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Tsiolkovskii and Our Times

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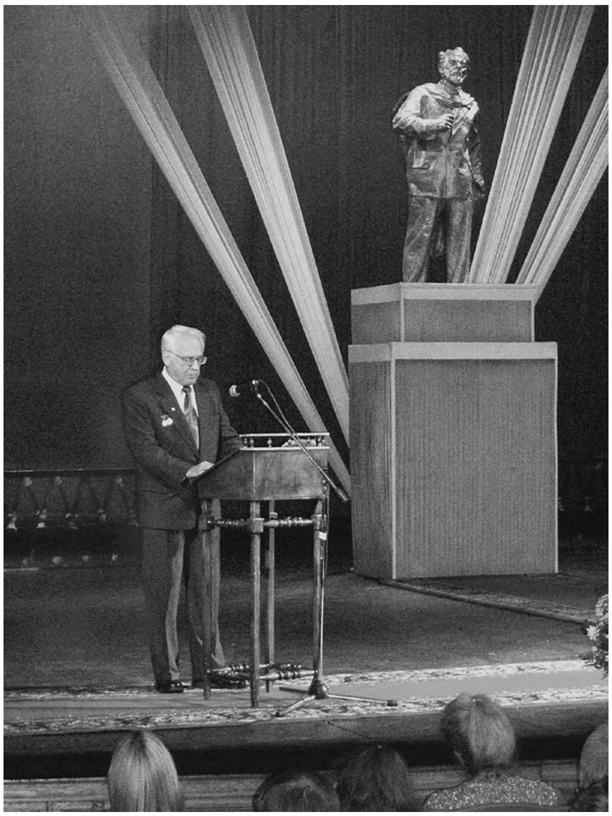

Today we are commemorating a remarkable date in the history of both Russian and world science and culture: the 150th anniversary of the birth of our outstanding compatriot Konstantin Eduardovich Tsiolkovskii.

Tsiolkovskii is a truly unique phenomenon. The scope of his scientific interests is impressive in its breadth, and his scientific legacy is enormous and diversified. His searching mind was able to reach various areas of natural science, technology, philosophy, and sociology. We feel equally amazed and fascinated by how this diversity of interests and originality of judgments could come together in the creative activity of a single person. Academician A.E. Fersman once said wonderful words about these surprising qualities:

> Scientific and literary creativity is inseparable from its creator's personality and life, and this is especially true of Tsiolkovskii's works, which are completely inseparable from their author's personality and from his entire inwardly focused figure; for him, there are no separate concepts of science disjoined from universal concepts; everything is united in his ideas; everything merges into the great unified laws of the universe and the human being.

The above noteworthy characterization of Tsiolkovskii's phenomenon can be complemented by his surprising gift of vision and his ability to find in his logic a distant perspective of the grandiose horizons of knowledge open for humankind and the possibilities to embody it in reality. Therefore, we have every right to say that his works are directly related to contemporaneity.

We can distinguish several periods in Tsiolkovskii's life and activity, which differ in the way his personality and creativity were perceived. In the mid-1930s, his name was associated with such attributes as "a famous worker of science" and a scientist in aeronautics, aviation, and interplanetary travel. In the late 1950s, after the Soviet Union launched the Earth's first satellite, he was referred to as an outstanding scientist in rocket engineering and rocket dynamics. By the mid-1980s, he had acquired the glory of the founder of theoretical cosmonautics. Finally, at the turn of the millennia, when his philosophical, sociological, and world-outlook works were published, many of which had remained in manuscripts, another aspect of his creative activity became public, and he was ranked among the fathers of the philosophy of cosmism.

Tsiolkovskii was interested in the problems of aeronautics and aerodynamics during his lifetime. He gave a special importance to the applied aspects of aerodynamic studies, primarily their support in creating airplanes and, in particular, airships. He tried to establish regularities for atmospheric flights, designing original schemes and constructing models of airships and simple aerodynamic installations for experiments in his workshop. According to the experts of the Zhukovskii Air Force Engineering Academy, the above studies' results are not only of historical value but also of great theoretical and applied significance. It is sufficient to mention, in addition to airships, his publication of 1894, *Airplane or Birdlike Flying Machine.* It contained his thoughts, in particular, about ways of decreasing aerodynamic resistance and prospects for using airplanes with internal-combustion engines and aluminum-based alloys, as well as aviation gyroscopic autopilot and coaxial propellers.

However, of course, his principal and universally recognized work among all others was his development of the problems of space travel using jet propulsion. His studies in rocket dynamics and cosmonautics are a treasury of original ideas, which were much ahead of their time and which preserve their significance today.

