The arduous life and prescient insight of Russia's largely unknown space visionary.

By Aimée deChambeau

Struggles of the "Father"

Known today as the father of Soviet cosmonautics rocketry, and space flight, Konstantin Eduardovich Tsiolkovsky traveled a long, difficult road to his place in history. Geographical isolation, poverty, deafness, and an indifferent scientific community had to be overcome before Konstantin Eduardovich would be recognized for his genius and contributions to various scientific disciplines. The driving force behind this man was a genuine desire to help mankind. About himself, Tsiolkovsky wrote: "The basic motive of my life is to make something useful for people, not to live my life in vain, and to move mankind ahead even if only a little. This is why I have been interested in that which has given me neither bread nor power. However, I hope that my works, perhaps quickly, and perhaps in the remote future will give to society mountains of bread and limitless power."

Tsiolkovsky was born on 17 September 1857 to Maria Yumasheva and Eduard Tsiolkovsky in the remote village of Izhevskoye in the Spassk District, Ryazan Guberniya, Russia. His father was a forester who had a passion for construction and invention; his mother was from a family of artisans. Tsiolkovsky once wrote that his father's primary quality was his strength of character and will, and that his mother's was talent. Tsiolkovsky, who was rigorously self-disciplined, as well as creative and talented, obviously inherited and benefited from what he regarded as his parents' best features.

As a young child, Tsiolkovsky was happy, inquisitive, and energetic. He had a kite, to which he attached a small box in which its passenger—a cockroach—could ride into the air. When he was eight years old, his mother gave him a small collodion balloon filled with hydrogen, and told him not to let go of the string or else the balloon might get away. Tsiolkovsky was delighted with this present, which must have made a lasting impression on him, as he spent a great deal of his life's work on the study of an all-metal aerostat (dirigible) capable of carrying passengers.

In 1867, at the age of nine, Tsiolkovsky became seriously ill with scarlet fever. A complication from the illness caused him to lose his hearing almost entirely and he was only able to hear indistinguishable and muffled sounds. He later wrote that the years between the ages of ten and fourteen were the

Preceding page: Konstantin Tsiolkovsky (top), memorial house museum (bottom). This page and opposite: views of Tsiolkovsky's study and workshop.

saddest and darkest of his life; he was deprived of the previous companionship of his playmates and was unable to attend school any longer. One morning, however, his mother came to sit beside him, her arms filled with books from his father's library, and they began to read together. At this point Tsiolkovsky felt that his "mind was awakened by reading…[and that] there was nothing dark about books and that I could understand all I read."

Tsiolkovsky noted later in his life that, although he was by nature a self-motivated person, his deafness and isolation helped him to develop, as well as broaden, his unique style of introspection and self-expression. Tsiolkovsky wrote: "I clearly realized that it was to my deafness that I owed the originality of my work." Beginning at the critical point when Tsiolkovsky realized that books held new meanings for him, he became a self-taught man. The more he read, the more questions he wanted to answer. Because of the remote location of the village in which the Tsiolkovsky's lived, as well as its relative poverty, there were almost no scientific journals and books for him to study. In addition, there were only a small number of people who understood the scientific concepts and ideas that Tsiolkovsky was investigating, and therefore he had very few human resources upon which to call for help. He wrote in his autobiography that there was much that he did not understand in the books that he read, and was therefore forced to figure everything out on his own. This, he felt, required him to learn how to think—especially how to think critically. He used the world around him to extrapolate larger ideas. For example, in teaching himself to calculate large distances, such as the distance between the earth and a star, he began by calculating the distance from the house to a fire-tower. From information he gathered in reading his father's books, he constructed an astrolabe-goniometer to help with his calculations. He then walked the distance, making actual measurements to check the accuracy of his calculations. Imagine how excited he was to discover that he was able to accurately calculate distances without actually traveling them! He later wrote that from that very moment he began to believe in theoretical knowledge.

Once he had exhausted the limited resources of the town in which he lived, his father felt that he should travel to Moscow to continue his self-education. In 1873 Tsiolkovsky went to Moscow and remained there until 1876; for these three years he primarily studied physics, chemistry, mathematics, and astronomy. Although he did not have enough money to formally enroll in a course of study, Tsiolkovsky attended free lectures, listening through an ear trumpet that he had designed and built for himself. Penniless and often hungry, Tsiolkovsky lived almost entirely on brown bread. He wrote that he would go to the baker's every three days to buy 9 kopeks worth of bread, spending only 90 kopeks on bread each month. Tsiolkovsky spent most of the money sent to him from home on experiments and books. Experiments were of particular importance to Tsiolkovsky as his primary way to understand and/or prove a concept and he conducted elementary physical and chemical tests when he could afford the materials. Similarly, when studying math he never looked at the proof for a problem until he was able to work it out for himself; he then looked at the proof only to check his own work.

