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Sputnik: The First Man Made Earth Satellites

by Andrew J. LePage

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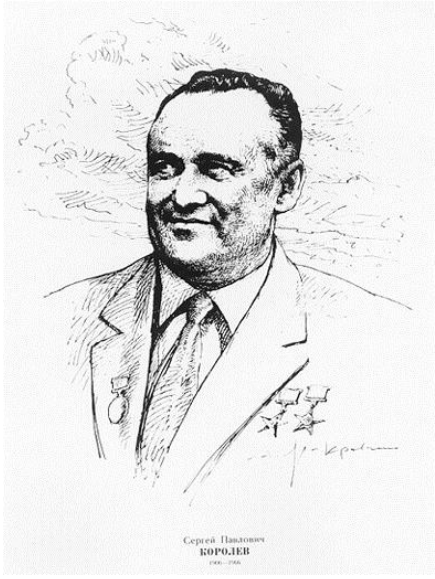
The Dream

This October 4th marks the 40th anniversary of one of the most historic events in the history of our species: the launching of the first satellite. The roots of this accomplishment, though, go back an additional 74 years. In 1883 a Russian schoolmaster named Konstantin Eduardovich Tsiolkovsky (1857-1935) was the first person to seriously address the question of spaceflight. During the next five decades he published a long series of works detailing the scientific principles behind such an endeavor. In the years to follow, Tsiolkovsky's writings inspired a generation of incredibly talented and driven Soviet engineers who began the difficult task of developing the technologies needed to make the dream of spaceflight come true. With the availability of the German V-2 rocket technology at the end of World War 2, scientists and engineers not only in the Soviet Union but in America and Europe as well soon realized that the first step into space -- an Earth-orbiting satellite -- was within reach.

In August of 1946 Sergei Pavlovich Korolev (1907-1966), who had survived his imprisonment during Stalin's pre-war purges, became the Chief Designer of OKB-1 (the Russian acronym for Experimental Design Bureau 1) which was part of NII-88 (Scientific Research Institute 88). Under Korolev's direction, OKB-1 successfully duplicated the V-2 design with a rocket designated R-1. Not long afterwards, subsequent rocket design innovations far exceeded this rocket's limited capabilities. While Korolev's superiors were only interested in the military applications of this new technology, Korolev and his closest colleagues always had the dream of spaceflight in the back of their minds. In October of 1951 one of Korolev's deputies, Mikhail Klavdievich Tikhonravov (1900-1974), presented a feasibility plan for an Earth-orbiting satellite showing that it was possible.



The Soviet Union's Chief Spacecraft Designer Sergei Pavlovich Korolev. (NASA)

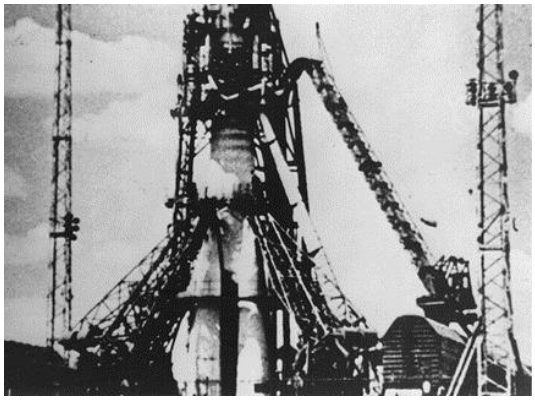
Efforts to launch a satellite remained subordinate to the need to develop new weapons until 1954 when planning for the International Geophysical Year (IGY) started. The intent of this unprecedented international scientific collaboration was to obtain data on Earth's upper atmosphere and its interaction with the Sun during the peak of the next sunspot cycle between July 1957 and December 1958. Probably spurred by these developments, Korolev published a scientific paper on Earth satellites in 1954. On January 9, 1955 a group of Soviet scientists, who had been inspired by Korolev's paper, met to promote his satellite project. They ultimately persuaded the Presidium of the Academy of Sciences to mail a brief questionnaire to several hundred Soviet scientists for their thoughts on the potential uses of satellites. The responses ranged from very positive to a terse "Fantasy" but on April 15, 1955 the Academy of Sciences established a "Permanent

Commission for Interplanetary Travel" to study the launching of a Soviet satellite and missions beyond.

Behind the scenes Korolev was busy selling the Soviet leadership on the idea of using one of his new long-range missiles not only to launch a satellite but men into orbit and probes to the Moon. On July 29, 1955 the Americans announced that they would launch a satellite as part of their IGY contribution. Three days later the Soviets made a similar announcement that seems to have been totally ignored in the West. With the clock already ticking, Korolev formally submitted his satellite proposal to the Soviet leadership on August 29, 1955.

