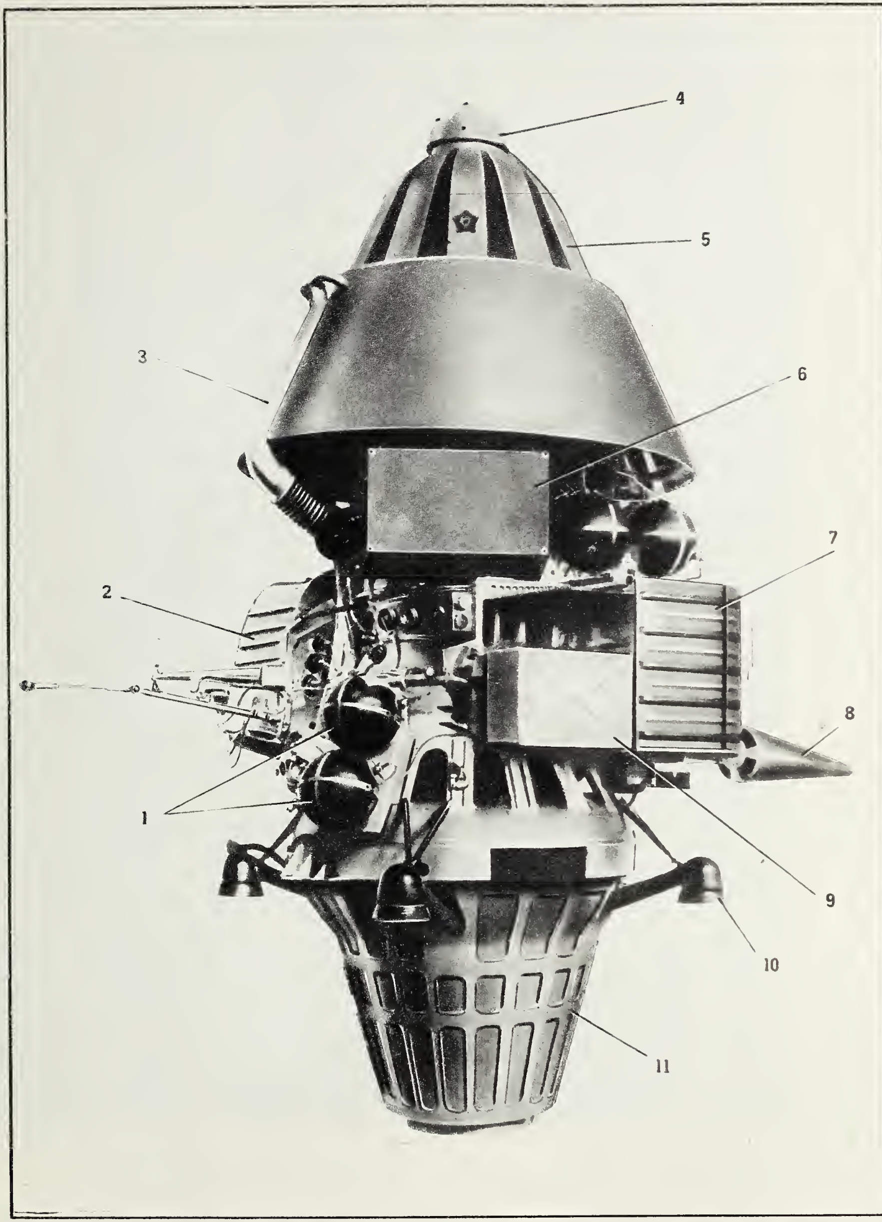
The Luna-9 **probe**

Television transmitter to send back to Earth the first ever pictures of the lunar surface

