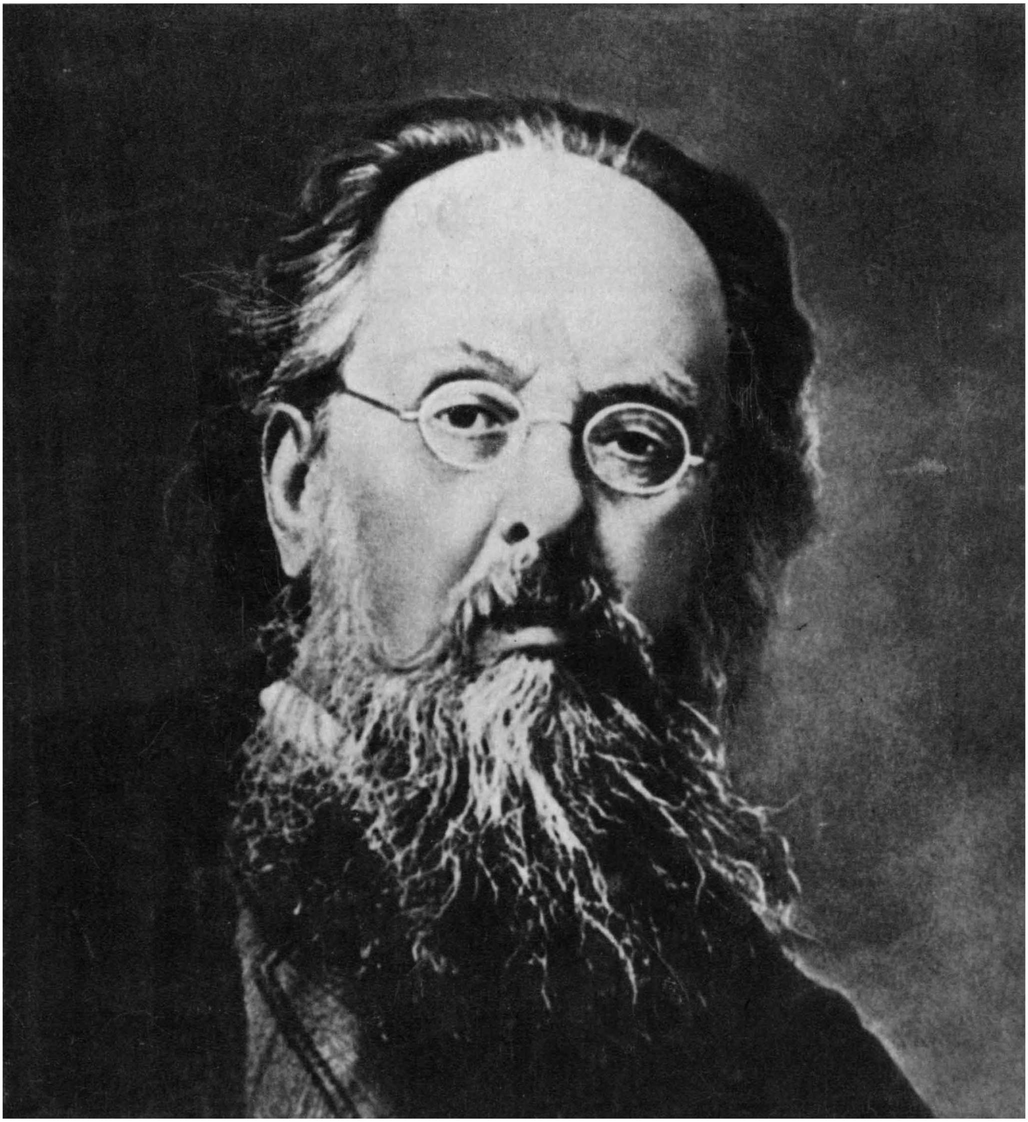
KONSTANTIN TSIOLKOVSKY



KONSTANTIN TSIOLKOVSKY

FOUNDER OF ROCKETRY, COSMONAUTICS AND THEORY OF INTERPLANETARY FLIGHT

Человѣчество не останется вѣчно на землѣ, но, въ погонѣ за свѣтомъ и пространствомъ, сначала робко проникнетъ за предѣлы атмосферы, а затѣмъ завоюетъ себѣ все около-солнечное пространство.

К. Циолковскій

If there is a town which will some day be called the Mecca of Astronautics, that town is Kaluga. Some day Kaluga will have its own space centre and space research academy. For the time being Kaluga boasts of a monument to its townsman Tsiolkovsky and a house, converted into a museum, where once lived a modest schoolmaster who became the father of astronautics.

Every large river starts from a tiny spring. A thousand-mile journey begins with the traveller's first step. Konstantin Tsiolkovsky's calculations made at the turn of the century became the basis of the theory of rocket flight. His models of interplanetary vehicles were the prototypes of those taking off today from the Baikonour and Cape Kennedy space centres.

A MISTAKE IN THE DATING

To many of his contemporaries Tsiolkovsky was just a naive eccentric day-dreamer who wrote books which did not seem to touch on reality at any point.

To mankind at large he has become known as a great scientist. He proposed an artificial Earth satellite as the first step in the exploration of interplanetary space, and his proposal is now a reality.

He proposed liquid oxygen and liquid hydrogen as fuel components for high jet velocities, and these components are used in present-day rocketry.

He proposed that the gyroscopic effect of rapidly revolving fly-wheels be used to stabilize the rocket's position, and this effect is employed today in all autonomous stabilization and flight control systems.

Tsiolkovsky predicted many developments of today. He even described in detail Alexei Leonov's walk in space. He made a mistake, however, in dating this journey 2017, i. e. 52 years later than it actually occurred.

PIONEER WORK

A vehicle must have a sufficiently high velocity to be able to escape from the Earth's gravitation. This was known long ago. However, practical ways and means had to be sought for its achievement, taking into account the limitations of the human body. The spacecraft's velocity must increase gradually to avoid injuring the crew. Moreover, it had also to be borne in mind that the spaceship would have to fly in a vacuum and hence the air could not be used for propulsion. Only one type of vehicle could meet these requirements: the rocket.

The principle of reactive motion attracted Tsiolkovsky's attention from the very start of his research. In 1883 he expounded the principle of jet propulsion for flight in the vacuum of space in his work **Free Space**. Later on Tsiolkovsky gradually passed from qualitative analysis to mathematical computations. In one of his manuscripts dated 1897 he gave an accurate engineering assessment of the possibilities of the rocket as a space vehicle. In 1903 he began to publish selected chapters of his famous book **Exploration of the Universe with Reactive Devices**. In this book he gave the first known exposition of theory of rocket flight and substantiated the possibility of using reactive flying devices for interplanetary travel.

It follows from this work that Tsiolkovsky considered the rocket the only practicable device for space flight with the following basic merits:

a) The rocket is cheaper and more easily designed than a giant gun;

b) Acceleration of the rocket during the powered flight phase can be changed at will and, consequently, excessive acceleration can be avoided;

c) The rocket's velocity can be changed by any law and in any direction; it is possible, for instance, to provide a soft landing on a planet that has no dense atmosphere;

d) While passing through the dense layers of the atmosphere the rocket's speed can be made relatively small, providing thereby for comparatively small forces of resistance and insignificant heating of the surface. In the rarefied layers of the atmosphere the speed can be increased without fear of excessive heating.

This publication proves Tsiolkovsky's priority as the author of the idea of employing the rocket for the exploration of outer space, as the initiator of modern liquid propellant rockets and the founder of rocket dynamics.

TSIOLKOVSKY' S ROCKETS

There had been research into the theory and practice of rocket engineering before Tsiolkovsky. Projects and studies had, however, been based on powder rockets. Tsiolkovsky was the first to propose long-range liquid propellant rockets for interplanetary flight. This was an essentially new and very important advance in the field.

Here is how Tsiolkovsky described his concept of the rocket space vehicle in his work **Exploration of the Universe with Reactive Devices** published more than sixty years ago.

"Let us imagine a missile as follows: an elongated metal chamber (the least resistant shape) supplied with light, oxygen and absorbers of carbon dioxide, miasmata, and other excretions, and intended not only for containing physical instruments, but also for carrying the man who controls the chamber... The chamber has a large store of substances which when mixed form an explosive mass. Exploding at a regular, uniform rate in a special place these substances flow as hot gases through tubes that flare towards the end like a speaking trumpet or any wind instrument... At the narrow end of the tube the explosive substances are mixed: condensed combustible gases are thus produced here. At the other, bell-like end, the gases expand, cool as a result and escape through the bell at an immense relative speed."

According to Tsiolkovsky's idea the liquid propellant rocket was to use a mixture of liquid hydrogen (propellant) and liquid oxygen (oxidizer). The design provided for the cooling of the combustion chamber walls and of the control nozzle by one of the components of propellant mixture. Tsiolkovsky suggested two methods for controlling the rocket's flight outside the atmosphere: jet vanes or turning the nozzle. It should be noted that these ideas are now extensively used in rocket engineering.

Later Tsiolkovsky improved his original concept. He considered different propellants (including kerosene and petrol) and worked out different methods for cooling the rocket shell and protecting it during re-entry into the atmosphere. He visualized rocket flight conditions in concrete terms and sought ways to protect living organisms against the effect of acceleration. Among other things he suggested that the crew be immersed in a liquid of the same density as the human body.

Of cardinal importance for the progress of rocket engineering was his idea of a composite or, as we call it now, a multi-stage rocket. Two types of "rocket trains" are described in his works. One of them anticipates the multi-stage rocket of today. Tsiolkovsky also calculated the optimal weight distribution of each rocket which made up the "train." The other type of multi-stage rocket which he proposed in 1935 envisaged the connection of rockets not in series but in parallel. The most rational design of a "rocket train," a question first considered by Tsiolkovsky, is still one of the crucial problems of rocket engineering.

His rockets were not brought to the full-fledged design stage. Rather they were the elaboration of new ideas. He concentrated on scientific and engineering calculations that would confirm the feasibility of his proposals and the creation of a new science — rocket dynamics.

ROCKET DYNAMICS

Tsiolkovsky pioneered in formulating and studying the problem of the rectilinear movement of rockets, proceeding from the laws of mechanics.

How should the velocity of a reactive vehicle be computed if its mass varies in flight? How should the altitude of a vertical take-off rocket be determined? How should the force of terrestrial gravitation be overcome? These are but a few of the questions answered by Tsiolkovsky.

In his Exploration of the Universe with Reactive Devices (1903) he examined the rocket's movement resulting from its thrust leaving out of account aerodynamic and gravitational forces. An illustration of this simplest case from which the theory of rocket flight must naturally begin may be found in interstellar flight when the gravitational pull of stars and planets is so small it can be neglected.

After thoroughly investigating the equation of the rocket's movement under the assumption that particles flow from the rocket's nozzle at a constant velocity, Tsiolkovsky obtained an important mathematical result known as the Tsiolkovsky formula:

$$V = 2.3\, V_1 \log \frac{M_o}{M},$$

where V is the velocity of the rocket when its mass is equal to M; V_1, the velocity of the particles leaving the engine's nozzle; and M_o, the rocket's mass at launching when its speed is equal to zero.

A very important practical conclusion follows from this formula: to develop the highest speed at the moment the engine is shut off, it is necessary to increase the relative velocities of the discharged particles and the relative stocks of fuel. In other words, the Tsiolkovsky formula indicated two ways of improving the rocket's performance: firstly, improvement of the engine and a reasonable choice of components of the propellant and, secondly, minimization of the weight of the rocket body and its mechanisms and instruments.

The formula marked the beginning of scientific rocket designing and laid the basis of rocket dynamics.

After a detailed analysis had brought Tsiolkovsky to the conclusion that cosmic speed could be attained with jet engines he made a thorough study of the effect of gravitational forces on a rocket's flight. He likened the force of gravity to a chain that fettered man to our planet and spoke of the region to which its influence extended as the "gravitational armour." Tsiolkovsky's calculations to determine the fuel store necessary to get through the "gravitational armour" were extremely interesting. It must be noted in the first place that gravitation decreases with the altitude. At an altitude equal to the Earth's radius (some 6,400 kilometres) a man's weight is only one-fourth of his weight at sea level. In other words, a man weighing 80 kilogrammes on the Earth's surface will weigh only 20 kilogrammes at the above altitude. What work has to be performed for the man to fully overcome the "gravitational armour?"

In his Exploration of the Universe with Reactive Devices Tsiolkovsky gives this answer: "Let us assume that the force of gravity does not decrease as a body moves away from the planet. Let us assume that the body has risen to an altitude equal to the planet's radius. Then it has performed work equal to that which is necessary to overcome the planet's gravitational pull." In other words, the work will be equal to the body's weight multiplied by the Earth's radius.

