The USSR—Pioneer of Space Exploration

On October 4, 1957, the Soviet Union launched the world's first artificial Earth satellite, inaugurating the era of space exploration.

Over the past fifteen years there has been swift progress in the development of space-oriented rocket systems, and the first manned space flights have been made. These achievements have left an indelible imprint in various fields of human endeavour.

For millenniums man dreamed of penetrating into outer space. The first primitive gunpowder rockets appeared in ancient times. They were originally used for shooting fireworks and later for military purposes. The idea of using rockets for interplanetary travel was advanced in a number of French novels: *A Voyage to the Moon* by Cyrano de Bergerac (1649), *Voyage to Venus* by Achille Eyraud (1865), and *Around the Moon* by Jules Verne (1870).

In his *System of the World* (1731) Isaac Newton described a hypothetical launching of a body that was imparted an escape velocity and so became an earth satellite.

In the novel *The Brick Moon* (1869-70) by Edward E. Hale, an American writer, there is a description of the creation of a habitable earth satellite and its various uses.

The idea of orbiting earth satellites by means of rockets fired from a huge cannon was first suggested by Jules Verne in the novel *Les cinq cents millions de la Begum* (1879).

The first scientifically conceived project of a piloted rocket-propelled vehicle was elaborated by N. I. Kibalchich, a Russian scientist and a revolutionary (1881). In 1893 Herman Ganswindt, a German inventor, suggested a project of a powder-propelled interplanetary passenger rocket.

The founder of space engineering was K. E. Tsiolkovsky. It was Tsiolkovsky who first formulated the theory of rocket flight and the basic principles of designing space rocket systems. He also elaborated scientifically feasible projects of interplanetary travel by man. Tsiolkovsky's classical work *Exploration of the Universe with Rocket-Propelled Vehicles* (1903) and subsequent works on the subject are a contribution of fundamental importance to world science.

Tsiolkovsky's theoretical conclusions were later corroborated and supplemented by research done both in the USSR (of which more will be said below) and other countries, for example, in France by Robert Esnault-Pelterie (1913), in the USA by Robert H. Goddard (1919), and in Germany by Hermann Oberth (1923).

Tsiolkovsky did not live to see his dream come true. Man-made craft emerged into space 22 years after his death. More than half a century passed between the date of publication of his classical work and the first manned space flight—an outstanding achievement of the Soviet people, signalling man's breaking of the fetters of terrestrial gravitation to face a new, unknown and immense world.

The Soviet people are justly proud of the many achievements of their country in space exploration. These include: the launching of the first earth, solar and lunar satellites, the first automatic lunar, venusian and martian probes, the first probes that soft-landed on these celestial bodies, the probe that photographed the reverse side of the Moon and transmitted back to earth moonscape panoramic pictures, the first recoverable probe that circled the Moon, the first probe that obtained lunar rock samples, and the first ground-controlled moonrover that investigated lunar terrain, the first manned solo and group flights in one-man and multiseater spaceships, the first walk in space, and the assembling of an experimental station in orbit.

Thus it is only natural that the story of Soviet rocket engineering and of the people who have made possible its achievements should evoke general and widespread interest.

This book comprising two parts is a short history of Soviet rocketry and space engineering. The first part, "At the Source of Soviet Rocketry and Space Engineering", covers the period of their development up to 1945; the second part, "Space Probe with Rocket Systems", deals with their development in the postwar period.

At the Source of Soviet Rocketry and Space Engineering

Rockets propelled with gunpowder have a history of their own in Russia. A "rocket-manufacturing establishment" was set up in Moscow as early as 1680. In the 18th and 19th centuries powder rockets were employed by the Russian Army and Navy.

A great contribution to the development of the theory, designing and technology of powder-propelled rockets was made by several Russian scientists and ballistics experts, including A. D. Zasyadko (1779-1837), K. I. Konstantinov (1817-1871), M. M. Pomortsev (1851-1916), and N. I. Tikhomirov (1860-1930).

In 1814 A. D. Zasyadko began working on various types of combat rockets and in 1817, having developed several effective models, demonstrated them in Petersburg. His rockets had a maximum range of 2,670 meters. The rockets were built in a pyrotechnical laboratory which he had set up in Mogilev.

A rocket institution was established in St. Petersburg in 1826 to accelerate missile production for the Russian army.

In 1834 K. A. Shilder, an engineer, designed a submarine equipped with six missiles both for surface and underwater launching.

In 1849 K. I. Konstantinov was appointed director of the St. Petersburg rocketry establishment, and in the following year he was made head of the St. Petersburg Rocket-Manufacturing Plant. Between 1859 and 1861 he delivered a course of lectures on powder-propelled combat rockets for artillery officers. In 1867 he was appointed head of the Nikolaev Rocket-Manufacturing Plant.

Konstantinov formulated the basic principles of military rocketry. From 1847 he concentrated on improving and building combat missiles and made a thorough study of their ballistic properties. Some of the models he developed were the most advanced at the time, with a flying range of four to five kilometers.

Konstantinov maintained that "at any moment during the burning of a propellant composition the momentum imparted to the rocket is equal to that of the jet of gas."

Quite independently K. E. Tsiolkovsky (1857-1935) arrived at the same formula and evolved the fundamental equation of rocket dynamics.

Konstantinov's numerous articles appeared in the *Artillery Magazine* (1845-67) and the *Naval Collection* (1854-66). He was the author of a book entitled *Combat Missiles* (1857), and the lectures he delivered at the Mikhailov Artillery Academy were published under the title *About Combat Missiles* (1864).

Konstantinov also designed a number of artillery instruments, including an electrical ballistic device for measuring artillery shell velocity, an instrument to determine the altitude of flying signal flares, an optical range-finder, and a ballistic pendulum.

In 1902 M. M. Pomortsev began his lifelong work on powder-propelled rockets with flight stabilization surfaces of different configurations. They had a maximum range of 9 kilometers. He also built a pneumatic rocket which was tested at the Aerodynamics Institute in Kuchino. The air in the steel cylinder of a rocket was compressed to 100 to 125 atmospheres. Petrol or ether was injected into the air to form the combustible mixture.

Between 1909 and 1912 N. V. Gerasimov worked on a gyroscopic rocket.

The irregular combustibility of black powder used as rocket propellant and its low efficiency led to the search of other kinds of powder free from those shortcomings. In 1915 I. P. Grave suggested that long-burning extruded pyroxilyne propellants be used for rocket propulsion. In the following year, cylindrical pyroxilyne grains, 70 mm in diameter, were made at the Shlisselburg Powder Plant and tested. But the use of a volatile solvent upset the stability of combustion and of grain geometry. Stable pyroxilyne powder with a non-volatile solvent (trotyl and, subsequently, nitroglycerin) was developed by S. A. Serikov and made at the Gas Dynamics Laboratory.

N. I. Tikhomirov, a chemical engineer, was the founder and first director of the Gas Dynamics Laboratory (GDL). He was the first Soviet rocket specialist to work on the development of missiles propelled by smokeless powder.

He had first tackled the problem of powder-propelled missiles in 1894. In 1916 his work, submitted in 1912, was approved by a commission of experts headed by N. Y. Zhukovsky.

Work to organize a research laboratory started on March 1, 1921. The Military Department furnished Tikhomirov with the necessary means to set up his laboratory and assigned a two-story building in Moscow to house its workshops equipped with 15 machine tools. Work to make an extruded smokeless powder propellant with a solid solvent and trial launchings were conducted in Leningrad.

By 1925, when such a propellant was developed, the laboratory had moved to Leningrad. After the first successful launchings the rocket laboratory was considerably expanded, and in July 1928 named the Gas Dynamics Laboratory (GDL).

The laboratory, the first in the Soviet Union to be engaged in rocketry research and development, was under the Military Research Committee of the USSR Revolutionary Military Council. The GDL occupied part of a one-story building at the artillery test ground not far from Leningrad. It also had a machine shop there. Besides, it had headquarters in the city, facilities for the production of smokeless powder grains, which were housed in the building of the Naval Department Research Laboratory, and other premises.

At the beginning of 1933 the GDL comprised five sections and workshops located at six places in Leningrad, and had a staff of almost 200.

The First Section of the GDL worked on the development of powder-propelled missiles, initiated by Tikhomirov and successfully carried through by B. S. Petropavlovsky, G. E. Langemak, V. A. Artemyev and other outstanding artillery engineers. The smokeless powder rockets of diverse calibers which they developed for the Army and the Air Force were successfully tested at proving ranges and in simulated battle conditions in 1932-33. Later they were further improved at the Research Institute of Jet Propulsion (RNII), and were widely employed with a devastating effect during the Great Patriotic War (1941-45). The mobile launcher, dubbed *Katyusha,* became widely famous towards the end of the war. By that time the country's rocket artillery units comprised 40 independent battalions, 105 regiments, 40 brigades and 7 divisions.

Between 1930 and 1933 the GDL developed rocket missiles with calibers of 82, 132, 245 and 410 mm, as well as ones of smaller calibers. By the end of 1933 the GDL had developed 9 types of rocket missiles which were successfully tested and officially approved. This fact was mentioned in a report by the Red Army Department of Military Inventions to M. N. Tukhachevsky, the Red Army Chief of Armaments.

Between 1927 and 1933 the Third Section of the GDL developed assisted-takeoff powder rockets for light and heavy aircraft (U-1, TB-1, and TB-3 types). The official tests of the TB-1 heavy bomber, conducted in 1933, showed its takeoff run to be 77 per cent shorter owing to the use of those rockets.

V. A. Artemyev (1885-1962) began work on rockets propelled by black powder in 1915. Between 1921 and 1933 he worked at the GDL and in 1934 joined the Research Institute of Jet Propulsion. He designed solid-propellant rocket engines for the Group for Studying Jet Propulsion in Leningrad between 1931 and 1933. Many of the smokeless powder rockets he had designed were successfully tested and officially approved.

B. S. Petropavlovsky (1898-1933) joined the GDL in 1929, and headed the Laboratory between 1930 and 1931.

G. E. Langemak (1898-1938) worked at the GDL between 1928 and 1933. He was Deputy Director and Chief Engineer of the Research Institute of Jet Propulsion between 1934 and 1937.

After N. I. Tikhomirov and B. S. Petropavlovsky, the GDL was headed by N. Y. Ilyin (1931-32) and then I. T. Kleimenov (1932-33). Both did much to advance rocket engineering in this country.

A number of inventors and designers in Russia had long been exploring the possibility of utilizing the principle of jet propulsion in aeronautics. In 1849 I. I. Tretesky (1821-1895), a military engineer, designed three lighter-than-air flying machines to be propelled with gas or steam jets. In 1866 Admiral N. M. Sokovnin (1811-1894) described in his book *Airship* a hypothetical jet-propelled balloon which was "to fly like a rocket".

In 1867 N. A. Teleshev (1828-1895), a retired artillery captain, took out a patent for a jet plane he had designed and named *Delta.* In 1887 F. R. Geshvend, an inventor from Kiev, published a brochure entitled "A Steam-Powered Airship. General Design Principles", in which he set forth the project of a flying machine with a steam jet engine. He also designed concentric jet nozzles.

N. I. Kibalchich (1853-1881) was the first in Russia to work out the design of a rocket-propelled vehicle. He was a prominent member of the *Narodnaya Volya,* a revolutionary organization, and was convicted and imprisoned for his revolutionary activity.

He studied Russian, French, German and English literature on explosives and powders, and showed remarkable ingenuity in his work. In the opinion of his contemporaries, government experts could learn a great deal from Kibalchich. A man of great erudition, he ran a perfectly equipped laboratory and had carried out a series of experiments which the experts who argued with him at his trial could not hope to repeat.

He had thoroughly examined the properties of nitroglycerin compounds and handled them with imaginativeness. Before his arrest Kibalchich was head of the laboratory of the *Narodnaya Volya* Executive Committee. The talented inventor, who gave his life for the struggle against tsarism, had elaborated the design of a "Flying Vehicle", an apparatus that was to be propelled by a rocket engine burning powder. He accomplished this work during a short term of imprisonment in St. Petersburg in March 1881 pending execution.

Kibalchich described the working principle of a powder rocket engine, and showed the possibility of controlling the vehicle by changing the angle of inclination of the engine and of utilizing controlled burning for achieving a continuous ascent or hovering of aircraft. He also indicated ways to ensure aircraft stability.

Two years later, in 1883, in his work *Free Space,* K. E. Tsiolkovsky wrote about a spaceship with an engine utilizing the principle of jet propulsion. His work *Dreams about the Earth and the Sky, the Effects of Universal Gravitation,* in which he set forth the idea of a man-made earth satellite,was published in Moscow in 1895.

Tsiolkovsky's major work entitled *Exploration of the Universe with Rocket-Propelled Vehicles* appeared in 1903, in the May issue of the St. Petersburg magazine *Science Review*. In it he formulated, for the first time, the basic principles of rocket flight and the working principle of rockets and liquid-fuel rocket engines. Later he published supplementary material on the subject (in 1911, 1912, 1914, and 1926). He set forth a plan for man's egress into space, for populating interplanetary expanses, and exploring celestial bodies and utilizing the inexhaustible solar energy. Tsiolkovsky also introduced the idea of an electric rocket engine in which thrust is attained by expulsion of charged particles, and pointed out the advantages of a nuclear rocket engine. But that was for the distant future. Meanwhile Tsiolkovsky suggested building liquid-propellant rockets using liquid oxygen, ozone, nitrogen pentoxide as oxidants, and liquid hydrogen, methane, hydrocarbons, benzene, gasoline, turpentine or some other substances as fuels.

In subsequent years Tsiolkovsky wrote more books dealing with space travel.

S. S. Nezhdanovsky (1850-1940), an inventor, also studied the problem of jet propulsion. As early as 1880 he envisioned the possibility of building rocket-propelled flying machines. Between 1882 and 1884, while investigating power characteristics of jet engines, in his manuscript he suggested using an explosive mixture comprising kerosene and nitrogen dioxide or nitric acid (oxidants) as rocket propellant.

The problem of jet propulsion was also investigated by A. V. Evald and A. P. Fyodorov. In 1896 Fyodorov (born 1872) published his *New Principle of Aeronautics* in which he described a vehicle that does not rely on the atmosphere for support. He suggested the use of steam, compressed air or carbonic acid as propulsive mass.

This work inspired Tsiolkovsky to further research on jet propulsion which ultimately led to his formulation of the basic principles of rocket dynamics.

Some elements of the theory of jet propulsion as applied to sea-going vessels were developed by N. Y. Zhukovsky (1847-1921), the founder of Russian aeronautics, and set forth in his articles "On the Reactive Effect of In- and Out-Flowing Liquids" (1882, 1885) and "Concerning the Theory of Vessels Propelled by the Reactive Force of Water" (1908).

In 1893 I. V. Meshchersky read a paper before the Petersburg Mathematical Society entitled "A Special Case of the Guldin Theorem", in which he described his investigations and findings concerning the theory of the motion of variable mass bodies. In another work entitled "The Dynamics of a Variable Mass Point" (1897) Meshchersky, to illustrate his point, cited the equation of motion for a rocket taking off vertically. In his article, "The Equation of Motion for a Variable Mass Point. The General Case" (1904), he formulated the general theory of motion for a variable mass point, first for the case of particles being separated (or adjoined) and then for the case of the simultaneous separation and adjoining of particles.

His article "A Problem Pertaining to the Dynamics of Variable Masses" dealing with motion of a system of variable mass points appeared in 1918. Thus Professor I. V. Meshchersky of the St. Petersburg Polytechnical Institute became the first scientist to formulate the fundamental equations of rocket dynamics.

In 1915 Y. I. Perelman (1882-1942), a well-known popular science writer, published in Petrograd his remarkable book *Interplanetary Travel,* which saw 10 printings within 20 years. He wrote the book on the basis of a report under the same title which he delivered in 1913.

The book is a survey of the techniques and modes whereby science fiction writers transported their heroes into space. The author discussed the gun of Jules Verne, the hypothetical material of H. G. Wells that protects from the force of gravity, and its opposite—one that is "transparent" for gravity and therefore unaffected by it, some screen of the pressure of light using the repellent effect of solar radiation, and, finally, Tsiolkovsky's rocket.

Perelman concluded that only rockets were capable of lifting man into space.

Other popular science books by Perelman include *Flight to the Moon* (1924), *Tsiolkovsky* (1924), *To the Moon by Rocket* (1930), *To the Stars by Rocket* (1933).

In the pre-revolutionary period, the conservatism of the tsarist government blocked the way of everything that was new and progressive in the development of rocket science and engineering. The projects of Kibalchich were locked away in the archives of the tsarist secret police until the October Revolution, Tsiolkovsky's brilliant research had no state support. Tikhomirow, too, was able to organize his laboratory only after the Great October Socialist Revolution.

The Revolution marked a turning point in the development of Soviet rocketry. Tsiolkovsky was 60 years of age then. In the next 18 years until his death he wrote and published many theoretical works, far more than he did in the pre-revolutionary period.

Scientists who continued the research initiated by Tsiolkovsky worked in well-equipped laboratories, institutes and design offices.

Tsiolkovsky went down in the history of space research as the founder of the theory of jet propulsion and an exponent of the principles governing the development of this new field of science and technology, as an imaginative proponent of space travel, inventor, and thinker.

Between 1917 and 1919 Y. V. Kondratyuk (1897-1942), a talented researcher, completed the first stage of his work on the fundamental problems of rocket propulsion, which he discussed in his work entitled *To Those Who Will Read in Order to Build*. In 1929 he published, in Novosibirsk, a theoretical work, *Conquest of Interplanetary Space,* which partly repeated and partly advanced the research of Tsiolkovsky. In it he used an original approach in solving a number of questions of rocket dynamics and rocket engineering. Independently of Tsiolkovsky, and unacquainted with his findings, Kondratyuk employed a new method to evolve the fundamental equation of rocket motion. In his works he dealt with the following problems: computation of optimal space-flight trajectories in terms of power consumption; the theory of multi-stage rockets; the construction of refuelling satellite stations in interplanetary orbits, and the utilization of atmospheric deceleration for effective rocket landing.

He suggested, as the most economical way of reaching the Moon and the planets, putting spacecraft in circumlunar and circumplanetary orbits and then sending onboard landing modules to their destinations. He also proposed the utilization of the gravitational fields of celestial bodies for acceleration and deceleration of spacecraft travelling within the Solar System and envisaged the use of some metals, metalloids and their hydrides, such as borohydrides, as rocket fuels.

F. A. Zander (1887-1933) was another outstanding Soviet rocket engineer who greatly contributed to the progress of rocketry in this country.

He began his theoretical research in 1907 and designing somewhat later. In 1921 Zander submitted a spacecraft design to the Moscow Conference of Inventors. In his article, *Flights to Other Planets,* published in the magazine *Technology and Life* in 1924, he set forth his idea of building a hybrid rocket-aircraft vehicle for an effective takeoff whereupon the aircraft would be burnt in the combustion chamber of the rocket engine as fuel, so as to increase the range of rocket flight.

In 1930 Zander used an ordinary blowtorch to construct the first Soviet experimental jet motor designated OR-1. The engine utilized compressed air and gasoline and had a thrust of 145 grammes. Zander later worked on liquid-propellant rocket engines which used liquid oxygen and gasoline for fuel.

Zander studied the following problems: utilization of the atmosphere for liftoff and landing, the possibility of utilizing light pressure for interplanetary travel, determination of flight paths for spacecraft, and similar questions associated with space travel.

In his book *The Problem of Flight with the Aid of Jet-Propelled Vehicles,* published in 1932, he discussed the questions of designing winged rockets and of achieving optimal thermodynamic cycles for jet engines, and suggested using certain metals and their alloys as fuel ingredients.

From 1921 V. P. Vetchinkin (1888-1950), another Soviet aerodynamics expert, studied the theory of rocket flight in the atmosphere and in outer space. Between 1921 and 1925 he delivered lectures on the subject, and between 1925 and 1927 he worked on flight dynamics of winged rockets and jet aircraft which he discussed in several of his articles including "Vertical Rocket Propulsion" (1935) and "Supersonic Flight of a Winged Rocket" (1937). Vetchinkin did much to popularize the idea of interplanetary travel and advance rocket technology.

In April 1924 a Section of Interplanetary Travel was set up in Moscow under the Military Research Society of the Air Force Academy (now the N. Y. Zhukovsky Air Force Engineering Academy). Later that year the section was reorganized into "Society for the Study of Interplanetary Travel". It was headed by G. M. Kramarov. The Society had a charter and a membership of 200. Tsiolkovsky, Zander, and Vetchinkin took part in its activities. The society existed for about a year and played an important role in popularizing the idea of space research in this country.

In 1925 Academician D. A. Grave founded a space studies society in Kiev. Among the members of its research council were Academician B. I. Sreznevsky, Y. O. Paton, K. K. Seminsky, and V. I. Shaposhnikov.

The society and the Kiev Section of the Association of Engineers and Technicians jointly sponsored an exhibition on space research which opened on June 19, 1925. It was visited by large numbers of people, who heard lectures delivered by scientists.

Numerous space travel circles sprang up around the country. On June 14, 1925, Academician Grave addressed a message of greeting to rocketry enthusiasts.

In April and June 1927 the Association of Inventors held the first international exhibition of spacecraft designs. On display were the works of K. E. Tsiolkovsky and F. A. Zander (USSR), R. Goddard (USA), H. Oberth, W. Hohmann and Max Valier (Germany), R. Esnault-Pelterie (France) and many others.

In late 1928 the Leningrad Institute of Railway Transport Engineers organized a Section of Interplanetary Travel. Professor N. A. Rynin (1877-1942), Dean of the Department of Air Communication, was elected chairman of the Section. Its members included instructors, engineers and students.

In 1929 Rynin suggested the setting up of a national or an international research institute of interplanetary travel and outlined its structure and objectives. Rynin did research on rocket engineering and studied the effects of inertial forces, induced by acceleration, on test animals. He is best known as the author of a three-volume encyclopedia of interplanetary travel, published in nine issues between 1928 and 1932. He meticulously collected material relating to space travel—antique myths and legends, science fiction, and findings of scientists who did fundamental and experimental research. One of the issues was devoted to an analysis of Tsiolkovsky's scientific legacy. The encyclopedia was a valuable aid to all interested in rocket engineering. It had a large bibliographical section. Its contents were as follows: Volume 1, issue 1—Dreams, Legends and Early Fantastic Tales; issue 2—Space Ships in Science Fiction; issue 3—Radiant Energy in Science Fiction and Scientific Projects; Volume 2, issue 4—Rockets and Direct Reaction Engines; issue 5—The Theory of Jet Propulsion; issue 6—Super-Aviation and Super-Artillery; Volume 3, issue 7—The Russian Inventor and Scientist K. E. Tsiolkovsky, His Life, His Research and Rockets; issue 8—The Theory of Space Flight; and issue 9—Astronavigation; chronology and bibliography.

Notwithstanding the fact that the material included was not always critically analyzed, the historico-bibliographical value of the work is unquestionable.

Following the publication of the encyclopedia Rynin collected much new material and was preparing a second, considerably enlarged edition. But his project was not realized. He died in 1942.

From 1934 A. A. Sternfeld began to publish scientific studies and also numerous popular science books on astronautics. His works have been put out in 35 countries in 31 languages. Among his more important works are *An Introduction to Astronautics* (1937) and *Artificial Earth Satellites* (1956, 1958). A. A. Sternfeld was awarded two international prizes in space research (1934 and 1963).

Experimental investigations to develop electrical and liquid-propellant rocket engines were started in this country on May 15, 1929, when the first experimental design organization was formed on the basis of the GDL (the Second Section of the GDL in Leningrad) at the suggestion of this author.

From 1921 the author became keenly interested in questions of astronautics. In 1930 he suggested and carried out research on the use of the following substances as liquid-propellant components for rocket engines: nitric acid, solutions of nitrogen tetroxide in nitric acid, tetranitromethane, hydrogen peroxide, perchloric acid, beryllium, tripropellants—oxygen with hydrogen and beryllium, and powder with dispersed beryllium; designed a contoured nozzle, and developed ceramic thermal insulation for combustion chambers (zirconium dioxide coating). In the following year, 1931, introduced gimbal mounting of liquid-propellant rocket engines as a method of flight path control; proposed the idea, which was put into practice in 1933, of using a hypergolic ignition system and a hypergolic propellant for liquid-propellant rocket engines. From 1931 to 1933 developed a piston double-acting pumping unit driven by gas from the combustion chamber for a liquid-propellant rocket engine with a thrust of 300 kg, and in 1933, a turbopump assembly with centrifugal pumps; proposed ways of raising the efficiency of fuels for liquid-propellant rocket engines by increasing their density through deep cooling and the introduction of a heavy inert additive, and in 1933 suggested the use of fluorine-oxygen oxidants, fluorine-hydrogen propellant, kerosene solutions in pentaborane as fuel, etc.

Between 1929 and 1933 the Second Section of the GDL theoretically and experimentally demonstrated the feasibility of an electric rocket engine using as propulsive mass solid and liquid conductors (continuously fed metal wires or liquid jets) electrically exploded with preset frequency in a chamber with a nozzle.

Work to develop the electrical rocket engine begun by the GDL has been steadily carried on.

Ion and plasma electrical jet engines were tested for the first time in actual space flight conditions, aboard the *Voskhod-1* spaceship and the *Zond-2* automatic probe launched in 1964.

The experimental rocket motor (ORM) with a thrust of 6 kg used a ready mixture comprising a liquid oxidant and a liquid combustible component, which was burned in a nozzled combustion chamber; the ORM-1, with a thrust of 20 kg, the ORM-2 and other motors of the same series had their oxidants and combustible components fed separately. In 1931 there were 46 bench fire tests of the first Soviet liquid-propellant engines burning nitrogen tetroxide with toluene and gasoline.

More experimental motors (from the ORM-4 to the ORM-22) were developed the following year with a view to determining the most effective type of ignition, starting method and mixing system. During the 53 bench tests of these motors, conducted in 1932, liquid oxygen, nitrogen tetroxide, nitric acid and solutions of nitrogen tetroxide in nitric acid were used as oxidants while gasoline, benzene, toluene and kerosene were used as fuels. Another series of experimental rocket motors (from the ORM-23 to the ORM-52) were built and bench-tested in 1933. They had pyrotechnic (cartridge) and hypergolic (self-energized) ignition systems and used nitric acid and kerosene as fuel components. The experimental motors ORM-50 with a thrust of 150 kg and ORM-52 with a thrust of 300 kg passed their official bench tests in 1933.