The lunar probe that soft-landed on the Moon



The Luna-10 and the Luna-12 probes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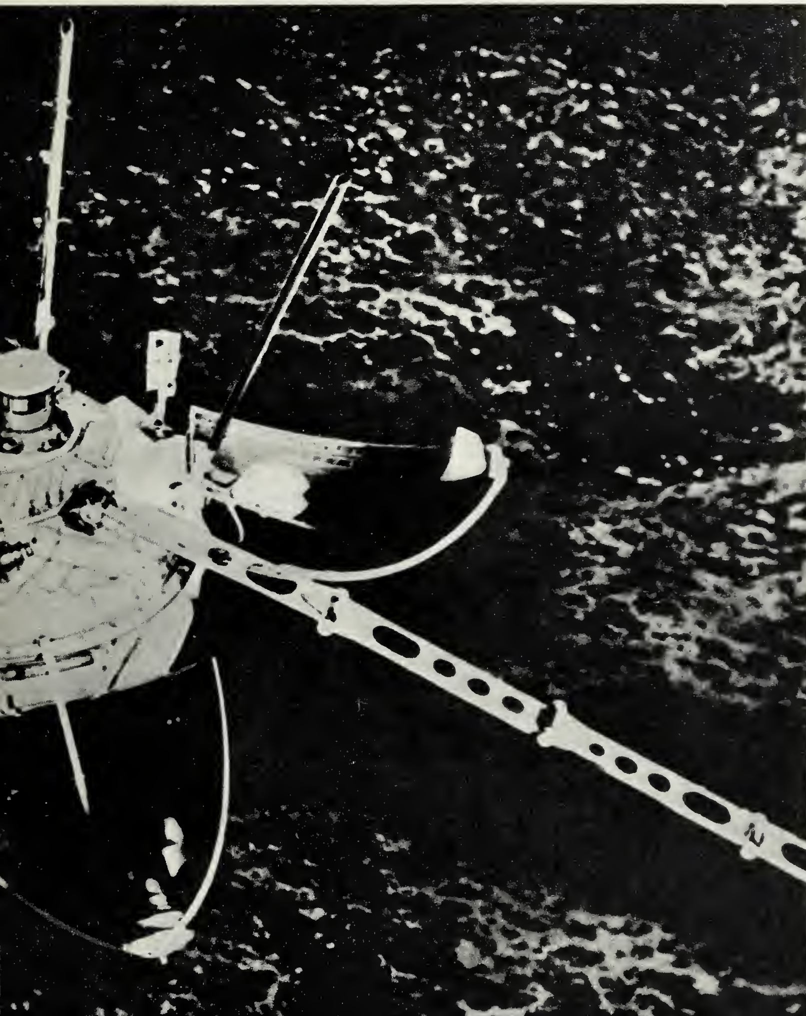
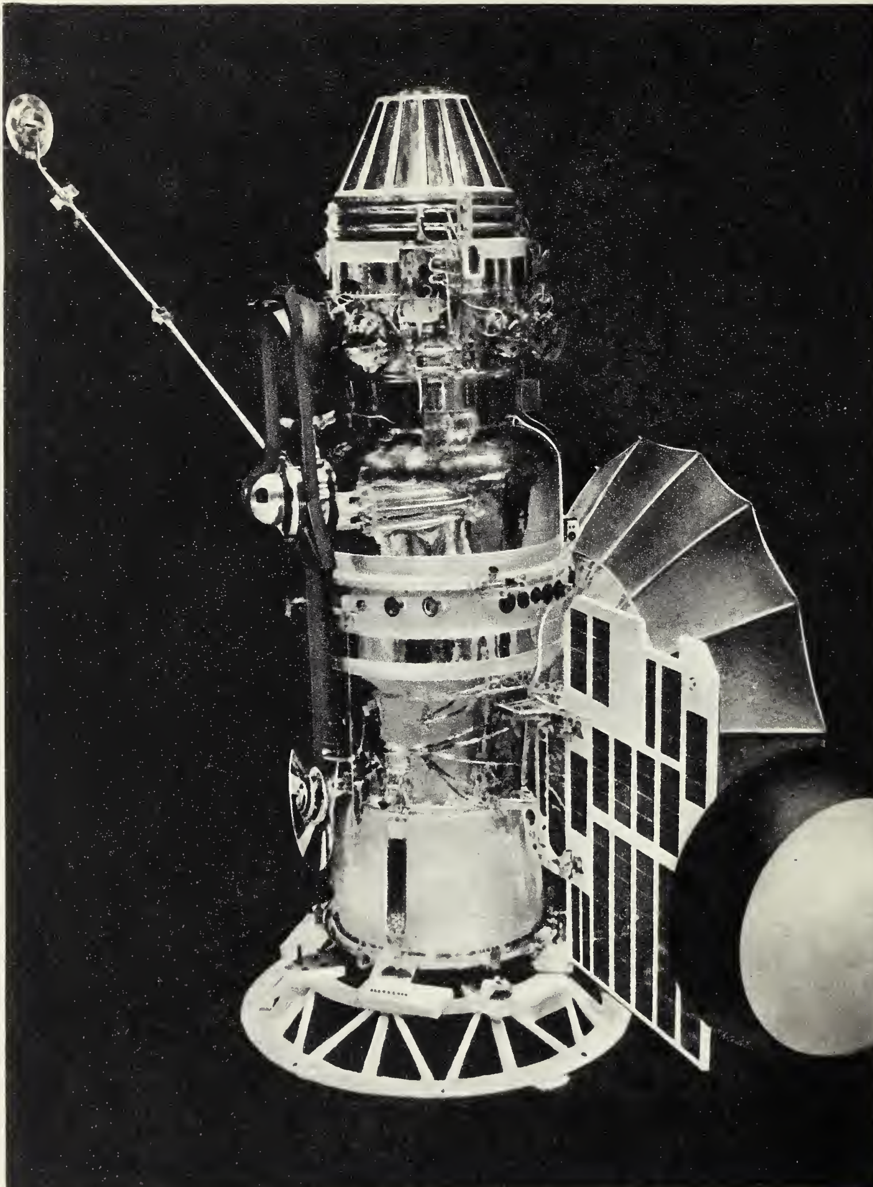
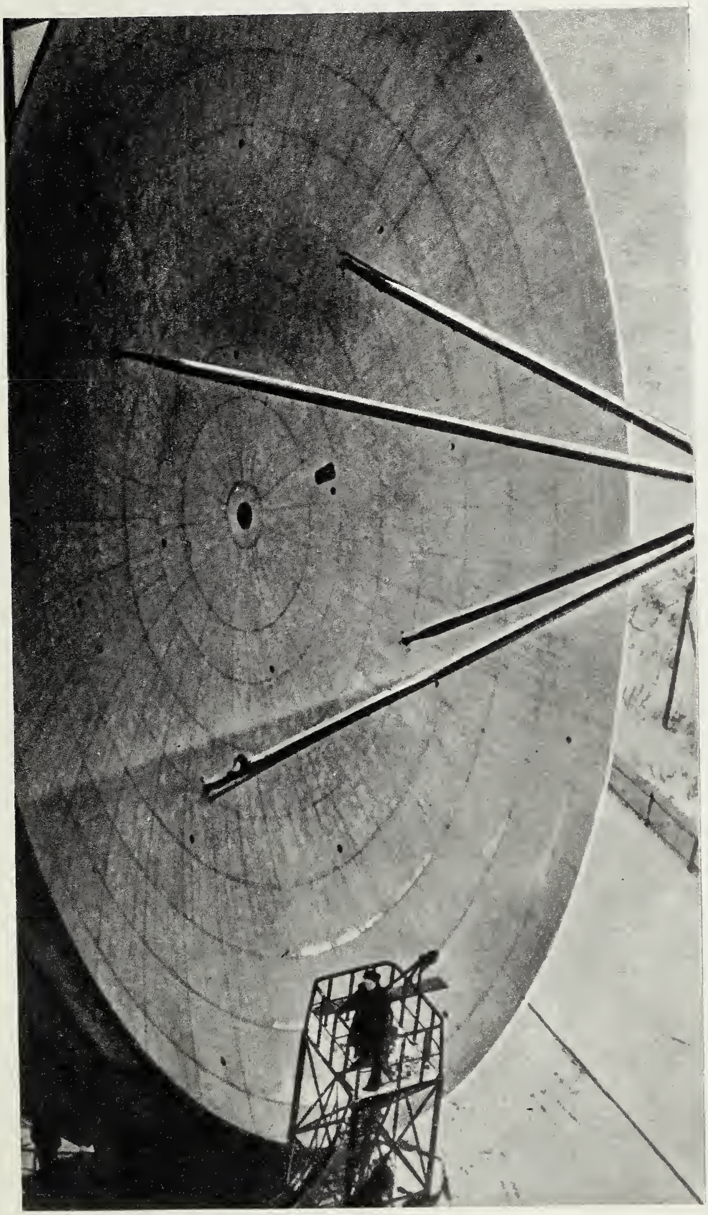