Taking air resistance into account, a rocket's vertical rise in the Earth's gravitational field requires selection of the optimum operating conditions for the jet engine, since it is obvious that a very high rate of combustion would result in excessive stresses caused by the jet thrust and excessive resistance in the dense layers of the atmosphere, while a slow rate of combustion might be insufficient to send the rocket up as the thrust would be less than the rocket's weight. This idea advanced by Tsiolkovsky initiated a series of investigations by Soviet and foreign scientists to determine the optimum speed of rockets moving in the gravitational field.

Tsiolkovsky did much work in investigating the forces of air resistance. He was the first in rocket engineering to estimate the amount of propellant necessary for a rocket to pierce the Earth's atmosphere. Since air resistance hinders an increase in the rocket's velocity, Tsiolkovsky called the region of air resistance the "atmospheric armour."

"The 'gravitational armour' and 'atmospheric armour' hold the rocket near the Earth. Overcome them and you will be an inhabitant of outer space; you will be able to send your rocket to any planet or asteroid!"

Tsiolkovsky was the first to calculate the optimal ascent angle of a reactive device moving through air layers of varying density. He also investigated the conditions of rocket launchings from various planets and asteroids and solved the problem of the fuel store necessary for the return to the Earth.

In his works Tsiolkovsky pioneered in determining the rocket's efficiency and pointed out the merits of jet engines for movement at high velocity.

In his last years Tsiolkovsky worked intensely on the theory of jet planes. In his paper The Jet Plane (1930) he gave an elaborate analysis of the merits and shortcomings of jet planes compared to prop planes and showed that the jet plane would pay in high-speed flights in a rarefied atmosphere. Tsiolkovsky concluded his paper with these prophetic words: "The era of propeller airplanes must be followed by that of jet airplanes or stratospheric airplanes." It should be noted that these lines were written ten years before the first Soviet-made jet plane took off. In his papers **Rocket Plane** and **Semi-Jet Stratoplane** Tsiolkovsky presented a theory of the flight of liquid propellant jet planes and elaborately developed the idea of the turboprop plane.

"Our plane," he writes, "can be likened to an ordinary aircraft, but its wings are small and it has no outside airscrew. The latter is replaced by a special propeller. The plane is equipped with a very powerful engine which discharges backwards through special cone tubes the stream of gases produced by combustion of the fuel. The result is a certain recoil, repulsion or reaction by virtue of which the rapid ascending motion of the vehicle is accelerated."

The rocket plane has an advantage over the ordinary rocket in that the oxidizer for burning the fuel in the combustion chamber is taken from the air, thus substantially increasing the fuel supply.

More than sixty years have passed since the publication of Tsiolkovsky's first work in rocket dynamics. The exceedingly rapid development of rocket engineering and jet aircraft has demanded further development of the ideas put forward by the great scientist. At the same time the progress of rocket dynamics emphasized the depth and magnitude of the investigations of Tsiolkovsky, who correctly set forth the basic laws of rocket motion.

THEORIST OF INTERPLANETARY TRAVEL

For Tsiolkovsky research in rocket dynamics and rocket engineering was a means to an end which he formulated as follows: "The idea of communication with outer space has never left my mind." The desire to make available reliable technical solutions of the problems of space flight guided him in his work in rocketry.

Interplanetary travel interested Tsiolkovsky from the very start. In his search of means of travel in the conditions of outer space he came to the conclusion that "a celestial vehicle must be like a rocket . . The rocket does not require any outside medium (outside support) for its propulsion. In a vacuum the rocket's velocity increases more rapidly since it is not necessary to overcome air resistance. Evidently, a device for moving in a vacuum must be like a rocket, i.e. it must contain not only the energy, but also the supporting mass within itself."

To set off on a journey into outer space a vehicle must have an enormous initial speed, no less than 11.2 km. per second. This speed seemed absolutely fantastic at the time when Tsiolkovsky began to lay down the foundations of astronautics, the science of space flight. Nevertheless, the scientist continued his stubborn quest for the means of attaining it. He thoroughly analyzed methods of obtaining great jet velocities and closely studied likely rocket propellants. As a result he succeeded in formulating the basic requirements for rocket fuel by which scientists and rocket engineers are guided to this day.

"Elements of the explosives for this machine must have the following properties:

"1. They must release maximum energy per unit mass in burning.

"2. When in contact they must form gases or volatile liquids that evaporate on heating.

"3. They must produce as low a temperature as possible when burning so as not to spoil the barrel (orifices).

"4. They must occupy a small volume, i.e. have the greatest possible density.

"5. They must be liquid and mix well. Use of powders is too complicated.

"6. They may also be gaseous but must have a high critical temperature and a low critical pressure to facilitate their use in the liquid state In general, liquefied gases are disadvantageous due to their low temperature—they absorb heat in warming up. Their use is also associated with losses from evaporation and explosion hazards. Expensive, chemically unstable or unavailable products are also unsuitable."

Having considered many different oxidizers and propellants Tsiolkovsky selected the following fuel pairs for practical use: liquid hydrogen and liquid oxygen, kerosene and liquid oxygen, alcohol and liquid oxygen, methane and liquid oxygen. In his last works Tsiolkovsky pointed out that the use of ozone as oxidizer would raise the jet velocity even more.

Analysis of the possibilities of a single-stage rocket led him to the conclusion that with this rocket it would be practically impossible to break through the "gravitational armour" and escape into outer space. In a search of a way out Tsiolkovsky suggested in 1929 a composite rocket or a rocket train which would make the orbital and escape velocity feasible if the propellant mixtures known at that time were employed.

"1. By rocket trains," Tsiolkovsky writes, "I mean the linking up of several similar reactive devices which at first travel along a road, then in the air, then in a vacuum outside the atmosphere and, finally, somewhere among the planets and suns.

"2. But only a part of this train speeds away into celestial space. The other parts, not having sufficient velocity, return to Earth.

"3. To achieve escape velocity a single rocket must have a large store of fuel. For example, to attain orbital speed, i. e. 8 km. per second, the weight of the fuel must be at least four times the weight of the rocket with everything it contains. This puts difficulties in the way of designing reactive vehicles. A train makes it possible either to achieve great cosmic speeds or limit oneself to a small store of explosive components."

Developing this idea Tsiolkovsky was the first to prove mathematically the feasibility of interplanetary travel in multi-stage rockets. The experience accumulated since then in rocket engineering has fully confirmed the validity of these ideas.

Tsiolkovsky put in much work on the problem of ensuring conditions in space flight which would support human life. In particular, he suggested the use of small plants for the absorption of carbon dioxide and other excretions. The plants could be used, according to Tsiolkovsky, as a source of oxygen and food. As he pondered over the problem of man's long stay in weightlessness, he came to the conclusion that artificial gravity should be created in spacecraft. In his description of a multi-stage passenger rocket in the book **Outside the Earth** he suggested that the rocket be rotated on its lateral axis to produce an artificial gravity effect by centrifugal force.

He well realized that interplanetary travels could not be made without detailed investigations of outer space and consequently paid great attention to the methodology of such investigations. In the essay **Dreams about the Earth and the Sky** published in Moscow in 1895, in which Tsiolkovsky considered the possibilities of man's penetration into space, he makes first mention of an artificial Earth satellite: "The fancied satellite of the Earth, something like a moon, but arbitrarily closer to our planet—only far enough away to be outside its atmosphere, that is, at a distance of some 300 versts[1] from the Earth's surface, will be, given a very small mass, an example of a medium free from gravity." He proceeded with the description of this satellite and the speed at which it should move in its orbit round the Earth.

And when 62 years later the first man-made satellite was launched, its orbit bordered on the Earth's atmosphere and its speed was 8,000 metres per second as predicted by Tsiolkovsky.

[1] Verst—a Russian measure of distance, 3,500 feet.

GENIUS FOR PREDICTION

Tsiolkovsky's plan for the conquest of space amazes one in its boldness and prophetic accuracy. Some items of the plan are worth quoting in this context.

"5. The velocity reaches 8 km/sec, the centrifugal force cancels gravity and the rocket goes beyond the boundaries of the atmosphere for the first time. After a flight which lasts as long as oxygen and food suffice, the rocket spirals back to Earth, braking itself against the air and gliding without explosions.

"6. . . .The reactive devices fly farther and farther from the Earth's air envelope and stay in space longer and longer. Still, they return because of the limited supply of food and oxygen.

"7. Attempts are made to get rid of carbon dioxide and other human excretions with the aid of selected small plants which at the same time serve as sources of nutrients. Slow yet steady progress is made in this field after much painstaking work.

"8. Spacesuits are made for a safe exit from the rocket into space.

"9. To obtain oxygen and food and purify the rocket air special containers for plants are devised. Sections thus built are folded and carried by rockets into space where they are unfolded and assembled. Man achieves greater independence from the Earth as he can procure means of subsistence by himself."

What is set down in the first two items of the plan began to be carried out only seven and a half years ago. The problems of ensuring conditions suitable for human life during lengthy flight are still in the centre of attention in space biology and medicine. Extensive work is still ahead before the ideas which Tsiolkovsky advanced decades ago in his numerous books can be realized.

FIRST LIBRARY OF BOOKS ON SPACE

In 1895 Tsiolkovsky published a science fiction story **On the Moon** and then an essay **Dreams about the Earth and the Sky**. These works contained the ideas with which the scientist had long been preoccupied. In his **On the Moon** he describes how people would feel if they found themselves on the nearest celestial body. It contains no conjectures as how to get to the Moon. His characters fall asleep and find themselves on the Moon. In his **Dreams about the Earth and the Sky** Tsiolkovsky suggested constructing a "falling laboratory" in which weightlessness could be created artificially. In his essays he also describes in detail the decreased gravity effects on dwarf asteroid planets. In 1896 he started another science fiction story entitled **Outside the Earth** in which he outlined the future conquest of interplanetary space. It is noteworthy that in this story fantasy is based on accurate calculations and the author even cites some figures characterizing the flight of a space rocket.

Several years passed before the scientist published the results of his research. His **Exploration of the Universe with Reactive Devices** appeared in 1903 but he returned to this book again and again, making additions and giving a more thorough treatment to some parts. Under the same title he published a paper in the journal **Vestnik Vozdukhoplavaniya** in 1911 and in 1914 a supplement in booklet form. Apart from recapitulating the conclusions drawn earlier he considered new problems in these works: rocket fuel, the possibility of interstellar flights, etc. "What is impossible today will be possible tomorrow." These words written at that time expressed his profound belief in the feasibility of his ideas.

In 1926 he published an enlarged and revised edition of his **Exploration of the Universe with Reactive Devices**. He analyzed in detail the conditions to be expected when the space rocket takes off, as well as the problems involved in space living conditions: respiration, nutrition, etc. In this book he also touched upon the problem of using nuclear energy, anticipating its vast importance for space flight.

In 1929 Tsiolkovsky published **Space Rocket Trains**, a book in which he returned to the idea of a composite rocket and developed the theory of its flight in detail.

It was the composite (multi-stage) rocket that on October 4,1957, put the first artificial satellite into orbit round the Earth from which, in Tsiolkovsky's words, the road to the stars begins.

GLIMPSES OF THE SCIENTIST'S LIFE

Konstantin Eduardovich Tsiolkovsky was born in 1857, in a forester's family, in the village of Izhevskoye (Ryazan Guberniya). His unclouded years of childhood were interrupted by a tragedy: at the age of nine he became deaf as the result of a severe cold and scarlet fever. This left an imprint on all his life. He could not attend school and gradually went in for independent studies, reading much in natural and mathematical sciences, and inventing. He displayed outstanding ability and at the age of sixteen his family sent him to Moscow where he could go on with his self-education. He led a hard life in Moscow, often going about hungry and penniless, but he would not drop his studies. He spent the money sent him from home on books and experiments. His chief pursuits were physics, chemistry, mathematics and astronomy. He tried to master everything independently, and this habit of being dissatisfied with ready knowledge, but gaining it independently, was a lifelong trait. The young inventor wanted to know more to be able to work on his new ideas, and he continued his studies with unusual energy and perseverance despite all privations.

However, his hard life in Moscow undermined his health and he was forced to return home and make a living by giving private lessons. He passed his schoolmaster's exams when he was 22. He never left off teaching afterwards. At first he was a schoolmaster in Borovsk, Moscow Guberniya, and then continued teaching in Kaluga where he spent most of his life. Along with teaching he continued inventing and doing research and literary work. "Thought precedes realization, fantasy precedes accurate calculation," he would say about his methods.

"All my life I have not only calculated but also worked with my hands," he wrote. This was characteristic of all his activities. In his house he had a workshop and laboratory with machine tools and instruments. He built Russia's first aerodynamic funnel and carried out numerous experiments with it. He made models of airships out of corrugated iron.