Towards the end of 1933 the GDL overcame the main obstacles that blocked the development of dependable and effective liquid-propellant rocket motors. Suitable propellants and durable structural materials were developed as well as hypergolic and pyrotechnic ignition systems, swirl-type injectors, a system of regenerative fuel cooling of nozzles with helix-type finning, internal fuel-spray cooling of combustion chambers, etc.

The working pressure in the combustion chamber ranged from 20 to 25 atm, the specific impulse was up to 210 sec and thrust reached 300 kg. The motors were capable of multiple restart. Thus the ORM-50 motor—the only one of its type—successfully passed three development tests and one acceptance durability test in 1933, and five bench tests in 1934 in assembly with the CIRD-05 rocket for which it was designed. During a trial launch at the Nakhabino test range near Moscow the ORM-50, working in the partial-thrust regime, used up all the fuel from the tanks of the rocket which never left the rig because its feed system failed to ensure the required pressure of fuel flow. After ten tests lasting a total of 314 seconds the motor retained its serviceability.

The ORM-52 motor had the largest thrust at the time and was designed to propel naval torpedoes, aircraft and the BLA-1, 2 and 3 rockets being developed by the GDL. Its reliability can be judged from the fact that the motor, during its 29 startings, was in continuous operation for a total of 533 seconds, developed a thrust of 300 to 320 kg and still retained complete serviceability.

In 1932 the GDL began developing experimental liquid-propellant boosters for the Air Force, to be installed on the I-4 plane. It was to impart additional thrust to the engine-propeller unit.

M. N. Tukhachevsky, the Red Army Chief of Armaments, who supervised the work of the GDL, attended the test. In 1932 he wrote to the head of the Red Army Military Engineering Academy:

"There is great promise in the experiments of the GDL with a liquid-propellant rocket engine which they have recently succeeded in building at the laboratory."

Vetchinkin, who watched in 1932 the testing of the ORM-9 using oxygen and gasoline as propelling agents, wrote: "The GDL has completed the main part of the work of making a rocket—a liquid-propellant jet motor... In this regard, the achievements of the GDL (mainly the work of engineer V. P. Glushko) must be acknowledged as brilliant."

A. L. Malyi, V. I. Serov, Y. N. Kuzmin, I. I. Kulagin, Y. S. Petrov, P. I. Minayev, B. A. Kutkin, V. P. Yukov, N. G. Chernyshev, V. A. Timofeyev, N. M. Mukhin, I. M. Pankin and other able engineers and technicians greatly contributed to the development of electrical and liquid-propellant rocket engines at the GDL.

In 1929-30 the GDL division concerned with the development and testing of the electrical rocket engines and liquid rocket engines was housed in the Leningrad Electrophysics Institute; then it was moved to the Rzhevka Artillery proving ground (not far from Leningrad); and in 1932-1933 it was housed at the Admiralty building and, partly, at the St. John Ravelin of the Peter and Paul Fortress.

One part of the building at the Rzhevka proving ground was taken up by the GDL; the other part housed a well-equipped chemical laboratory in which the GDL did research on liquid propellants.

In the autumn of 1931 the Society for the Promotion of Defence and the Aero-Chemical Industry organized the Groups for Studying Jet Propulsion in Leningrad and Moscow (GIRD).

Moscow's GIRD, formed on November 18, 1931, was first headed by F. A. Zander, who was succeeded by S. P. Korolev. Among its organizers and active members were: B. I. Cheranovsky, V. P. Vetchinkin and Y. A. Pobedonostsev. Moscow's GIRD started a course of lectures and set up (in 1932) courses for studying the theory of jet propulsion, and began designing the OR-2 aircraft liquid-propellant jet engine and the RP-1 rocket glider.

As the head organization, Moscow's GIRD aided groups and societies studying jet propulsion in other towns and cities. In 1934 Moscow's GIRD was directed to popularize rocketry and was renamed the Jet Propulsion Group under the Central Council of the Society for the Promotion of Defence and the Aero-Chemical Industry. It functioned till the late 1930s and produced a number of small ingeniously designed experimental rockets.

Among the organizers and active members of Leningrad's GIRD, formed on November 13, 1931, were Y. I. Perelman, N. A. Rynin, V. V. Razumov (1890-1967), who was the first chairman of Leningrad's GIRD, A. N. Stern and Y. Y. Chertovsky (engineers), M. V. Gazhala, and I. N. Samarin and M. V. Machinsky (physicists). In 1932 Leningrad's GIRD had a membership exceeding 400. B. S. Petropavlovsky, V. A. Artemyev and other members of the GDL helped to organize Leningrad's CIRD and to plan its work. Leningrad's GIRD publicized innovations in rocketry, staged launchings of small powder rockets for demonstration purposes and designed a series of original experimental rockets including a photorocket, a meteorological rocket, and the Razumov-Stern rocket powered with a spin liquid-propellant engine. In 1932 Leningrad's GIRD set up courses on the theory of jet propulsion. In 1934 it was renamed Section of Jet Propulsion, and under the direction of M. V. Machinsky continued its popularization work and studied the effects of G-forces on test animals. It carried on work on the development and testing of liquid-propellant and other types of rockets until the outbreak of the Second World War.

The example set by Muskovites and Leningraders served to spark off a movement to organize GIRDs in other towns and cities, among them Kharkov, Baku, Tiflis, Arkhangelsk, Novocherkassk, and Bryansk. Popularization work by F. A. Zander, N. A. Rynin, V. P. Vetchinkin, V. O. Pryanishnikov and others did much to further this movement.

In June 1932, a decision was taken by the Presidium of the Central Council of the Society for the Promotion of Defence and the Aero-Chemical Industry to establish in Moscow, on the basis of the GIRD, an experimental organization for the development of rockets and rocket engines. The organization was provided with premises and funds. S. P. Korolev (1906-1966), Chairman of the Research Council of Moscow's GIRD who later became the chief designer of space rocket systems, was appointed chief of the organization. The team led by F. A. Zander, which had been working at Moscow's GIRD on a voluntary basis on the design of the OR-2 liquid-fuel engine for the RP-1 rocket glider, joined the staff.

From August 1932 the GIRD was additionally financed by the Red Army Department of Military Inventions. Later on three more project teams were formed, whose tasks were to develop liquid-propellant ballistic missiles, ramjet engines and gas dynamic facilities, and rocket gliders and winged rockets.

The three teams were led by M. K. Tikhonravov, Y. A. Pobedonostsev and S. P. Korolev respectively. In addition, there were formed a production team (workshops) and a test station.

Other able engineers, such as A. I. Polyarny, V. S. Zuyev, Y. S. Shchetinkov, I. A. Merkulov, M. S. Kisenko and Y. K. Moshkin, also worked at the GIRD and did much to advance Soviet rocket engineering.

The members of the GIRD, drawing on the legacy of Soviet scientists, began work on experimental rocket construction.

In the summer of 1932 and in January 1933 the GDL was visited by S. P. Korolev, his deputy Y. S. Parayev, F. A. Zander, M. K. Tikhonravov, Y. A. Pobedonostsev and others from Moscow's GIRD. They were shown a liquid-propellant rocket engine in operation. This visit marked the beginning of cooperation between the GDL and the Moscow rocket-builders. For more than a third of a century, all winged rockets, aircraft rocket installations, long-range and intercontinental missiles, powerful meteorological and geophysical rockets as well as all space rockets developed by S. P. Korolev and his colleagues were propelled by engines designed by the engineers trained at the Leningrad Gas Dynamics Laboratory.

In 1933 the first Soviet hybrid-propellant rocket, designed by M. K. Tikhonravov and built by the Korolev team, was launched at the Nakhabino test range.

The takeoff weight of the 2.4-meter-long rocket was 19 kg; its propellant weight—5kg; the engine produced a thrust of 25 to 33 kg; its thrust chamber pressure ranged from 5 to 6 atmospheres. The engine used liquid oxygen delivered into the chamber under the pressure of its own vapours, and solidified gasoline which was placed in the combustion chamber (1 to 1.5 kg.). It was fired from a vertical ramp. During the first trial launching on August 17, 1933, it reached a height of aobut 400 meters before the combustion chamber burned through. The flight lasted 18 seconds. During the second launching (autumn 1933) the rocket reached an estimated height of 100 meters when the engine exploded. In 1934 the rocket underwent several successful trials and reached a height of 1,500 meters.

The GIRD built two liquid-propellant rocket engines designed by F. A. Zander: the OR-2 to be installed on the RP-1 tailless rocket glider (designed by B. I. Cheranovsky), and the engine for the GIRD-X rocket. The design thrust of the first engine was 50 kg; its nozzle was cooled with water and the combustion chambers were cooled with gaseous oxygen. It burned oxygen and gasoline and was first tested in March 1933. During the tests the engine disintegrated. The colleagues of Zander, who did not take part in the tests and who died that month, built another engine, replacing gasoline with ethyl alcohol to reduce gas temperature and facilitate cooling, and introducing ceramic coating of the chamber.

The other engine (under development from January 1933) had a pyriform oxygen-cooled combustion chamber and used liquid oxygen and gasoline. During the first tests in August 1933 chamber burn-throughs necessitated structural changes, and gasoline was replaced with alcohol. In October 1933 the engine was successfully tested. It had a thrust of 70 kg; the specific impulse was 162 to 175 sec, combustion chamber pressure—8 to 10 atm, and firing duration—16 to 22 seconds. It burned a mixture of liquid oxygen and 78 per cent ethyl alcohol.

The GIRD-X liquid rocket built by the Korolev team was first tested on November 25, 1933. The rocket was initially designed by Zander. The all-up weight of the 2.2-meter-long rocket was 29.5 kg, its propellant weight—8.3 kg; the propellant was pressure-fed.

The rocket took off vertically, reached an estimated height of 75 to 80 meters whereupon its engine disintegrated and it veered away and hit the ground 150 meters from the starting point. The design principles of the GIRD-X rocket were further developed between 1935 and 1937. Zander's design for rocket engines was further worked on by his colleagues but was never brought to successful completion.

Tikhonravov built and tested other unguided missiles of the 07 type and of the 05 type. Pobedonostsev supervised the development of different versions of the ramjet engine and the building of a supersonic wind tunnel with flow velocities 3.2 times the Mach number.

The flight test data yielded by the first Soviet rockets built by the GIRD, which functioned for nearly a year and a half as a development organization, helped define further research guidelines.

With the passage of time the need to solve critical problems of rocket construction became increasingly felt. It was necessary to intensify rocketry research efforts. Back in 1931 it was proposed that the Gas Dynamics Laboratory be reorganized as an Institute of Gas Dynamics with emphasis on the development of liquid-propellant rockets. In April 1932 Leningrad's GIRD suggested to M. N. Tukhachevsky that a Research Institute of Jet Propulsion be established on its basis. The Society for the Promotion of Defence and the Aero-Chemical Industry and Moscow's GIRD supported the idea. In 1932-1933 the question was considered by M. N. Tukhachevsky, V. V. Kuibyshev, K. E. Voroshilov, G. K. Ordzhonikidze and other government leaders. On September 21, 1933, the GDL and Moscow's GIRD merged to form the Research Institute of Jet Propulsion (RNII), the first of its kind in the world.

I. T. Kleimenov (1898-1938) was appointed its Director. S. P. Korolev was named Deputy Director. In January 1934 G. E. Langemak took over as Deputy Director. Until the end of 1937 I. T. Kleimenov and G. E. Langemak (both had formerly headed the GDL) directed the work of the Institute and greatly contributed to the development of rocketry in this country.

On October 31, 1933, the Council of Labour and Defence issued a Decree whereby the Institute was to become part of an industry. The Decree opened with these words: "Considering the present achievements in the utilization of jet engines and, particularly, liquid jet motors, and the vast prospects they offer..."

The Institute maintained close contact with K. E. Tsiolkovsky. The RNII worked on fundamental problems of rocketry and developed a series of experimental ballistic and winged rockets and engines for them.

Between 1934 and 1938 prototype rockets designated 06, 13, RDB-01, 48, 216, 217, etc., were tested. The 212 winged rocket designed by S. P. Korolev (propelled by the ORM-65) was tested in 1939.

The RNII conducted extensive research on winged rockets and also worked on other projets that were of immense importance for the development of rocketry in the Soviet Union.

In 1937 and 1938 the RP-318 rocket glider designed by S. P. Korolev, with the ORM-65 liquid-propellant motor, underwent a series of ground tests. In 1940 V. P. Fyodorov, a pilot, tested it in flight. The engine was RDA-1-150, a modification of the ORM-65. In 1942 G. Y. Bakhchivandzhi tested the first Soviet rocket plane (BI-1) developed by A. Y. Bereznyak and A. M. Isayev under the direction of V. F. Bolkhovitinov. It was powered by the D-1-A-1100 liquid-fuel rocket engine with a thrust of 1,100 kg, designed at the RNII.

The RNII carried out an extensive and diversified research programme. They developed and tested two powder-propellant missiles of different calibres (RS-82 and RS-132) to be borne by combat aircraft. On May 28, 1939, Japanese invaders experienced the effect of the RS-82 near the Khalkhin-Gol river. The legendary Ilyushin attack planes equipped with RS-82 and RS-132 missiles were dubbed "Black Death" by Nazi invaders.

The *Yak* and *La* fighters also carried these missiles. Work to develop rocket missiles initially undertaken by the GDL was carried through by the RNII. The efforts of many specialists bore fruit: by the time of Nazi Germany's attack against the USSR in 1941 the RNII had developed the BM-13 rocket missile launcher. The BM-13 launcher, popularly known as *Katyusha,* firing M-13 missiles, was first battle-tried in 1941 and proved highly effective. On July 14, 1941, a *Katyusha* salvo literally obliterated the railway station of Orsha held by Nazi forces. Rocket artillery, developed at the RNII, was being steadily improved and mass-produced. During the Great Patriotic War (1941-1945) this formidable weapon was employed on all fronts, and it inflicted heavy losses on the enemy. Thus Soviet rocketeers made their worthy contribution to the defeat of Nazi Germany.

The RNII was also concerned with the development of control systems which it designed, manufactured, installed on rockets and tested. They included the GPS-2 instrument on the 216 rocket, the GAT-1—on the 201 rocket, the GPS-3 and RA-2 on the 212 rocket and on the 609 rocket respectively.

Those instruments were gyroscopic autopilots. They served to optimize the automatic takeoff of rockets fired from the catapult car and secure a steady flight during the acceleration phase.

But to return to the prewar period. The first nationwide conference on stratospheric research, sponsored by the USSR Academy of Sciences, was held in Leningrad in 1934. It was chaired by Academician S. I. Vavilov. In 1935 the Aviation Research Society organized a conference on rocket technology, which was held in Moscow. The conference heard papers read by many specialists from the RNII and other organizations.

In 1935 L. K. Korneyev, who had formerly worked at Moscow's GIRD, proposed the setting up of a design bureau for the development of liquid rockets. Design Bureau Seven (KB-7) as it came to be called, failed to produce the desired results and was dissolved.

The first Soviet two-stage rocket (the first stage propelled with powder, and the second with a ramjet engine), designed by I. A. Merkulov and built by the Jet Propulsion Section of the Stratospheric Committee of the Society for the Promotion of Defence and the Aero-Chemical Industry, was fired at a Moscow test range on May 15, 1939.

A team of liquid-propellant rocket engine specialists, who formerly worked at the GDL, developed at the RNII, between 1934 and 1938, a series of experimental rocket motors (ORM-53 to ORM-102), which used nitric acid and tetranitromethane as oxidants, and the first gas generator (the GG-1) which burnt a mixture of nitric acid, kerosene and water to generate inert pure gas at 580°C and at a pressure of 25 atmospheres and worked for hours (officially tested and accepted in 1937).

The ORM-65, officially tested and accepted in 1936, was the best engine of its time (using nitric acid and kerosene, having a controllable thrust of 50 to 175 kg and a specific impulse of 210-215 seconds; and with manual and automatic starting). It was a multiple-start engine: prototype-1 underwent 50 ground startings lasting a total of 30.7 minutes, including 20 static firing tests, 8 startings in assembly with the 212 winged rocket and 21 startings in assembly with the RP-318 rocket glider; and prototype-2 underwent 16 startings, including 5 startings in assembly with the 212 winged rocket and 9 startings with the RP-318 rocket glider.

The GDL division concerned with the development of electrical and liquid rocket engines (1929-1933) had traversed a long and difficult path. Later it functioned as a division of the RNII, from 1934 to 1938, and then as an independent organization from 1939 to 1940. It was eventually reorganized and became an experimental design bureau (OKB) named the GDL-OKB. It was awarded the Order of Lenin and the Order of the Red Banner of Labour. It developed in the 1940s a whole series of auxiliary liquid-propellant rocket engines to assist aircraft manoeuvring. These engines used pump-fed nitric acid and kerosene, had a hypergolic ignition system, and permitted an unlimited number of fully-automated startings within engine service life; they provided a controllable thrust, and developed a maximum ground-level thrust ranging from 300 to 900 kg.

Besides development and official rig tests, these engines also underwent, between 1943 and 1946, ground and flight tests (400 startings) in assembly with planes designed by V. M. Petlyakov (Pe-2R), S. A. Lavochkin (La-7R and 120R), A. S. Yakovlev (Yak-3), and P. O. Sukhoi (SU-6, Su-7).

S. P. Korolev, G. S. Zhiritsky, D. D. Sevruk, V. A. Vitka, N. N. Artamonov and a few others worked in the GDL-OKB as deputy chief designers. S. P. Korolev supervised flight tests (1942-1946). The experience gained by the GDL-OKB in the development of that family of liquid-propellant rocket engines was later utilized in the development of engines to propel space rockets.

Between 1947 and 1973 the GDL-OKB produced several dozen types of powerful liquid-propellant engines which were installed on various rockets. Such engines propelled most of the Soviet long-range and intercontinental ballistic missiles, and all the geophysical and space rockets launched up to date.

Memorial plaques were put up on the Admiralty building and the St. John Ravelin of the Peter and Paul Fortress in Leningrad on the occasion of the 40th anniversary of the founding of the GDL-OKB (1929-1969). Leningrad is thus not only the cradle of the socialist revolution in Russia; it is also the birthplace of Soviet rocketry. Here Zasyadko, Shilder and Konstantinov designed and built their black-powder rockets, and Kibalchich, Fyodorov, Meshchersky, Pomorsky, Rynin, Perelman and Razumov began their projects and theoretical investigations. Tsiolkovsky's classical works were first published here. And it was in Leningrad that the Gas Dynamics Laboratory, the first Soviet organization to undertake the development of rockets and rocket engines, built smokeless powder rockets, and created the world's first electrothermal rocket engine and the first Soviet liquid-propellant engines, the prototypes of the present-day rocket engines with a capacity of millions of kilowatts.

The efforts of the GDL, the GIRD and the RNII have greatly contributed to the advancement of Soviet rocket engineering.

The research and development organizations concerned with the designing and building of efficient onboard and ground-based flight control systems and ground support facilities have also made a notable contribution to the development of space rocket systems. It is the collective efforts of these organizations, together with the efforts of many other research and industrial establishments, that lifted man into space. Also, of decisive importance here were the high standards of Soviet industrial development, the advances made by Soviet science and the efforts of the entire Soviet people led by the Communist Party and its Leninist Central Committee.

Space Probe with Rocket Systems

The Soviet Union is conducting a comprehensive research programme on outer space with the aid of geophysical rockets, vertical sondes, automatic and piloted satellites and planetary probes (of fly-past, fly-over, and landing types).

Indicative of the scope of the programme is the fact that by July 1, 1973, the Soviet Union had launched 742 terrestrial, solar, lunar and martian satellites weighing a total of 4,388 tons (including the weight of the final stages of the carrier rockets). These satellites weighed together 2,233 tons. Forty-one vehicles, with a combined weight of 167 tons (inclusive of the final stages of the carrier rockets) and themselves weighing 110 tons, were imparted speeds close to the escape velocity.

From 1949 the Soviet Union started probing the upper atmosphere and outer space by geophysical rockets which lifted payloads from hundreds of kilograms to several tons to altitudes exceeding 500 kilometers. The V2A geophysical rocket was used to probe the upper atmosphere, photograph the solar spectrum, conduct medico-biological investigations and test the descent system of the instrument module weighing 1,340 kg and geophysical containers weighing 860 kg. The payload was 2,200 kg, and the altitude 212 km. The V5V geophysical rocket was used for astronomical, physical, geophysical, biological and ionospheric investigations. The payload was 1,300 kg; the peak altitude, 512 km. An extensive medico-biological research programme was carried out on test animals (mainly dogs) taken aloft with the aid of these rockets. A parachute system to recover the animals and equipment was tested during those flights. Recovery was effected either by soft-landing pressurized modules with test animals or by ejecting space-suited animals from descending rockets and bringing them down by parachute.

During the International Geophysical Year (1957) the world witnessed an outstanding achievement of Soviet science and engineering. On October 4, 1957, man for the first time pierced the armour of terrestrial gravity: a Soviet rocket, accelerated to the first cosmic velocity, put the world's first artificial sattelite, *Sputnik-1,* into orbit around the Earth.

The satellite, an aluminium shell sphere 580 mm in diameter, weighed 83.6 kg and carried four whip antennas measuring from 2.4 to 2.9 metres. Encapsulated were a scientific equipment package and power sources. The onboard transmitters operating on two different frequencies issued signals of 0,3 seconds' duration each, which told the world from an apogee altitude of 947 km that a man-made vehicle had broken the ties of terrestrial gravity and soared into space. The satellite stayed in orbit for 92 days during which it circled the Earth 1,400 times covering a distance of nearly 60 million kilometers. The density of the upper atmosphere was estimated for the first time on the basis of the deviations observed in the orbital flight path; data on radiowave propagation in the ionosphere were obtained, and the calculations that had been made and the principal engineering solutions that had been evolved for the creation of an artificial satellite, and for ensuring its functioning in space were checked and verified.

A month later, on November 3, 1957, the Soviet Union launched its second satellite which was heavier than its predecessor, more advanced in design and better equipped. *Sputnik-2* was the final stage of a carrier-rocket which contained sets of measuring instruments. It was the world's first satellite with a test animal on board: a separate pressurized cabin carried the dog Laika. The satellite weighed 508.3 kg (including the equipment, the test animal and power supply units). It carried two radio transmitters, a telemetry system, a programmer and instruments to measure solar and cosmic radiation. The environmental control system (regeneration and thermal control) maintained living-environment conditions inside the cabin. The satellite was put into an orbit with an apogee of 1,674 km and with an orbital inclination of 65.1°. The second satellite orbited the Earth for almost 160 days, during which it made 2,370 circuits covering a distance of more than 100 million kilometers.

The third Soviet satellite weighing 1,327 kg and hard-packed with equipment was orbited on May 15, 1958. It was a space laboratory which carried 12 scientific instruments, a multichannel telemetry system with data storage, orbit-estimating radio equipment, a radio beacon, a thermal control system, a programme timer and other onboard equipment. *Sputnik-3* measured 3.57 meters in length; its research and measuring equipment weighed a total of 968 kg. The apogee altitude was 1,881 km, the orbital inclination — 65.1°. The satellite orbited for 691 days during which it made 10,037 circuits around the Earth and traversed a path of almost 450 million kilometers.

It carried out an extensive research programme in near space (it measured and investigated upper atmospheric pressure and composition, concentrations of charged particles, cosmic radiation, magnetic and electrostatic fields, meteoric particles, etc.). The measurements pointed to the existence of an external zone of the terrestrial radiation belt.

Mankind achieved its second and complete victory over the Earth's gravity on January 2, 1959, when the *Luna-1* space probe attained the escape velocity (11.2 kilometers per second). The probe weighing 1.5 tons passed within 5,000 to 6,000 kilometers of the Moon and settled into a circumsolar orbit to become the first artificial satellite of the Sun.

Called by the world press *Mechta* this planetoid travels by a flight path whose perihelion is 146.4 million kilometers and aphelion — 197.2 million kilometers. The *Luna-1* probe carries radio equipment, a telemetry system, five different instruments to investigate interplanetary space and other equipment. Special equipment to form an artificial comet was installed in the rocket's final stage.

Soviet science and engineering scored another major success on September 14, 1959, when the *Luna-2* automatic probe reached the Moon. It was the first man-made craft to cut across the abyss of space and reach the celestial body nearest to us.

The Soviet state emblems and other tokens were delivered to the lunar surface by *Luna-2* in the vicinity of the Archimedes Crater in Lunik Bay.

Twenty days after the *Luna-2* mission, the *Luna-3* probe weighing 278.5 kg was fired into a circumlunar orbit. It photographed the far side of the Moon and transmitted the images to the ground-based radio stations. Another space secret was thus unlocked.

Luna-3 passed within a distance of 6,200 km of the lunar surface. That was the first experiment in which a celestial body was observed from a travelling space vehicle.

It took many months to study and interpret the televised images beamed by the probe. As a result, 498 lunar features (including 400 which are not discernible from the earth's surface) were distinguished, selenographic coordinates were established, and a map and an atlas of the far side of the Moon were compiled and later (in 1960) published by the USSR Academy of Sciences. Some of the newly discovered lunar formations were given names by an Academy Commission.

Thus, there appeared the Sea of Moscow with its Bay of Astronauts, the Mechta Sea, the Tsiolkovsky Crater, the Lomonosov Crater, the Lobachevsky Crater, the Jules Verne Crater, the Giordano Bruno Crater, the Maxwell Crater, the Popov Crater, the Edison Crater, the Pasteur Crater, the Hertz Crater, the Joliot Curie Crater, the Mendeleyev Crater, the Kurchatov Crater, and others.

Investigations of near and lunar space carried out by the *Luna-1, 2* and *3* automatic probes yielded invaluable data; notably, neither a perceptible lunar magnetic field, nor a radiation belt was detected.

A series of tasks were to be carried out to soft-land a probe on the Moon. For this purpose, a more powerful carrier rocket was developed.