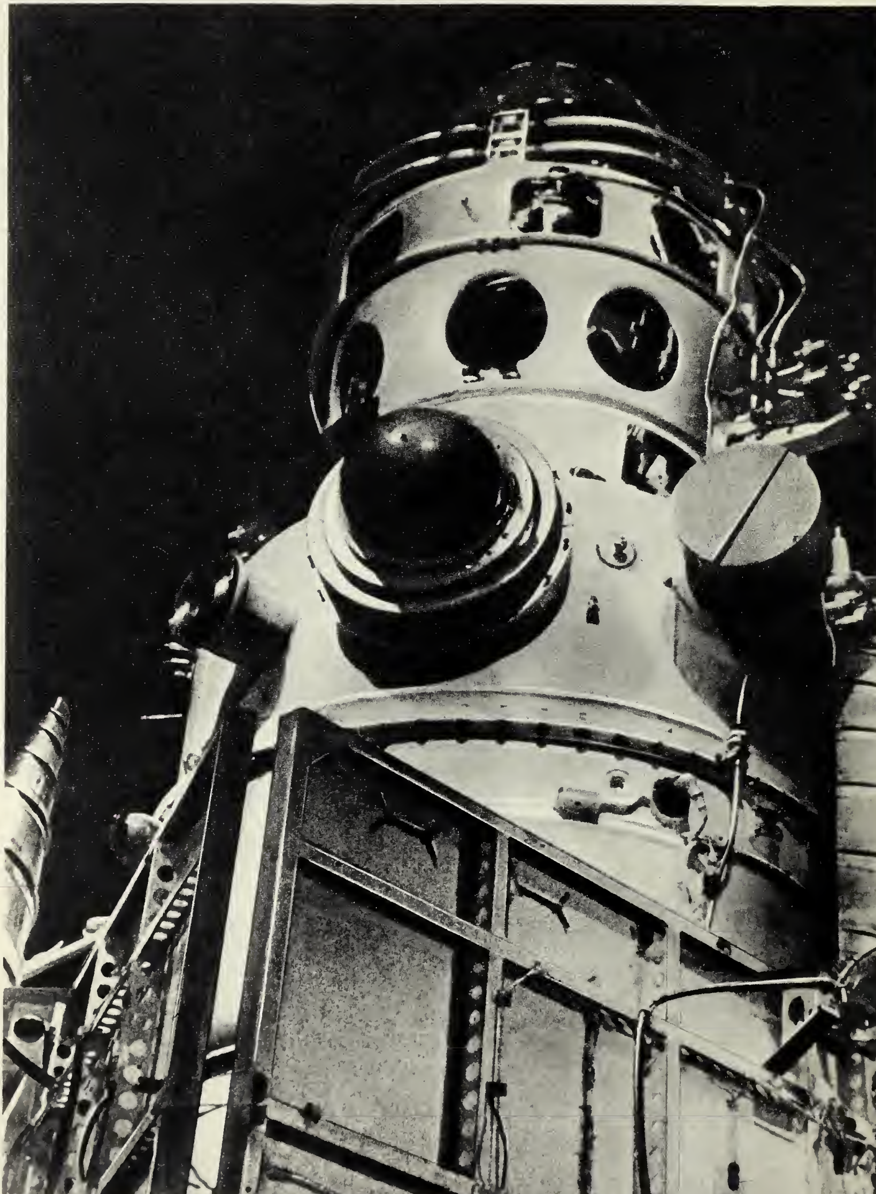
The Luna-13 probe

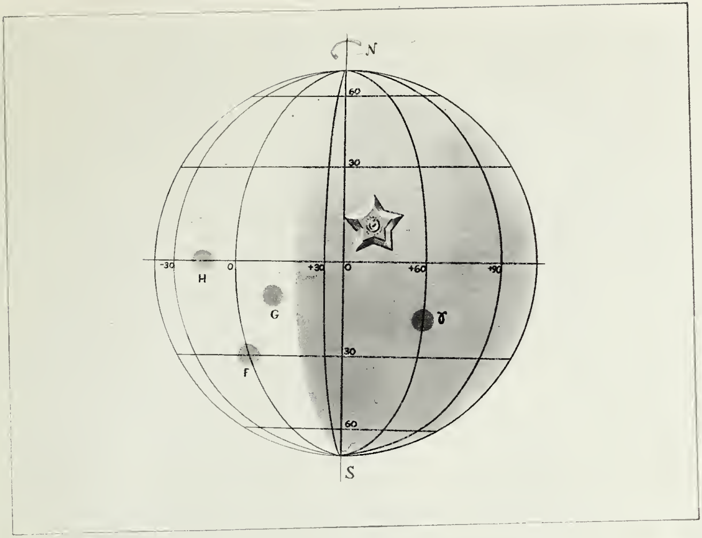


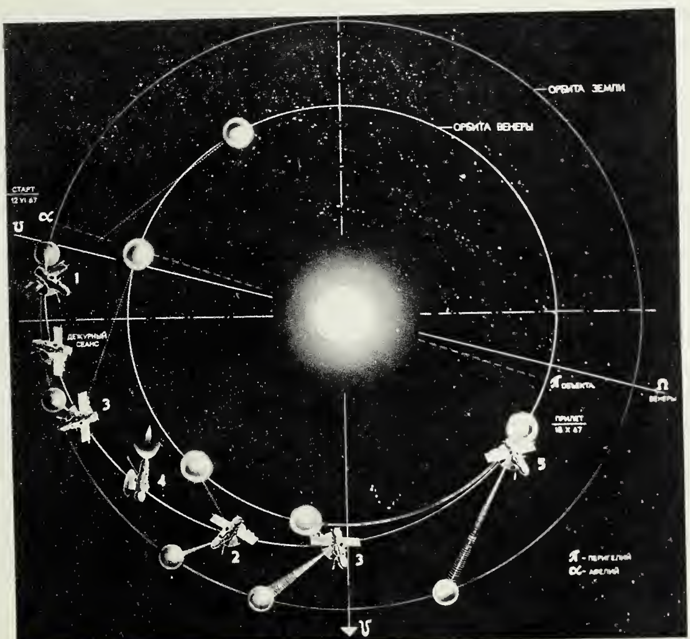


The Zond-3 probe

The Academy of Sciences Institute of Physics radio telescope (the mirror has a diameter of 22 meters)