Tsiolkovsky's works in aerodynamics were new and highly original for his day and were appreciated in scientific quarters. The results of his aerodynamic investigations were recognized to be of value by the Russian Academy of Sciences and he recieved a grant in cash to continue his experiments and was even elected Member of the Physical and Chemical Society.

However, before the 1917 Revolution he was pitted against heavy odds as a scientist and inventor. Except for this single grant from the Academy of Sciences he met with neither understanding nor sympathy anywhere and carried out all his research on his own scanty means.

His appeals for assistance went unheeded: official science could not look so far ahead. He was regarded as a day-dreamer, he was even laughed at and he had to gather all his will and faith to continue his work under such conditions.

"It is hard to work all alone for many years in unfavourable conditions without a gleam of hope or support anywhere." These words from an essay of his aptly entitled Woe and Genius describe well his life before the October Revolution of 1917. He remained alone in his research work, without disciples or followers and had very poor facilities for his investigations. He was isolated from the scientific world at large.

Despite the difficulties caused by the Civil War and economic disruption the Soviet Government immediately provided adequate living and working conditions for the great scientist. He was granted a personal pension, and elected Member of the Socialist Academy; the public became interested in his work and groups of disciples and followers began to appear.

In 1924 a section of interplanetary communications was set up under the Military Scientific Society of the Air Force Academy. Its twenty-five members decided to study the jet engine and to find ways and means for its practical application. At their first meeting they unanimously agreed to ask Tsiolkovsky to be their scientific adviser.

Between 1917 and 1935 four times as many papers, brochures and books by Tsiolkovsky came off the press as during the entire preceding period of his life. Some 60 papers on physics, astronomy, mechanics and philosophy were published in the seven-year period from 1925 to 1932. The Party and the Soviet Government's constant concern for Tsiolkovsky's research work contributed to his national popularity and recognition.

"We are confident of the brilliant prospects of jet flying in our country," young engineers attending an USSR Conference on Stratospheric Studies wrote to Tsiolkovsky in 1934, "Our Soviet rockets must fly higher and farther than the rockets of any other country in the world... Jet engines will help to solve many problems relating to the training of Soviet stratonauts and this will pave the way for the realization of the daring idea you have been successfully working on for many years—that of interplanetary communications."

In 1932 the country marked his 75th birthday. The scientist had become world-known. Numerous organizations and individuals sent their greetings. He was awarded the order of the Red Banner of Labour. The Government granted him a new house in Kaluga and the publication of his works was launched. But probably Tsiolkovsky's greatest award was the beginning of the realization of his dreams. In 1930-31 the workers of the gas dynamics laboratory designed the first Soviet liquid-fuel rocket engine, and the enthusiasts who were studying jet propulsion built the first liquid-fuel rocket which went up on August 17, 1933. Up to his very death Tsiolkovsky was the principal adviser and confidential friend of the engineers who were striving to materialize his wonderful ideas.

But he was not destined to see the first Soviet space flight: he died on September 19, 1935, in Kaluga where he had been engaged in rocket research for more than forty years.

Monuments in his memory have been erected in Moscow and Kaluga. His name is inscribed on the monument in honour of the launching of the first satellite and one of the Moon's craters bears his name. For his name and space conquest are linked inseparably.

"YOU HAVE KINDLED A LIGHT..."

Tsiolkovsky's first papers on rocket dynamics were not endorsed by the tsarist government and official science in pre- revolutionary Russia. His outstanding ideas on long-range rockets were looked upon as fantastic and amateurish.

His fate was no better than the lot of many scientists and inventors in tsarist Russia. In 1913 the French engineer Esnault-Pelterie published his paper **Considerations Concerning the Results of Infinite Reduction of Engine Weight** which set forth certain formulas of rocket dynamics. There is no mention of Tsiolkovsky in this article though it appeared 10 years after Tsiolkovsky had published his first work.

In 1919 Professor Goddard in the United States published a paper on the theory of rectilinear rocket movement. He came to the same formula as Tsiolkovsky and stressed the need of finding the optimum conditions of a vertical take-off. He also was unacquainted with Tsiolkovsky's results though by that time several works by the Russian scientist had been published in the form of brochures and articles in journals.

Tsiolkovsky's priority in the development of rockets for space flights was eventually recognized by foreign scientists only due to the persistent efforts of many Russian scientists and engineers and a large number of polemic articles in the Soviet press.

In 1929, Oberth, the German investigator of jet motion, wrote to Tsiolkovsky: "You have kindled a light and we shall never let it go out. We shall bend every effort to realize mankind's greatest dream."

The foreign press more and more often mentioned Tsiolkovsky as the founder of the theory of interplanetary communications though certain scientists continued to ignore his work. In his article **The History of Interplanetary Communications** published in Munich in the collection of works entitled **Interplanetary Communication Researches** and edited by H. Hartmann, Prof. Willy Ley pointed out that Tsiolkovsky's first publication on space flights had appeared in the last century. "Tsiolkovsky," he wrote "correctly understood the nature of the reactive principle; he was the first to outline the idea of using liquid fuel for jet engines."

An English journal carried an article by Mr. Thompson entitled **Tsiolkovsky—Founder of Astronautics** which, in particular, mentioned that Tsiolkovsky had suggested a series of constructive solutions for spaceships with a rocket engine. He pointed out that they were not working blueprints of the devices, but only draft sketches of the equipment and facilities that could be used in the case in question. Some of them had come into use in guided missiles. Among them he noted the placing of control vanes in the jet of the engine's exhaust gases; by inclining the vanes the power jet was diverted and the rocket simultaneously changed its course...

The author went on to say that Tsiolkovsky's words had not been based on projects alone. From 1903 to 1926 he had published several articles and books on the mathematical theory of rocket flight and space travel. He developed an equation which could be used to determine the speeds and power consumption necessary for flights at different trajectories, calculate flight time, etc. His computations showed that space rocket flights were quite realistic and that it was even possible to erect inhabited space stations revolving round the Earth. . .

The Russian Revolution, the author stressed, had not hampered Tsiolkovsky's work, contrariwise, it had given him still greater inspiration.

In his article **Astronautics over the Past Twenty Five Years** published in an American journal M. W. Rosen pointed out that Tsiolkovsky had developed the method of calculating the flight of a rocket in free space. Proceeding from the need of effective fuel he had carried out a series of thermochemical computations to determine the thermal efficiency of various fuel combinations. After establishing the speed that could be attained on that fuel he had arrived at the conclusion, at least theoretically, that it was sufficient to escape from the Earth.

A DOOR INTO OUTER SPACE

A two-storey house in a quiet street in the suburbs of Kaluga bears the inscription: "K. E. Tsiolkovsky Museum."

Much has been preserved in this house exactly as it was when the scientist was alive. The staircase leads to his study on the second floor where he worked. The furniture is modest: a desk, an arm-chair, bookshelves and books everywhere. On many of them the visitor can read the scientist's name and the inscription: "Published by the author." These are his works, a series of small-size, modest-looking booklets published by the local printers. In a small adjacent room there is an old bicycle on which the scientist often went for a ride, his habits unchanged to the last days of his life. The room adjoins a roofed porch, which housed the scientist's workshop. Tsiolkovsky made his models and devices himself and constantly experimented. The rest of the family jokingly called the door leading from the porch onto the flat roof of the house where the scientist carried out his astronomical experiments and observations "the door into outer space."

In April 1965 Alexei Leonov, the Soviet astronaut, approached this door and opened it. He saw a panorama of one-storey houses running in tiers down to the Oka River sparkling in the sun. The astronaut recalled the infinite world which had unfolded before him when the rocket hatch opened—the violet-black sky and a neat round Sun.

"We entered space through different doors," he remarked. "But had it not been for this wooden door here there would not have been mine in the spaceship, nor would there have been that April 12 when Yuri Gagarin's name went down into history forever."

On the eve of that day Soviet astronauts came to Kaluga to pay tribute to the man whose work blazed the way to the Universe.

LEONOV COMMENTS

At the Tsiolkovsky Museum astronaut Leonov was leafing through Tsiolkovsky's **Outside the Earth** which the author published in 1920. Leonov found the episode where the first space travellers "fly out of the rocket into surrounding space."

"This is more than a mere coincidence, this is the prediction of a man of genius," said Leonov. "Tsiolkovsky is accurate in details and absolutely correct in essence.

"He used different terms but words don't matter. Tsiolkovsky writes about 'light white overalls' which must be put on over the spacesuits for protection against sharp temperature changes. That is precisely what the white coating of our spacesuits was meant for.

"Tsiolkovsky wrote that before leaving the rocket the traveller had to sit for a while 'enclosed in a chamber like a small case' waiting until the air was evacuated. This was also correct.

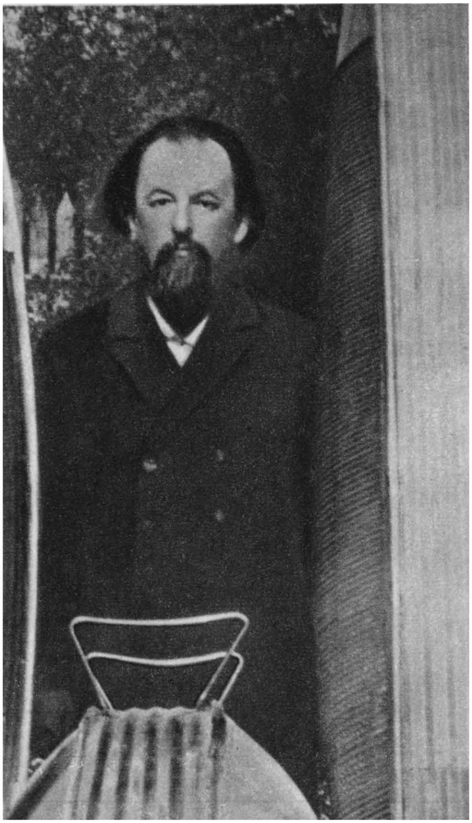
"He referred to the 'chain' necessary to prevent the cosmonaut from losing his spacecraft. And that chain was the lifeline which connected me to the rocket like an umbilical cord.

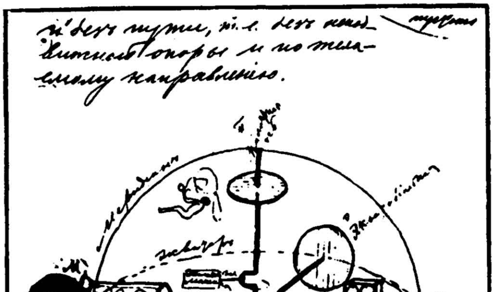
"At one point, however, I disagree with Tsiolkovsky. This is how one of his travellers describes his sensations: 'When the outside door was opened and I stood at the threshold of the rocket my heart sank and I made a convulsive movement which pushed me out of the rocket. It might seem that I would have got used to hanging without support between the walls of the cabin, but when I saw the abyss under me with no support whatsoever I fainted and came to only when the chain had been unwound to the end and I was a kilometre away from the rocket.'

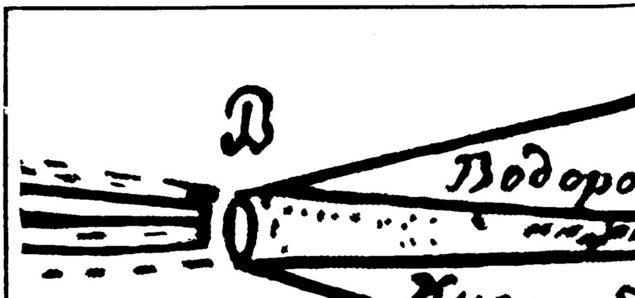
"It was also an emotional impulse that put me out of the rocket, but the sensation was joy and the state exhilaration. I felt no fear, nor did I feel sick. . ."

In the Visitors' Book astronauts Belyaev and Leonov made this entry: "Let mankind remember for ever the work and ideas of Konstantin Tsiolkovsky. It is a great pity that he cannot see with his own eyes his work and ideas being realized."