Tsiolkovsky's ideas about space flight developed more fully during his stay in Moscow. He was an avid reader of Jules Verne's space novels, and he spent a great deal of time immersed in the scientific literature at Rumyantsev's Public Library. Philosopher-librarian Nikolai Fyodorov, in whose library Tsiolkovsky studied, also had a tremendous influence on him at this time. Fyodorov's philosophy included the idea that human beings required space for material and spiritual development—living space or *lebensraum*—and that humans should seek other habitable planets. It is said that Fyodorov read every book that he cataloged, and he was known for bringing additional and unexpected resources to scholars studying in his library. Fyodorov helped Tsiolkovsky in a number of practical ways beyond providing him with library resources: he gave Tsiolkovsky food and clothing, assisted him with his mathematical studies, and helped him establish a regular routine of study, thus enabling him to pass his qualifying exams and thereby obtain teaching positions.

Tsiolkovsky left Moscow in 1876, probably at the request of his father who had heard from a friend that Tsiolkovsky was sickly and emaciated. He returned home and became a mathematics and physics tutor. In the autumn of 1878 Tsiolkovsky passed his teaching examination, becoming a "people's school teacher," and accepted a position as an arithmetic and geometry teacher at the Borovsk Uyzed School. Compensating for his deafness in the classroom, Tsiolkovsky resorted to lecturing and extensive experimentation for his classes. To understand questions from his students, he generally had an older student stand near him at the front of the

class and repeat the questions to him. Tsiolkovsky was a dedicated and thorough teacher, and wrote that he "did not stint on interesting experiments, so that we had 'real' performances; a part of my salary went for these experiments."

While Tsiolkovsky's students thought a great deal of him as a teacher, many of his colleagues took advantage of any opportunity to poke fun at him. They were resistant to his ideas for new teaching methods, and were probably unable to fully grasp many of his scientific ideas. They were also resentful that he was able, as poorly paid as they all were, to privately publish his research as short pamphlets and books. Kosmodemianskii, a biographer of Tsiolkovsky, wrote that "his deafness probably saved his greatness," for if he had been able to hear much of what was said about him he might have become discouraged. On the other hand, it is unlikely that Tsiolkovsky would have, for any reason, given up his research, as it was as natural a part of him as breathing.

In 1881, at the age of 24, Tsiolkovsky wrote a paper entitled *The Theory of Gases*, in which he outlined the fundamentals of the kinetic theory of gases, a theory very similar to that developed by James Clerk Maxwell twenty years earlier. Although some of the members of the Society for Physics and Chemistry, to whom he had submitted his paper, thought that he had copied these principles from earlier works by others, Dimitri Ivanovich Mendeleyev (creator of the periodic system of the elements) pointed out that the method Tsiolkovsky had used was original and unique. They concluded that he had not in fact known about the earlier discoveries, but still did not publish his paper. About this misunderstanding Tsiolkovsky later said, "I studied very little systematically, especially in the later years; I read only what could be of help to me in solving questions which interested me, which I considered important. One could say that I studied by way of creating—although often unsuccessfully and too late."

The second paper that he submitted to the Society, *The Mechanics of a Living Organism*, in which he analyzed the ways that natural forces such as gravity affect the structure and movement of human beings, was approved by the well know physiologist M. Sechenov and the Society invited him to become a member, although they again did not publish his paper. It is quite possible that Tsiolkovsky was considered to be something of a crackpot at the time. He was relatively unknown, did not possess a formal university education, and had ideas that were decades ahead of his time. It wasn't until 1891 that Tsiolkovsky officially published a paper, when an excerpt from his manuscript *The Problem of Flying by Means of Wings* appeared in the *Proceedings of the Society of Nature Lovers*. It was in this work that he provided a mathematical analysis of the importance of using elongated wings on an aeroplane, confirmed by the results of experiments conducted using a device of his own design.

By 1897 Tsiolkovsky had completed what he considered to be a preliminary study of the use of rockets as a mode of propulsion in empty space. In 1898 he submitted part of this work to *Nauchnoye Obozreniye* (*Scientific Review*), whose editors for some reason did not see fit to publish the article until 1903—five years after he submitted it. This article, *A Rocket Into Cosmic Space*, was in fact Part 1 of Tsiolkovsky's work *Exploration of Cosmic Space by Means of Reaction Devices*. In the original manuscript of *Exploration of Cosmic Space by Means of Reaction Devices*, Tsiolkovsky recorded the date 10 May 1897 as the day he arrived at the fundamental formula for rocket motion. Interestingly enough, while Tsiolkovsky's work was the feature article in that particular 1903 issue of *Scientific Review*, another article offended the Tsar's secret police and as a result they confiscated the entire run. Tsiolkovsky received a copy, but very few others actually made it into circulation. The article was rewritten and expanded upon later, appearing as a series of articles from 1911-1913 in the magazine *Aviation Reporter*.