The Rocket

While Korolev's proposal only obliquely referred to the rocket that would make these missions possible, he intended from the start to use the new R-7 (also known as Sapwood or SS-6 in the West). The genesis of its design can be traced back to a proposal presented to Korolev by Tikhonravov in mid-1947 called the "Rocket Packet". This long-range missile concept used parallel staging and called for a cluster of five identical rockets to ignite simultaneously at liftoff. From 1949 to 1951 MIAN (the Mathematical Institute of the Academy of Sciences) under the direction of Korolev's good friend and ally, Academician Mstislav Vsevolodovich Keldysh (1911-1978), began detailed studies of this concept. By December of 1950 OKB-1 began feasibility studies of a number of long-range missiles concepts that would build on their previous work. This lead to a design study called T-1 which made use of Tikhonravov's innovative rocket packet concept.



An R-7 rocket being prepared for launch. (NASA)

The design, whose study was authorized in February of 1953, called for a five-unit rocket packet weighing 200 metric tons (440,000 pounds) that was capable of carrying a three metric ton (6,600 pound) payload over an astounding range of 8,500 kilometers (5,300 miles). After the detonation of the Soviet's first H-bomb in October of 1953, however, it became apparent that a missile with a five-plus metric ton (11,000+ pound) payload capability would be required. A scaled up version of the T-1 was immediately proposed to fill this requirement. On May 20, 1954 OKB-1 was given the authority to begin designing article 8K71 and the R-7 was born.

The R-7 was a truly enormous rocket whose size would not be surpassed in the West until the development of the Saturn I. It consisted of a cylindrical core (called Blok A) surrounded by four tapered strap-on boosters (designated Bloks B, V, G, and D). The total length of the missile, including warhead, was about 34 meters (111 feet) and it had a launch weight of 274 metric tons (603,000 pounds). The R-7 was designed so that the core and all four boosters would ignite on the pad, thus avoiding the untried procedure of starting large engines at high altitude. After the boosters had exhausted their propellants 120 seconds after liftoff, they would be jettisoned. The core would then continue alone until the proper velocity had been reached 320 to 330 seconds after liftoff at which time the warhead would be released. The R-7 was designed to throw a 5 megaton nuclear warhead weighing 5.4 metric tons (12,000 pounds) over a distance of 8,000 kilometers (5,000 miles). This range would be sufficient to hit any target in Eurasia and most of Africa or North America including much of the continental US. The R-7 was truly an Intercontinental Ballistic Missile (ICBM).

At lift off the engines of the R-7 generated an unequaled 3,904 kilonewtons (876,000 pounds) of thrust. Each booster of the R-7 was powered by an RD-107 engine that produced 795 kilonewtons (178,000 pounds) of thrust at sea level using kerosene and liquid oxygen (LOX) as propellants. The core used an engine of similar design called the RD-108 that produced 726 kilonewtons (163,000 pounds) of thrust at sea level and 912 kilonewtons (205,000 pounds) at altitude. They were designed and built by OKB-456 under the direction of Valentin Petrovich Glushko. The RD-107/108 consisted of a single turbopump assembly feeding a cluster of four combustion chambers. The major external difference between the RD-107 and 108 was that they incorporated two and four small gimbaled vernier engines, respectively, to steer the R-7 and trim its velocity. The RD-108 also ran at a lower thrust level so that it could operate up to 210 seconds longer than the boosters' RD-107 engines and its nozzles were optimized for operation at high altitudes. Glushko had unsuccessfully tried to develop the larger single-

chambered RD-105/106 engines from 1951 to 1953 that would have provided the T-1 with a total liftoff thrust of 2,700 kilonewtons (600,000 pounds). In the RD-107/108 concept, however, each chamber produced about the same amount of thrust as the successful single-chambered RD-100 which powered the Soviet R-1. The clustered nozzle approach of the RD-107/108 totally bypassed the numerous problems encountered during the work on the larger RD-105/106 combustion chamber so that development could proceed quickly. Test firings of a single chamber began in the middle of 1955 followed by tests with a pair of chambers in December. In January of 1956 trials with the full four chamber configuration started.