ILLUSTRATIONS

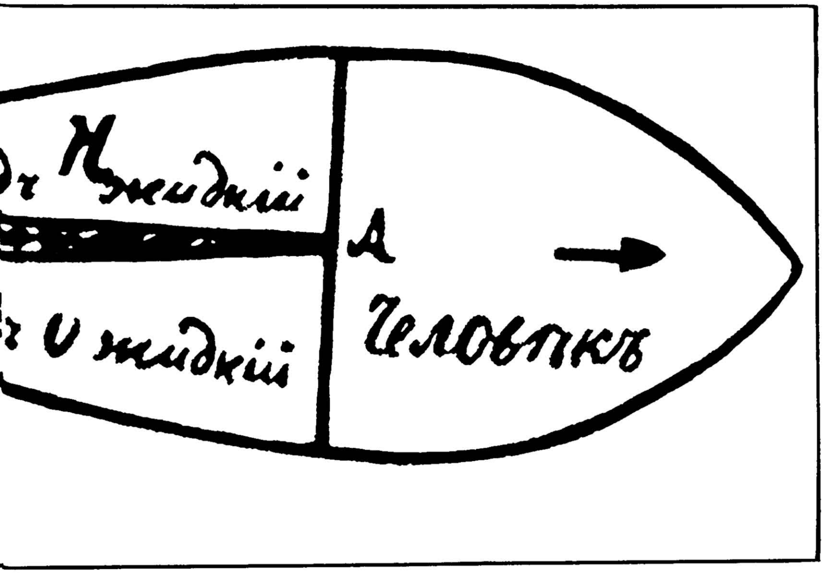





Д

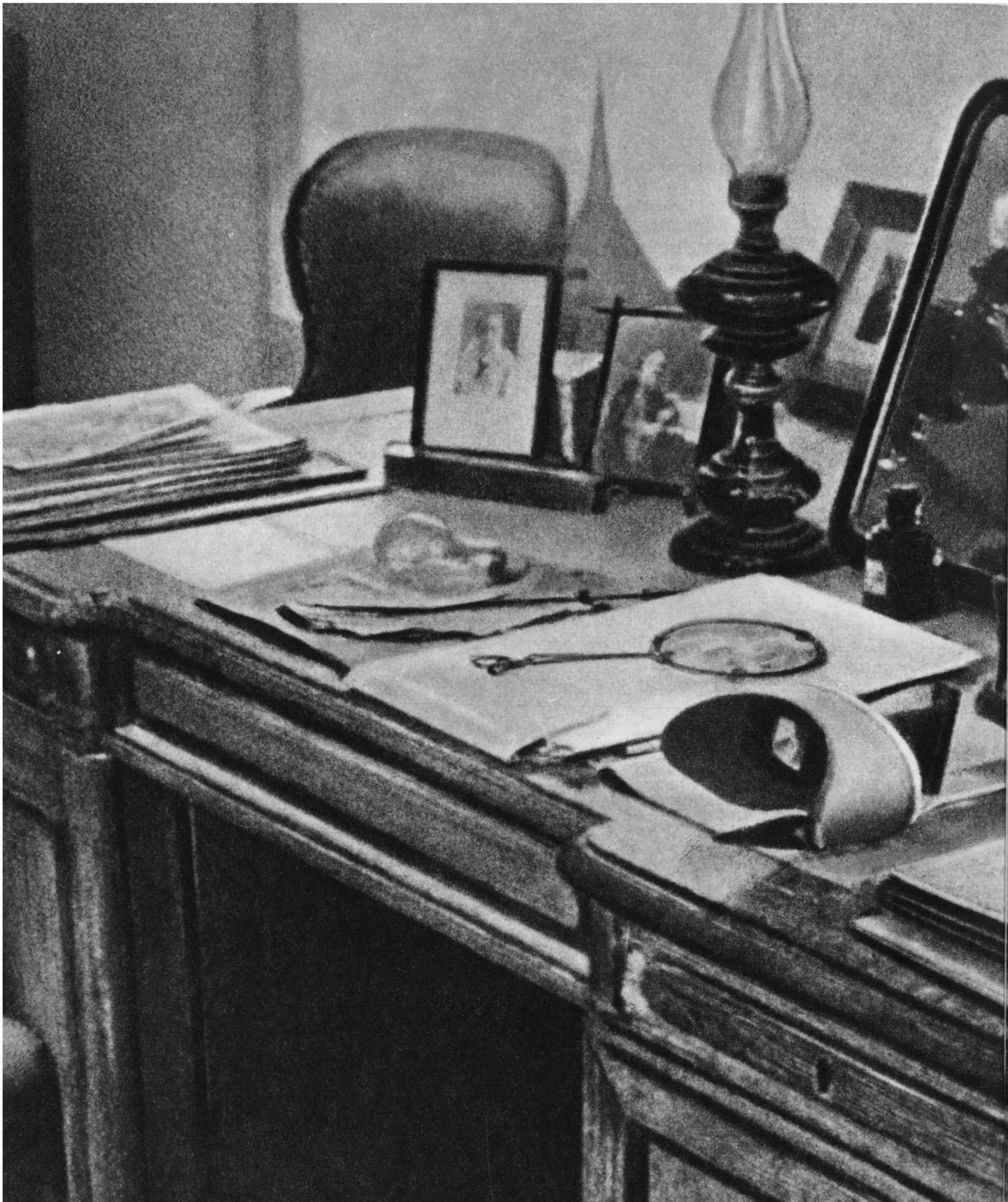
K. E. Tsiolkovsky.

The Tsiolkovsky Memorial Museum in Kaluga.

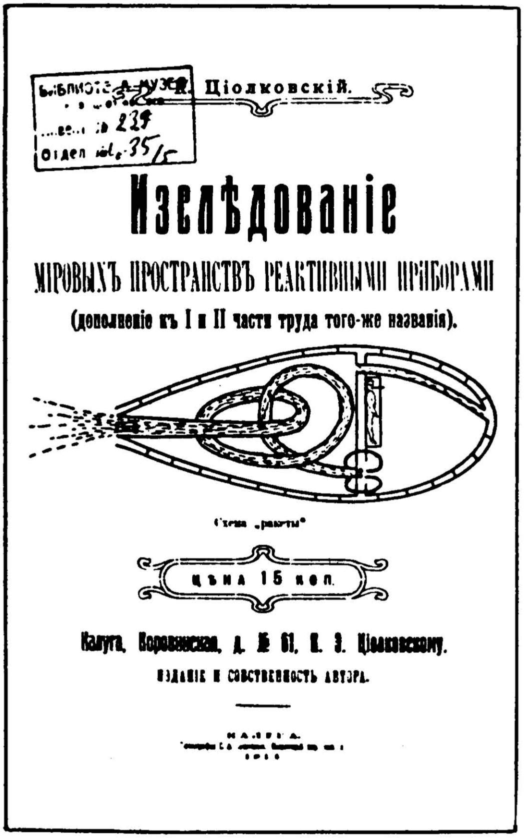


Drawing of a man in a state of weightlessness. Page from a manuscript by K. E. Tsiolkovsky.

Design of a jet apparatus by K. E. Tsiolkovsky.



Tsiolkovsky's study.



К. Ціолковскій.

Изслѣдованіе

мировыхъ пространствъ реактивными приборами

(дополненіе къ I и II части труда того-же названія).

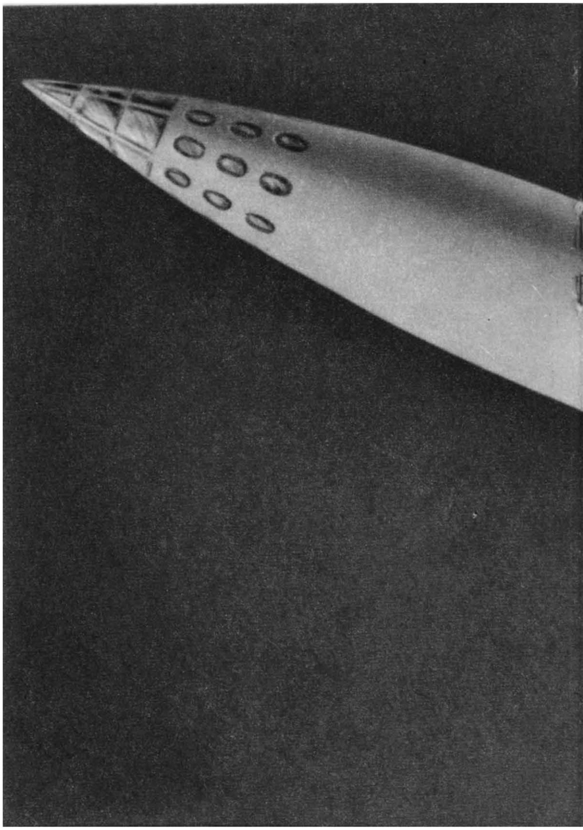
Схема „ракеты"

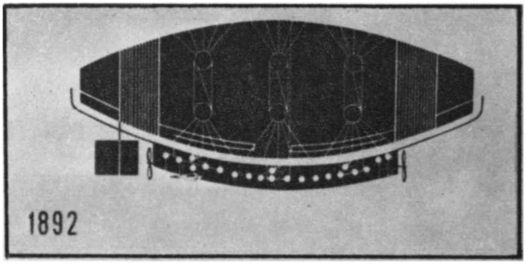
цѣна 15 коп.

Калуга, Коровинская, д. № 61, К. Э. Ціолковскому.

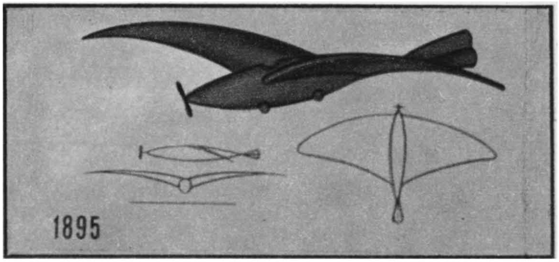
Изданіе и собственность автора.

Калуга.





1892



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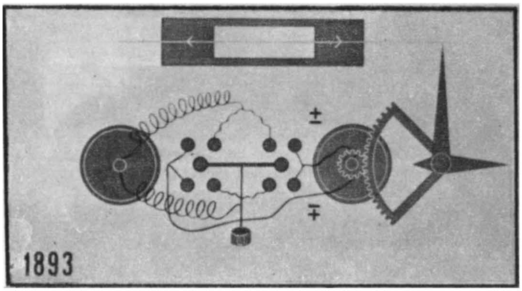

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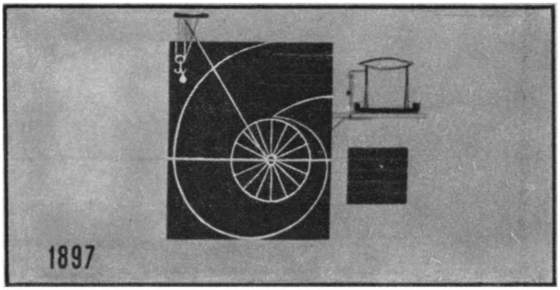
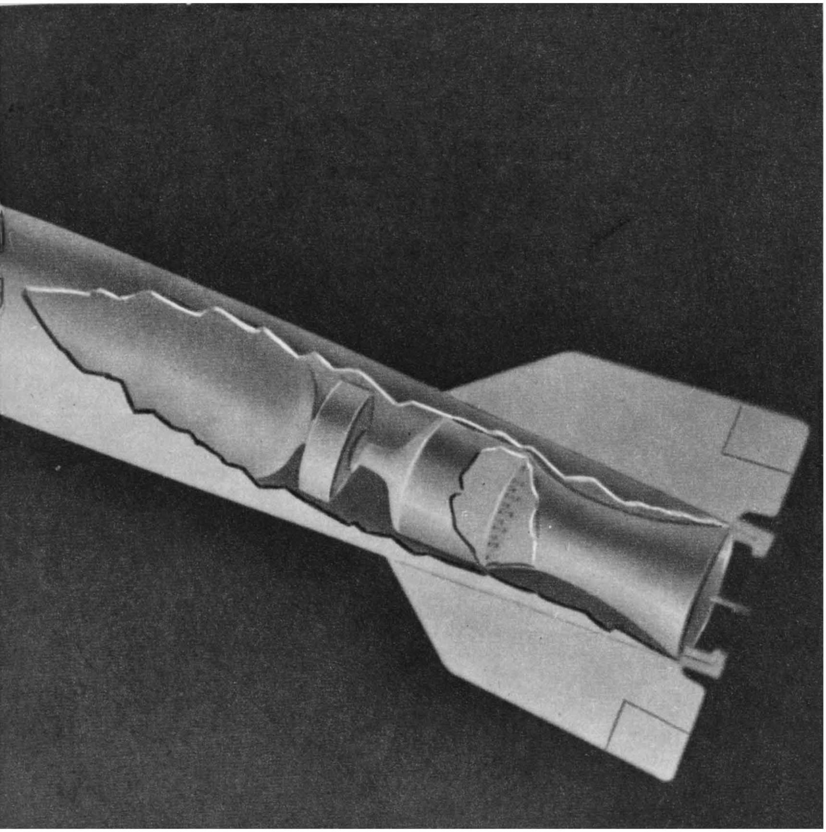
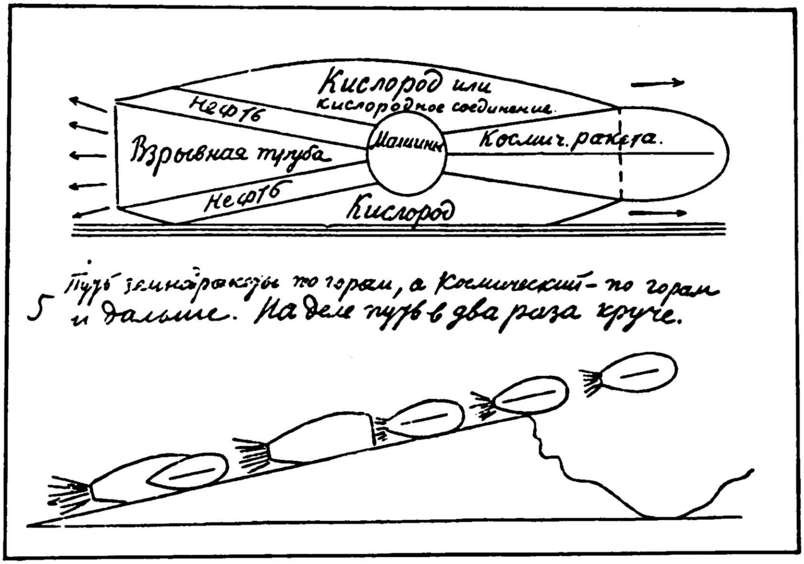