In 1924, Tsiolkovsky republished Part 1 of *Exploration of Cosmic Space by Means of Reaction Devices* under the new title *Rocket in Cosmic Space*. Tsiolkovsky was motivated to change the title and republish his work by the publication and subsequent popularity of Hermann Oberth's book *Die Rakete zu den Planetenräumen* (*Rocket into Outer Space*), published in 1923. Oberth's book was hailed as a new discovery, when in fact Tsiolkovsky had proposed many of the same ideas as far back as 1897.

Most of Tsiolkovsky's ideas were theoretical, and he knew that they required proof through experimentation. Toward this end Tsiolkovsky developed, in 1897, the first wind tunnel ever built in Russia. This wind tunnel was first put to use in Kaluga, and created a stream of air that could be directed across wings and aircraft bodies. Tsiolkovsky was curious to learn how much skin friction a metallic ship such as his all-metal dirigibles would create at a certain

An obelisk marks Konstantin Tsiolkovsky's grave in Kaluga, carved upon which are the words "Mankind will not remain bound to the earth."

speed. He describes the results of his wind tunnel experiments in his paper *Air Pressure on Surfaces Introduced into an Artificial Air Flow* published in 1898 in *The Courier of Experimental Physics and Elementary Mathematics.*

Up until this time Tsiolkovsky had not received funding for any of his research. Everything—all of his experiments, models and most of his publications—he did at his own expense. In 1899 he applied to the Russian Academy of Science to carry out further, larger scale wind tunnel experiments. He received a grant of 750 rubles (about $235 dollars at that time) to build a larger wind tunnel and to conduct "experiments in determining the resistance of bodies to artificial air flow." He received about 55 additional rubles from newspaper readers who were eager to support his endeavors with small individual contributions. Construction began on the new wind tunnel in May of 1900. Experiments utilizing the wind tunnel were underway before the end of the same year and by December of 1901 he was able to deliver his report of investigations to the Academy. The funding that he received for his wind tunnel was the only monetary assistance he received under the tsarist governments.

After writing the supplement to *Investigation of Universal Space by Reactive Devices* in 1914, Tsiolkovsky did not publish again until after the October Revolution in 1917. The first years after the October Revolution were difficult for everyone. Around 1921 Tsiolkovsky became accepted as a serious scientist, and was finally officially recognized for his research. Stalin wrote a letter of praise to him, and in 1932 M. Kalinin presented him with the Order of the Labor Red Banner for outstanding service to the Land of the Soviets. He became an elected member of the Socialist Academy (later known as the USSR Academy of Sciences) and received a life pension from the Council of Peoples' Commissariats of the Russian Federation. This pension allowed Tsiolkovsky to end his career as a schoolteacher and to concentrate on his research with some degree of comfort. The impact of the pension, as well as acceptance as a bona fide scientist, on Tsiolkovsky's research can be seen by the increase in his output, as he wrote about three-quarters of his scientific papers after 1917.

In 1935 Tsiolkovsky must have sensed that the end of his life was approaching. On 13 September Tsiolkovsky bequeathed all of his books and papers to the Communist Party and the Soviet Government, to whom he felt he owed a great deal for allowing him to pursue his research. Six days later, on 19 September, Tsiolkovsky died at home in Kaluga from brain cancer. An obelisk marks his grave in Kaluga, carved upon which are the words "Mankind will not remain bound to the earth."

Due to his relative isolation (both geographical and because of his deafness), the political instability in Russia, lack of resources and financial support, and the lack of translations of his works, Tsiolkovsky's actual contribution to early practical developments made in rocket science during the 1920s and 1930s in America and Germany is hard to assess. Most of his books were published at his own expense and not many copies were in circulation even in Russia. His works themselves were not widely translated until the 1940s, before which Goddard and Oberth had arrived, independently, at similar theories.

Tsiolkovsky wrote over 500 papers in the course of his life, and although he did not develop any rockets himself, he did influence many young Russian engineers and rocket designers through his writings. Although he wrote about a wide variety of scientific, technical, and philosophical issues, Tsiolkovsky is primarily known for his theories that most influenced the Soviet/Russian and worldwide space program. He predicted that liquid-fuel rather that solid-fuel rockets would be used to propel mankind into space; he calculated mathematically the efficiency of liquid fuels for rockets and proposed the use of a rocket-train to efficiently leave earth (Tsiolkovsky's rocket-trains are today's multi-stage rockets); and he arrived at the fundamental formula for rocket motion, mathematically demonstrating that the velocity of a rocket is proportional to its exhaust velocity.

Tsiolkovsky lived long enough to see a younger generation of Russians begin to implement many of his imaginative concepts. One of these young engineers was Sergey Korolev, who later became the Chief Designer of the Soviet space program, and who has said of Tsiolkovsky: "It is difficult to overestimate the importance of the suggestion of Konstantin Eduardovich concerning compound multi-stage rockets and rocket trains. In essence, this suggestion has opened the path for mankind into outer space."

Aimée deChambeau is an Assistant Professor of Bibliography at The University of Akron's Science and Technology Library (Akron, OH). She would like to acknowledge Irada Isayava for her extensive help in translating materials from their original Russian for this article.