The *Luna-1, 2* and *3* probes were fired, and after achieving the required velocity they headed for their destination in the so-called power-off flight. The subsequent *Luna* missions had more complex flight patterns. The probes were first injected into circumearth orbits whereupon, at a present moment, they were accelerated to approach the escape velocity, and then they headed for the Moon. There was a trajectory correction on the way to the Moon, and the retro-engines were started to decelerate the flight and ensure a soft landing.

The complexity of the project made it necessary to optimize all operations. That took time and effort.

Between 1963 and 1965 the *Luna-4, 5, 6, 7,* and *8* probes were successively launched to continue the investigation of the Moon and solve the problem of safely landing an instrument package on its surface. *Luna-5* reached the moon surface on May 12, 1965. The first experimental data on the performance of the lunar soft-landing systems were thus obtained. *Luna-6* skirted the Moon on June 11, 1965; *Luna-7* reached the Moon on October 8, 1965, and *Luna-8* on December 7, 1965.

On January 31, 1966, the *Luna-9* automatic probe was launched. It touched down in the Ocean of Storms on February 3. It was the first successful soft-lander. The probe weighing 100 kg transmitted back to Earth TV photographs of the lunar surface and telemetered a wealth of other data.

Thus panoramic pictures of the lunar surface were obtained for the first time. They permitted the discerning of particles 1 to 2 mm in diameter in the immediate proximity of the probe. Soviet state emblems were again placed on the Moon.

This experiment blasted the lunar dust surface hypothesis. The surface was found to be hard, hummocky, strewn with rocks and covered with craters of diverse sizes ranging from tiny holes to large formations. The radiological conditions were also explored.

On April 3, 1966, the *Luna-10* probe was for the first time put into a circumlunar orbit. The probe weighing 245 kg carried devices and instruments to register the radioactivity of the lunar surface, the meteoroid intensity, infrared and gamma radiation, the composition of lunar rock, the lunar magnetic field, solar plasma in lunar space and the lunar gravitational field. The radio beacon on board *Luna-10* played *Internationale*, the Communist Party anthem. Its pericynthian was 350 km, the apocynthion — 1,017 km, and the orbital inclination was 71°54′.

In 1966 *Luna-11* and *Luna-12* were injected into lunar orbits. Both functioned for several months and transmitted valuable data back to Earth. *Luna-12*, which carried a TV photo system with a high resolution (1,100 lines), flashed to Earth a series of lunar pictures taken from altitudes ranging from 100 to 340 kilometers.

On December 24, 1966, another Soviet automatic probe — *Luna-13* soft-landed on the Moon in the Ocean of Storms. It measured the density and mechanical properties of lunar soil. Lunar soil density was found to be up to 1 gram per cubic centimeter. Again televised images of lunar surface illuminated by the sun at different angles were obtained.

The fourth lunar orbiter, *Luna-14*, was launched on April 7, 1968. Its pericynthian was 160 km, the apocynthion — 870 km, the orbital inclination was 42° and the orbital period — 2 hours 40 minutes. The *Luna-14* mission was to ascertain the Earth-and-Moon mass ratio, the lunar gravitational field, and the conditions attending the propagation and stability of radio signals transmitted to the satellite while it changed position with respect to the Moon; to measure cosmic rays and charged particle fluxes emanating from the Sun, and to obtain additional information for building a more accurate theory of lunar motion.

Luna-15, the fifth lunar satellite, was launched on July 13, 1969. Upon its circumlunar injection two orbital corrections were made to place the satellite within 16 kilometers of the lunar surface. The probe explored lunar space, and data concerning the probe's new systems which were to ensure landing in different regions of the lunar surface were obtained. After circling the Moon 52 times *Luna-15* reached its surface.

Luna-16 demonstrated the possibility of using robots in the exploration of other celestial bodies. It was the first automatic probe to collect lunar rock samples. *Luna-16* was launched on September 12, 1970, and on September 20 it soft-landed on the Moon at a point in the Sea of Fertility. Commands were issued from the Earth whereupon a soil sampler drilled lunar soil, collected lunar rock and loaded it into a sample-return box in the recoverable module. On September 21 the Moon-Earth ascent stage took off and set out for the Earth. On September 24, 1970, the recoverable module was detached from the rocket and landed by parachute not far from the town of Dzhezkazgan (Kazakhstan). Lunar rock samples weighing a total of 100 grams were studied in laboratories and then displayed at exhibitions.

In further developing effective and economical methods of exploring outer space and celestial bodies with robots, the Soviet Union launched *Luna-17* which carried to the Moon an automatic self-propelled vehicle, *Lunokhod-1,* remote-controlled from Earth.

The probe lifted off on November 10, 1970, and followed the course of its predecessors: it was first injected into a geocentric orbit and then shifted to a circumlunar orbit. It made a soft landing on the Moon, in the Sea of Rains, on November 17.

On the same day *Lunokhod-1* rolled off its ramp and started the *Luna-17* programme of scientific and engineering experiments. *Lunokhod-1* has an eight-wheel running gear with an electrical motor to drive each wheel separately. The moonrover was powered by solar batteries, and demonstrated excellent manoeuvrability in negotiating or bypassing obstacles. Provided with an isotopic heat source *Lunokhod-1* functioned for 322 days (from November 17, 1970, to October 4, 1971) and covered a preset route of 10,540 meters. It made a detailed topographical exploration of an area of 80,000 square meters. A total of 171 communication sessions were conducted during which 24,829 commands were issued. The *Lunokhod's* radiotelevision system transmitted to Earth 206 panoramic photographs and over 20,000 ordinary moonscape pictures. The physicochemical properties of the surface layer were studied at more than 500 points; chemical analyses were made at 25 points. The results of experiments conducted with the aid of an X-ray telescope, radiation measurement equipment and a French-made laser angle reflector, all mounted on the *Lunokhod,* were obtained. The experiment was continued with the aid of *Luna-21* which landed *Lunokhod-2* on the eastern edge of the Sea of Serenity on January 16, 1973. Compared with its predecessor, *Lunokhod-2* had additional equipment and improved running gear. In five lunar days *Lunokhod-2* covered 37 km over rugged terrain.

Luna-18 launched on September 2, 1971, settled into a circumlunar orbit and made 54 circuits, but an attempt to land it on the edge of the Sea of Fertility failed. On September 28, 1971, *Luna-19* was launched to carry out a series of scientific investigations from a lunar orbit. On February 14, 1972, *Luna-20* lifted off; it made a soft landing on the edge of the Sea of Fertility, drilled the surface layer, collected lunar rock samples and brought them back to Earth. Some of the lunar soil delivered by *Luna-16* and *Luna-20* was given to France, Britain, the German Democratic Republic, Czechoslovakia and some other countries for study. The Soviet Union and the United States exchanged samples of lunar rock.

Another outstanding achievement was the launching of the Soviet *Zond-3* interplanetary probe which on July 20, 1965, photographed the reverse side of the Moon from a distance of 10,000 km and produced pictures of a very high quality. It photographed two-thirds of the far side of the Moon, mainly the areas which had not been covered by the *Luna-3* photographic mission in 1959. As a result, only 5 per cent of the entire lunar surface remained unphotographed.

Studies of the photographs of the reverse side of the Moon furnished by the *Luna-3* (1959) and the *Zond-3* (1965) enabled scientists at the Sternberg State Astronomical Institute, jointly with other organizations and under the direction of Y. N. Lipsky, to compile an Atlas of the Reverse Side of the Moon (part 1 — in 1960; and part 2 — in 1967) with a catalogue listing nearly 4,000 newly-discovered formations and lunar terrain features. The USSR Academy of Sciences Commission set up to name the said formations and features named some of them in honour of outstanding Soviet and foreign scientists in the field of space research and rocketry.

After 1960, lunar craters were named in honour of Zasyadko, Konstantinov, Kibalchich, Ganswindt, Meshchersky, Fyodorov (A. P.), Tikhomirov, Pomortsev, Artemiev, Perelman, Kondratyuk, Zander, Vetchinkin, Grave (D. A.), Rynin, Petropavlovsky, Langemak, Korolev, Razumov, Ilyin, Kleimenov, Bakhchivandzhi, Vasilchenko, Rastorguyev, Konoplev, Voskresensky, Gagarin, Komarov and others. Some lunar craters are given the names of those who worked at the GDL-OKB: Malyi, Petrov, Chernyshev, Zhiritsky, Artamonov, Gavrilov, Firsov, Alekhin, Grachev, and Mezentsev. The legendary names of Icarus and Daedalus, Wan-Hu and the names of noted writers such as Cyrano de Bergerac, Eyraud and Wells were also used.

In appreciation of the pioneering contributions of the GDL, GIRD and RNII, the newly-discovered chains of craters on the far side of the Moon were named after these organizations. Thus, a chain of craters stretching for 1,100 km was given the name of the GDL; two other chains spanning 520 and 540 km were given the names of GIRD and RNII respectively. The Commission called the *Luna-2* impact area Lunik Bay and the *Luna-9* landing site — the Bay of Soft Landing. The International Astronomical Union has endorsed most of the names.

Between 1966 and 1967 the Sternberg State Astronomical Institute and the USSR Topographic and Geodesic Service, on the basis of the Atlas of the Reverse Side of the Moon and photographs of the visible side of the Moon, compiled and published the world's first general lunar map (1 : 5,000,000) and globe (1 : 10,000,000). An Atlas comprising seven maps of the equatorial zone of the visible hemisphere (1 : 1,000,000) was published in 1968. The work was directed by Y. N. Lipsky. Later, lunar maps and globes were published both in the USA and the USSR based on the photographs furnished by *Zond-3* and US *Lunar Orbiter*.

The *Zond* automatic probes, the first of which was launched in 1964, are designed for outer space exploration and for achieving the optimization of onboard systems on long-duration space missions. *Zond-1, Zond-2* and *Zond-3* weighed about 950 kg each, and were equipped with a star-pointed attitude control system (with respect to the Sun, the Earth and the star Canopus) and a trajectory correction engine. The onboard equipment used power supplied by solar batteries. The temperature control system was designed to operate at varying distances from the Sun. The final stage of the launch vehicle was started off from a transfer geocentric orbit.

Zond-1 launched on April 2, 1964, was put into a heliocentric orbit. *Zond-2* launched on November 30, 1964, on a course towards Mars was the first to use six electrical plasma jet engines which functioned as actuators of the attitude control system.

Zond-3 was launched on July 18, 1965, on a course towards the Moon. It carried, besides scientific equipment, a phototelevision system (with film being processed automatically onboard) which had a high resolution (1,100 lines per frame; images could be trasmitted across hundreds of millions of kilometers).

The probe obtained 25 photographs while flying over the far side of the Moon at distances ranging from 11,570 km to 9,960 km. It photographed an area of 19 million square kilometers including 10 million square kilometers unphotographed by the *Luna-3* probe.

The pictures were originally transmitted to Earth from a distance of 2.2 million kilometers; repeated transmissions were made from a distance of 31.5 million kilometers. Having skirted the Moon *Zond-3* continued exploring outer space travelling by a heliocentric path.

Zond-4 through *Zond-8,* orbited by more powerful carrier rockets, had the object of testing and optimizing the construction of an automatic-version vehicle in a flight around the Moon; they also carried out scientific investigations and returned to Earth with the second cosmic velocity. The final stage of the launch vehicle was fired from a transfer geocentric orbit.

The probe carries a descent module with heat protective coating, an instrument module with the principal onboard systems (radio-communication, telemetry, attitude control and stabilization, power supply, heat control) and a vernier engine. The attitude control system is of the active type and provided with an array of optical (solar and earth) sensors and a system of low-thrust vernier engines. The onboard equipment uses power supplied by solar batteries unfolded in flight. The descent module houses scientific equipment, a photo camera, radio and telemetry equipment, a descent control system and a parachute landing system.

Zond-4 launched on March 2, 1968 was inserted into a heliocentric orbit. On September 18, 1968, *Zond-5* circled the Moon within a minimum distance of 1,950 km and photographed the Earth from a distance of 90,000 km. On its reaching terrestrial environs a trajectory correction was made to ensure the vehicle's injection into the re-entry corridor. On September 21 the descent module re-entered the atmosphere, and made a ballistic descent and a splashdown in the Indian Ocean.

For the first time a space vehicle returned to Earth with the second cosmic velocity after a flight around the Moon. *Zond-5* carried tortoises, the first living beings to make a flight around the Moon and return to Earth.

Zond-6 was launched on November 10, 1968. The flight programme envisaged a circumlunar pass, a series of scientific investigations and a return to Earth by means of controlled descent. On November 14 *Zond-6* circled the Moon within a minimum distance of 2,420 km and carried out a series of investigations including the photographing of the lunar surface at distances of 11,000 km and 3,300 km. On the way back trajectory corrections were made to ensure precise injection into the re-entry corridor. The descent trajectory was nearly 9,000 km long and comprised the initial atmospheric immersion phase (during which velocity dropped to 7.6 km per second), an exoatmospheric ballistic flight, and a second immersion phase during which the vehicle was decelerated to almost 200 meters per second. The descent trajectory movement was controlled by lift force regulation through changes in the descent capsule's roll. On November 17 the descent module landed in the designated area on Soviet territory.

The flight path and programme of *Zond-7,* launched on August 8, 1969, were identical to those of its predecessor, *Zond-6*. On August 11 *Zond-7* circled the Moon and on August 14 returned to Earth landing at a point south of the town of Kustanai. It carried out the planned programme and delivered colour photographs of the Moon and the Earth taken at different ranges.

Zond-8, the last in the series, circled the Moon on October 24, 1970, within a distance of 1,120 km of its surface. The high-altitude observatory of the Sternberg State Astronomical Institute, situated in the mountains of Trans-Ili Alatau, photographed *Zond-8* at a distance of 348,000 km with the aid of optical TV photographic equipment. The descent module splashed down in the preset area of the Indian Ocean — 730 km south-east of the Chagos Archipelago. Tested during the flight was re-entry from the Northern hemisphere side.

Simultaneously with lunar research the Soviet Union was sending probes to Venus and Mars—the nearest planets.

The first automatic venusian probe was launched on February 12, 1961. *Venera-1* weighing 643.5 kg was fired from an orbiting earth satellite which weighed 6.5 tons. On May 19-20, 1961, the probe passed Venus at a distance of less than 100,000 km, after covering a distance of 270 million kilometers. It settled into a heliocentric orbit to become a second Soviet solar satellite.

Venera-2 (963 kg), launched on November 12, 1965, passed Venus on February 27, 1966, at a distance of 24,000 km and also settled into a heliocentric orbit.

Venera-3 (960 kg) was launched on November 16, 1965. The descent module it carried was a sphere 900 mm in diameter, covered with a heat resistant coating to withstand heating during deceleration in the venusian atmosphere and provided with a landing parachute. There were 63 radio-communication sessions during the flight and a trajectory correction was made to ensure an accurate landing.

On March 1, 1966, after three and half months in flight the probe reached Venus and planted a sphere bearing the Soviet State emblem on its surface. That was a pioneer mission.

Unfortunately, radio communication failed when the probes reached venusian environs and the research programmes were not completed.

On June 12, 1967, *Venera-4* (weighing 1,106 kg) was sent to the planet. Much information was transmitted during the 114 communication sessions held during the flight. A trajectory correction to ensure an accurate venusian landing was made when the probe was 12,000,000 km from the Earth. On October 18, 1967, having travelled nearly 350,000,000 km, the probe entered the venusian atmosphere with the second cosmic velocity whereupon a descent module was separated from it. The descent module carried two microwave transmitters, a telemetry system, scientific equipment, a radio altimeter, a thermal control system, and power sources. Upon aerodynamic braking the speed dropped (from 10.7 km per second to 300 meters per second) and the parachute system was deployed. During the parachute descent which lasted 90 minutes the onboard instruments registered the pressure, density, temperature and chemical composition of the venusian atmosphere. The descent module (weighing 383 kg) delivered to Venus a second sphere with the Soviet national emblem.

That was the first-ever smooth descent of a man-made vehicle onto the surface of another planet. Data on the parameters of the venusian atmosphere within the pressure range of 0.5 to 18 atm were transmitted to Earth.

Venera-5 was launched on January 5, and *Venera-6* on January 10, 1969. The probes weighed 1,130 kg each, and carried ruggedized descent modules weighing 405 kg each; with their wider range of onboard instruments they were to continue investigations of interplanetary space and the venusian atmosphere. The descent modules carried spheres bearing the Soviet national emblem and a portrait of Lenin done in bas-relief. Communication and data-transmission sessions were regularly conducted in flight.

After mid-course trajectory corrections at distances of 15.5 and 15.7 million kilometers from the Earth, the two probes reached Venus on May 16 and May 17, 1969, respectively. The descent modules were separated from the service modules; their speeds dropped from 11.17 km per second to 210 meters per second owing to aerodynamic deceleration in the planet's atmosphere; the parachute systems were deployed and the modules made a smooth descent lasting 51-53 minutes. They touched down on Venus's nocturnal side.

Venera-5 and *Venera-6* obtained extensive information. The venusian atmosphere was probed within the pressure range of 0.5 to 27 atm.

Venera-7 launched on August 17, 1970, was the first soft-lander. It reached Venus on December 17, 1970. The probe weighed 1,180 kg; 124 communication sessions were conducted. Upon its separation from the carrier and aerodynamic deceleration the ruggedized descent module began a parachute descent during which it, for 35 minutes, transmitted radio signals, and soft-landed on the planet having carried out important measurements all the way to the surface. Venusian surface pressure was found to be in the region of 90 atm and temperature — nearly 470°C.

Venera-8 launched on March 27, 1972, reached Venus on July 22, 1972, having travelled a path of over 300,000,000 kilometers. The descent module made a gliding atmospheric descent and a soft landing on the planet's sunward side. As the module descended through the venusian atmosphere and when it functioned for 50 minutes upon the planet's hot surface it transmitted invaluable data on Venus's diurnal side (illuminance, atmospheric temperature and pressure, etc.) and carried out measurements of venusian surface parameters. The launching of the probe was timed for the 50th anniversary of the formation of the Union of Soviet Socialist Republics. The probe carried tokens bearing the Soviet national emblem and Lenin's portrait in bas-relief.

Martian investigations were started on November 1, 1962, with the launching of the *Mars-1* interplanetary probe weighing 893.5 kg. Two-way radio contact with the probe was maintained in the course of 61 communication sessions, even at a maximum distance of 106,000,000 km. The probe transmitted interplanetary-space data, skirted Mars on June 19, 1963, and settled into a heliocentric orbit with a perihelion of about 148,000,000 km and an aphelion of about 250,000,000 km.

Mars-2 (4,650 kg) lifted off on May 19, 1971, and 192 days later reached Martian environs having covered 470,000,000 km. On November 27, 1971, it was injected into a circum-martian orbit and its descent module alighted on the planet. That was the first-ever Martian landing. *Mars-3* was sent on its way on May 28, 1971, and on December 2, 1971, its descent module entered the martian atmosphere, descended by parachute and made the first-ever soft landing on the martian surface between the regions called Electris and Phaethontis in the planet's southern hemisphere. The signals emitted by the descent module were relayed through the *Mars-3* satellite (which continued circling Mars) to Earth. However, transmission soon stopped. Investigations of the martian atmosphere and surface and of planetary space with the aid of a complex of research apparatus borne by *Mars-2* and *Mars-3* added considerably to our knowledge of the planet.

Along with the development and improvement of interplanetary probes efforts were made to develop heavy recoverable manned orbital spacecraft and suitable carrier-rockets. At first, spaceships carrying various instruments were controlled by automatic devices. They also carried one or two test animals (dogs), other living objects, and a dummy cosmonaut.

Between May 15, 1960, and March 25, 1961, five spacecraft of this type were put into circumterrestrial orbits. Their weight ranged from 4,540 to 4,700 kg. As the spaceships descended they ejected capsules with the passenger dogs (Belka, Strelka, Chernushka, Zvezdochka) and other living objects, which landed by parachute in preset areas.

As a result, manned spacecraft were designed and all their numerous systems were tested and optimized. These included: a life support and safety system, a multichannel radio communication system, a trajectory-estimating system, a television system, a telemetry system, an attitude control and stabilization system, a retro-rocket system, and a soft landing system.

Progress in Soviet space-oriented rocket engineering found embodiment in the world's first manned space flight: on April 12, 1961, the *Vostok* spaceship was successfully launched, piloted by Major Yuri Gagarin. Having circled the Earth on an elliptical orbit and carried out the assigned programme the *Vostok* spaceship safely landed in the preset area on Soviet territory. An obelisk was unveiled at the landing site near the village of Smelovka, Ternovsk District, Saratov Region, to commemorate the event.

To mark the world's first manned space flight the USSR Supreme Soviet Presidium instituted "Cosmonautics Day" to be observed on the 12th of April.

The International Aeronautical Federation (FAI) passed a resolution making the 12th of April the world's Day of Aviation and Astronautics. It has been observed since 1968.

A new era has dawned for mankind. Man has emerged into space. Between 1961 and 1965, eight spaceships of the *Vostok* and *Voskhod* series, designed for solo and group flights, lifted Soviet cosmonauts into space. Their names will be remembered forever.

They are: Yuri Gagarin—the first man to make an orbital flight around the Earth at a maximum altitude of 327 km.

Herman Titov, who soared into space inside *Vostok-2* on August 6, 1961, and orbited the Earth for 24 hours.

Andrian Nikolaev, who was carried aloft by *Vostok-3* on August 11, 1962, and made a record flight lasting four days. He was joined by Pavel Popovich in *Vostok-4* who spent three days in space. That was the first group flight. Radio contact between the ships and the Earth was maintained throughout the flight. The cosmonauts' images were televised to Earth and shown on the USSR national TV and Intervision. That was the first telecast from space.

Valery Bykovsky, who stayed in orbit for five days (from June 14 to June 19, 1963) aboard *Vostok-5,* and demonstrated that man could live and work in outer space.

Valentina Tereshkova, the world's first and only woman cosmonaut, who piloted *Vostok-6* for three days (June 16-19, 1963) in a twin flight with Valery Bykovsky.

Vladimir Komarov, Konstantin Feoktistov and Boris Yegorov—the crew of the first *Voskhod* multiseater spaceship who spent 24 hours (October 12-13, 1964) in orbit at an altitude of 408 km. They carried out a series of experiments and were the first cosmonauts to work without protective suits.

Pavel Belyaev and Alexei Leonov, the crew of the *Voskhod-2* two-seater spaceship, who made an orbital flight (March 18-19, 1965) at an altitude of 498 km during which Alexei Leonov stepped off the ship into space. That was an experiment of tremendous importance. The egress into space was made through an airlock. Alexei Leonov wearing an extravehicular space-suit with an individual life-support system was able to move five meters away from the ship. Although he spent only 20 minutes outside the space craft (including 12 minutes outside the airlock) the experiment demonstrated that man could work in outer space protected only with a space-suit. The movie cameras installed outside the ship and in the airlock filmed the egress and the extravehicular walk. *Voskhod-2* was landed by manual controls.

Each of these eleven Soviet cosmonauts was a pioneer, a trail-blazer who carried out a new type of mission.

The cosmonaut training centre had successfully carried out its challenging task.

The *Vostok* spaceship consists of a spherical re-entry capsule which is also the cosmonaut's cabin, and an instrument compartment housing all vehicle-borne equipment and a retrorocket engine (designed by A. M. Isayev). The ship's weight, in assembly with the final stage of the carrier-rocket, is 6.17 tons (4.73 tons without the final stage), and its length—7.35 meters; the weight of the re-entry capsule is 2.4 tons, and its diameter—2.3 meters. The pilot wearing a space-suit is seated in an ejectable chair; the ship is controlled either automatically or manually by the cosmonaut. The life-support system is designed to function for ten days; radio contact with ground-based facilities is maintained continuously. To land the ship, the retro-engine is switched on to decelerate the ship and put it onto a descent path; then the re-entry capsule is separated and after its atmospheric deceleration the cosmonaut is ejected at an altitude of 7 kilometers and brought to the ground by parachute.

The *Voskhod* multiseater spaceship differs from the *Vostok* craft both in design and equipment; it has a soft-landing system, a standby retro-engine, and additional instrumentation (an extra attitude-control system with ionic sensors, advanced television and radio-engineering equipment, etc.).

The Soviet artificial Earth satellites, interplanetary probes and piloted spaceships were orbited by powerful, continually improved carrier rockets.

Back in 1957 the world learned that the first intercontinental missile had been successfully tested in the Soviet Union. That rocket was meant for peaceful use. That two-stage rocket powered by five engines orbited the first three artificial earth satellites in 1957 and 1958.

More powerful three-stage carrier rockets 38 metres long, with a maximum diameter of 10.3 meters (measured between fin tips), orbited the spaceships of the *Vostok* family. The rocket burns oxygen and kerosene; it has a parallel arrangement of the first and the second stages, and a tandem arrangement of the second and the third stages. The first stage consists of four lateral units, 19 metres long and 3 metres in diameter, each unit being provided with the RD-107 engine; the central unit (second stage) is 28 meters long and 2.95 meters in diameter, and provided with the RD-108 engine; the third stage is 10 metres long and 2.58 meters in diameter, and it is provided with a single chamber rocket engine with four rudder nozzles.

The six-engine propulsion system of the rocket attains a total thrust of 600 tons and a maximum useful power in flight of 20 million h. p.

Advanced rocket engines and rocket design features are decisive factors making possible a space flight. The rocket velocity is primarily determined by engine power characteristics.

The specific impulse of rocket engine is the main characteristic of its efficiency. The specific impulse of the RD-107 engine powering the first stage of the *Vostok* carrier-rocket (in operation since 1957) exceeds by almost 30 units that of the advanced US engine (H-1) of the same thrust (also using oxygen and kerosene) which has powered the first stage of the *Saturn-1B* rocket since 1966.

The specific impluse of the RD-107 engine in a vacuum is 314 seconds; its thrust is 102 tons.

The swinging rudder chambers fed from the general turbopump unit reduce the specific impulse by a mere second.

The rocket engines developed in the USSR in subsequent years have considerably superior characteristics. The high specific impulse of the engines installed in Soviet carrier-rockets permitted the use of vast power with a moderate fuel consumption. The development of such engines was one of the outstanding achievements that made possible Soviet successes in space exploration.

Perfect engine designs, control systems and ground-based launching facilities combined to make possible the creation of a powerful carrier-rocket and its extensive utilization for space exploration. An advanced carrier-rocket was used to orbit the *Voskhod* and *Soyuz* spacecraft. More complicated four-stage modifications of the *Vostok* carrier-rocket injected into orbit the *Luna* automatic probes (from *Luna-4* to *Luna-14*), the *Mars-1* probe and the *Venera* series (from 1 to 8).