1897



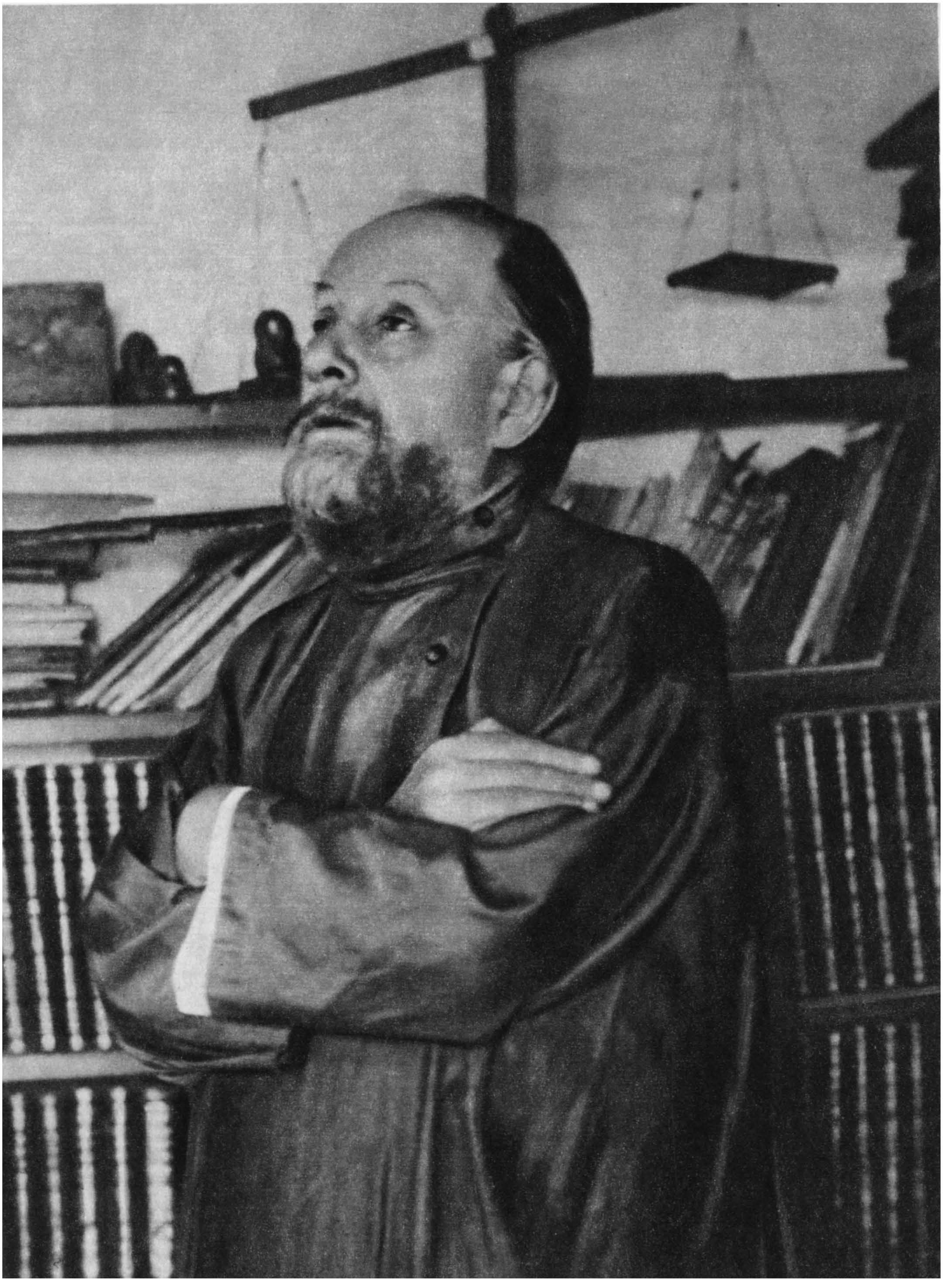
Title-page of Tsiolkovsky's book "Exploration of the Universe with Reactive Devices," published in 1911.

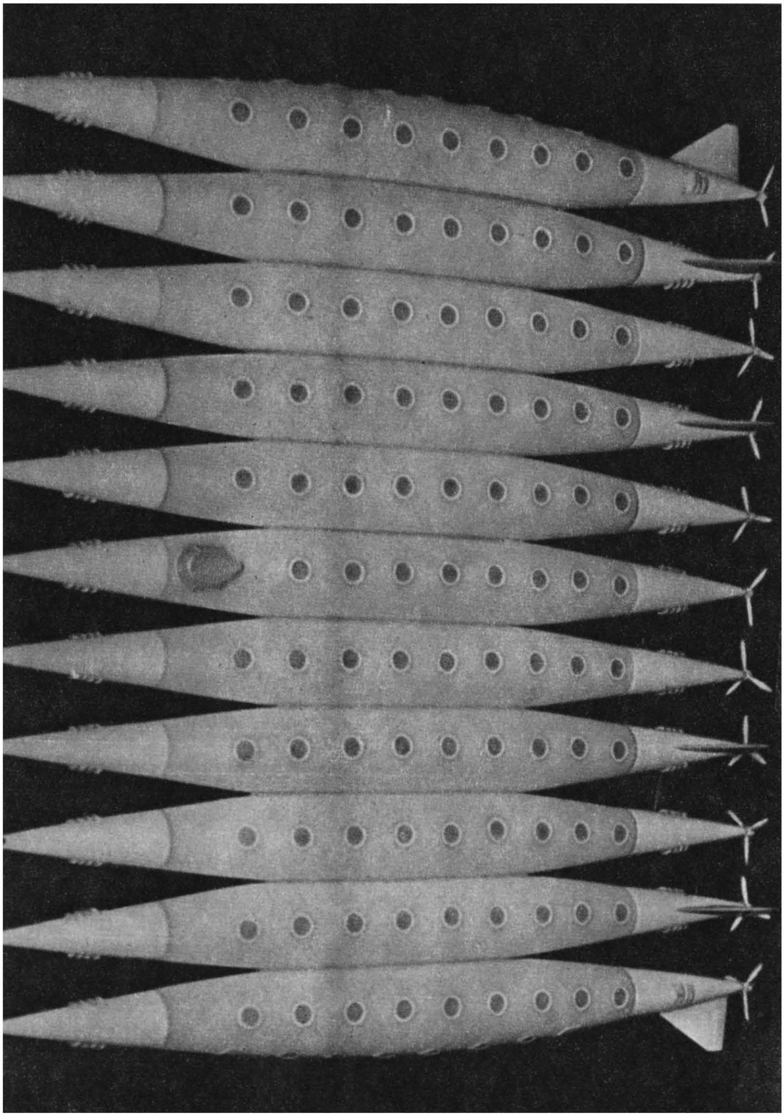
In 1911 Tsiolkovsky advanced the idea of utilization of radium decay energy in rocketry. Nuclear-propelled rocket.



Suggestions by K. E. Tsiolkovsky on aviation and air navigation. Model of all metal dirigible with a device to change the volume (1892). Diagram of a device for automatic control of aircraft—autopilot (1893). Sketch of aircraft with free supporting surface (1895). First honeycomb wind tunnel (1897).

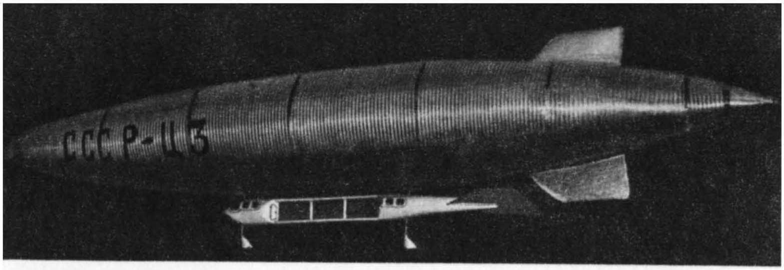
Diagram of space rocket launching. Page from Tsiolkovsky's manuscript.



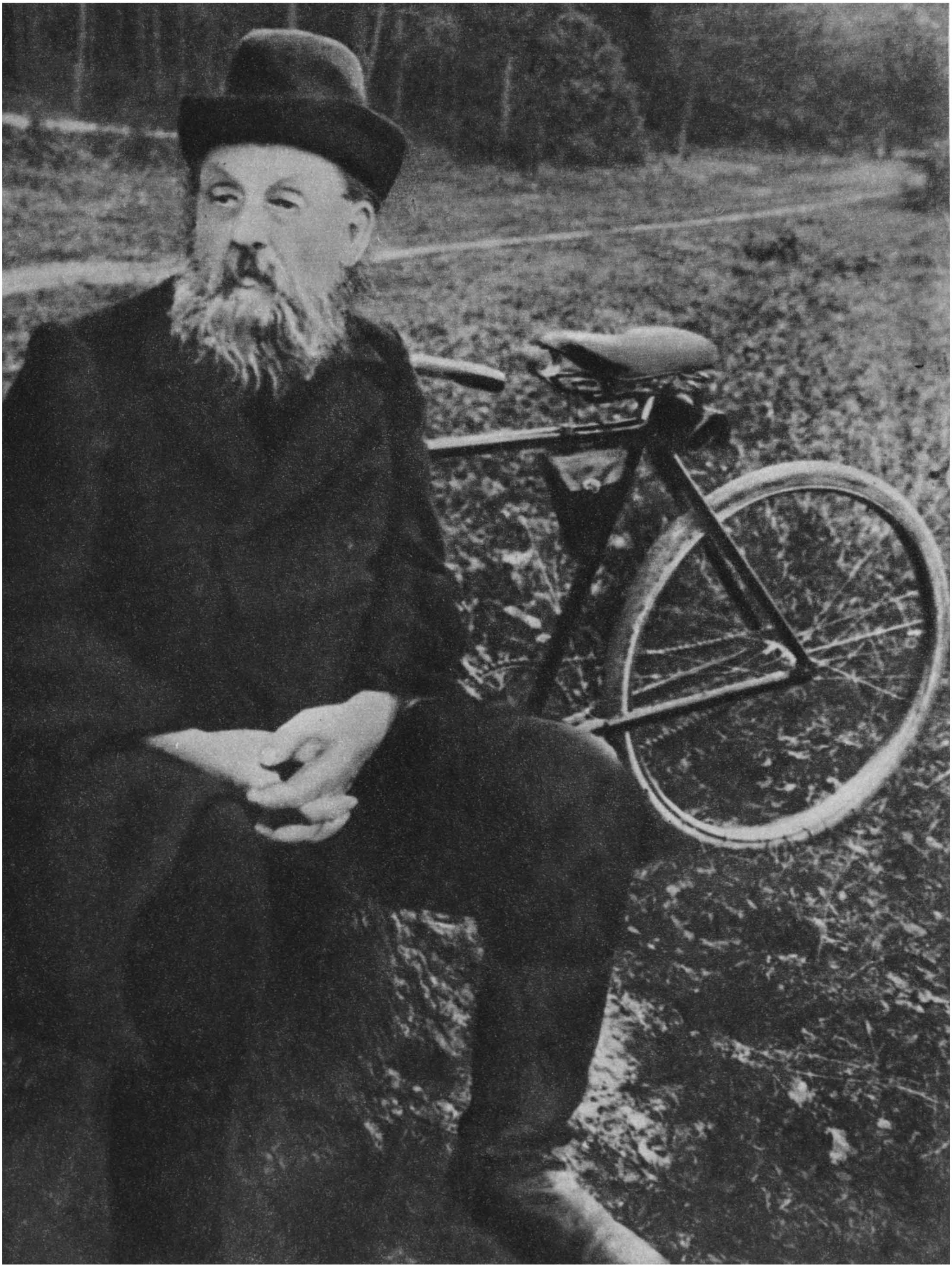


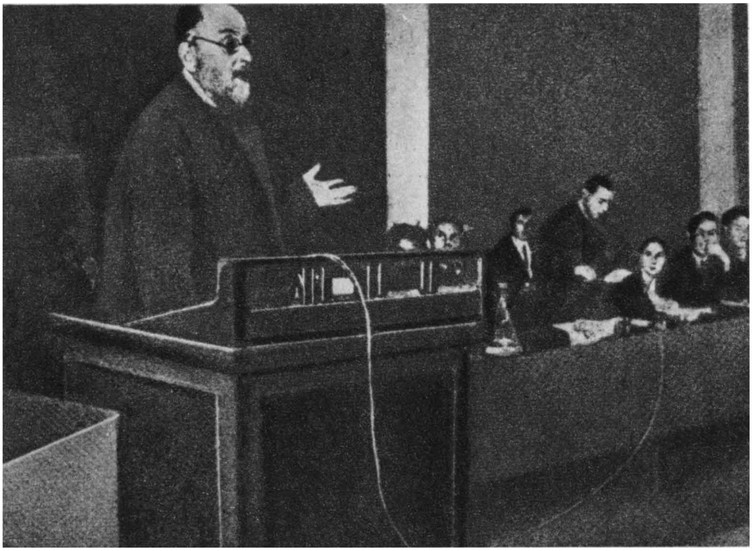
K. E. Tsiolkovsky in his study.