From his youth until his last days, Tsiolkovskii dealt with space exploration and the creation of rockets. “The main ideas and love for ever reaching there, the Sun, and freedom from the chains of gravity have been rooted in me almost since my birth,” he wrote in 1911. His thought about the use of the jet motion principle for spaceflights and establishing “settlements beyond the atmosphere” appeared already in 1883 at the very start of his scientific activity in his manuscript “Free Space” (he used this term to describe the absence of gravitational forces and environmental resistance). We find there the following words: “Generally, curved even motion or straightforward uneven motion is associated in a free space with a continuous loss of substance (support).” Therein we find a series of considerations on the character of a body’s motion in a free space. In addition, the idea of space control was first expressed: “a barrel is given that is filled with a very compressed gas,” and Tsiolkovskii suggested controlling its motion using six “very fine faucets.” From the height of contemporary knowledge, this may seem primitive, but we must not forget that this idea dates back to the late 19th century, when the author was 25, while the practical need for orienting Earth’s artificial satellites and spacecraft appeared half a century later, and nozzles with pressurized air are a clear embodiment of Tsiokovskii’s idea.

The idea to explore outer space was further developed in a science-fiction story by Tsiolkovskii *Dreams about the Earth and the Sky and the Effects of Universal Gravity*, published in 1895, in which he expressed his idea about the possibility to create an artificial satellite of the Earth, not as a mathematical illustration of the universal gravity law, discovered by I. Newton, but as a real object. He wrote, “An imaginary satellite of the Earth, like the Moon, but arbitrarily close to our planet, just outside its atmosphere, that is, about 300 km from its surface (with its very small mass), is an example of a weightless medium.” Note that the idea of launching a satellite into orbit made its way with a certain difficulty even in the late 1940s and early 1950s, and there were many skeptics (among scientists too!) who doubted the very possibility of launching it.

Tsiolkovskii laid the foundations of theoretical cosmonautics, which he was consistently developing, beginning from his classical work *Investigations of Outer Space Using Jet Machines,* first published in 1903 and then, with many amendments, in 1911–1912. Analyzing and discarding the before-known ways of “taking-off beyond the atmosphere,” Tsiolkovskii suggested, as he defined it, a “jet device, namely, a kind of a rocket, but grandiose and specially structured.” “This thought is not new,” he wrote. “But the relevant calculations give such remarkable results that not disclosing them would be a big sin.” He insistently stood for the possibility of reaching space with a jet draught on chemical fuels, convincingly debating with skeptics, including, in particular, a famous French aviation designer R. Esnault-Pelterie, who stated faultily that a manned spaceflight would be impossible without using nuclear power.

Tsiolkovskii obtained a remarkable result, deriving and analyzing in detail the simple ratio that is now widely known as Tsiolkovskii’s formula. It establishes the dependence of the final velocity of a rocket in its straightforward motion in a free space on the exhaust velocity of the products of combustion and on the ratio of the initial mass of the rocket to its final mass (in the contemporary language, on the design and power parameters of a flying apparatus). It was thus concluded that in empty space a rocket’s final velocity is theoretically unlimited; so, it is possible to break the “gravity chains.” Note that, almost simultaneously with Tsiolkovskii, a study of the motion laws for a point of a variable mass was conducted by our outstanding mathematician and mechanic I.V. Meshcherskii, but unlike Tsiolkovskii, he did not see the grand prospects that these ratios opened for rocketry.

It proceeds from the Tsiolkovskii formula that there are only two ways of increasing a rocket’s final velocity: to increase the exhaust speed of combustion products and to increase the ratio of the initial mass of a rocket to its “dry” mass together with its useful load, that is, to decrease the relative mass of the construction. As Academician B.V. Raushenbakh noted, “the eminence of Tsiolkovskii is not at all in the fact that he derived some elementarily simple formula. Many had known it for a long time, but Tsiolkovskii was the first to show that this formula was opening a road to space.”

Later on, Tsiolkovskii firmly and consistently sought ways to help empirically achieve certain cosmic velocities to bring nearer the time of the first space missions. He made some calculations that allowed him to make a series of suggestions very principal for rocket engineering, and almost all of them would be in demand and would find their use in particular designs. It is sufficient to list some problems included, for example, under the working plans of the Group of Engineers for Studying Jet Motion and the Jet Research Institute in the 1930s: the use of liquid oxygen as an oxidizer in combination with various propellants, primarily with hydrogen and hydrocarbons; the creation of an all-metal liquid rocket engine with through cooling by one of the propellant’s components and a liquid rocket engine with ceramic thermoinsulation of the inside surface of the combustion chamber; the development of a pump feed for liquid fuels; and the creation of a rocket-plane with a liquid rocket engine and a controlled winged rocket.