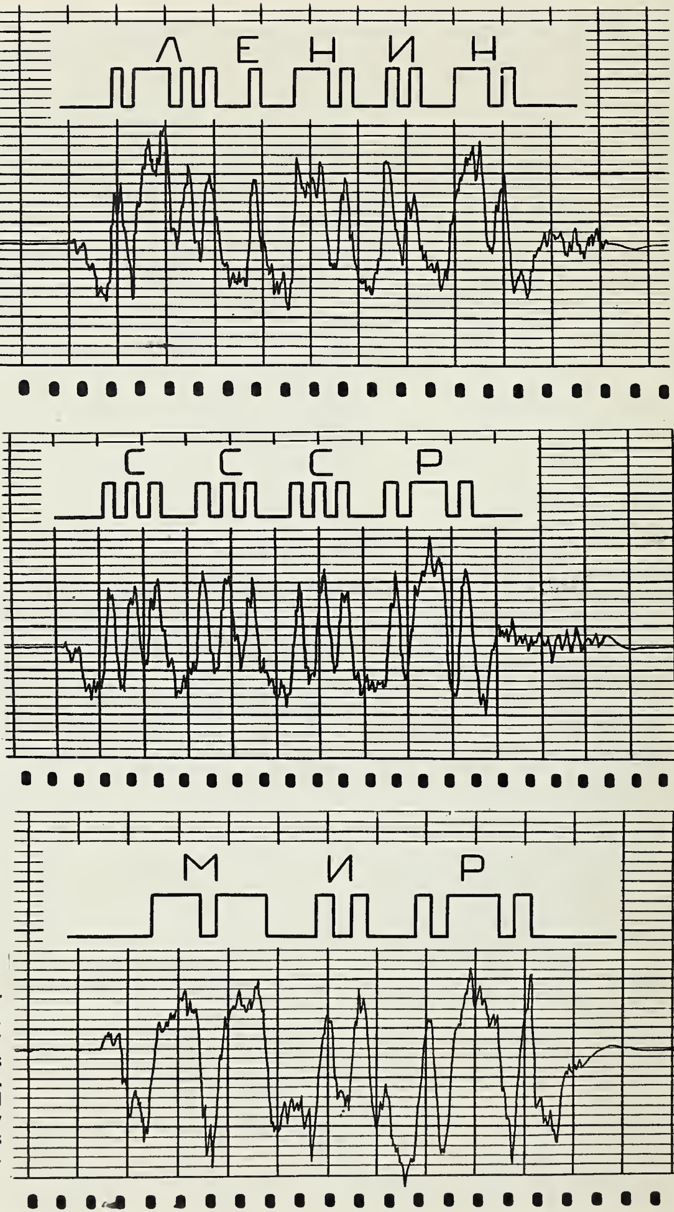




The Venera-4 probe

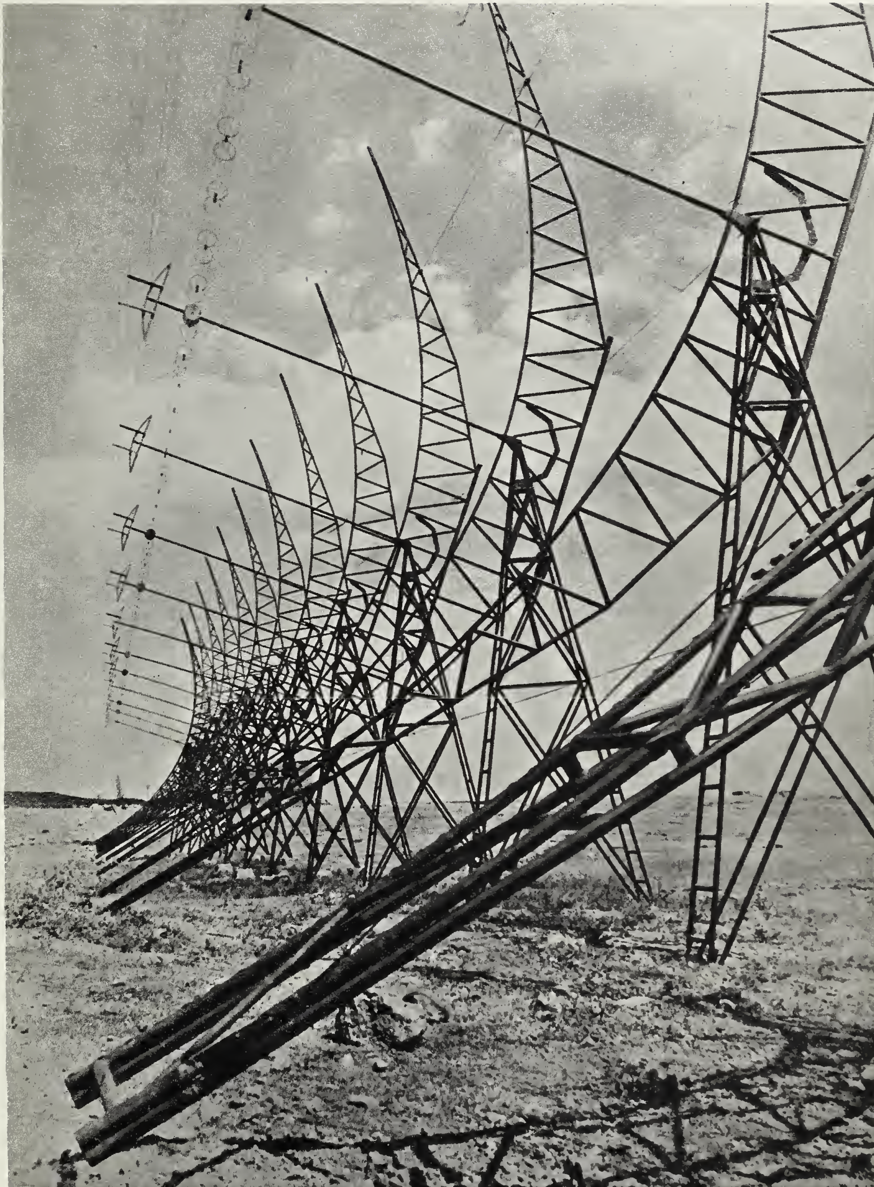
Map of Venus. The arrow shows the spot where Venera-4 landed