The powerful engines installed on the first stages of all carrier-rockets and on the second stages of most of them were developed by the GDL-OKB; the main sustainer engines that propelled automatic interplanetary probes and piloted spaceships were developed by the design bureau headed by A. M. Isayev.

A. M. Isayev (1908-1971) had worked in the aircraft industry from 1934; he took part in the development of the BI-1 rocket plane and from

1942 and onward worked on the development of liquid-propellant rocket engines; in 1944 he became chief of an experimental design bureau which produced a whole series of rocket engines. A. M. Isayev was among the first designers and builders of rocket engines in the country.

Engines for the upper stages of many launch vehicles were developed by S. A. Kosberg (1903-1965) who had begun work on liquid-propellant rocket engines in 1954.

S. P. Korolev (1906-1966), the outstanding designer of the world's first spaceship and intercontinental ballistic missiles and space rockets, played an exceptionally important role in space exploration. He closely cooperated with the chief designers of engines, control systems and ground support facilities and other onboard and ground-based systems.

The joint efforts of the experimental design bureaus, a number of industrial research institutes and the USSR Academy of Sciences led to the development of the numerous prototypes of space rocketry.

The Tsiolkovsky gold medal, awarded by the USSR Academy of Sciences, bears the inscription: "For Outstanding Achievements in the Field of Interplanetary Travel." In 1958 the first Tsiolkovsky medal was conferred on the Chief Designer of Rockets and Spaceships, the second—on the Chief Designer of Rocket Engines, and the Third—on the Chief Designer of Rocket Control Systems. The Soviet space pilots also received that medal along with Academician M. V. Keldysh, a theoretician of cosmonautics who made an outstanding contribution to the scientific solution of problems associated with the exploration and use of outer space.

Development of the space rocket systems, which made possible the launchings of the world's first earth and solar satellites, the flights of the first eleven Soviet cosmonauts who piloted the spaceships of the *Vostok* and *Voskhod* series, the flights of the first lunar, venusian and martian probes and the soft lunar landing, was under the direction of S. P. Korolev. He also supervised the development of satellites of the *Elektron* series, the *Molnia-1* satellite, many of the *Kosmos* satellites, and the first in the *Zond* series.

Over 15 years ago new teams led by chief designers of rockets, spaceships, engines, control systems, launch systems were formed to cope with the growing need to develop new space rocket systems.

This not only augmented Soviet techno-scientific capability in the field of space rocketry, but also permitted the exploration in depth of diverse trends in the development of rocket technology and the evolution of optimum solutions.

The new teams developed a number of remarkable intercontinental rockets, launch vehicles and space vehicles. There appeared the *Kosmos* satellites, the lunar robots and the lunar satellites (*Luna-15—Luna-21*), the *Venera* interplanetary probes (2 to 8), *Mars-2* and *Mars-3,* the *Polyot* manoeuverable automatic spacecraft, and the powerful *Proton* space rocket system.

M. K. Yangel (1911-1971) was an outstanding Soviet designer in the field of space rocketry. The team which he trained and directed, jointly with the teams led by other chief designers of engines, control systems and launch systems, has made an invaluable contribution to the development of space rocketry and the exploration of near space.

G. N. Babakin (1914-1971) was another outstanding designer and scientist in the field of space engineering, he continued the work started by S. P. Korolev and developed a series of automatic space vehicles for lunar and planetary investigations.

The *Kosmos* satellites, regularly orbited since March 16, 1962, are of diverse types and purposes. They are launched by several types of two-, three- and four-stage carrier rockets of different load-lifting capacity (from hundreds of kilograms to dozens of tons), launched from several cosmodromes.

The first two-stage *Kosmos* carrier-rocket, launched on March 16, 1962, was 30 meters long and 1.65 meters in diameter.

On October 14, 1969, this rocket orbited the first earth satellite of the *Interkosmos* series. The first stage is powered by the RD-214 with a thrust of 74 tons, burning a mixture of an oxidizer based on nitric acid and hydrocarbon as fuel. The final stage is powered by the RD-119 with a thrust of 11 tons, burning liquid oxygen and dimethylhydrazine. The artificial Earth satellite is housed in the final stage under the nose cowling which is jettisoned upon passing the dense atmosphere.

The RD-214 has the largest thrust and specific impulse (264 sec in a vacuum) of all the engines of this type, i. e. those using nitric acid and hydrocarbon. This engine, used since 1957, is installed on the *Kosmos* rocket prototype. It is one of the early versions developed by the GDL-OKB (1952-57).

The RD-119 engine powering the second stage of this rocket (developed between 1958 and 1962) is made chiefly of titanium alloys. Its gas generator uses a monopropellant (dimethylhydrazine) and this engine has the highest specific impulse—352 seconds (in a vacuum)—among rocket engines burning oxygen and a high-boiling-point fuel.

Under the *Kosmos* programme 576 Earth satellites were orbited between March 16, 1962 and July 1, 1973. This programme is concerned chiefly with the study of the upper atmospheric layers, and near space, and the optimization of many structural elements of space vehicles. The programme also provides for medico-biological investigations, the investigation of charged-particle concentration, corpuscular, fluxes, radiowave propagation, the Earth's radiation belt, cosmic rays, the Earth's magnetic field, solar radiation, meteoric matter, cloud patterns in the atmosphere, and the effects of outer space factors.

The *Kosmos* missions also explored a number of engineering problems of space flight (e. g. docking in orbit, spacecraft atmospheric re-entry, attitude control in space, life support, protection against radiation hazards) and tested many structural elements and spacecraft onboard systems.

The *Kosmos* satellites travel at altitudes ranging from 145 km to 60,000 km (*Kosmos-260*); at times several satellites were orbited by one carrier-rocket (for instance: *Kosmos-38, 39,* and *40; Kosmos-71* through *75; Kosmos-336* through *343; Kosmos-411* through *418, Kosmos-444* through *451; Kosmos-504* through *511, Kosmos-528* through *535,* and *Kosmos-564* through *571*). The *Kosmos* satellites are widely different in design and instrumentation. Many of them use Sun or Earth orientation systems (some use the aerodynamic attitude control system); the onboard equipment is supplied with power from solar batteries and chemical energy sources (a system with a radioisotope battery was also tested); and multichannel telemetry systems with onboard storage devices transmit scientific and metric data to Earth. Some of the satellites (*Kosmos-110, Kosmos-186, Kosmos-188,* and others) carry recoverable capsules with scientific instrumentation and experimental objects. A number of satellites are standard in design and the main onboard systems, which makes il comparatively easy to vary their instrumentation to achieve satellite modifications.

Kosmos-1 and *Kosmos-2* conducted ionospheric research by radio techniques. *Kosmos-3* and *Kosmos-5* were automatic geophysical satellites, *Kosmos-4* measured radioactivity following the US nuclear test explosion in space under the *Starfish* programme. The measurements made by *Kosmos-7* ensured radiation safety for *Vostok-3* and *Vostok-4, Kosmos-26* studied the geomagnetic field, while *Kosmos-97* carried a quantum molecular generator for the purpose of long-range radio communication experiments in space.

Kosmos-110 launched on February 22, 1966, carried two test dogs, various plants and scientific equipment.

Since the satellite's apogee was 904 km it remained in the terrestrial radiation zone. After a 22-day flight, having completed 329 circuits, the satellite landed in the preset area (March 16, 1966). The medico-biological experiment, which was successfully carried out, greatly added to our knowledge of the effects of high-level radioactivity in near space and prolonged weightlessness on living organisms.

Kosmos-122 tested the equipment for meteorological observation. *Kosmos-144, Kosmos-156, Kosmos-184, Kosmos-206* and some other satellites are part of the *Meteor* system. They collect data for the weather service.

Kosmos-186 and *Kosmos-188* launched on October 30, 1967, were the first vehicles to effect an automatic rendezvous and docking in orbit; upon undocking they continued their autonomous flights and then landed on Soviet territory. On April 15, 1968, the experiment was repeated by *Kosmos-212* and *Kosmos-213. Kosmos-261* launched on December 20, 1968, carried out investigations of the upper atmosphere and the polar aurora. The experiment was a joint undertaking of the People's Republic of Bulgaria, the Hungarian People's Republic, the German Democratic Republic, the Polish People's Republic, the Socialist Republic of Romania, the Union of Soviet Socialist Republics and the Czechoslovak Socialist Republic.

The employment of communication, weather, navigational, astronomical, geodesic, geophysical and other satellites opens up new possibilities for the carrying out of economic tasks.

The *Elektron* space system comprised the *Elektron-1* and *Elektron-2* scientific satellite stations which were launched in January 1964 by a single rocket into two different orbits with apogees of 7,000 km and 70,000 km respectively. In July 1964 the experiment was repeated by *Elektron-3* and *Elektron-4*. Both systems investigated the Earth's radiation belt, the magnetosphere and the outward atmospheric zones, solar and remote galactic radiations and cosmic rays.

Molnia-1 communication satellites launched between 1965 and 1973 into orbits with a period of revolution of 12 hours, an apogee of nearly 40,000 km in the Northern hemisphere and a perigee of up to 500 km, made possible long-range re-transmission of telecasts as well as two-way telegraph, telephoto, and telephone communications (e. g. between Moscow and Vladivostok, Murmansk, Arkhangelsk, Krasnoyarsk, Yakutsk, Magadan, Yuzhno-Sakhalinsk, Ashkhabad, etc., as well as between Moscow and Paris).

The satellites are part of a long-range space communication system functioning in conjunction with the *Orbita* ground-based receiving stations. They ensure communication sessions lasting eight to ten hours at a time via each satellite. *Molnia-1* has an engine for orbit-corrections. The output power of the *Molnia-1* onboard transmitter (40 watt) is considerably greater than that of any other known communication satellite. During the flight the solar batteries are oriented towards the Sun while the parabolic antenna points to Earth.

The TV camera installed aboard *Molnia-1* has been transmitting images of the Earth from altitudes of 30,000 to 40,000 km since May 1966, thereby providing a global picture of the cloud canopy over the Earth. The first colour image of the Earth was obtained from outer space in 1967. A total of 23 satellites of the *Molnia-1* series had been launched by July 1, 1973 to provide communications and telecasting on Soviet territory and in other countries.

The first satellite in the *Molnia-2* series was orbited on November 24, 1971, to further the development of communication systems. It carried radio relay equipment operating in the centimeter wave band. By April 5, 1973, four more *Molnia-2* satellites had been orbited.

Of great practical value are weather satellites designed for continuous collection of meteorological data. This ensures efficient operation of the weather service and facilitates the elaboration of a general theory of atmospheric circulation and reliable long-term weather forecast techniques.

Soviet weather satellites include some of the *Kosmos* and all of the *Meteor* satellites. Equipment for meteorological satellites was tested by the *Kosmos-23* type satellites orbited between 1963 and 1964. The *Kosmos-122* satellite carrying a package of meteorological instruments was built and tested in 1966.

The *Meteor* weather system began functioning with the launching of *Kosmos-144* and *Kosmos-156* (February 28 and April 27, 1967, respectively). Their orbits are close to circular, at altitudes ranging between 600 and 700 km, and with inclinations of 81°. In flight the satellites are continuously oriented in an orbital co-ordinate system (with the transverse axis pointed vertically); the onboard equipment is powered by solar batteries located on two panels oriented perpendicularly to the sun's rays by the acquisition system. Fifteen *Meteor* satellites were orbited between 1969 and 1973.

The orbital parameters of meteorological satellites make possible the observation of weather conditions in any given area at an interval of about 6 hours. The satellites carry TV and infrared equipment to register cloud patterns, the snow and ice caps on the diurnal and nocturnal sides of the Earth, and actinometric equipment to measure radiation emitted and reflected by the Earth and the atmosphere. Two satellites, within 24 hours, collect weather information on half the Earth's surface.

A network of ground-based points equipped with recording and information-processing facilities and linked by direct communication channels with the USSR Hydrometeorological Centre, receive meteorological data sent by satellites. Information processing is automated and is completed within an hour and a half. Data obtained by the *Meteor* system considerably increase the reliability of weather-forecasts, and detect powerful oceanic cyclons and tornadoes, select optimum routes for merchant vessels and fishing fleets, and determine ice-bound and ice-free areas in polar regions and along the Northern Sea Route.

Two automatic stations of the *Prognoz* series were launched in 1972 into a high elliptical orbit (with an apogee of 200,000 km) to investigate solar activity and its effects on the interplanetary space and the terrestrial magnetosphere. The *Prognoz-3* station continued the investigations in 1973.

Meteorological rockets are a variety of geophysical and high-altitude rockets launched in this country since 1949 to measure atmospheric temperature, density and pressure and wind velocity. The MR-1 rockets attain a maximum altitude of 100 km; the MR-12 lift a payload of 50 kg to a height of 180 km. The nose cone houses a thermal-conduction manometer and a membrane manometer, resistance thermometers, bolometers (for measuring radiant heat), a radiotelemetry system, storage batteries and other equipment. At a preset altitude the nose cone is separated from the rocket body, and both are brought to the ground by parachute.

The M-100 is a two-stage rocket, both stages being propelled by powder rocket engines; its takeoff weight is 475 kg, the maximum altitude is 100 km; the weight of the research equipment package is 15 kg. The MMR-06 (minor meteorological rocket) is a small single-staged powder rocket designed to carry out weather research; its takeoff weight is 135 kg; it lifts a 5 kg research equipment package to an altitude of 60 km. Meteorological rockets are fired from Soviet territory, from the Arctic and the Antarctic, and from research ships.

Greater altitudes are also probed by rockets. The *Yantar-1* automatic probe was lifted to an altitude of 400 km by a geophysical rocket in October 1966. Its purpose was to investigate the interaction between the jet of an electric rocket engine and ionospheric plasma. The experimental plasma-ion engine was started up at a height of 160 km, and during further flight there were 11 power-on cycles. The jet velocity was found to be nearly 40 km per sec. The data obtained are of immense importance for solving the problem of controlled flights of a vehicle powered by an electric rocket engine at altitudes exceeding 100 km.

On October 12, 1967, a probe was fired vertically to an altitude of 4,400 km to investigate the upper atmospheric layers, the ionosphere and near space, and register radiation doses behind different protection shields during the flight through radiation belts. To obtain accurate measurements, the probe was made from special materials. The carrier-rocket, upon launching the probe, veered away to a considerable distance to avoid the discharge of gases into the ambient medium. Besides research equipment the probe carried, as usual, a radiotelemetry system and trajectory measuring equipment.

In 1963 and 1964 the *Polyot-1* and the *Polyot-2* automatic manoeuvring satellites were successfully tested. During the tests, engines for stabilizing the ships and for all-direction manoeuvres were repeatedly turned on. Altitude and orbital-plane changes were made many times.

The development of the powerful *Proton* space rocket system in 1965 was a signal achievement of Soviet science and engineering. The lifting capacity of the multistage *Proton* carrier-rocket exceeds many-fold that of the *Vostok* carrier. The overall maximum useful engine power of the *Proton* carrier-rocket exceeds 60,000,000 H.P.; that is, it is thrice that of the *Vostok* carrier.

The development of the *Proton* space rocket system marked a new stage in space exploration. It opened up new possibilities for the study of the planets and other celestial bodies of the solar system.

The *Proton* space rocket system is built on the basis of the latest scientific and technological achievements and has superior power and service characteristics. The *Proton* carrier-rocket is fitted with newly-developed powerful engines of the most advanced design in which the exhausted generator gas spent in the turbine is completely burned in the main combustion chamber where it is mixed with the required fuel component. By this means the actuation of the turbopump unit is achieved with practically no loss of energy. Because of this, pressures measured in hundreds of atmospheres can be attained in the combustion chamber. A considerable pressure developed in the engine, high combustion efficiency and a balanced and steady efflux of exhaust gases from highly divergent nozzles made possible the construction of compact engines with exceptionally high performance characteristics. The excellent overall design of the rocket, its advanced engines, control systems and the launching complex are a major success of Soviet rocket engineering.

The heavy *Proton-1, 2, 3* and *4* stations equipped with instruments to investigate cosmic-ray particles and high and ultra-high energy particles, were put into geocentric orbits between 1965 and 1968. Each of the first three satellites launched on July 16 and November 2, 1965, and July 6, 1966, respectively, weighed 12.2 tons (including the equipment housed in the final stage of the carrier-rocket); the package of research equipment weighed 3.5 tons. The perigee was 190 km, and the apogee nearly 630 km. The research equipment included an ionization calorimeter for measuring particles with energies of up to 10^{13} electron volts. *Proton-4* launched on November 16, 1968, was provided with a new complex of research equipment which made possible the investigation of particles with energies of up to 10^{15} electron volts. The weight of *Proton-4,* without the final stage of the carrier-rocket, was nearly 17 tons; the weight of the research equipment complex was 12.5 tons. The perigee was 255 km, and the apogee—495 km.

The *Proton* satellites studied the energy spectrum and the chemical composition of primary cosmic rays, the intensity and the energy spectrum of gamma radiation and electrons of galactic origin.

New research possibilities have thus opened up before scientists who are now able to fathom the mysteries of the fine structure of the so-called elementary particles and the nature and origin of cosmic rays.

The heavy satellites *Kosmos-186* and *Kosmos-188,* launched in 1967, and *Kosmos-212* and *Kosmos-213,* launched in 1968, carried out successful experiments involving their mutual automatic search, rendezvous, docking, joint flight and undocking. The entire instrumentation including radio equipment, computers, automatic systems and propulsion installations performed reliably throughout the experiments.

The experiment involving automatic docking opened up the possibility of building large orbiting space stations, and their servicing and the orbital assembly of large spaceships for interplanetary missions.

Work began on the development of the *Soyuz* multiseater spaceships designed for extended space missions, manoeuvring and docking in orbit. The *Soyuz* programme envisaged extensive scientific and engineering research in near space and the construction of habitable orbital stations.

The *Soyuz* spaceship weighing 6.45 to 6.65 tons consists of an orbital module housing research equipment and serving as a room for rest for the crew; a re-entry module which is simultaneously a crew module; an instrument module with the main equipment and a two-engine vernier installation. Passage from the orbital module to the re-entry module, whose combined volume is 9 cubic meters, is via a pressurized hatch. The re-entry module has a heat protective coating, and it is shaped so as to ensure its controlled descent with the use of the aerodynamic factor. It accommodates the cosmonauts' seats, the control panel, the descent control system, the radio-communication system, the environmental control system, the parachute landing system, and the powder rocket engines for soft landing. The g-forces during the descent were brought down to 3 or 4 units, and touch-down accuracy was increased; the touch-down speed did not exceed 2 or 3 meters per second. The attitude control system ensures the ship's spatial orientation, control and stabilization in a power-on flight, approach to and manoeuvring in close proximity of another spaceship; the system is operated both automatically and manually. The ship has an automatic docking system which was tested during the flight of the *Kosmos* automatic satellites. The onboard equipment is powered by solar batteries arranged on two opening panels. A complex of radio aids determines orbital parameters, receives radio commands from and maintains two-way communication with the Earth, and transmits TV images (there are four onboard TV cameras) and telemetery data. The ship is equipped for autonomous flight and piloting; the propulsion unit permits manoeuvres to an altitude of 1,300 km.

The path of space exploration is not an easy one. The *Soyuz-1* spaceship was first tested by Cosmonaut Vladimir Komarov on April 23, 1967. Having completed the flight programme on April 24 he began descent during which the parachute system failed, and the pilot was killed. Earlier Komarov had flown aboard the *Voskhod* spaceship.

Soyuz-2 was orbited on October 25, 1968. While it flew over the cosmodrome on the next day, *Soyuz-3* piloted by Georgi Beregovoi went aloft. It sought *Soyuz-2* by radio and automatically approached it within 200 meters, then the pilot took over and performed a series of manoeuvres by means of manual controls. On completion of the experiments *Soyuz-2*, followed by *Soyuz-3* (on October 30), landed on Soviet territory.

Soyuz-4 piloted by Vladimir Shatalov was orbited on January 14, 1969; the next day, *Soyuz-5* carried into space a crew of three: commander Boris Volynov, Alexei Yeliseyev (flight engineer) and Yevgeny Khrunov (research engineer). On January 16 *Soyuz-4* and *Soyuz-5* rendezvoused automatically and their docking was performed by manual controls.

Thus the world's first experimental space station was assembled and began functioning. Following the docking Alexei Yeliseyev and Yevgeny Khrunov left their ship and effected a transfer to the other via open space, where they spent 37 minutes.

The apogee of the experimental station was 250 km; its total weight—12,924 kg. Then the ships were undocked and continued the flight separately. Techno-scientific experiments and medico-biological investigations were carried out during the flight. The men observed geological and geographical terrain features and celestial bodies, filmed and photographed what they saw, and their information was sent to Earth by television, etc. The programme fulfilled, *Soyuz-4* with the three cosmonauts landed on January 17. Boris Volynov in *Soyuz-5* landed the next day.

Soyuz-6 piloted by Georgy Shonin and Valery Kubasov (flight engineer) was orbited on October 11, 1969. They carried out an extensive research programme and tested several methods of welding metals in conditions of high vacuum and weightlessness. The tests included the welding of fine-sheet stainless steel and titanium alloys, the cutting of stainless steel, titanium alloys and aluminium, and the working of non-metallic materials.

Soyuz-7 orbited the next day (October 12, 1969) carried a crew of three: Anatoly Filipchenko (commander), Vladislav Volkov (flight engineer), and Viktor Gorbatko (research engineer). *Soyuz-7* executed orbital manoeuvres together with the other spaceship, and carried out navigational observations and a series of experiments.

On October 13, 1969, *Soyuz-8* carried Vladimir Shatalov (commander) and Alexei Yeliseyev (flight engineer) into space.

During the group flight the seven cosmonauts aboard the three ships carried out extensive simultaneous investigations in near space under a wide programme; the ships executed manoeuvres, approached one another, and their control systems were being tested. *Soyuz-6* and *Soyuz-8* repeatedly came close to *Soyuz-7* — to a distance of a few hundred metres.

The ships' orbital parameters were similar, the average perigee and apogee being 200 km and 225 km respectively, with an orbital inclination of 51.7° and an orbital period of 88.6 min. The ships maintained constant contact with the ground flight control centres on Soviet territory and aboard research vessels of the USSR Academy of Sciences stationed at various points of the world ocean. Upon completion of the programme the ships landed near Karaganda: *Soyuz-6* on October 16, *Soyuz-7* on October 17, and *Soyuz-8* on October 18, 1969. The experiment lasted seven days, with each ship spending five days in orbit.

Soyuz-9 captained by Andrian Nikolayev, with Vitaly Sevastyanov as flight engineer, was orbited on June 1, 1970. It spent 425 hours in space and landed on June 19, 1970. A series of engineering experiments and medico-biological tests were carried out and two orbit corrections made. Andrian Nikolayev, who had earlier piloted *Vostok-3,* had spent in space a total of 519 hours. The flight during which two cosmonauts spent almost 18 days in conditions of weightlessness demonstrated that man could withstand the stress of prolonged space travel.

A long-endurance orbital station named *Salyut* was launched on April 19, 1971. It circled the Earth for almost 6 months. The flight consisted of several stages. During the first stage the station and the *Soyuz-10* spaceship, orbited on April 23, travelled side by side. *Soyuz-10* had a crew of three: Vladimir Shatalov, Alexei Yeliseyev and Nikolai Rukavishnikov. The object of the experiment was to test and check out the functioning of advanced systems designed to ensure mutual search, rendezvouz, link-up, docking and undocking of the ship and station. After the flight of the docked spacecraft which lasted 5 hours 30 minutes the ship separated from the station and landed on April 25, 1971. *Soyuz-10* had made 30 circuits around the Earth. The station continued functioning automatically. The second stage of the experiment began on June 6, 1971, with the launching of *Soyuz-11* with a crew of three: Georgi Dobrovolsky (commander), Vladislav Volkov (flight engineer) and Viktor Patsaev (test engineer).

Docked with the ship the *Salyut* station became the first long-enduarance piloted orbital research station. Its weight was more than 25 tons.

During the flight of 23 days the crew carried out comprehensive engineering and medico-biological tests and investigations which yielded invaluable scientific data. The crew spent a total of 570 hours in space both aboard the ship and aboard the station.

Having fulfilled the programme aboard the station the cosmonauts returned to *Soyuz-11,* which was then separated from *Salyut* at which point automatic control again took over. During descent, after the braking rocket engine was switched on, and as the re-entry capsule separated from the ship, it suddenly became depressurized. Following its programme automatically the re-entry capsule soft-landed in the preset area. The crew, however, were dead.

Space exploration takes its toll of human life. Mankind will never forget the exploits of its heroes.

Between 1961 and 1971, 25 Soviet cosmonauts made orbital geocentric flights in 18 one-, two- and three-man spacecraft belonging to three types: six *Vostok* ships, two *Voskhod* ships, and ten *Soyuz* ships. Besides, a few of them flew aboard the *Salyut* station.

The invaluable scientific information obtained by Soviet vertical sounders, satellites, planetary probes and piloted spacecraft has been processed and published for the purpose of promoting world science. The Soviet Union cooperates with many countries in conducting space research with rocket systems. This cooperation started in 1957 with joint observations of the first Soviet satellites. The *Intercosmos* (Council for International Cooperation in Space Exploration under the USSR Academy of Sciences) has concluded multilateral and bilateral agreements with many of its counterparts in other countries.

In 1967 the socialist countries adopted a programme entitled "Cooperation of socialist countries in the exploration and use of outer space for peaceful purposes," under which the People's Republic of Bulgaria, the Hungarian People's Republic, the German Democratic Republic, the Republic of Cuba, the Mongolian People's Republic, the Polish People's Republic, the Socialist Republic of Romania, the USSR and the Czechoslovak Socialist Republic undertake to carry out joint space research. The programme includes exploration of outer space and the upper atmosphere, meteorological observation by satellites, space communication, research in space biology and medicine, satellite and rocket launchings, the holding of conferences and symposiums, exchanges of specialists and mutual visits by groups of scientists.