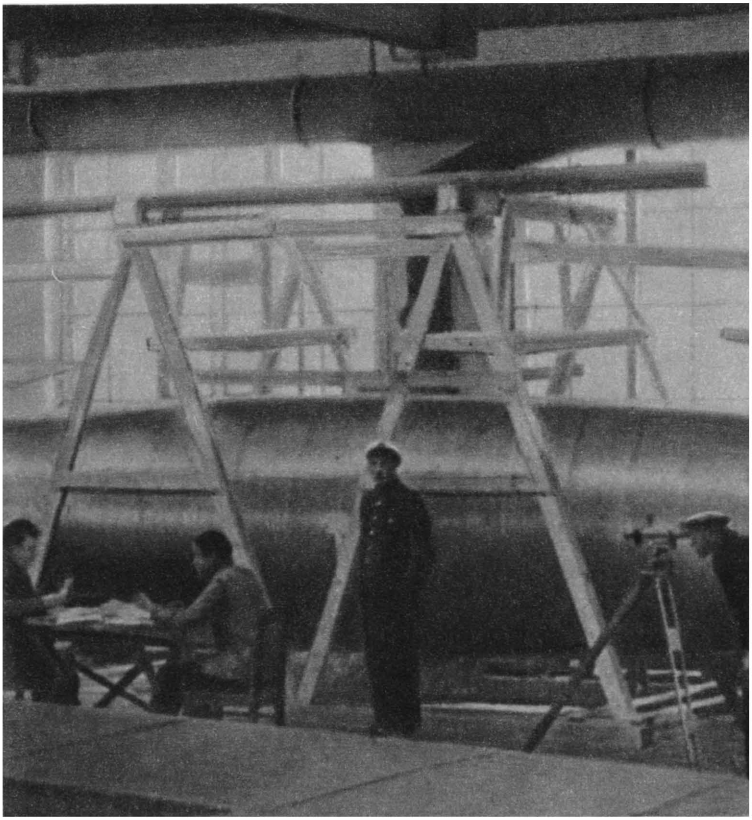
Sectional rocket, suggested by K. E. Tsiolkovsky in 1935.



Airship by K. E. Tsiolkovsky (model).



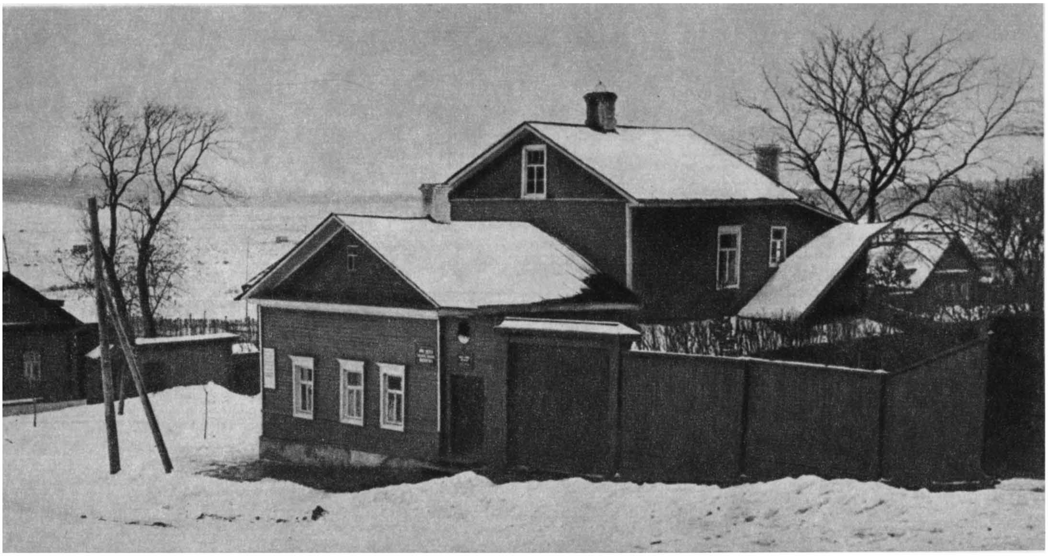


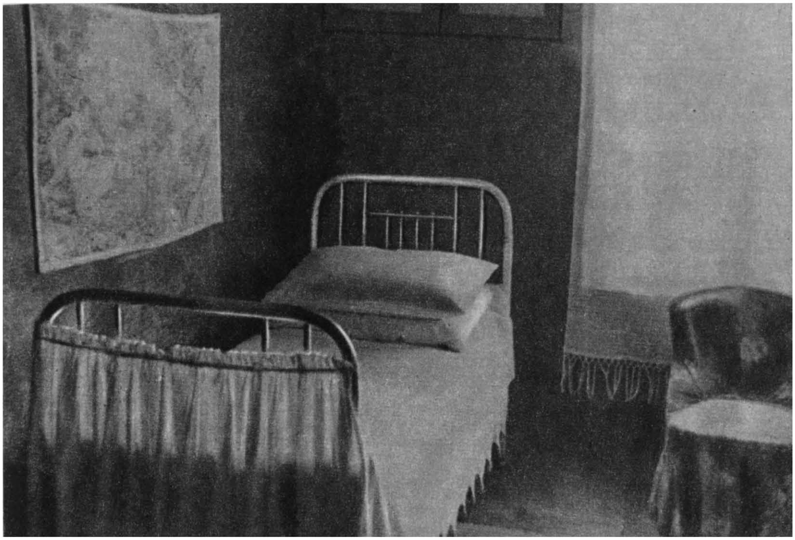


Taking a rest.

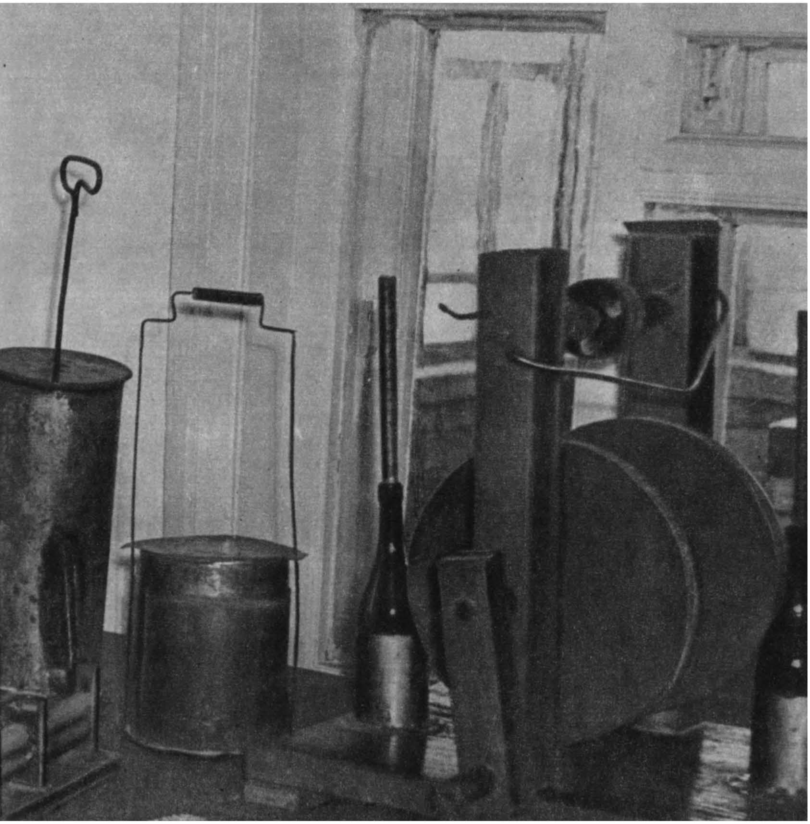
Meeting to mark Tsiolkovsky's 75th birthday. K. E. Tsiolkovsky addressing the meeting in the Hall of Columns, House of Trade Unions, Moscow.

Model of an all-metal airship designed by K. E. Tsiolkovsky is in the making.



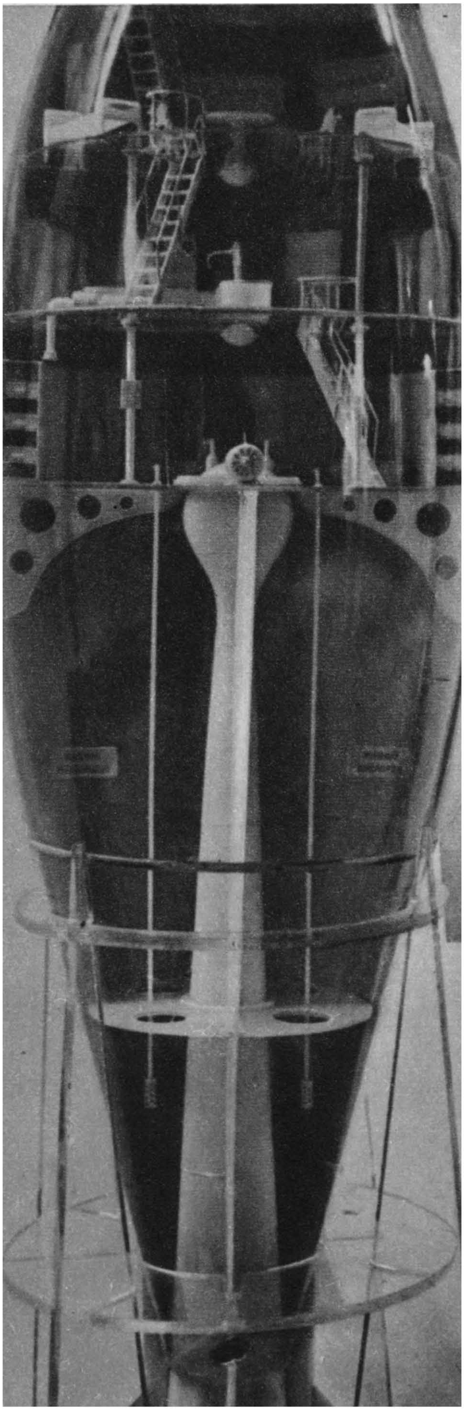


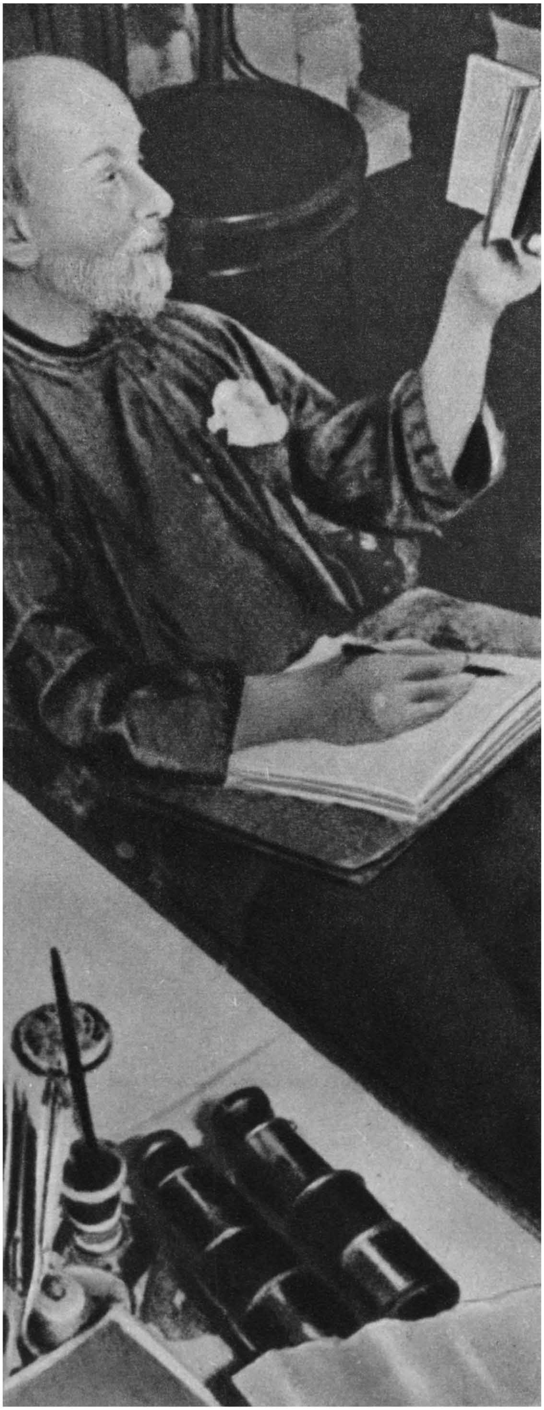
In this house in a quiet street on the outskirts of Kaluga K. E. Tsiolkovsky lived and worked between 1902 and 1914.