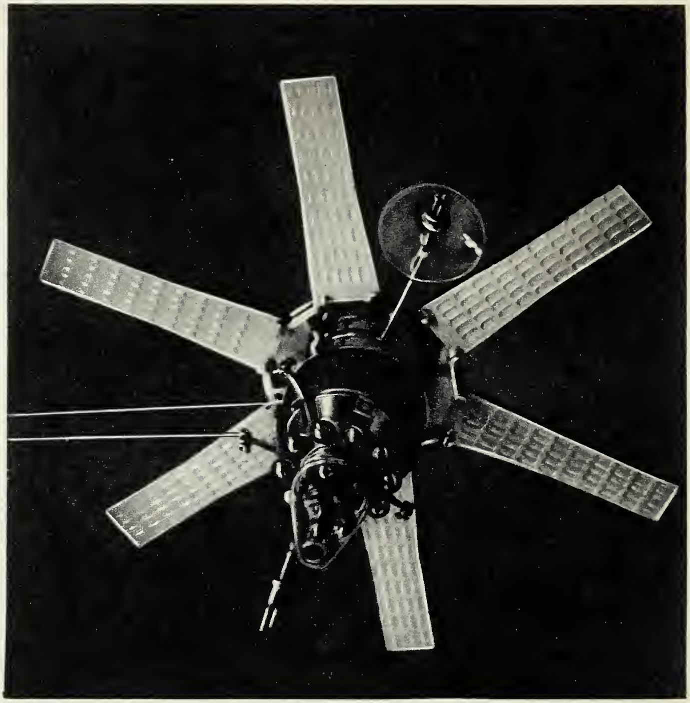
Diagram of flight, radio communication sessions and path corrections (Venera-4)



Signals reading: "Peace, the USSR, Lenin" were beamed to Venus in November, 1962. They were received on Earth after they had bounced off Venus