The first space vehicle launched under the Cooperation programme was *Kosmos-261,* which went up on December 20, 1968, to study the upper atmosphere and polar aurora. From 1969 Soviet satellites and geophysical rockets carried into space instrumentation made by other socialist countries. The first such satellite—*Intercosmos-1*—was launched on October 14, 1969 to investigate ultra-violet and X-ray emissions of the Sun and their effects on the structure of the Earth's upper atmosphere. The satellite carried scientific instruments designed and manufactured in the German Democratic Republic, Czechoslovakia and the Soviet Union. Specialists from these countries took part in the assembly and testing of the satellite-borne equipment and were on the flight control team.

Intercosmos-2 was launched on December 25, 1969, to explore the ionosphere. Between 1970 and 1972 six more satellites of the *Intercosmos* series were orbited to continue joint research under an enlarged programme.

On April 19, 1973, *Intercosmos-Copernicus 500* carrying scientific equipment was put into earth orbit. The launching, prepared by Polish and Soviet specialists, marked the 500th anniversary of the birth of Nicolaus Copernicus, the great Polish scientist.

The launchings of the *Vertical-1* geophysical rocket (November 20, 1970) and *Vertical-2* (August 20, 1971), which carried scientific equipment developed in socialist countries, had the object of studying solar radiation and its absorption by the atmosphere and the properties of the ionosphere and meteoric particles. The rocket's nose cone and the recoverable container weighed nearly 1,300 kg, the maximum altitudes ranged from 463 to 487 km.

On June 30, 1966, the USSR and France signed an agreement on co-operation in the exploration of outer space, space communication, and research in space meteorology and aeronomy. Under the agreement a colour TV "bridge" was to be established between Moscow and Paris via the *Molnia-1* satellites, and Soviet-made instruments were to be carried by French launch vehicles and vice versa.

The *Lunokhod-1* and *Lunokhod-2* moonrovers each carried a French-made angle reflector for laser ranging of the Moon; and the *Mars-3* planetary probe carried the French *Stereo* equipment for studying solar radio emission in the metric wave band.

On December 27, 1971, the *Oreol* satellite was launched in the Soviet Union to study physical phenomena in the upper atmosphere in high latitudes and polar aurora. The instrumentation and the programme of the experiment were developed by Soviet and French specialists under the joint Soviet-French project *Arcade*.

On April 4, 1972, one carrier-rocket put the *Molnia-1* communication satellite and the French SRET satellite, which was to study the operation of various types of solar batteries in space conditions, into an orbit with an apogee of 39,260 km.

The agreement between the USSR and the USA on the implementation of the joint *Soyuz-Apollo* programme is an important and promising step. The programme envisages carrying out in July 1975 the docking of a *Soyuz* and an *Apollo* space craft, their joint flight, an exchange of crews, undocking and landing.

The development of compatible facilities for the ships' rendezvous and docking, and for the crew exchange opens up the possibility of joint space experiments by Soviet and American scientists and of mutual assistance and rescue of crews in distress.

As the exploration of near space, the Moon and other celestial bodies proceeds apace the problem of mutual aid in space by space pilots of different countries acquires growing importance.

Article 5 of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, concluded in 1967, and the international Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched in Outer Space (1968) furnish the necessary legal foundations for cooperation. But the work of elaboration of space laws has only just begun.

In conclusion of this short review of the highlights in Soviet rocketry and space exploration, it should be stated that many events and names, some more and some less important, have not been mentioned in this work for various reasons.

Of the distinguished group of pioneers of Soviet rocket engineering one should note particularly the names of K. E. Tsiolkovsky, whose investigations were followed by those of Y. V. Kondratyuk, F. A. Zander and others, S. P. Korolev, who together with the chief designers of engines, control systems and other equipment, translated into reality man's centuries-old dreams of space flight, and, of course, Yuri Gagarin and those who followed him. The names of M. K. Yangel, A. M. Isayev, S. A. Kosberg and G. N. Babakin have also gone down in the history of Soviet space rocketry.

Museums and exhibitions on rocketry and space engineering tracing the path traversed by Soviet space science and technology have been opened and new exhibits are being added to them. Mention should be made here of the State Museum of the History of Cosmonautics named after Tsiolkovsky in Kaluga, the Tsiolkovsky Museum in Kaluga, the Cosmonautics Memorial Museum in Moscow, the "Space" pavilion at the All-Union Exhibition of Economic Achievements in Moscow, the Central House of Aviation and Cosmonautics in Moscow, the GDL Museum located in the Peter and Paul Fortress in Leningrad, the Kibalchich Museum in Korop, the Gagarin Museum in the town of Gagarin, the Korolev Museum in Zhitomir, and various displays in planetariums.

Following the USSR, which inaugurated the space era by orbiting the world's first satellite on October 4, 1957, the USA launched its first, *Explorer-1*, satellite on February 1, 1958. France became the third space power after launching its *Asterix-1* satellite on November 26, 1965. Japan orbited its *Osumi* satellite on February 11, 1970 and China launched its first satellite on April 24, 1970. Great Britain launched its *Prospero* satellite into orbit on October 28, 1971, becoming the sixth space power.

Other countries are also preparing satellite launchings into geocentric orbits. Many countries have a space programme of their own.

In recent years the USA has made impressive advances. Between 1958 and 1972, about 700 US satellites were launched. Among them were research vehicles, and meteorological, communication, biological, navigational, astronomical, geodesic, and geophysical satellites travelling by various geocentric orbits including stationary ones. Lunar exploration programmes with the aid of the *Ranger* automatic lunar probes (3 missions between 1964 and 1965), the *Surveyor* lunar soft-landing vehicles (5 landings between 1966 and 1968), the *Lunar Orbiter* satellites (5 missions between 1966-1967) have been successfully carried out.

The *Pioneer* series of automated solar satellites have also been launched by the USA. *Pioneer-10* will pass Jupiter and travel outside the Solar System. The *Mariner* automatic interplanetary probes were used twice (in 1962 and in 1967) for a venusian fly-by, and thrice (in 1965 and twice in 1969) for a martian fly-by. In 1971 the first satellite was launched around Mars to observe the planet at close range. The results obtained are an outstanding scientific achievement. The main radiation belt surrounding the Earth (the Van Allen radiation belt) has been discovered as well as craters on Mars, etc.

Spaceships of three types were used in the USA for manned missions: the *Mercury* one-man spacecraft weighing 1.3 to 2 tons which made two suborbital flights in 1961 and four in geocentric orbits between 1962 and 1963; the *Gemini* two-seater craft weighing 3.2 to 3.8 tons which made 10 geocentric flights between 1965 and 1966; the *Apollo* three-seater craft weighing up to 46.8 tons which made 11 geocentric flights between 1968 and 1972 in carrying out which 3 circumlunar missions and 6 lunar landings were made.

The *Gemini* spaceships were the first to execute orbital manoeuvres by means of manual controls, a link-up of the ships, connection between the ship and the target by rope, docking by manual controls, and a flight lasting nearly 14 days.

The *Saturn-5* heavy carrier-rocket weighing 3,000 tons at takeoff placed a load of 135 tons (including the final stage) into a geocentric orbit. It also injected manned spacecraft into a circumlunar orbit and landed man on the Moon.

The *Apollo-7* spaceship with a crew of three (Walter Schirra, Walter Cunningham and Donn Eisele) made an eleven-day flight around the Earth during which the ship's systems were tested for reliability. The circumlunar flight made by *Apollo-8* manned by Frank Borman, James Lovell and William Anders, between December 21 and 27, 1968, was an epoch-making event.

The ten-day geocentric flight of *Apollo-9* with James McDivitt, David Scott and Russel Schweickart aboard had the purpose of optimizing the systems of the ship's lunar module.

A more complicated circumlunar flight was made by Thomas Stafford, John Young and Eugene Cernan aboard *Apollo-10*.

The flight of *Apollo-11* which carried Neil Armstrong, Edwin Aldrin and Michael Collins to the Moon (July 16-24, 1969) will be forever remembered by mankind. On July 20, the lunar module carrying Neil Armstrong and Edwin Aldrin touched down on the lunar equator, in the Sea of Tranquillity, and stayed 21 hours and 36 minutes there while Michael Collins remained aboard the ship circling the Moon. Neil Armstrong spent 2 hours 31 minutes on the Moon surface, outside the lunar module, and Edwin Aldrin—two hours. They carried out the assigned research programme.

The second Earth-Moon-Earth flight was successfully made by Charles Conrad, Richard Gordon and Alan Bean aboard *Apollo-12* between November 14 and 25, 1969. On November 19, Charles Conrad and Alan Bean landed in a lunar module in the Ocean of Storms and spent 31 hours and 31 minutes there. Each of them left the module twice spending a total of 7.5 hours on the lunar surface.

The flight of *Apollo-13* (with James Lovell, Jack Swigert and Fred Haise) had to be limited to a circumlunar fly-by because of an emergency situation aboard the ship.

The third lunar landing was made by *Apollo-14* which carried Alan Shepard, Stuart Roosa and Edgar Mitchell. The mission lasted from January 31 to February 9, 1971. On February 5 and 6, Alan Shepard and Edgar Mitchell spent 33 hours 30 minutes in the proximity of the Fra Mauro Crater on a rugged terrain. They carried out an important exploratory programme during the two lunar excursions which took 4 hours 47 minutes and 4 hours 35 minutes respectively.

An extended lunar exploration programme was carried out during the fourth lunar landing mission (between July 26 and August 7, 1971) undertaken by David Scott, Alfred Worden and James Irwin who piloted the *Apollo-15* advanced spacecraft. David Scott and James Irwin spent 66 hours 55 minutes (from July 30 to August 2, 1971) in the landing area situated between the Hadley Furrow and the Lunar Appenines. During the three lunar excursions which took a total of 18 hours 36 minutes the astronauts drove a distance of 27.2 kilometers in a moonrover and carried out a large exploratory programme.

The fifth lunar-landing mission took place between April 16 and 27, 1972. The lunar module of *Apollo-16* which carried John Young and Charles Duke landed near the Descartes Crater and stayed 71 hours 2 minutes there. The astronauts made three lunar excursions (20 hours 14 minutes in all) and moonrover trips. Meanwhile Thomas Mattingly remained in the parent ship in a circumlunar orbit.

The sixth lunar-landing mission was carried out between December 7 and 19, 1972. It terminated the *Apollo* lunar programme. The lunar module of *Apollo-17* which carried astronauts Eugene Cernan and Harrison Schmitt made a landing on the edge of the Sea of Serenity and spent 75 hours on the lunar surface. Meanwhile Ronald E. Evans continued flying in the command ship in a circumlunar orbit.

As a result of the six successful lunar missions, lunar rock samples weighing a total of nearly 400 kg were brought to Earth.

To mark the successful completion of the *Apollo* programme a big crater on the reverse side of the Moon was given the name of Apollo.

By the end of 1972, 34 US astronauts had made flights in 25 orbital spaceships. Altogether 59 Soviet and American cosmonauts have made flights aboard 45 spaceships and one orbital station.

To perpetuate the memory of the space pilots who made outstanding contributions to the development of astronautics some craters on the far side of the Moon have been named in their honour. The names are those of Gagarin, Komarov, Belyaev, Grissom, White, Chaffee (all given posthumously), Titov, Nikolayev, Tereshkova, Feoktistov, Leonov, Shatalov, Borman, Lovell, Anders, Armstrong, Aldrin, and Collins.

Fifteen years have passed since man's first space exploits marking the beginning of the space age. Great advances have been made in this period, and yet these are only the first steps. Mankind has crossed the threshold of outer space.

It is a concern of all nations to ensure that outer space be used for peaceful purposes for the good of mankind.

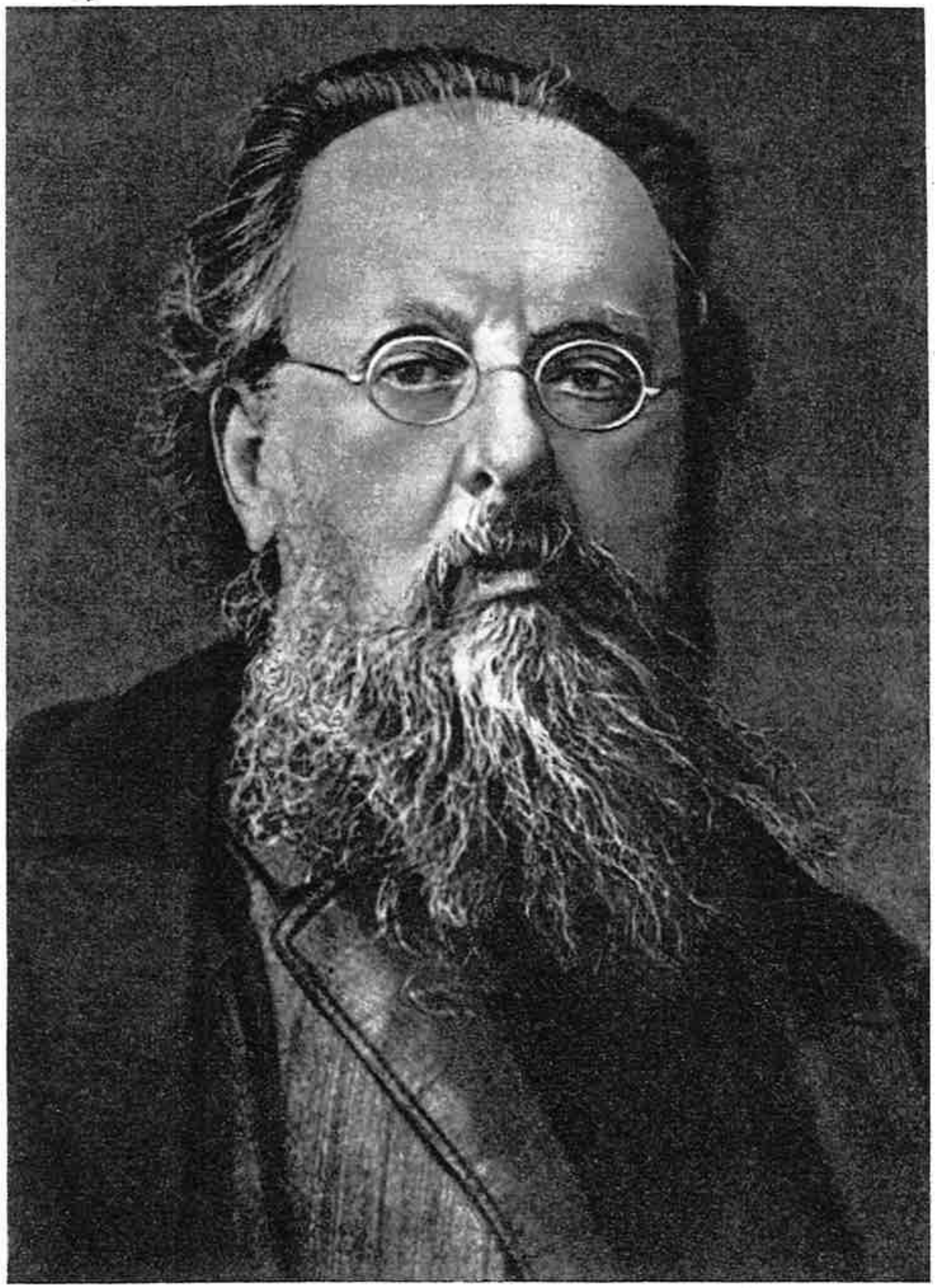
The signing by all states in early 1967 of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, which has been endorsed by the UN General Assembly, is an event of great significance.

Under this historic treaty outer space, including the Moon and other celestial bodies, is open for exploration and use by all states; no state has the right to lay claim to outer space, including the Moon and other celestial bodies, either by proclaiming its sovereignty over them or by occupying them or by any other means. Under the Treaty all states undertake not to put into terrestrial orbits any vehicles carrying nuclear weapons or any other weapons of mass destruction; neither will they install such weapons on celestial bodies or place them in outer space in any other way. The Moon and other celestial bodies are to be used for peaceful purposes only. It is forbidden to set up on celestial bodies military bases, installations and fortifications, or test any types of weapons and conduct military manoeuvres.

The Treaty is infused with a spirit of cooperation and mutual assistance, and is inspiring to all countries engaged in space exploration and research.

Human society must develop harmoniously. Man will continue to unlock the secrets of space and utilize its incalculable energies. That will multiply his own powers. To be able to use them rationally he must strive towards a new, a higher level in his intellectual development.

The Land of Soviets is proud in the knowledge that its sons and daughters have blazed the trail into space and made a fundamental contribution to the exploration of the Universe with the aid of rocket-propelled vehicles.



Konstantin Eduardovich Tsiolkovsky, father of space science

▲ Alexander Dmitrievich Zasyadko

Konstantin Ivanovich Konstantinov ▲

Nikolai Ivanovich Tikhomirov ▶

▼ Vladimir Andreyevich Artemyev

Boris Sergeyevich Petropavlovsky ▼

Georgy Erikhovich Langemak ▼

Nikolai Ivanovich Kibalchich

Nikolai Yegorovich Zhukovsky

Ivan Vsevolodovich Meshchersky

Yuri Vasilyevich Kondratyuk

Fridrikh Arturovich Zander

Yakov Isidorovich Perelman

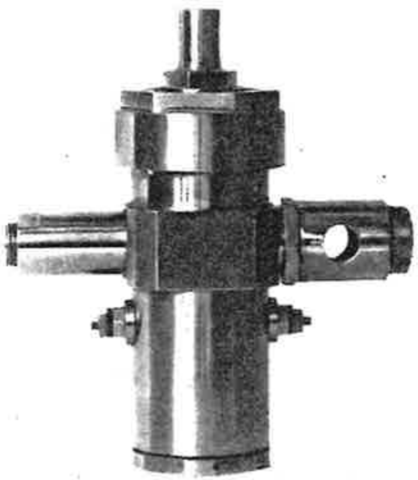
Vladimir Petrovich Vetchinkin

Nikolai Alexeyevich Rynin

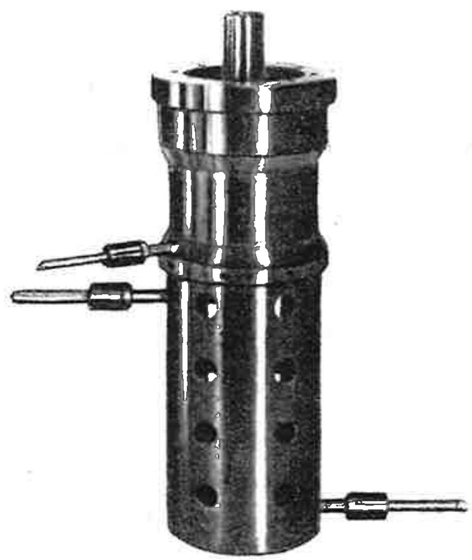
The world's first experimental electrical rocket engine (ERD) of the electro-thermal type designed by V. P. Glushko (1929-1933)

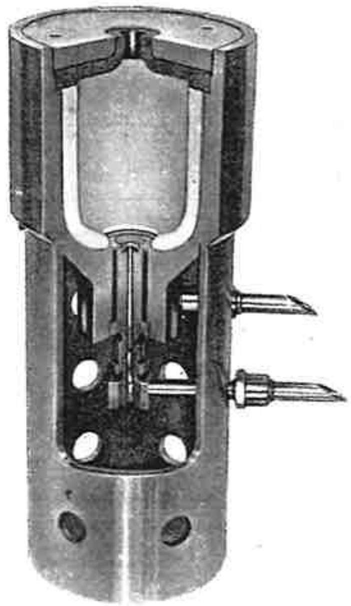
The first Soviet liquid-propellant rocket engines designed by V. P. Glushko: the ORM with a thrust of 6 kg; ORM-1 with a thrust of 20 kg developed during 1930 and 1931; ORM-9 and ORM-12 tested in 1932; ORM-50 with a thrust of 150 kg and ORM-52 with a thrust of 300 kg which passed official bench tests in 1933

ORM



ORM-1



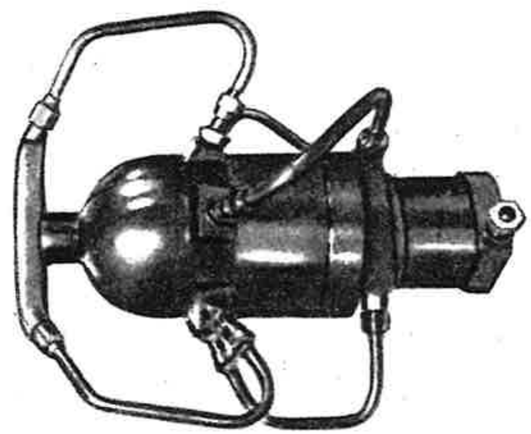


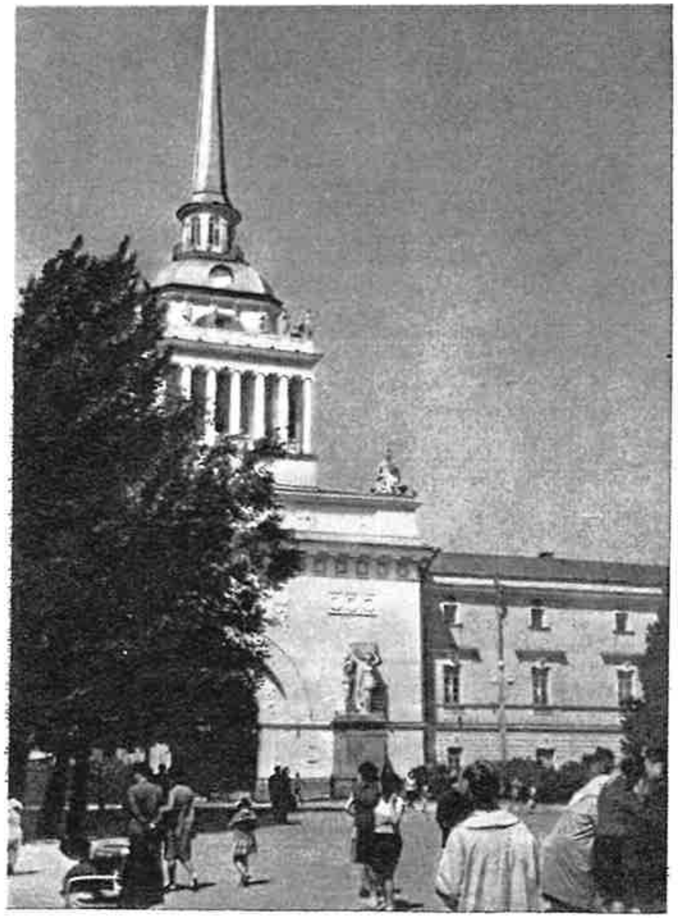
ORM-9

ORM-12

ORM-50

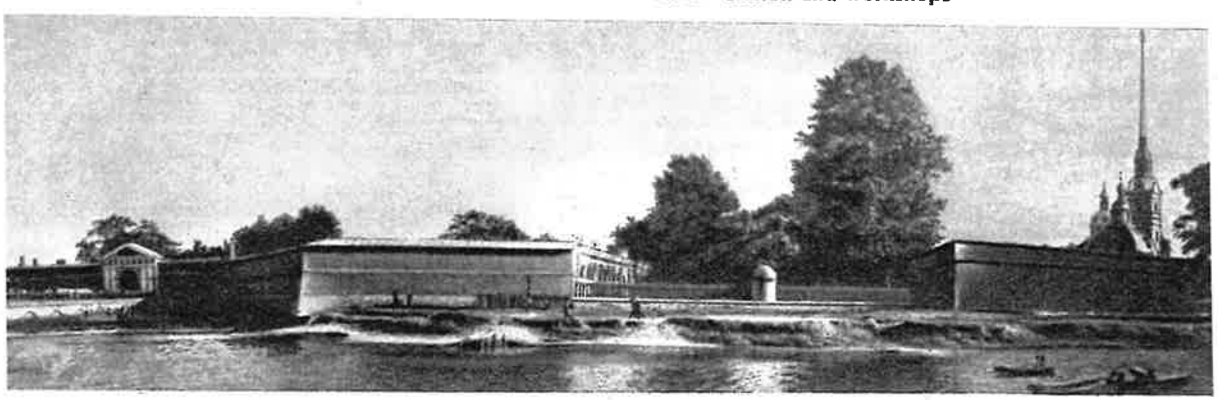
ORM-52





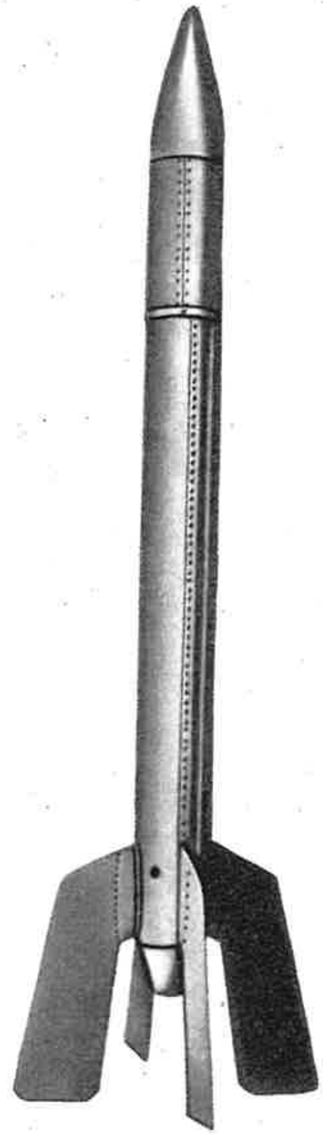
The Admiralty building in Leningrad. The GDL design bureau for electrical and liquid-propellant rocket engines was located on the second floor, right of the arch

The Peter and Paul Fortress (Leningrad). The St. John ravelin contained the GDL test station and workshops



Mikhail Klavdievich Tikho-
nravov

Vladimir Vasilyevich Ra-
zumov



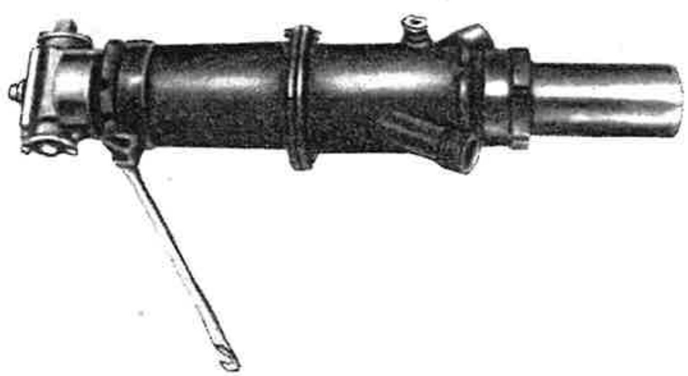
The first Soviet hybrid propellant rocket [09], designed by M. K. Tikhonravov, was tested in 1933