The Satellite

These events could not have come soon enough for Korolev. On January 30, 1956 the Soviet government authorized Korolev's satellite program. Korolev gave Tikhonravov and his design team the job of building the heavy satellite designated "Object D". Object D, which would weigh about 1.0 to 1.4 metric tons (2,200 to 3,100 pounds) and carry 200 to 300 kilograms (440 to 660 pounds) of geophysical instrumentation, would be launched into orbit using a special version of the R-7 designated 8A91 (also known as the SL-2 in the West). The 269 metric ton (593,000 pound) 8A91 would be similar to the 8K71 except that it would be stripped of all the equipment needed to precisely guide an ICBM and it would make use of specially modified versions of the RD-107/108 engines. These engines would be lower thrust, more efficient versions of engines used on the ICBM configuration and would produce 3,806 kilonewtons (854,000 pounds) of thrust at liftoff. Seven missiles were set aside for Korolev's satellite launches which were to be conducted as part of the larger R-7 development program.

Progress on the development of the R-7 proceeded quite quickly through 1956. That summer saw the first static test firings of a single strap-on booster. The first static tests of the core started in August and by the winter of 1956-57 the entire R-7 was being static tested at a facility outside of Moscow. As a result of Korolev's growing influence as well as his skill as an engineer and manager, OKB-1 became independent of the more research and development oriented NII-88 in October of 1956.

Earlier, on May 31, 1955, construction had begun on the new R-7 launch facilities near the town of Tyuratum in Soviet Kazakhstan. This new facility, initially known by its railway stop designation of "Tashkent 50", was designed and built by the Moscow-based design bureau GSKB SpetsMash under Vladimir P. Barmin. Years later these facilities would become the focus of the sprawling Baikonur Cosmodrome. By December of 1956 a nonflight R-7 test article, designated 8K71SN, was delivered to Tashkent 50. On March 4, 1957 the first R-7 launch pad was completed and fit tests using the 8K71SN began.

While the preparations for the satellite project were well underway, a Soviet delegate to a conference of the Special Committee for IGY held in Barcelona announced on September 11, 1956 that the Soviet Union would launch a satellite during the IGY. But by December of 1956 it had become apparent to Korolev that progress on the complex Object D was proceeding more slowly than originally hoped. To guarantee a satellite launch as soon as possible, Korolev ordered the construction of another, much less complex satellite called "Object PS" ("PS" standing for "Preliminary Satellite"). Initially there was some resistance to this change in plan, most notably from Academician Keldysh, but it was quickly approved and design work started.

Object PS would be a simple 58-centimeter (23-inch) polished metal sphere with four antennae weighing about 80 kilograms (180 pounds). It was equipped with a pair of battery powered transmitters operating at the frequencies of 20 and 40 megahertz. The radio signals would be frequency modulated to transmit information on the satellite's interior temperature and pressure. Studies of these signals would also provide information on the propagation of radio signals through the upper ionosphere. Observations of changes in the satellite's orbit would give scientists much needed data on the density of the upper atmosphere and the precise shape of the Earth. All of this data would be a valuable contribution to the upcoming IGY.

Since the 8A91 launch vehicle would not yet be available, Object PS would have to be launched into orbit using a stripped down version of the R-7 designated 8K71PS (known as the SL-1 in the West). It would be nearly identical to the 8K71 ICBM save for the absence of the warhead and 300 kilograms (660 pounds) of extraneous radio telemetry equipment. A payload adapter, a separation system, and a nose cone were also added to the top of the missile to accommodate the small satellite. The shutdown sequence of the R-7 core's RD-108 engine was also simplified so that it would burn until its propellants were exhausted thus guaranteeing the highest possible speed. All together, the 8K71PS

was 7 metric tons (15,000 pounds) lighter than the 8K71. While this plan might not have been elegant engineering, at very least the launch of Object PS would demonstrate that a satellite could be placed into orbit. In addition, Object PS would still be much more massive than what the Americans had planned to launch during the IGY.

Model of the first artificial satellite, Sputnik 1. (NASA)

Testing the R-7

In March of 1957 OKB-1 delivered the first flight model of the R-7 to the new facility at Tashkent 50. Finally on May 15, 1957 the first R-7 (serial number M1-5) was launched on a test flight carrying a dummy warhead. All seemed to be going well until 98 seconds after launch when one of the strap-on boosters broke away from the core. Afterwards the rocket tumbled out of control and crashed 400 kilometers (250 miles) down range. An investigation showed that a type of excessive vibration, known as "pogo", started a fuel leak that lead to a fire in the booster's engine compartment. Eventually the RD-107 engine overheated and shut down leading to the booster breaking away.