Numerous calculations drove Tsiolkovskii to the conclusion that achieving the cosmic velocity by "a single" rocket is a technically difficult-to-solve problem, that is why he suggested to use combined rockets. Initially he studied a combined rocket with successively joined stages (a "rocket train," as he defined it). Although this pattern was earlier suggested by other researchers, Tsiolkovskii was the first who formulated in his work *Space Rocket Trains*, published in 1929, the structural principles and flight theory for such rockets. Continuing to develop the idea of combined rockets, he came to the thought of launching similar rockets in parallel and called this method a "squadron of rockets."

He studied the dependence of the final velocity of the "last" rocket on the number of rockets, gas exhaust velocities, and relative fuel masses and efficiencies, or, in his terminology, "the percentage of heat utilization." The number of stages turned out to be too great "for wandering," as Tsiolkovskii wrote, "amid the suns of the Milky Way," but he added, "the main goal is to fly beyond the Earth's atmosphere and to get fixed there as its satellite. A further increase in velocity can be achieved through other ways and much more easily than on the Earth." How can we avoid mentioning here the fact that interplanetary vehicles start off from the intermediary orbit of an artificial satellite of the Earth!

Undoubtedly, Tsiolkovskii's works on multistage rockets had equally principal importance for the development of space rocketry as his suggestion to use a liquid rocket engine. The task of designing multistage rockets became really in demand in the late 1940s and early 1950s. In our country the "squadron-rocket" scheme was taken as the basis, and the use of stages joined in parallel resulted in the "magnificent seven," designed by Academician S.P. Korolev, an outstanding designer of space rocket systems and a follower of Tsiolkovskii's ideas. Various modifications of the above rocket still operate successfully. Our other designers and the Americans made their choice in favor of "rocket trains," that is, schemes with the successive location of stages, while European and Chinese designers preferred the bundle of rockets.

Considering humankind's passage into outer space and "farther to the stars" inevitable, Tsiolkovskii tirelessly sought a way to increase the rocket's escape velocity. Already in his works from 1911–1912, he questioned himself if "it is possible, using electricity, to impart an enormous velocity to the particles expelled from a jet device." He developed this idea later in the work *Spacecraft*, which contained considerations about the possibility to use the disintegration energy of radioactive particles, solar light pressure, and cathode and anode rays and in which he came very close to the idea of creating electric jet engines. F.A. Tsander and Yu.V. Kondratyuk studied the same problem in those years. That first research prepared the base for creating low-thrust engines, which are now widely used in spacecraft orbit orientation and correction systems. The use of such engines for missions to planets and small bodies of the solar system will open breathtaking prospects. In particular, the Lavochkin Research and Production Association has developed the new-generation basic space vehicle for planetary studies *Fobos-Grunt*, which, equipped with low-thrust engines, will be able to fly to comets and return their rock samples to the Earth.

Tsiolkovskii suggested using solar light pressure for interplanetary spaceflights, installing "big light mirrors for gaining considerably higher added velocities" and thus "traveling for free across the solar system." In fact, this is the idea of spacecraft moving with solar sails, and attempts are now being made to implement it. A variation of Tsiolkovskii's idea of photon rockets was his suggestion to transmit energy from the Earth to a space vehicle with a parallel bundle of electromagnetic rays. Tsiolkovskii characterized his suggestion as the "most attractive way of acquiring a velocity" and described its practical implementation. So far, this is a goal for the future, but its variation may be implemented, in a much nearer perspective, as the transmission of electric energy from orbital solar power stations to the Earth.

The idea of a *manned flight into space* passes as a bright motif through Tsiolkovskii's whole creative life. He considered the main problems related to the implementation of such flights and expressed a series of ideas, many of which have already been implemented. In his early works he depicted a spaceflight as if he had personally participated in it and had seen all with his own eyes; he described the conditions of human existence in a spaceship's cabin, predicted problems that people would encounter there, and suggested ways to resolve them. In particular, apart from the closed cycle of a life-support system, he suggested a double-layer wall for a spaceship to protect it from overheating and overcooling, as well as from the impacts of meteorites. He considered a water-filled "case of nearly the same shape and volume as the tested object" for "saving from enforced heaviness," while, for combating weightlessness, he suggested creating gravity artificially by rotating the space vehicle.