The first Soviet liquid-propellant rocket (GIRD-X) designed by F. A. Zander was flight-tested in 1933

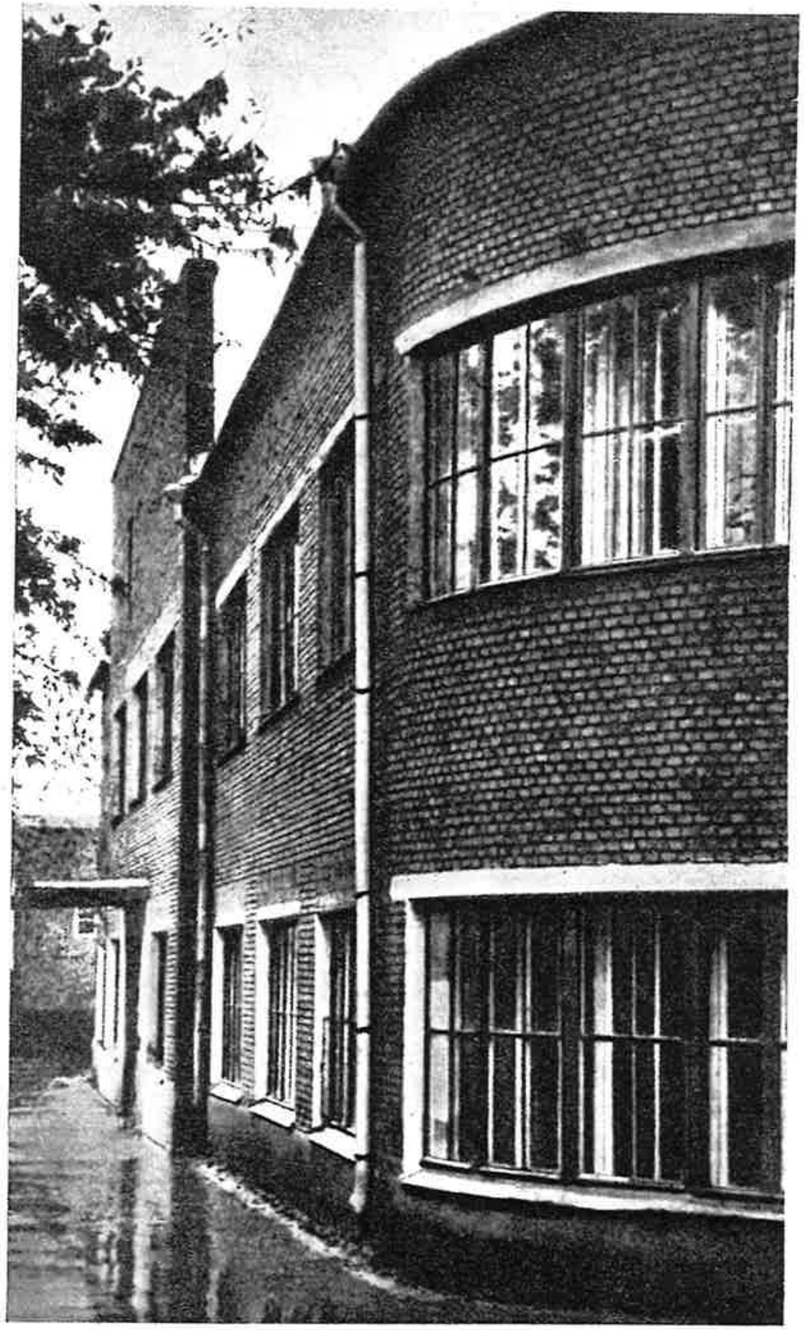
10

Liquid-propellant rocket engines designed by F. A. Zander: OR-2 with a design thrust of 50 kg; 10, with a thrust of 70 kg. Both were tested in 1933

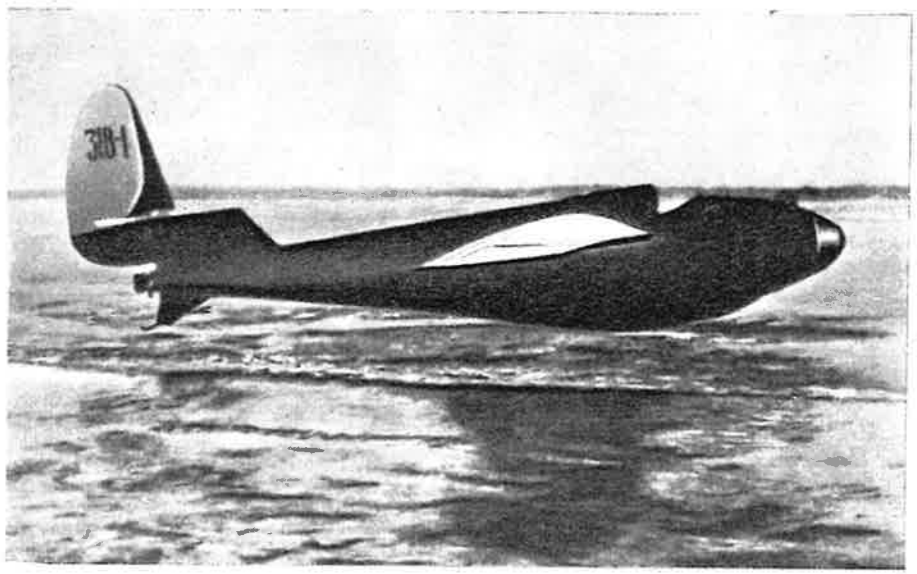
OR-2

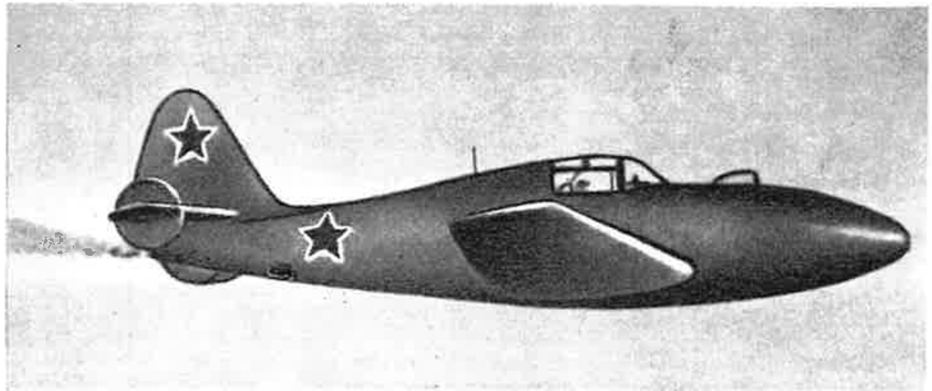


van Terentievich Kleime-
nov



The Jet Propulsion Re-
search Institute (RNII)



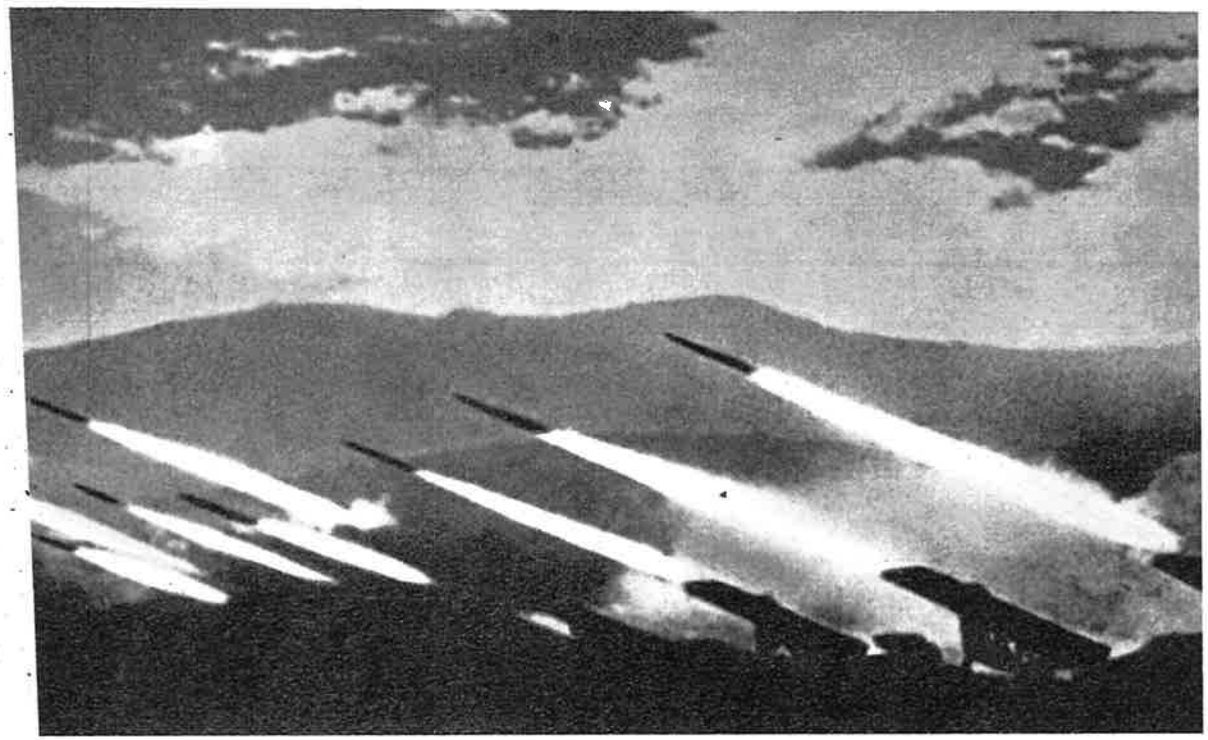


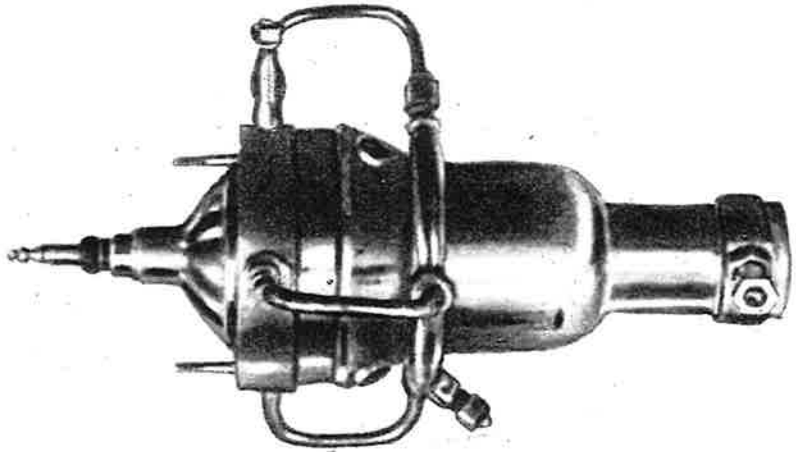
◀ The 212 winged rocket in assembly with the ORM-65 engine on a powder-type catapult (1937-1939)

▲ The BI-1 rocket aircraft with the D-1-A-1100 engine in flight (1942)

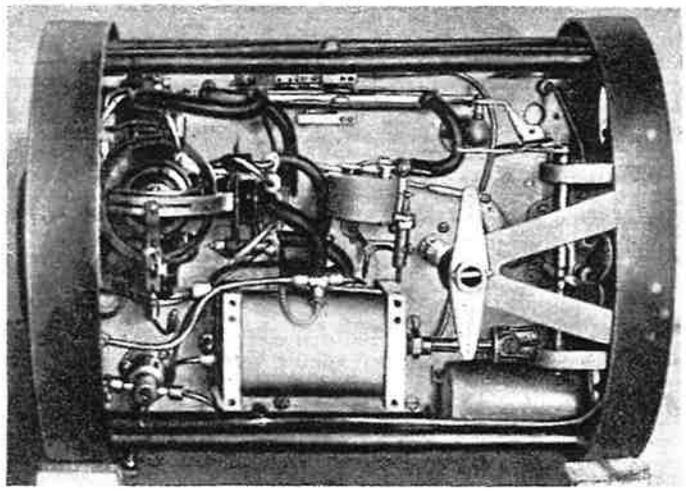
◀ The RP-318-1 rocket glider with the ORM-65 engine (1937-1938)

A salvo from KATYUSHA rocket launchers ▼

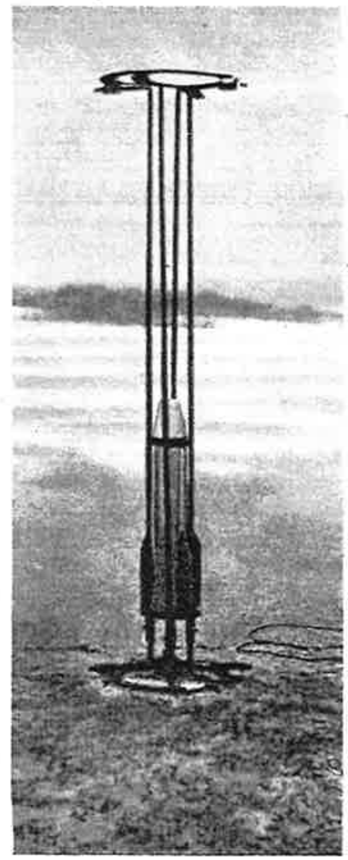




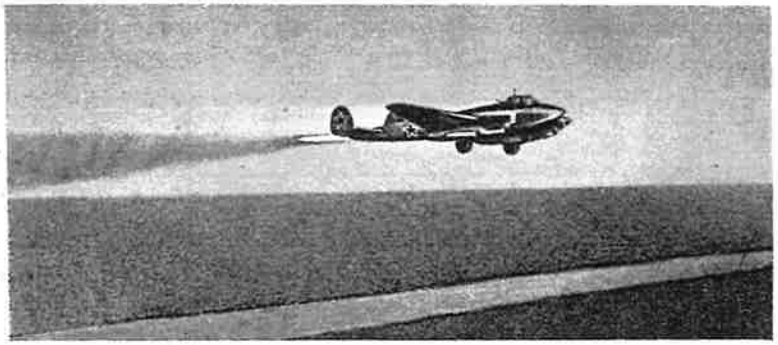
The ORM-65 engine designed by V. P. Glushko for the RP-318 rocket glider and the 212 winged rocket designed by S. P. Korolev. The engine was officially bench-tested in 1936



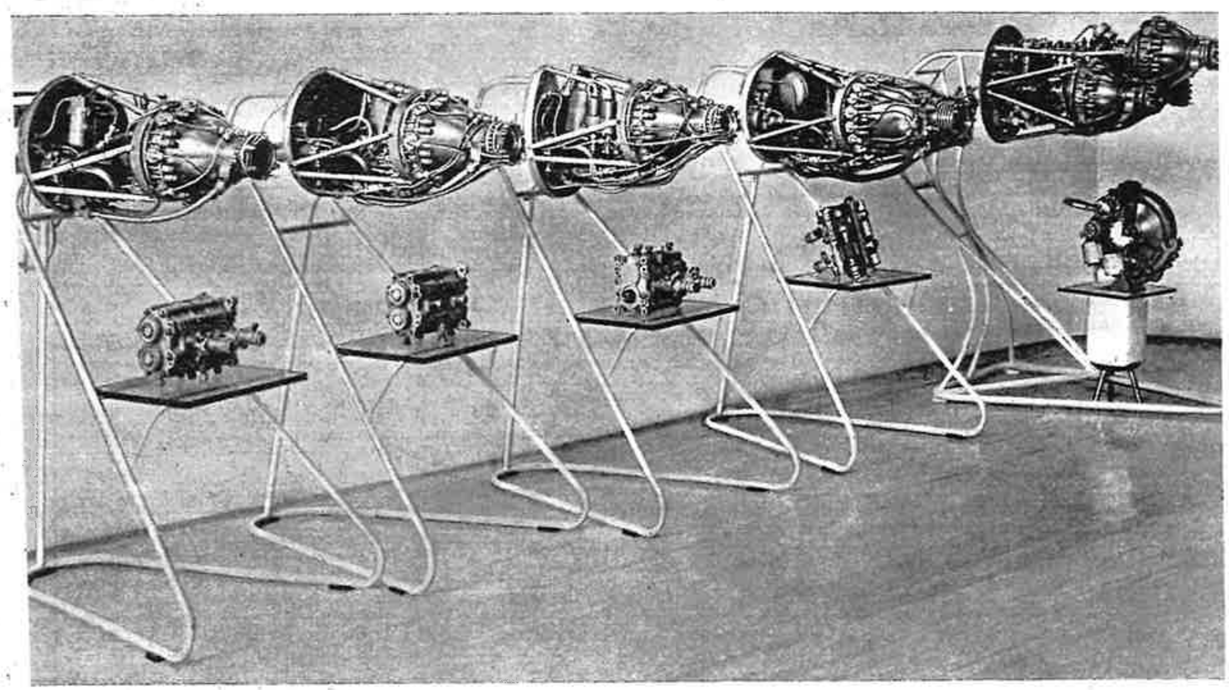
The GPS-3 automatic gyroscope for rocket flight-path control designed by S. A. Pivovarov (1937-1938)



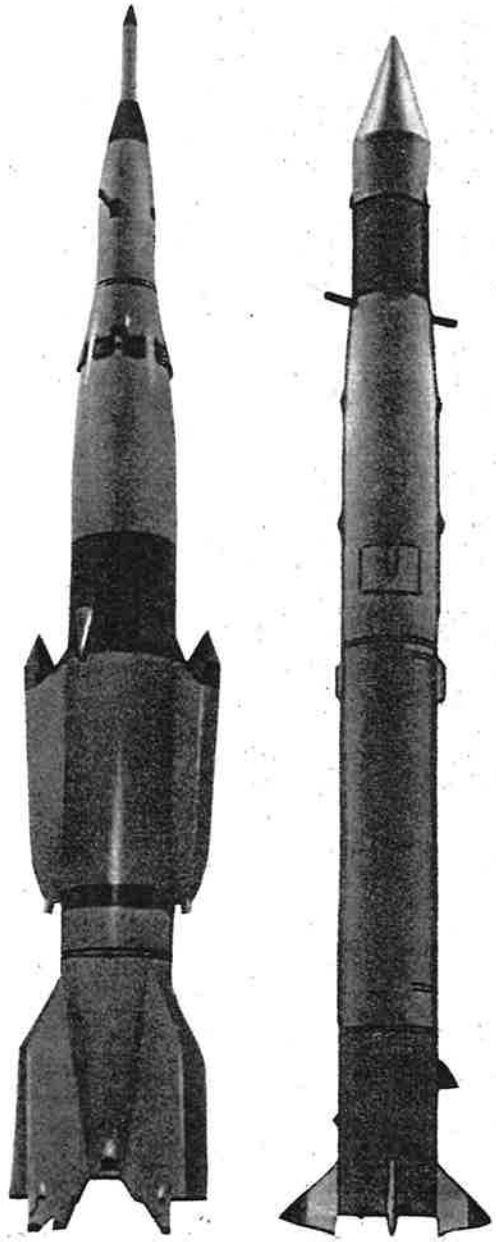
Two-stage rocket designed by I. A. Merkulov before takeoff (1939)



Pe-2R aircraft powered by a RD-1 engine, taking off (1943)

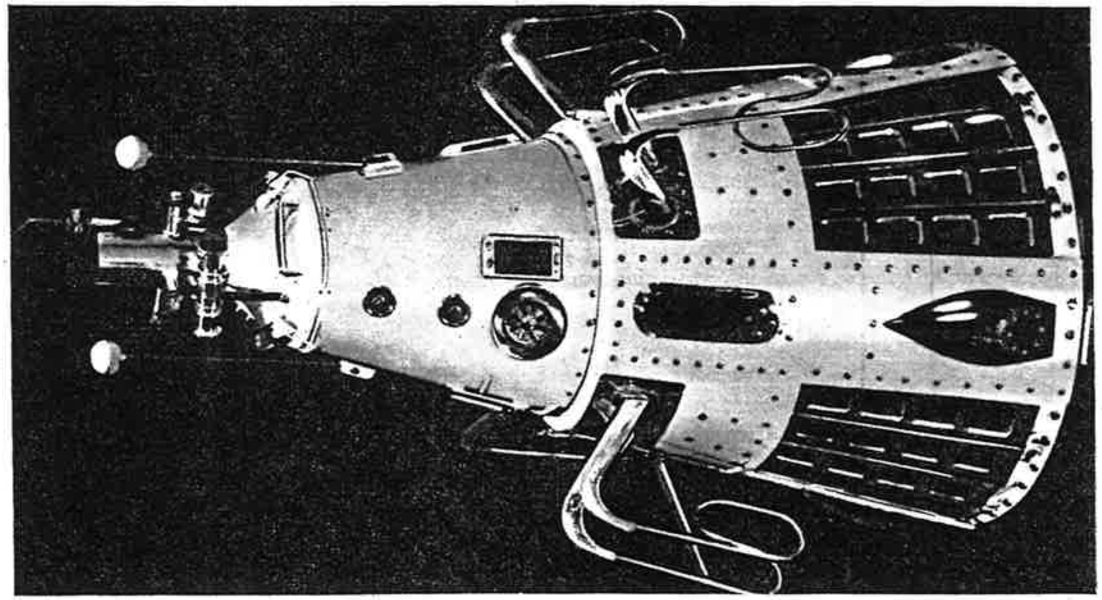


Family of aircraft rocket engines designed by V. P. Glushko. They used pump-fed propellant (nitric acid and kerosene). RD-1, RD-1HZ (two modifications); RD-2 and RD-3 (1940-1946)

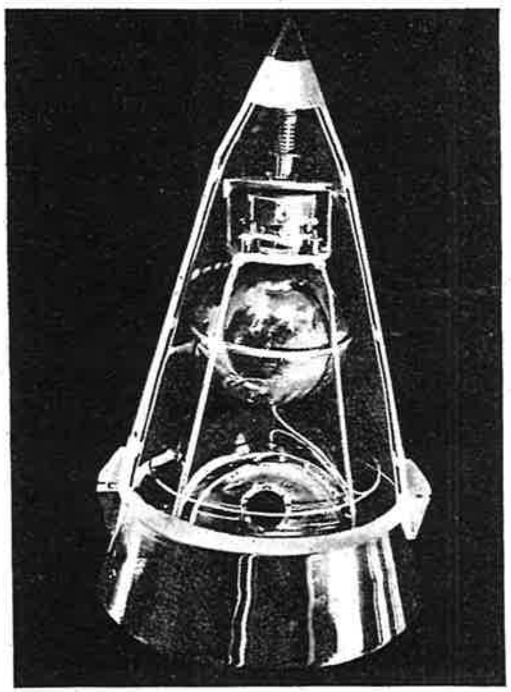


The V2A geophysical rocket which lifted a payload of 2,200 kg to an altitude of 212 km. The rocket is 20 meters in length, with a maximum body diameter of 1.66 meters (1957) (left)

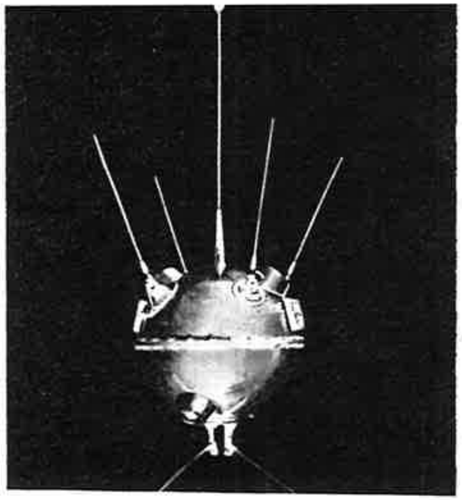
The V5V geophysical rocket which lifted a payload- of 1;300 kg to an altitude of 512 km. The rocket is 23 meters in length, with a maximum diameter of 1.66 meters (1958) (right)



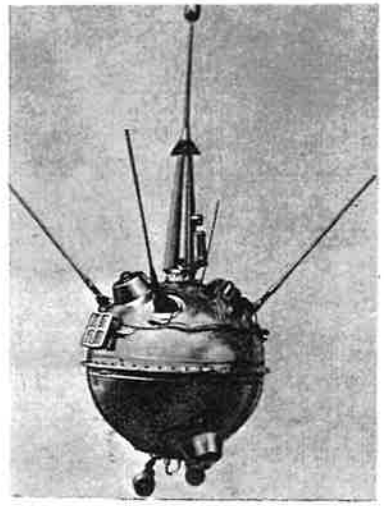
The third Soviet artificial satellite orbited on May 15, 1958



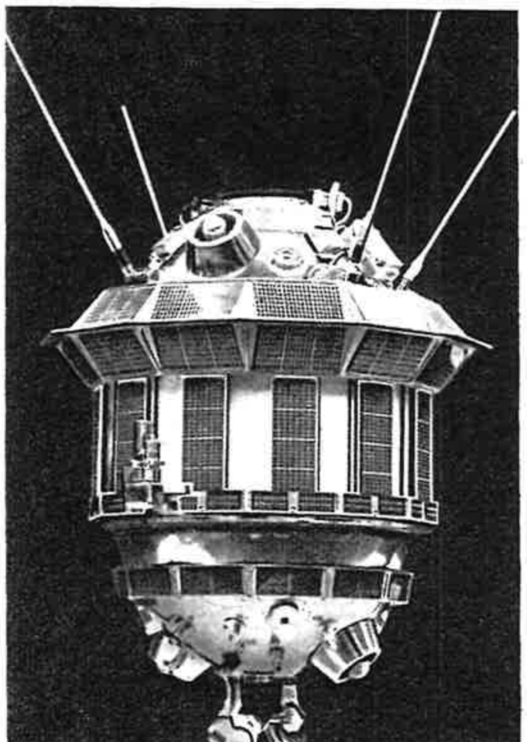
The world's second artificial earth satellite orbited on November 3, 1957



LUNA-1 automatic probe, the world's first artificial solar satellite, launched on January 2, 1959