Undeterred, another R-7 (serial number M1-6) was modified and prepared for flight. A launch attempt was aborted at the last second on June 9 followed by two more aborts on June 10 and 11. The uncooperative rocket was removed from the pad and inspected. Eventually it was discovered that an incorrectly installed nitrogen valve was the source of the problem. In the mean time another R-7 (serial number M1-7) was erected on the pad and launched on July 12. Unfortunately a short circuited battery caused a malfunction in the ascending rocket's control system which sent the R-7 spinning until it broke up after only 33 seconds of flight. Meanwhile on July 9, 1957 the Soviets publicly announced that a satellite was being prepared for launch as well as the radio frequencies it would use. Once again the United States and the rest of the West seemed to dismiss the announcement as Soviet propaganda.

The timing of these R-7 failures could not have been worse for Korolev. He had been constantly under attack from rival Chief Designers for much of his career but, with the string of R-7 failures, his support in the Soviet government was beginning to falter. At one point he even lost the support of his staunchest ally in the upper echelons of Soviet government, Premier Nikita Khrushchev. Because of building pressure in the Kremlin, Khrushchev, who was in the process of consolidating his power after an unsuccessful attempt to oust him, ordered the shutdown of OKB-1.

Knowing how close he was to success, Korolev stubbornly disobeyed orders and continued work on the R-7. Finally on August 21, 1957 Korolev's fortunes changed when R-7 serial number M1-8 was successfully launched. The missile sent a dummy warhead to its target on the Kamchatka peninsula 6,500 kilometers (4,000 miles) away. While the warhead broke up at an altitude of ten kilometers (33,000 feet) during descent, the R-7 design itself was vindicated and OKB-1 was saved. Although much work still lay ahead to fine tune the R-7 as well as develop a viable warhead design, the Soviet government officially announced that they possessed an operational ICBM only five days after this first successful test. The impact in the West was slight at best.

The Launch

With a successful test of the R-7 under his belt and OKB-1 secure, Korolev was in a position to seek final approval for the launch of an Earth satellite. In early September 1957 Khrushchev gave his approval but for his own political reasons. He felt that a successful satellite launch would show his enemies in the Party that he could lead the Soviet Union towards a glorious future. It would also demonstrate to the West that the Soviets did indeed possess an ICBM capability, thus serving as a deterrent to any outside aggression. Finally, it would give Khrushchev the excuse he needed to reorganize the Soviet military and form the Strategic Rocket Corps on equal footing with the other branches of the military.

With Khrushchev's blessing, Korolev set out to launch a satellite as soon as possible. The 8K71 missile serial number M1-10 was stripped of non-essential systems and converted into 8K71PS serial number M1-1PS. On September 18, the 100th anniversary of the birth of Tsiolkovsky, Radio Moscow announced that the satellite launch was imminent with the West again turning a deaf ear. On September 20 Korolev left OKB-1 in Moscow for Tashkent 50 so he could personally supervise the final preparations for the launch. During this time he lived in a small wood framed house with the hanger-like MIK assembly building a ten minute walk away in one direction and the launch pad ten minutes away in the other. On the night of October 2 the 8K71PS carrying Object PS left the MIK for the launch pad. The next day the rocket was erected on the pad and it was fueled for the coming launch.

During the day of October 4 several attempts were made to launch the R-7 but they were repeatedly delayed due to a string of technical glitches. As night fell, Korolev decided to make one more attempt. As Korolev himself was counting down the final minutes to launch from a bunker 100 meters (330 feet) from the pad, a lone bugler briefly appeared on the concrete apron to blow a long series of trumpet blasts. Finally at 10:28:04 PM Moscow time, the 20 engines of the R-7 ignited lifting the missile and its payload off the launch pad. The rocket quickly gained speed, pitched on command towards the northeast and disappeared into the night sky.

Korolev and the rest of the people who witnessed the sight had no way of knowing if the satellite made it to orbit. A radio receiver and loud speakers were set up in the MIK where everyone waited to hear from Object PS as it flew overhead for the first time. An hour and a half after launch the "beep, beep, beep" from the satellite's transmitter, now designated Sputnik (Russian for "fellow traveler"), echoed throughout the MIK. There was now no doubt about the outcome of the launch: The 83.6 kilogram Sputnik was successfully placed into a 228 by 947 kilometer (142 by 589 mile) orbit inclined 65.1 degrees to the equator with a period of 96.17 minutes.

After the cheers of the people gathered in the MIK died down, Korolev stood before them and spoke: "The conquering of space has begun. Today we have witnessed the realization of a dream nurtured by some of the finest minds who ever lived. Our outstanding scientist Tsiolkovsky brilliantly foretold that mankind would not forever remain on the Earth. Sputnik is the first confirmation of his prophecy. We can be proud this was begun by our country."

With these words, the Space Age had begun.

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