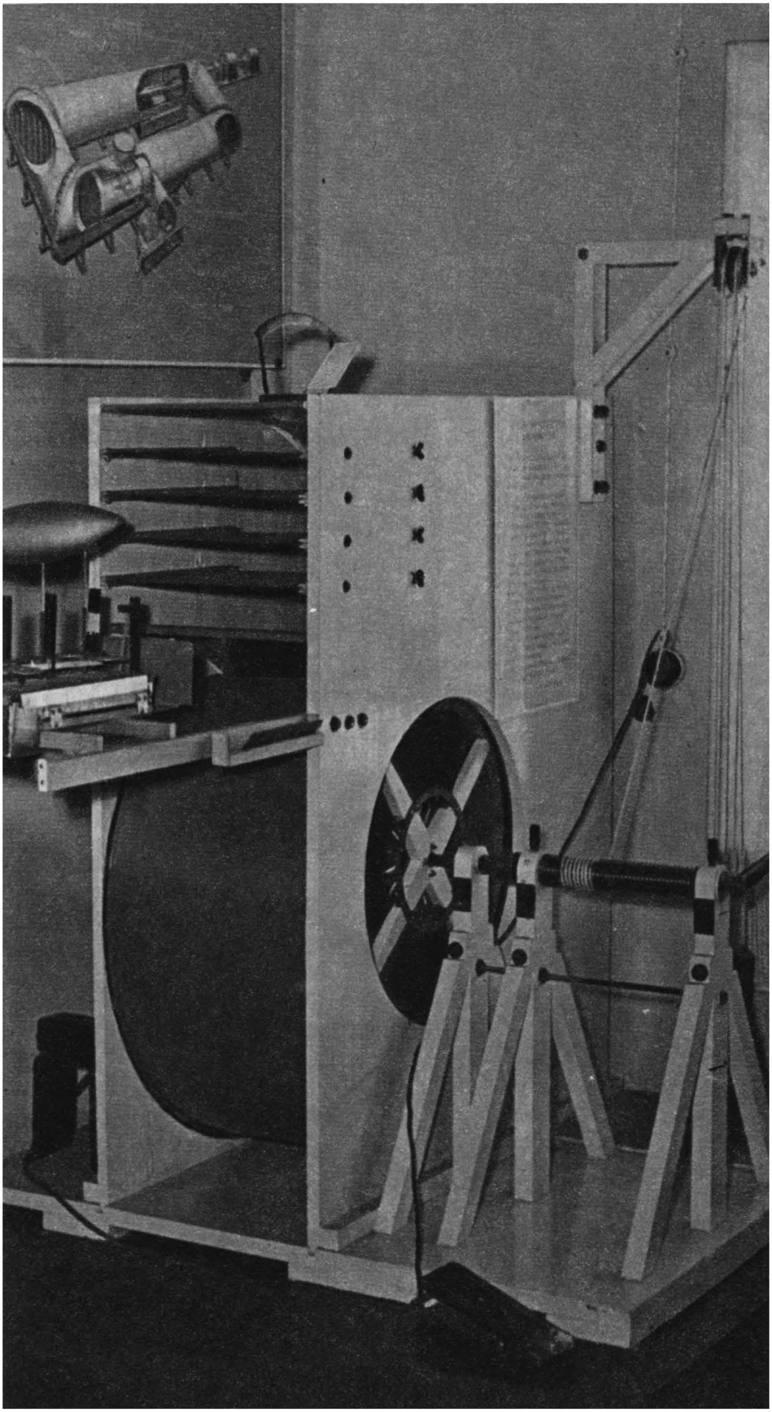


Tsiolkovsky's workshop.

The room where K. E. Tsiolkovsky lived and worked.



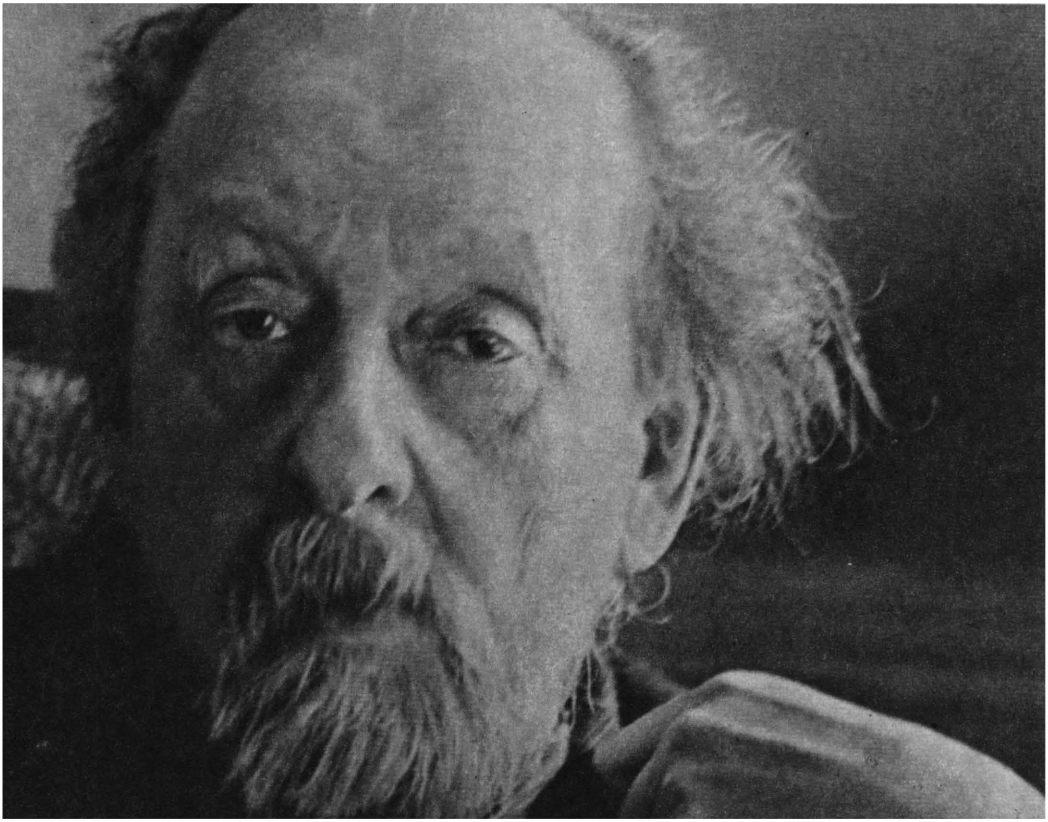




Rocket designed by K. E. Tsiolkovsky (model).

At work.

First honeycomb wind tunnel built to Tsiolkovsky's design.




РУССКИЙ ИЗОБРЕТАТЕЛЬ
1857-1957

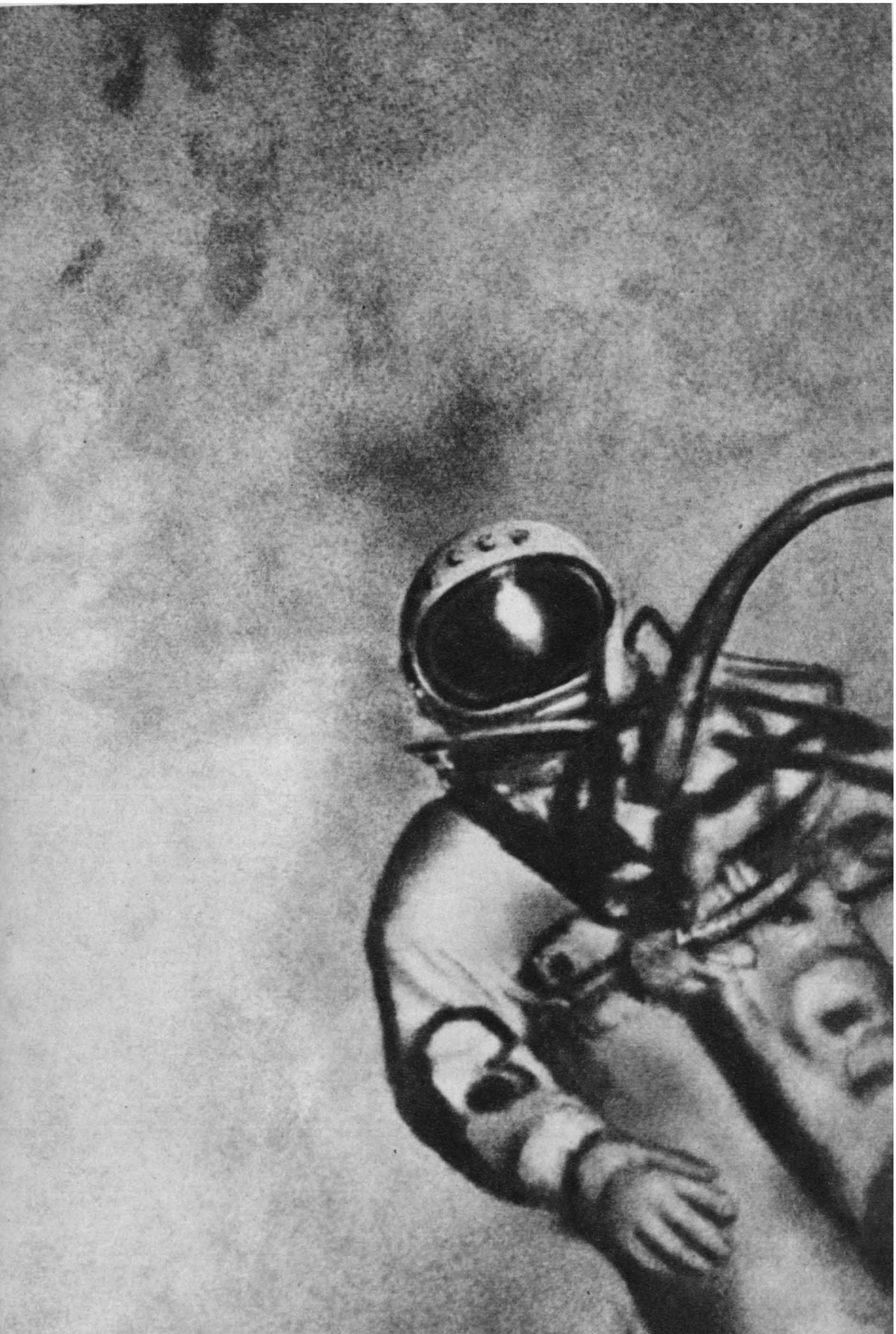

„Я верю, что многие из вас будут свидетелями первого заатмосферного путешествия"

Monument to K. E. Tsiolkovsky in Kaluga.