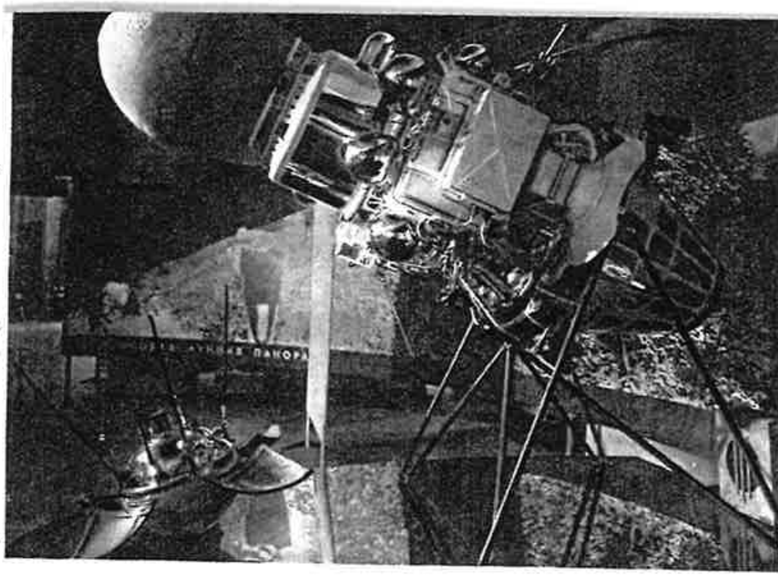


LUNA-2 probe, the first to reach the Moon, September 14, 1959

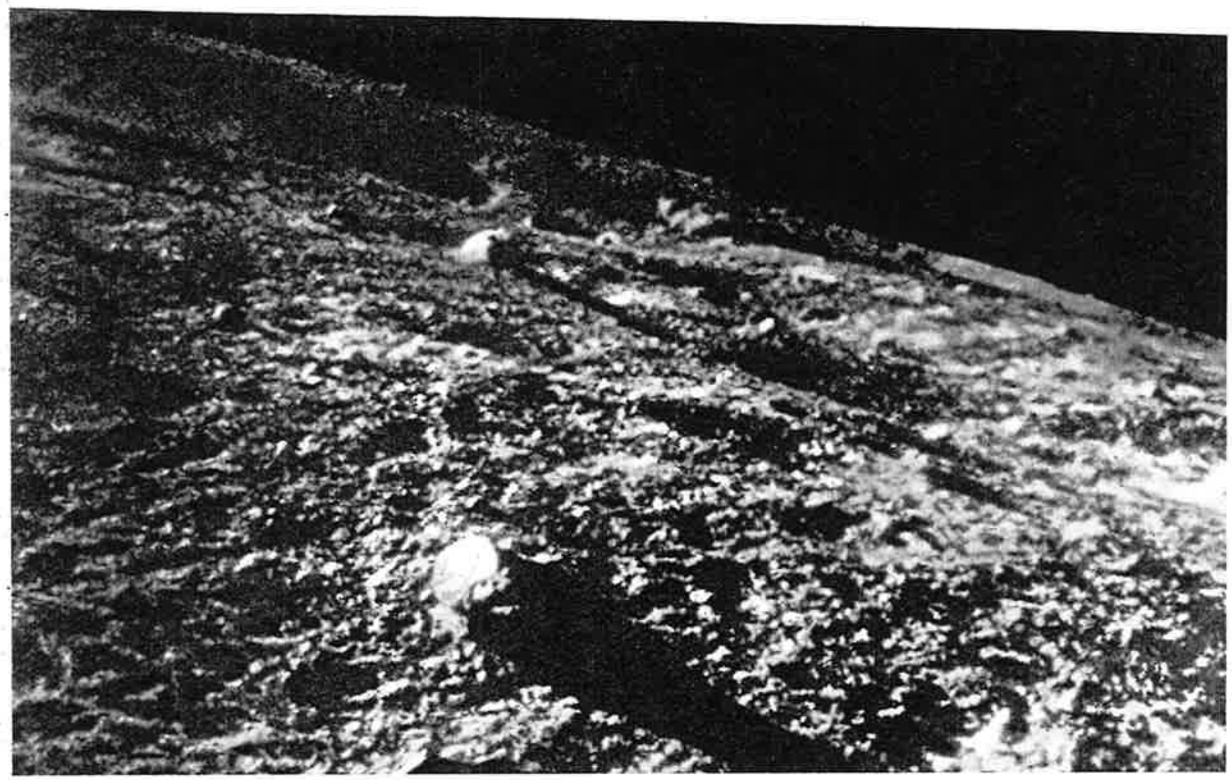


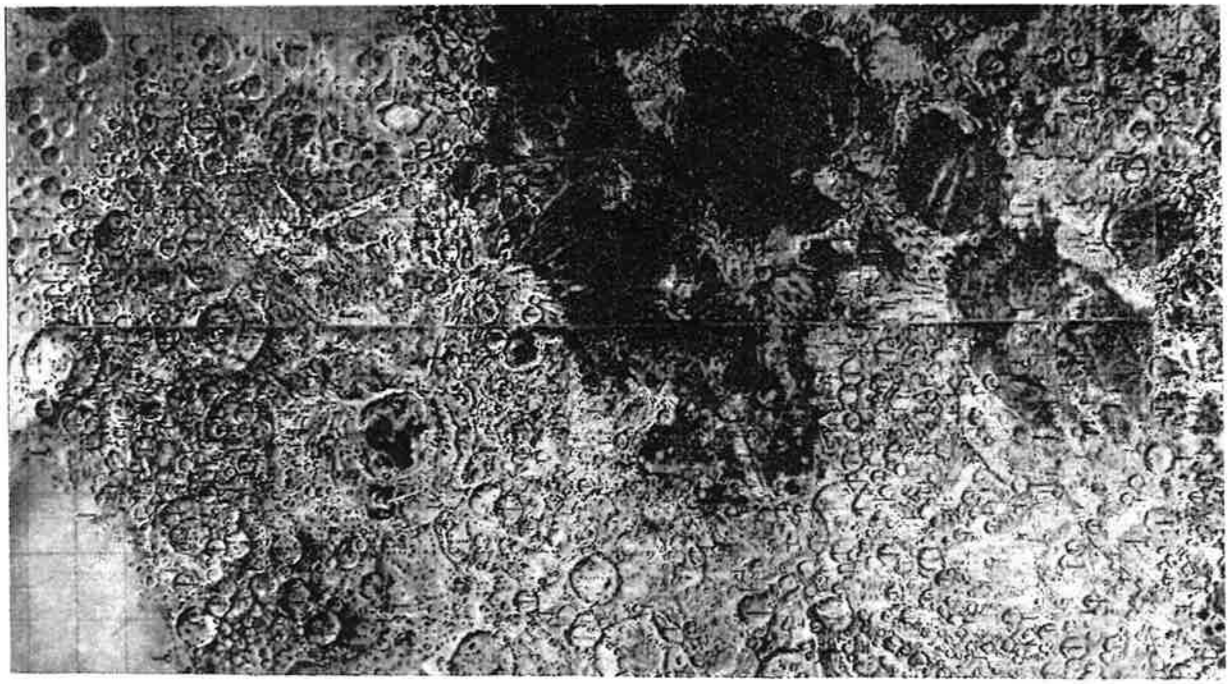
LUNA-3 probe, the first to fly around the Moon and relay to earth televised pictures of the far side of the Moon. It was launched on October 4, 1959

Part of the lunar panorama flashed to earth by LUNA-9 (1966)



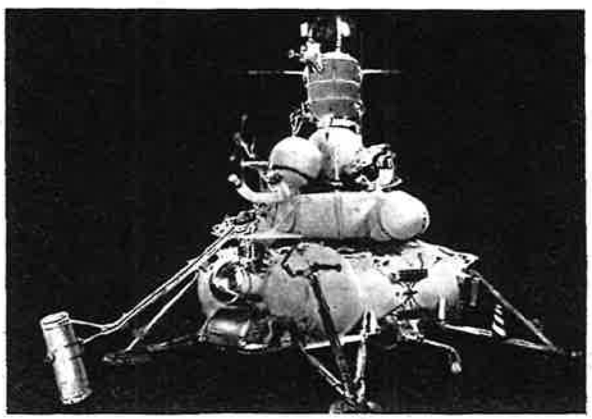
LUNA-9 probe, the first to soft-land on the Moon. February 3, 1966



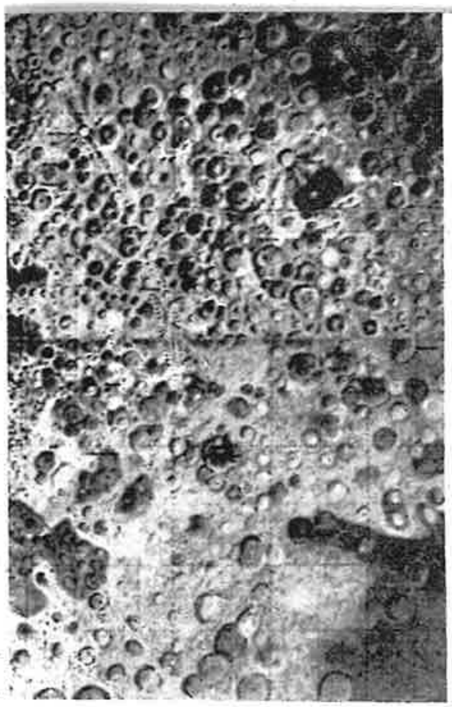


The first complete map of the Moon compiled in 1966 from photos obtained by LUNA-3 and ZOND-3 probes

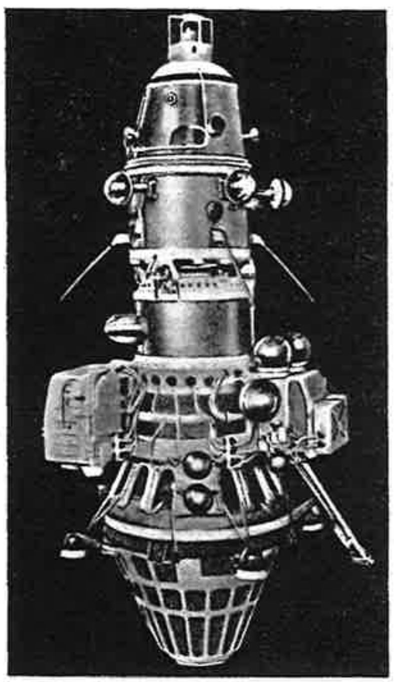
LUNA-16 probe, the first to fetch lunar rock samples to Earth on September 24, 1970



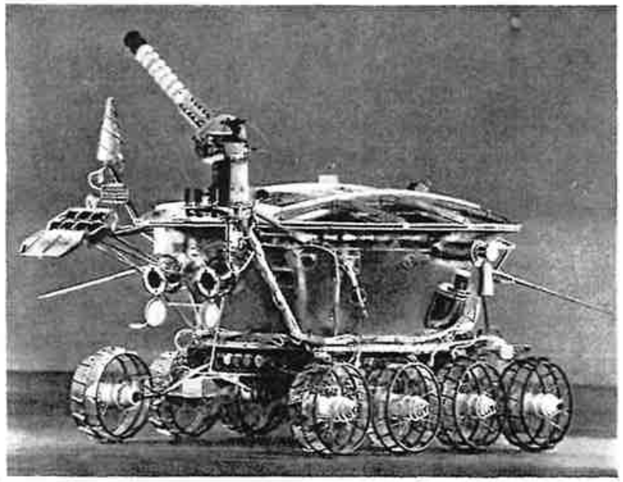
Lunar rock samples delivered by LUNA-16 (1970)



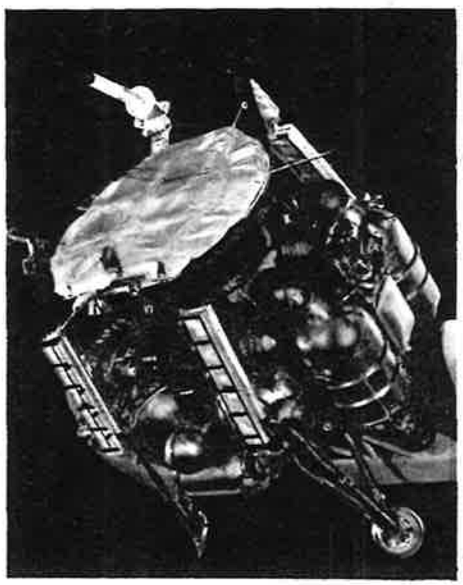
Picture of the terrestrial surface taken at a distance of nearly 90,000 kilometres and delivered to Earth by the ZOND-5 automatic spacecraft on September 21, 1968



LUNA-10 probe, the first artificial lunar satellite, launched on April 3, 1966

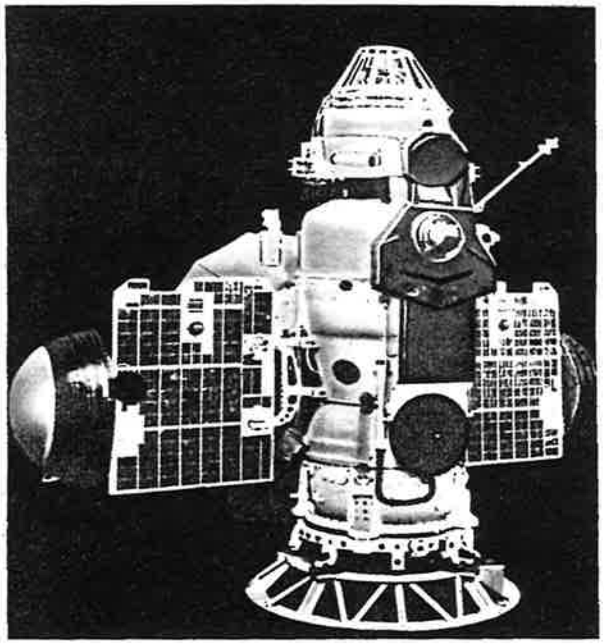


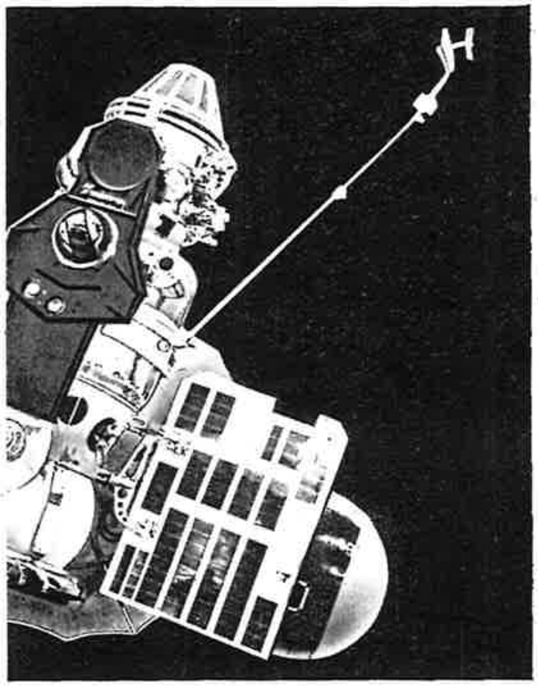
LUNOKHOD-1 moonrover (1970-1971)



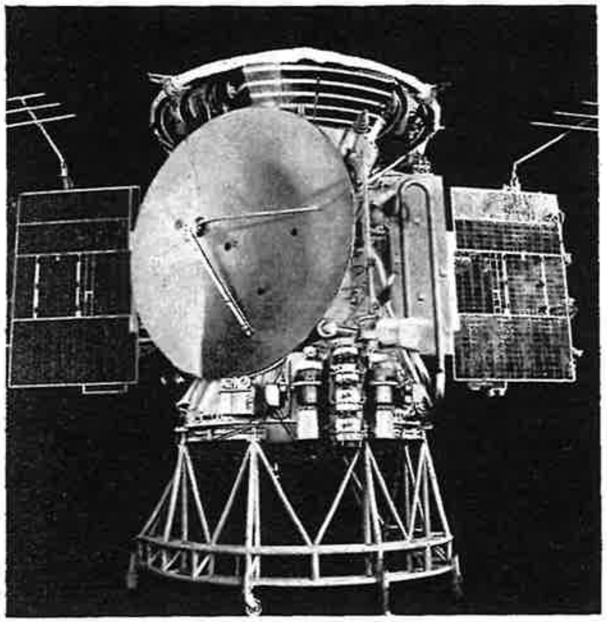
LUNA-17 probe which delivered to the Moon the LUNOKHOD-1 moonrover controlled from Earth (November 17, 1970)

MARS-1 probe, the first Mars-bound vehicle, launched on November 1, 1962



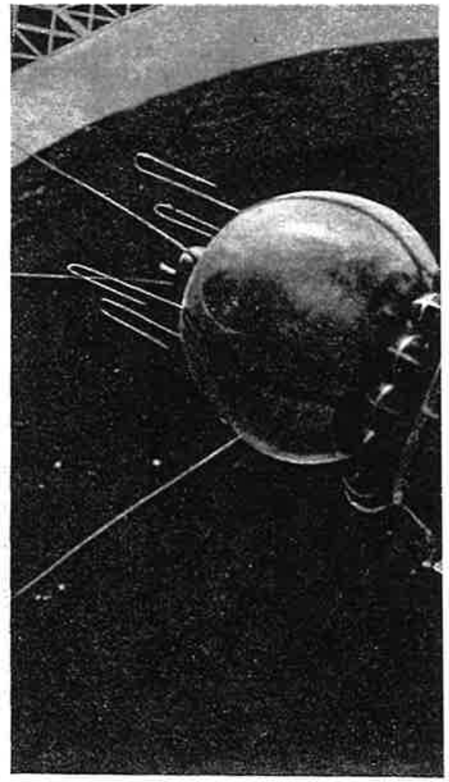


VENERA-3 probe, the first to reach the surface of Venus, March 1, 1966



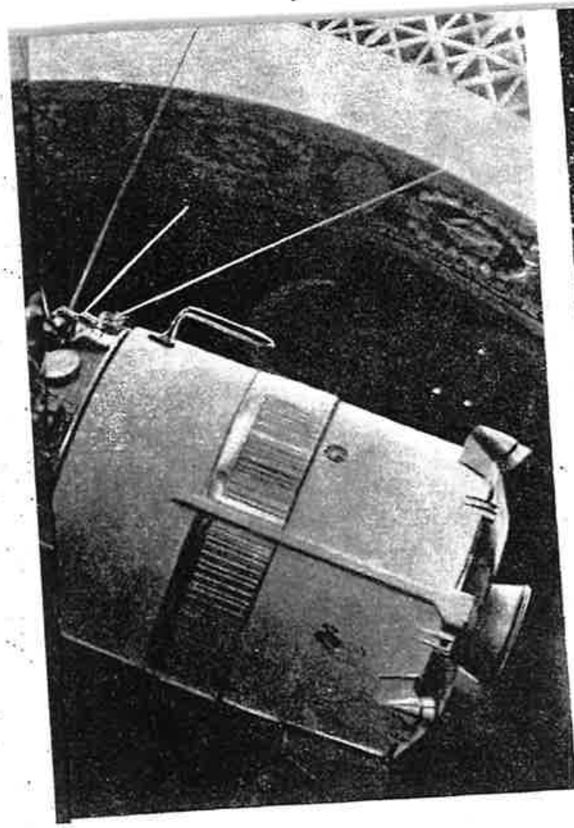
MARS-3 probe, whose descent module made a soft landing on Mars on December 2, 1971

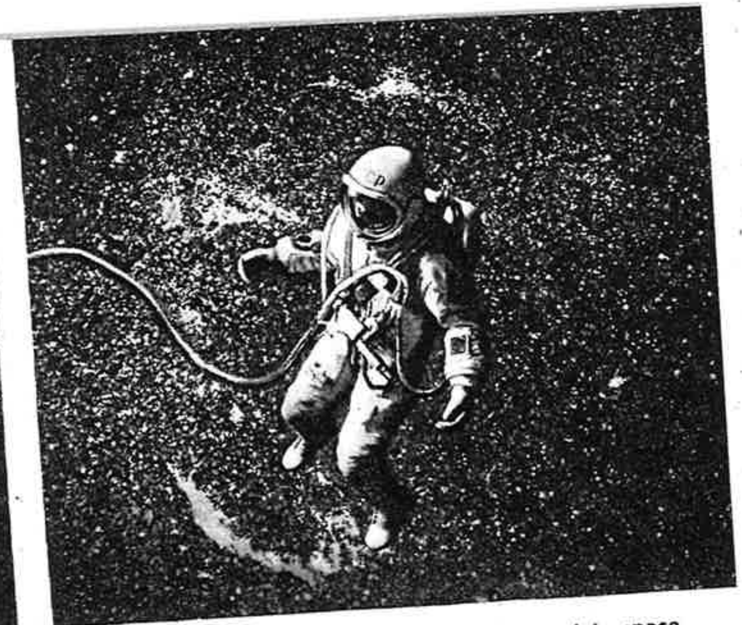
Yuri Alexeyevich Gagarin



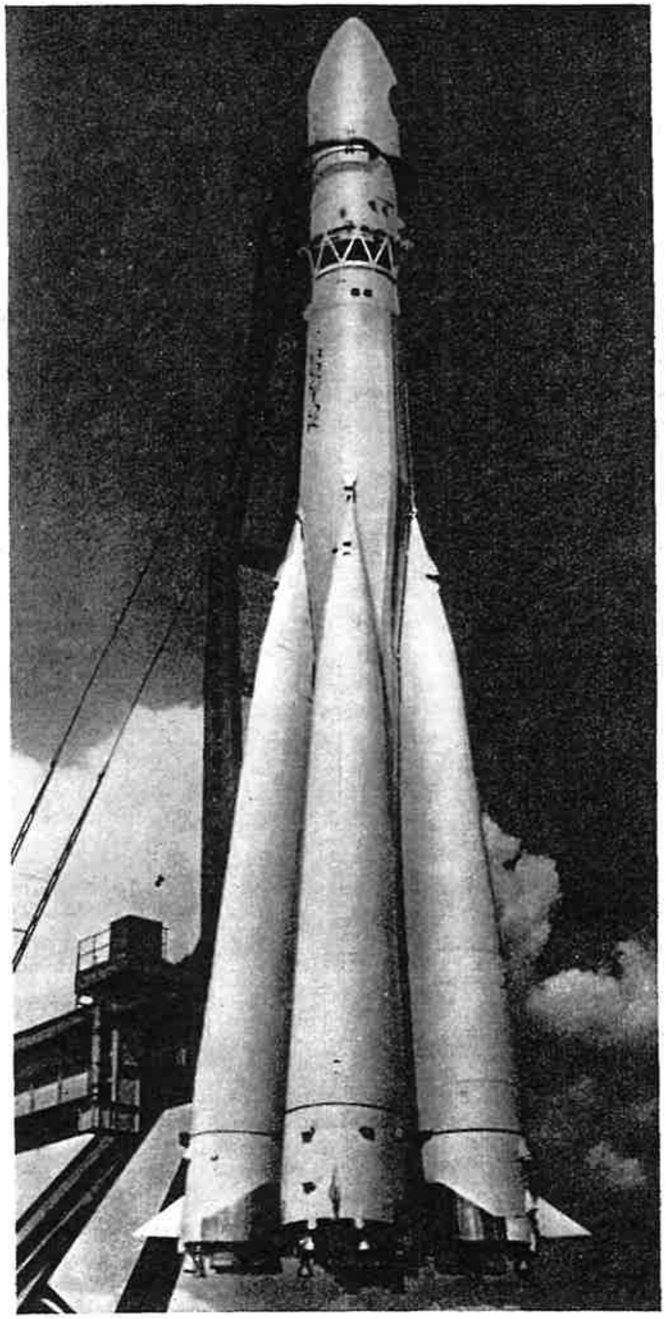
VOSTOK spacecraft

The Soviet cosmonauts who piloted the spaceships of the VOSTOK and VOSKHOD series; upper row, left to right: Yu. A. Gagarin, V. F. Bykovsky, B. B. Yegorov, P. I. Belyaev, P. R. Popovich, V. M. Komarov. Below: K. P. Feoktistov, V. V. Tereshkova, A. A. Leonov, A. G. Nikolayev, H. S. Titov



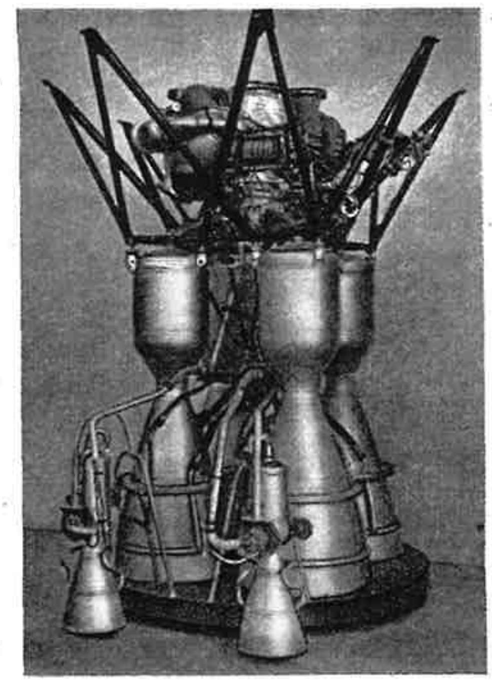


A. A. Leonov's egress into space from VOSKHOD-2 spaceship on March 18, 1965



The three-stage VOSTOK carrier-rocket, in service since May 15, 1960

The RD-107 four-chamber engine which powers the first stage of the VOSTOK carrier-rocket, has a thrust of 102 tons and a thrust chamber pressure of 60 atmospheres. It uses oxygen and kerosene, and is provided with two vernier engines. It was developed by the GDL-OKB between 1954 and 1957