Tsiolkovskii predicted the creation of orbital stations, as he wrote, "with all appliances for the life of rational beings," which "can serve as a base for future human colonization." This is exactly the mainstream of manned cosmonautics, beginning with our first orbital Salyut stations via Mir towards the currently functioning International Space Station. Tsiolkovskii described the design of an airlock and a spacesuit for coming out into open space. He foresaw the creation of orbital constructions, the elements of which are delivered to space folded and then are unfolded and assembled in orbit, which has already been practiced and, certainly, will be practiced on a larger scale.

Tsiolkovskii focused particularly on the problems of living in space. He dreamed of dissemination of "a human being across the ethereal space," of the "masses colonizing, every place like asteroids and lesser bodies," and he dreamed that "with time people will conquer planets, but this goal is very distant, and even to talk about it is too early so far." However, the reality made its corrections: already in the early 1960s, Korolev proposed a design of an interplanetary spaceship for a manned mission to Mars, which was based on Tsiolkovskii's ideas. Now the world's space agencies include manned missions to Mars in their space exploration programs.

Tsiolkovskii was a greatest humanist. He wrote in 1913: "The main motivation of my life is to promote humankind at least a little forward …. I hope that my works will give, maybe soon or maybe in the distant future, mounts of bread and depths of power to the community." He believed that the key objective was the improvement of humankind and the creation of new conditions for the life of society. He was convinced that the ultimate objective in exploration of the entire near-the-sun space was humanity's chance to elevate to a much higher development stage.

In the twilight of his life, addressing his sympathizers in the matter of space exploration, he wrote: "So far this activity is unrewarding, risky, and extremely difficult. It will require not only an excessive strain of forces and gifts of genius, but also sacrifices." He proved right in many points. He wrote in his *Spacecraft*: "I am going to play the leading solo. More learned and capable mathematicians will, possibly, finish solving the problems that I raised. Learned and experienced engineers will help them implement the spacecraft itself." He fully succeeded in "playing the leading solo" and not only in his native country. "You have lit the fire, and we shall not let it extinguish, but we will apply all our efforts to implement the greatest dream of humanity," a famous German scientist and a pioneer in rocket engineering and cosmonautics H. Oberth wrote to Tsiolkovskii in 1929.

It is worth mentioning that among the pioneers in cosmonautics—Tsiolkovskii, Goddard, and Oberth—the name of our compatriot is always cited first. W. von Braun, recognizing Tsiolkovskii's priority in theoretical cosmonautics, wrote in 1966: "The Russian scientist Tsiolkovskii was the first who realized and solved the idea of using a rocket for spaceflights." Three years later, he would write, paying tribute to Tsiolkovskii's practical ideas, that "the knowledge of fuels, chemistry, and jet motion, which his works contained, became our starting point for creating the engines of the Saturn-5 rocket, used for the Apollo space missions to the Moon."

To become acquainted with Tsiolkovskii's life and works, many cosmonauts and astronauts visited Kaluga; among them were the participants of the Soviet–American joint space project Soyuz–Apollo, and 88-year-old Oberth also came there. Neil Armstrong, the first man to step on the lunar surface, who took part in the COSPAR session in Leningrad in 1970, left the following autograph on Tsiolkovskii's book *Dreams about the Earth and the Sky and the Effects of Universal Gravity*: "I was greatly honored to take part in the implementation of his dream—the deployment of man on the lunar surface in the Sea of Tranquility."

Speaking on the radio in 1935, Tsiolkovskii said: "I have worked for 40 years over a jet engine, and I thought that a walk on Mars would begin in many hundreds of years. But times change. I believe that many of you will witness the first transatmospheric voyage." His prophecy came true. Yuri Gagarin made his flight when many of those who heard Tsiolkovskii were still alive. It is truly wonderful how Tsiolkovskii himself envisioned the first cosmonaut: "I could describe him without difficulty, so close and understandable is he to me. He is Russian. I have no doubt about it. I said so many times. He is a citizen of the Soviet Union. He is most probably a professional pilot. He is young, physically strong; his muscles and mind are harmoniously developed. I see his Russian open face and eyes of a falcon." This is exactly how our Gagarin appeared before the world.

The contemporary progress of cosmonautics is really impressive; space is penetrating still deeper and more sensitively into our daily life, constantly extending the horizons of knowledge; and the mysterious secrets of nature are opening to us. We believe that in the near future humans will begin to colonize the Moon, and that a mission to Mars will happen in tens of years, not in hundreds of years from now, and that our children and grandchildren will witness this event.

Our task is to preserve in the future generations' grateful memory Tsiolkovskii's basic contribution to humanity's exploration of the boundless spaces beyond our own planet and, at the same time, pride in our country, which gives birth to such great sons as Tsiolkovskii.