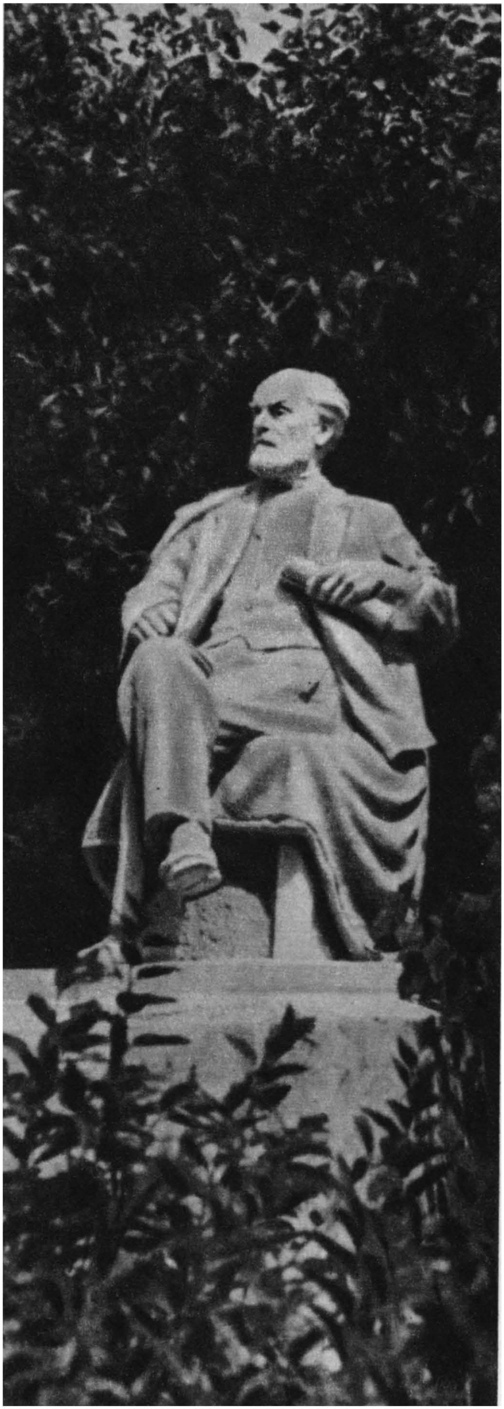
K. E. Tsiolkovsky in his last years.

Kaluga schoolchildren bring flowers to the site of the future monument to the scientist.

The Tsiolkovsky Medal instituted to mark the centenary of his birth.

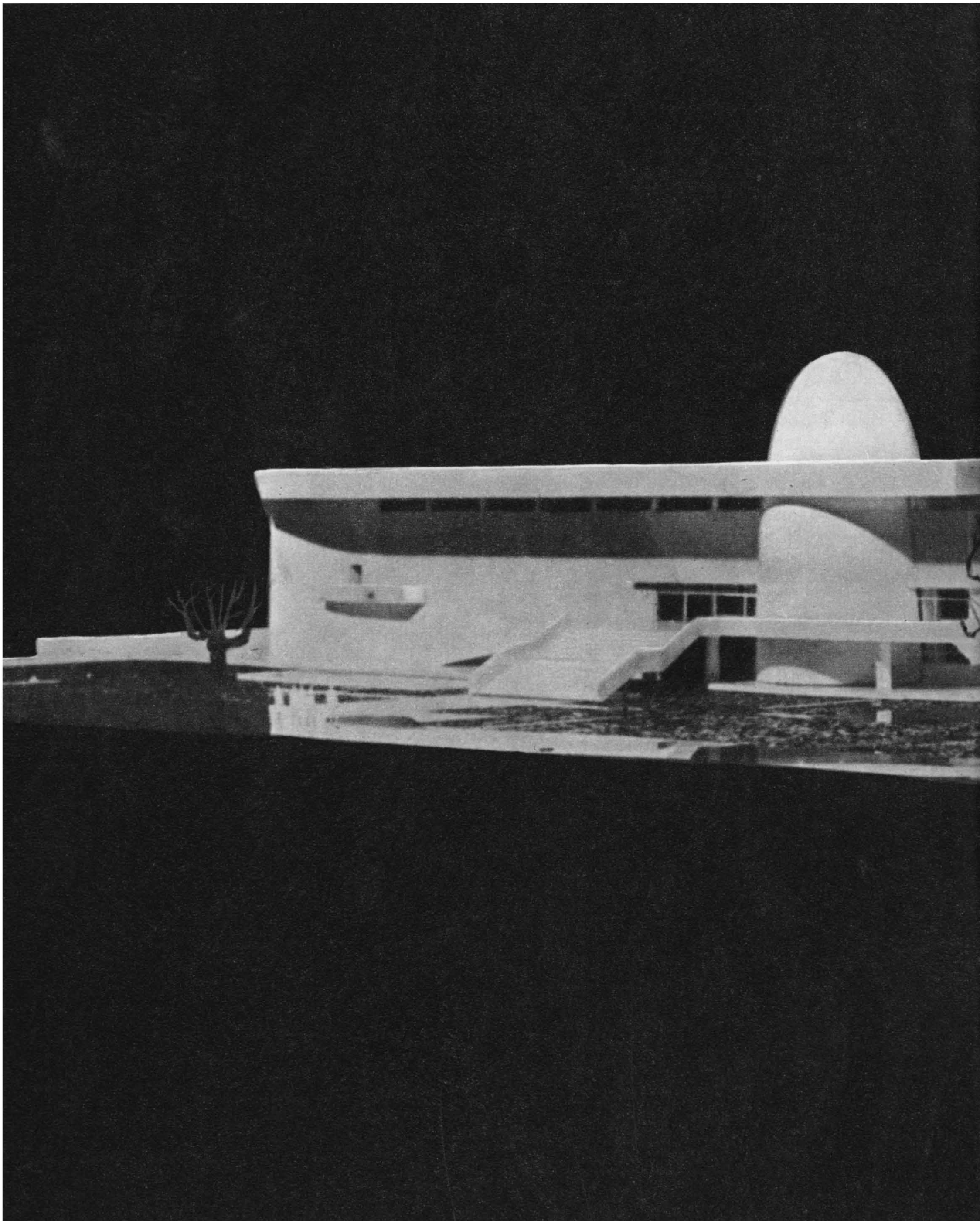


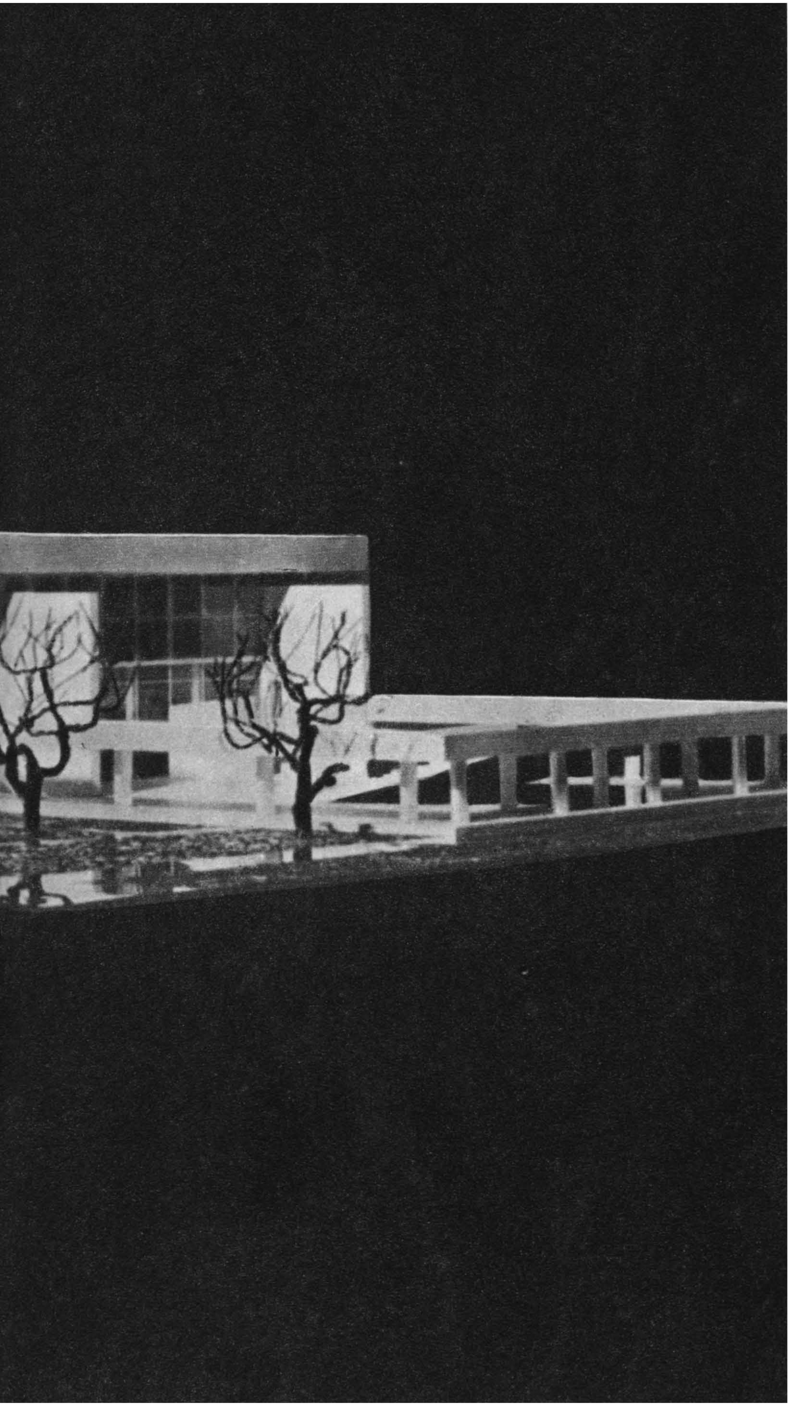
Into outer space.



The Tsiolkovsky family. From left to right: Lena Kostina, great-granddaughter of Tsiolkovsky; V. E. Kiselev, grandson; M. V. Samburova, granddaughter; Andrei Kiselev, great-grandson; and A. V. Kostin, grandson.

Monument to K. E. Tsiolkovsky in front of the Memorial Museum, Kaluga.

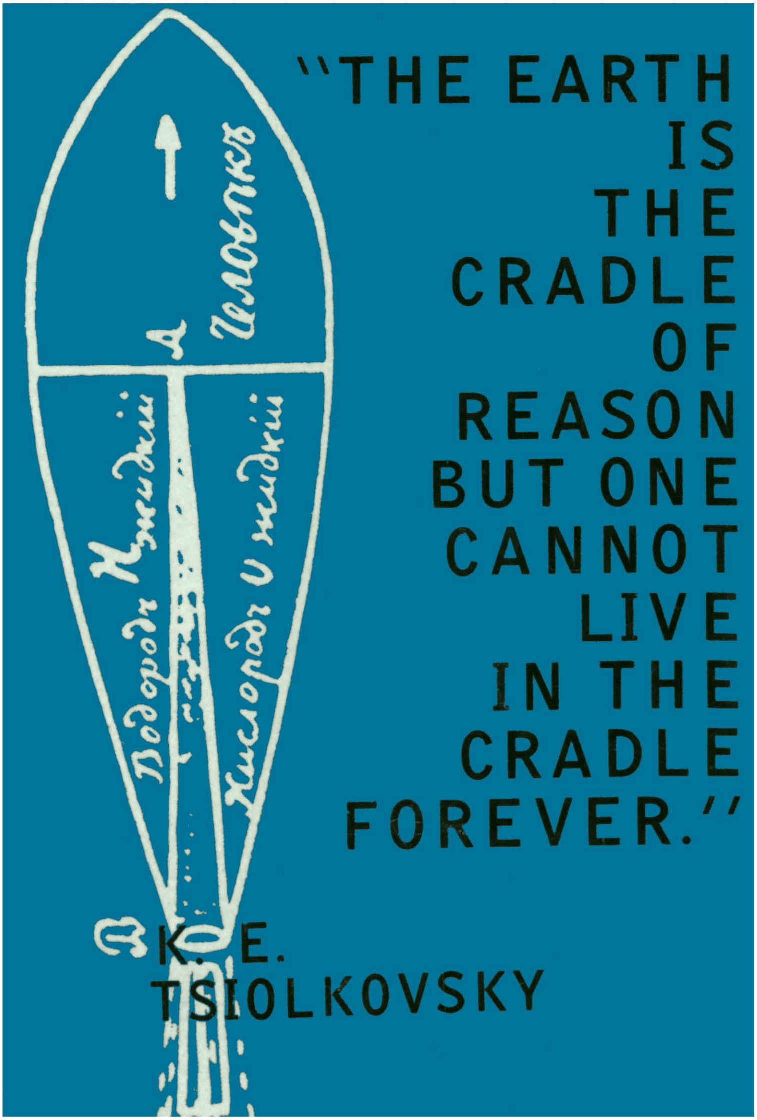




Design of a new building for the Tsiolkovsky Memorial Museum in Kaluga.

Коллектив авторов
К. ЦИОЛКОВСКИЙ
на английском языке

Novosti Press
Agency Publishing
House



"THE EARTH IS THE CRADLE OF REASON BUT ONE CANNOT LIVE IN THE CRADLE FOREVER."

K. E. TSIOLKOVSKY