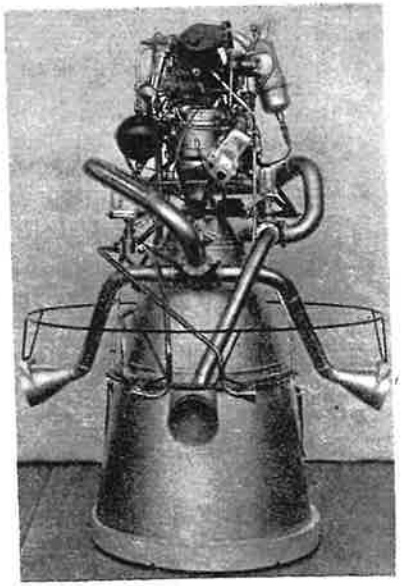
Sergei Pavlovich Korolev

Mikhail Kuzmich Yangel

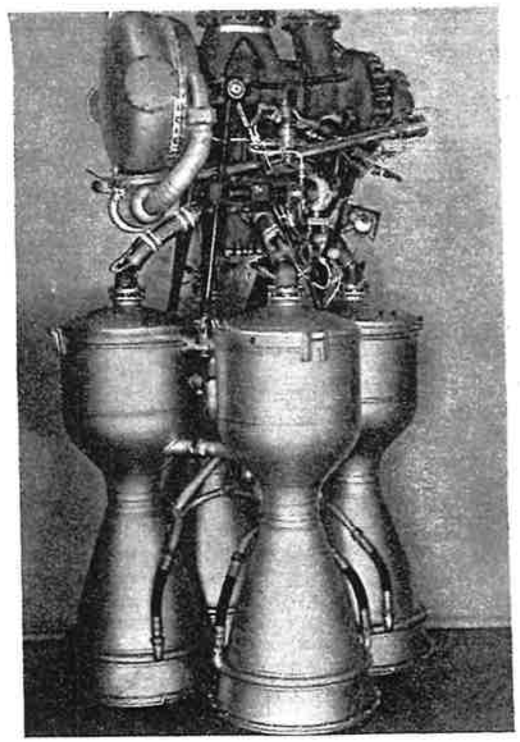
Alexei Mikhailovich Isayev

Georgy Nikolaevich Babakin

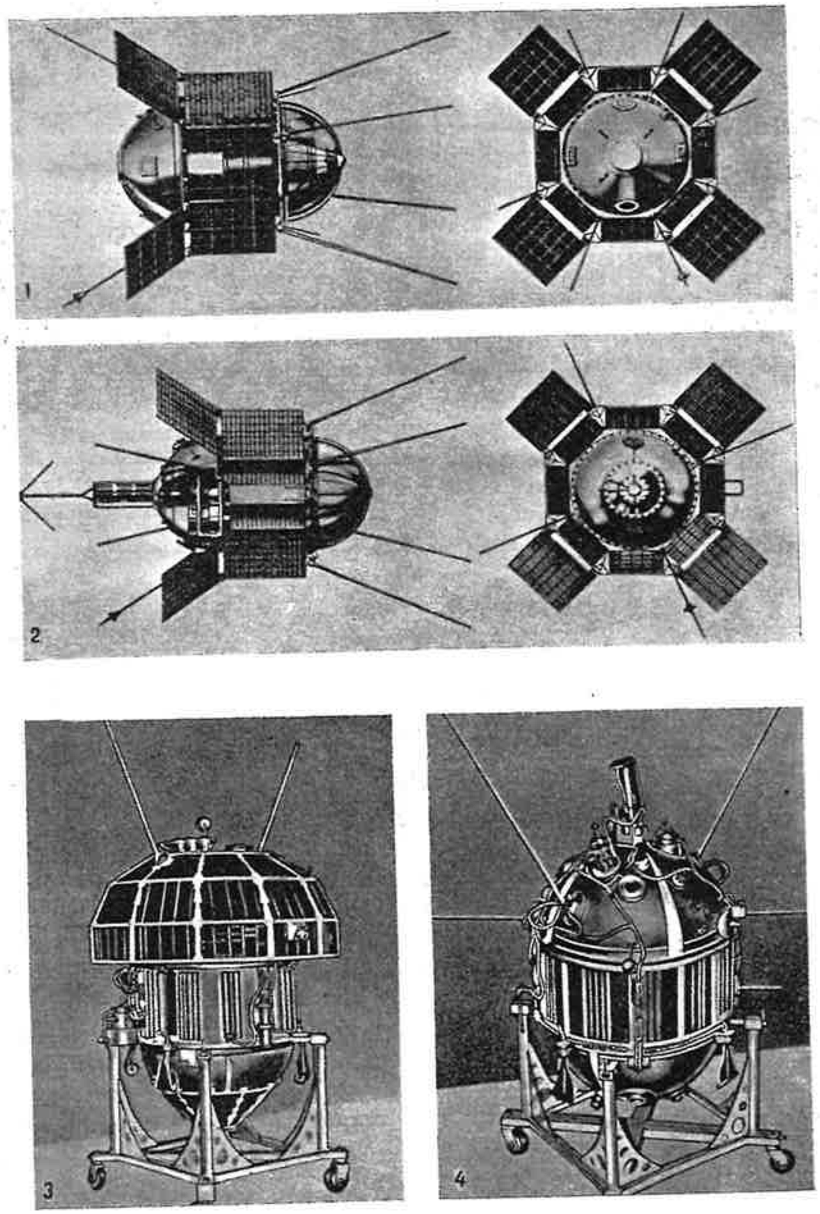
The two-stage KOSMOS carrier-rocket is 30 meters in length and has a maximum body diameter of 1.65 meters. In use since 1962 ▶



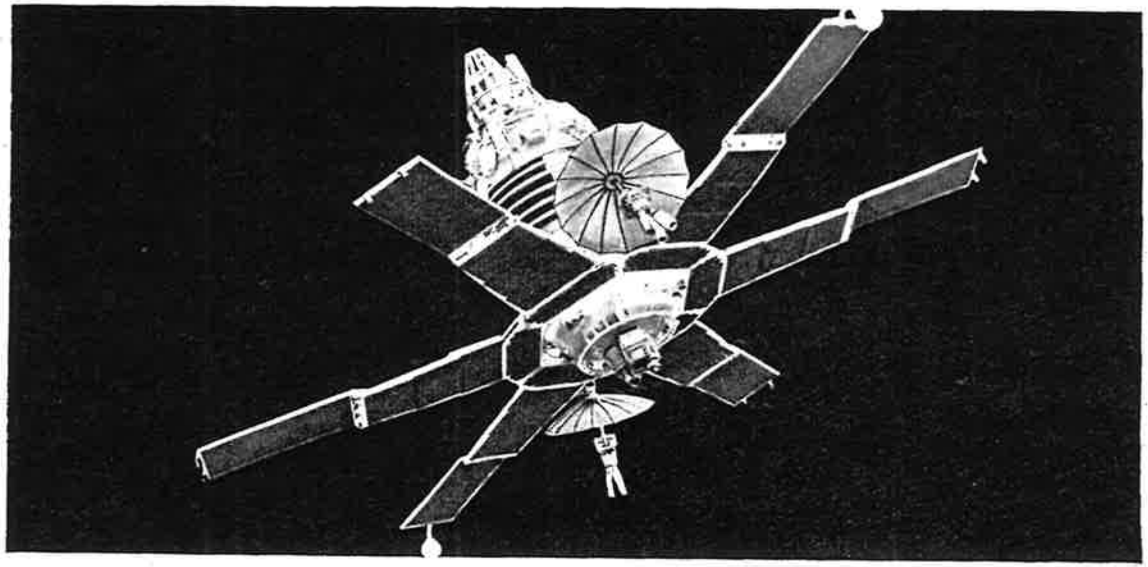
The RD-119 engine of the second stage of the KOSMOS carrier-rocket with a thrust of 11 tons, and a rudder control system, using oxygen and dimethylhydrazine; the combustion chamber pressure is 80 atmospheres, the specific impulse is 352 seconds. Developed by the GDL-OKB between 1958 and 1962



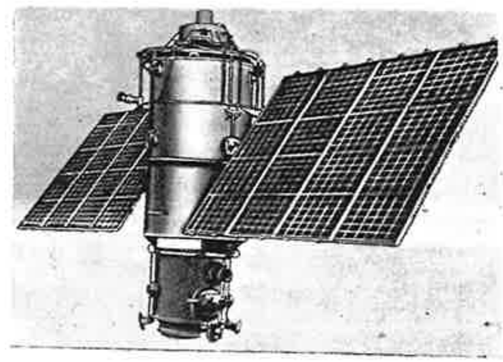
The RD-214 four-chamber engine of the first stage of the KOSMOS carrier-rocket using a nitric acid and hydrocarbon propellant, with a thrust of 74 tons. Developed by the GDL-OKB between 1952 and 1957



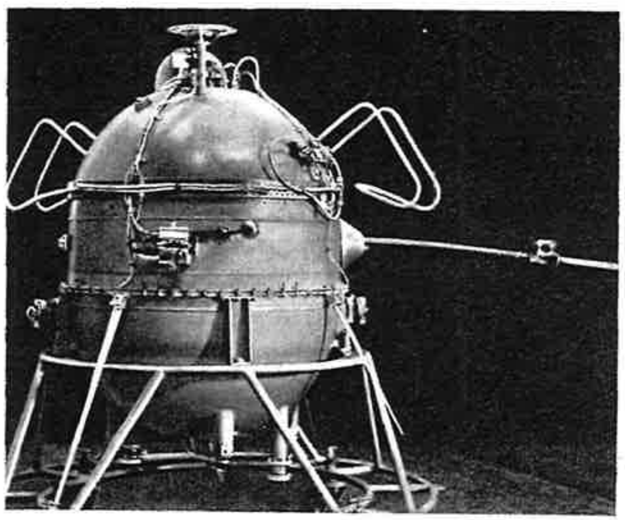
Some of the KOSMOS probes: 1. KOSMOS-137 for the investigation of the Earth's radiation belt; 2. KOSMOS-97 carrying a molecular oscillator; 3. KOSMOS-3 for the investigation of low-energy particles; 4. KOSMOS-2 for ionospheric research



MOLNIA-1 communication satellite (1965-1973)

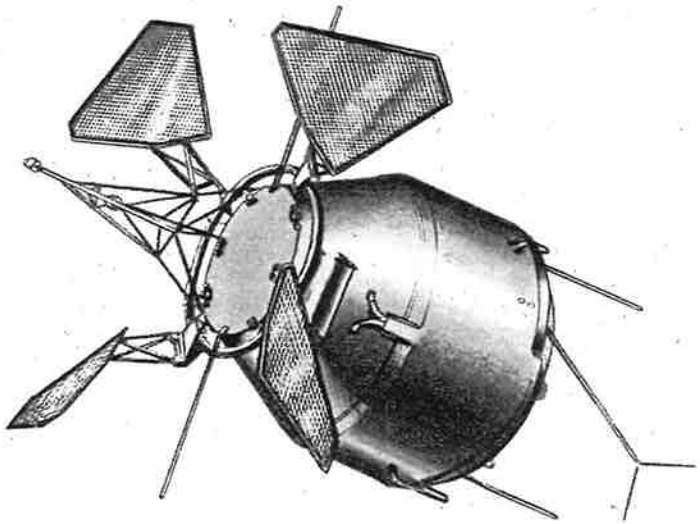


KOSMOS-144 weather satellite (1967)

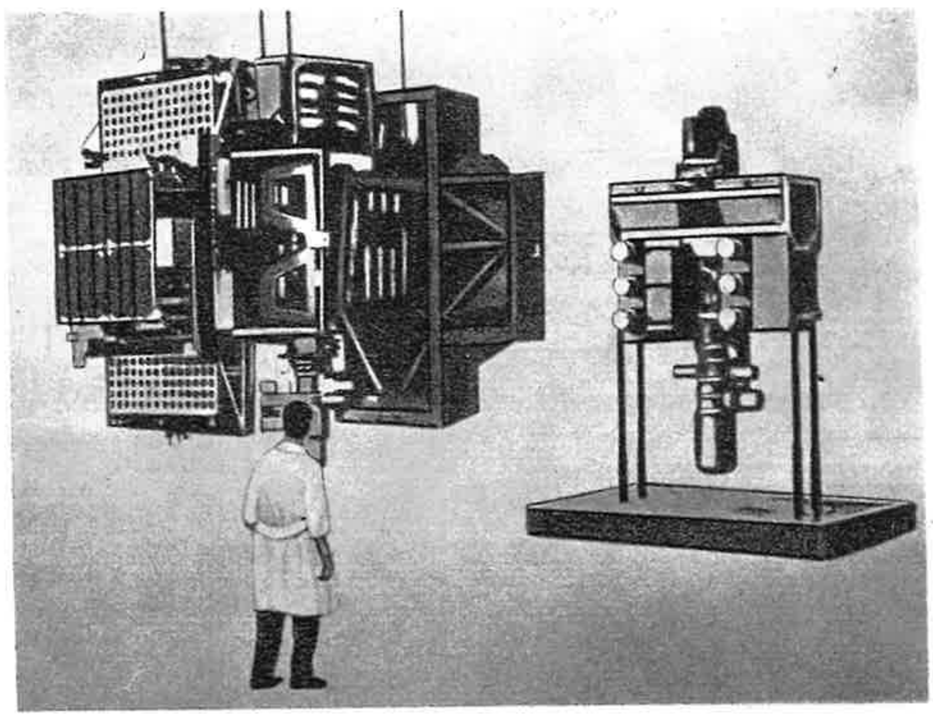


Vertical space probe lifted to an altitude of 4,400 km on October 12, 1967

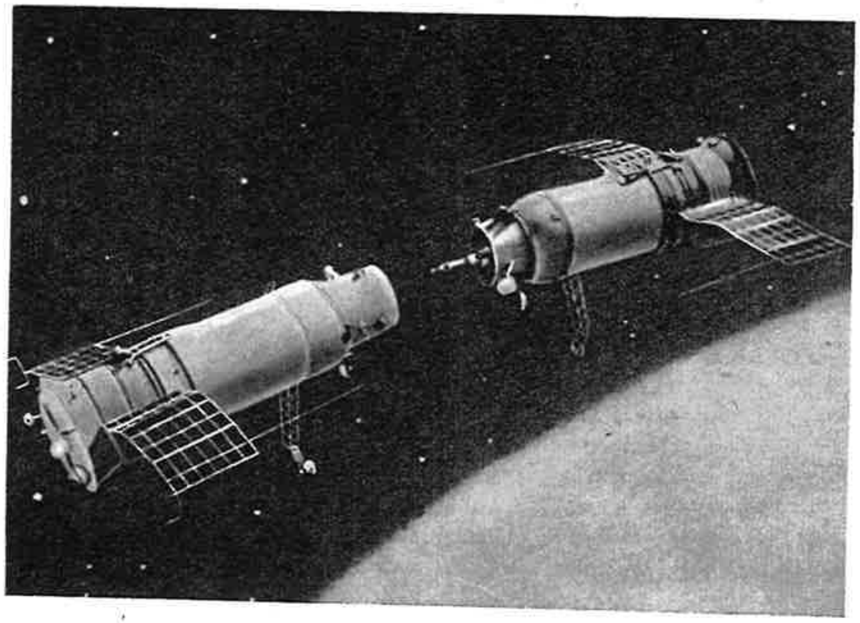
PROTON-4 automatic research station, over 4 meters in diameter and weighing nearly 17 tons, put into a geocentric orbit on November 16, 1968



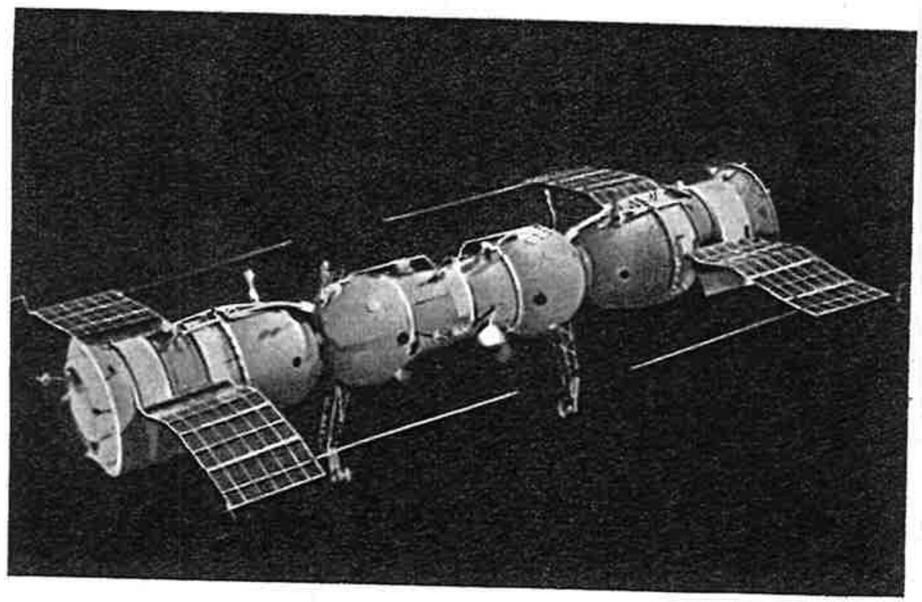
Scientific equipment of the PROTON-1, 2 and 3 Earth satellites (right) and PROTON-4 (1965-1968)



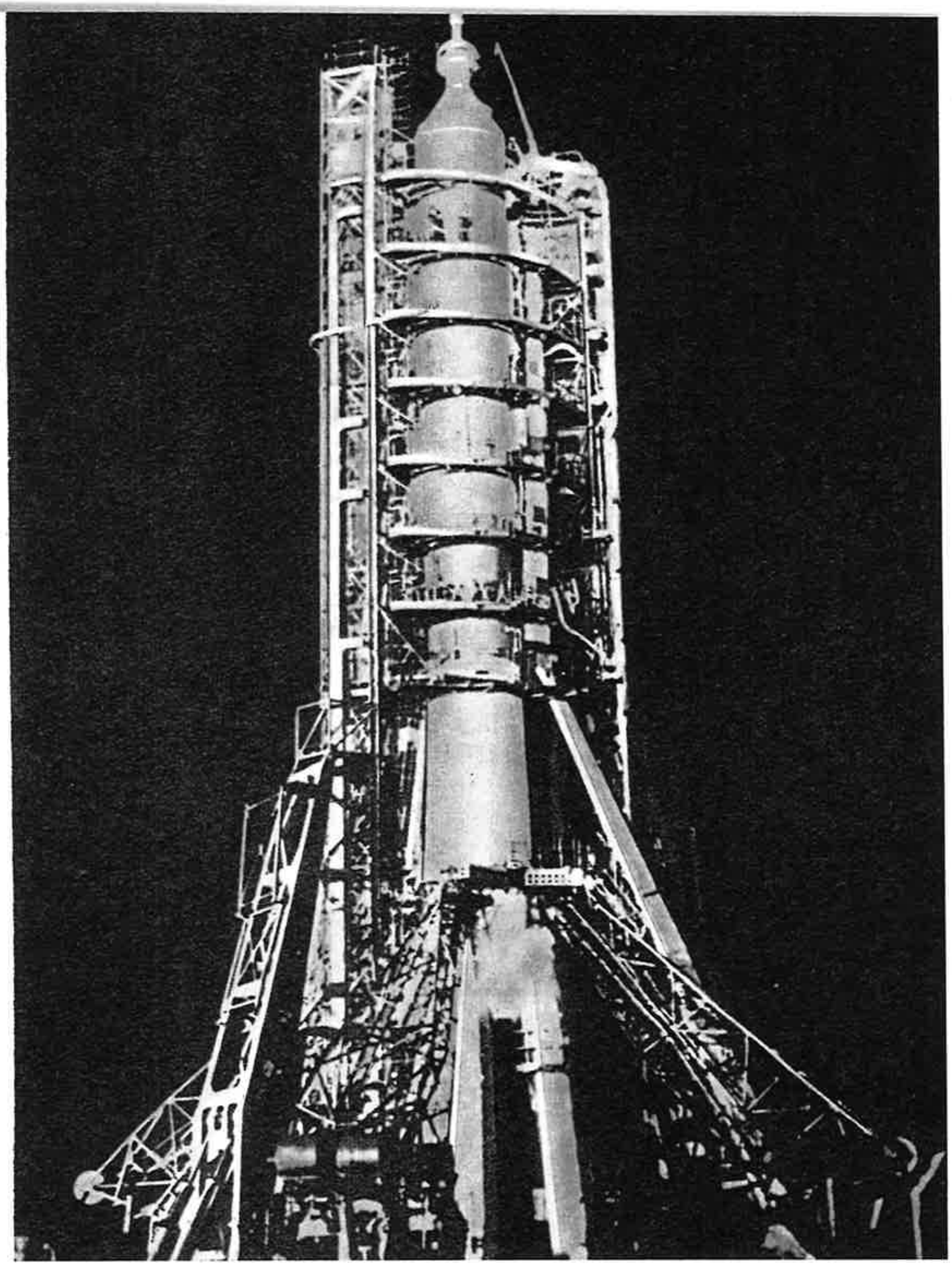
Carrier-rocket in assembly with the SOYUZ spacecraft on the launching pad. This type of rocket has been in service since 1967



Satellites KOSMOS-186 and KOSMOS-188 approaching for an automatic docking (1967)



SOYUZ orbital station (1969-1970)



The Soviei cosmonauts who piloted the spaceships of the SOYUZ series

G. T. Beregovoi

V. A. Shatalov

B. V. Volynov

A. S. Yeliseyev

V. N. Volkov

V. V. Gorbatko

A. G. Nikolayev

Ye. V. Khrunov

G. S. Shonin

V. N. Kubasov

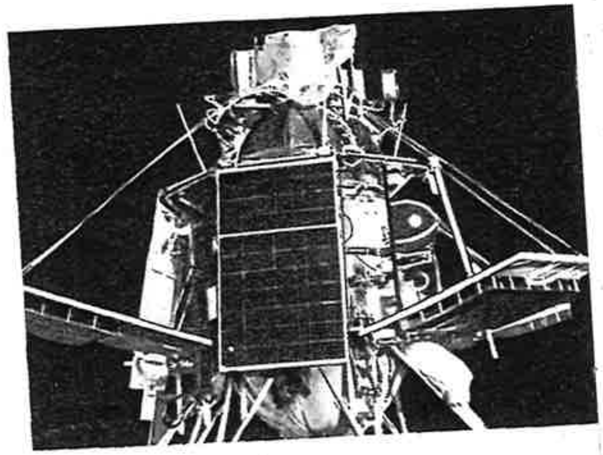
A. V. Filipchenko

V. I. Sevastianov

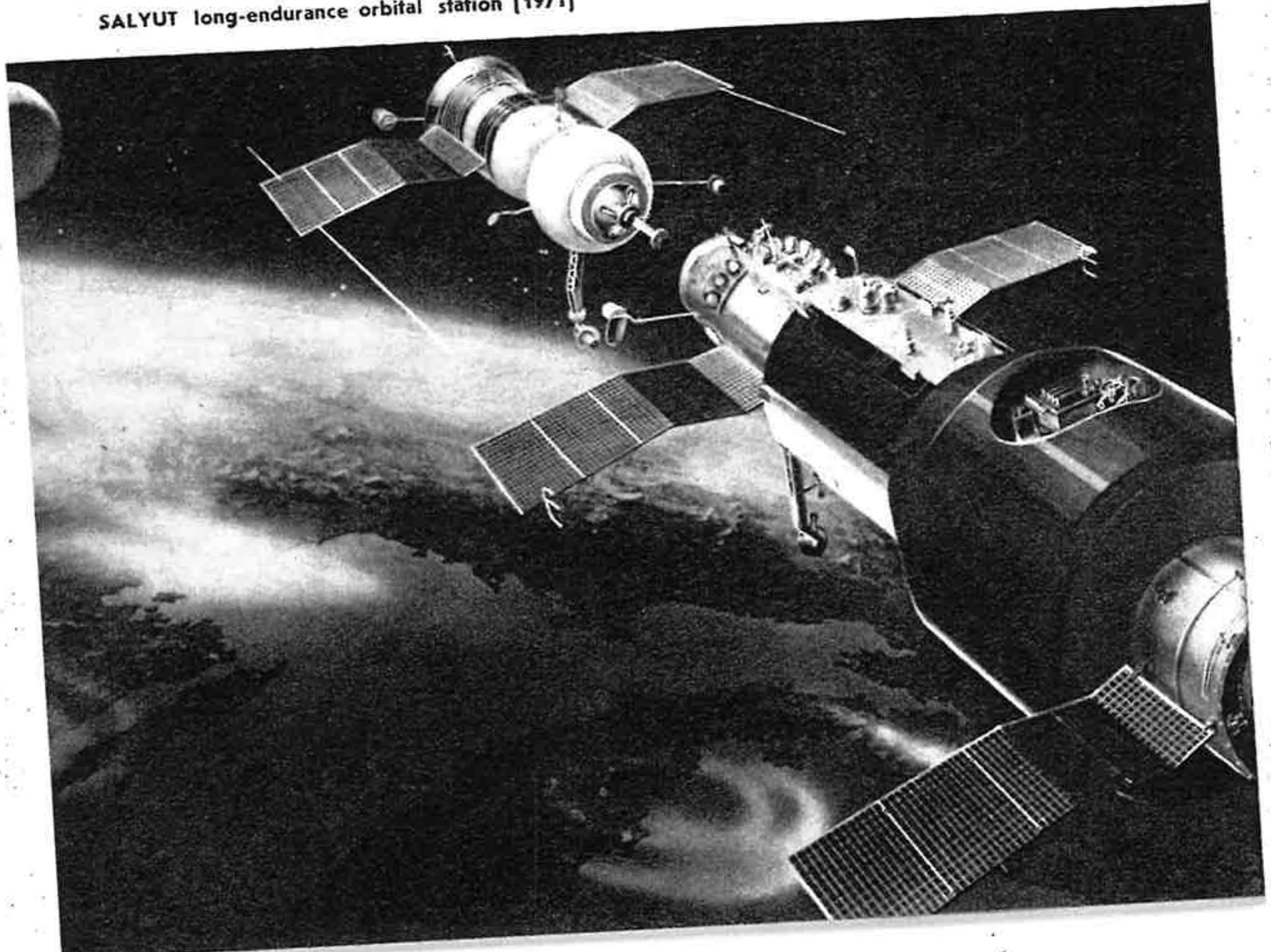
G. T. Dobrovolsky

V. I. Patsayev

INTERCOSMOS-1 research satellite (1969)



SALYUT long-endurance orbital station (1971)



Liftoff of a KOSMOS carrier-rocket in assembly with the INTERCOSMOS satellite (1969-1973)