Antenna fields

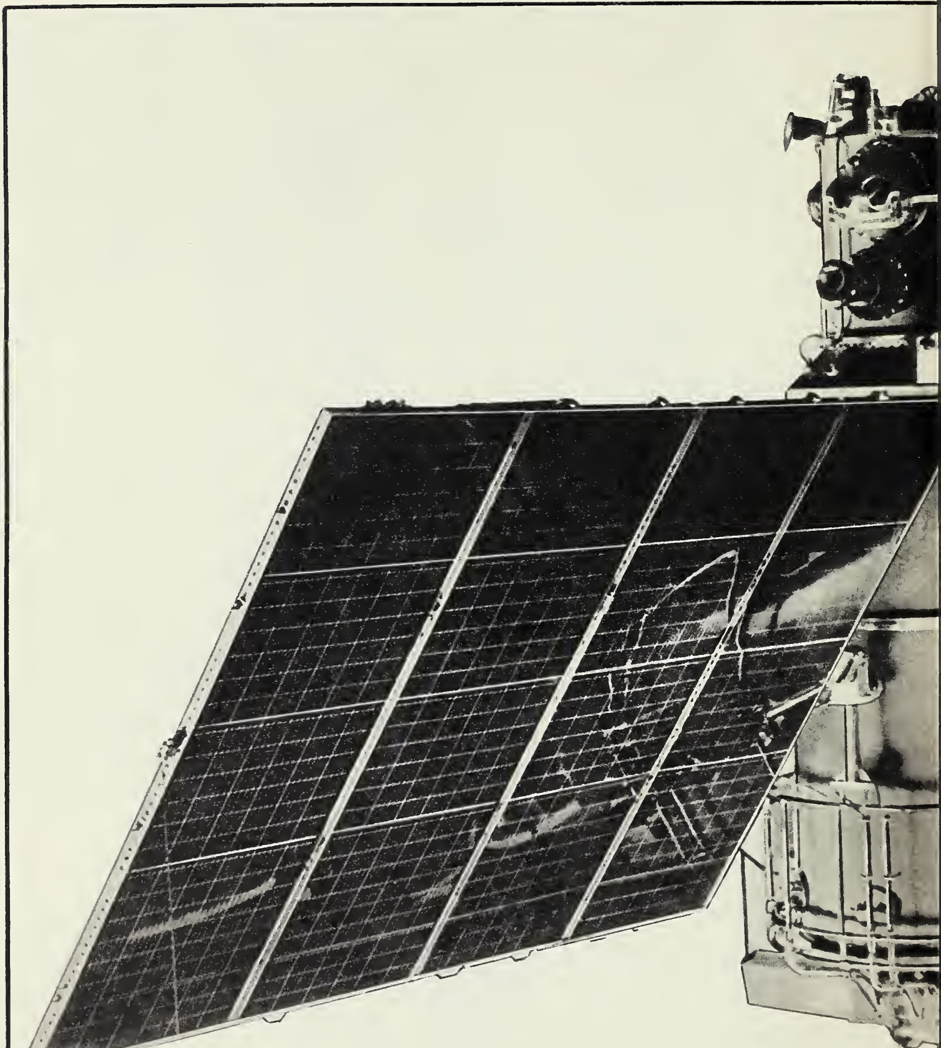


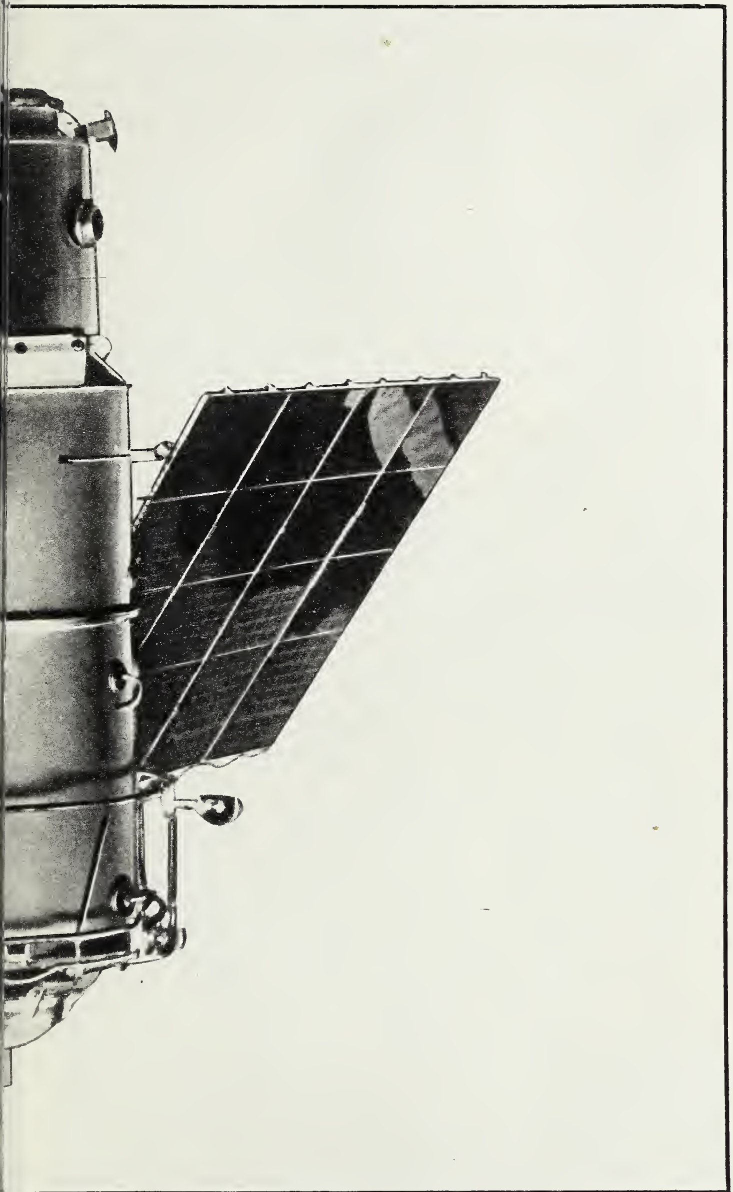


Molnia-1 communications satellite

The ground end of the space bridge

Ground reception station Orbita





Soviet weather satellite

Academician Mstislav Keldysh addressing a press conference of Soviet and foreign newsmen

Moscow greeting astronauts

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