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This still from a film made post-Sputnik, gives a good sense of the size of the actual satellite. (credit: Don Mitchell)

Sputnik remembered: The first race to space (part 1)

by Asif A. Siddiqi
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On the early morning of September 20, 1956—just before 2 am—the US Army launched a Jupiter C intermediate range ballistic missile from Launch Pad 5 at Cape Canaveral. Basically a souped-up version of Wernher von Braun's Redstone rocket, it had a dummy fourth stage loaded with sand. The missile lifted off successfully, generating a thrust of over 35 tons from its first stage engines, which burned for 150 seconds. The upper stages continued to arc over the Atlantic, reaching an altitude never reached before by any human-made object: nearly 1,100 kilometers. The payload itself traveled downrange about 5,400 kilometers from the launch site before burning up in the Earth's atmosphere. As radio systems beamed back information to the blockhouse on the record-breaking flight, von Braun was said to have "danced with joy."[1] Although the Army did not publicly announce the launch or the results of the flight, information about the event leaked out to the mainstream press within a week.[2] This somewhat obscure missile launch may have irrevocably changed the course of the "space race," serving as one of the main catalysts for the world's first artificial satellite, Sputnik.

By the time of the Jupiter C launch, Soviet scientists and engineers had been engaged in research and development on satellites for quite some time.

For being one of the most cataclysmic events of the Space Age, there are relatively few accounts of the actual launch of Sputnik. When we remember it, we usually focus on the aftermath: the shock of the satellite, especially in the United States. For good reason, there has been much rumination, both academic and popular, on its meaning, impact, and long-term reverberations. But the story of its genesis and the event itself remains murky and full of speculation, lacking detail. We have some specific technical details filled in—the type of rocket used, the time of the launch, and so on—but the larger story, besides some scattered anecdotal accounts, is fragmented. The goal here in this piece is to focus on the actual events of 1957: how was Sputnik designed? How was it built? What happened during the launch? Who publicized it? Who tracked it? The goal here is to revisit, with the benefit of many new declassified documents from Russian archives, the "opening shot" of the Space Age.

By the time of the Jupiter C launch, Soviet scientists and engineers had been engaged in research and development on satellites for quite some time. Satellite studies in the Soviet Union had begun in the early 1950s under the tutelage of famous Soviet rocket designer Mikhail Tikhonravov (1900–74) at a secret military organization known as the Scientific-Research Institute No. 4 (NII-4 or "nee-4") based in the northeastern Moscow suburb of Bolshevo.[3] Tikhonravov had already enough achievements under his belt to guarantee a place in the annals of Soviet space history. In 1933, a rocket he designed, the "09," became the very first Soviet rocket to fly using liquid propellants. Later, at NII-4, he had led early design studies on clustered staging concepts that ended up being used (in much modified form) in the famous R-7 intercontinental ballistic missile. More than 60 years after he proposed the clustering concept, the R-7 continues to be used today, albeit in significantly uprated versions.

The R-7 was designed at the famous Experimental Design Bureau No. 1 (OKB-1) based in the Moscow suburb formerly known as Kaliningrad under the leadership of legendary Chief Designer Sergey Korolev (1906–66). Much has been written about Korolev's life:his apprenticeship in the 1930s as a young amateur rocket enthusiast, his arrest and incarceration in the Stalinist Gulag, and his meteoric postwar rise as one of the geniuses behind the Soviet missile and space programs. Yet, Korolev's early successes might not have been possible without the help of Tikhonravov. Korolev had known Tikhonravov since the late 1920s, when they both participated in amateur glider competitions, and it was under Korolev's overall direction that Tikhonravov had designed the famous 09 rocket. In the mid-1950s, OKB-1's primary goal was to develop increasingly powerful ballistic missiles capable of delivering nuclear warheads to strategic targets. Although they worked in different organizations, Korolev remained close to Tikhonravov and followed the latter's satellite work with keen interest.

The possibility of actually launching a satellite remained more or less a fantasy until the advent of the ICBM, which theoretically could impart sufficient velocity to a small object for it to enter a freefall trajectory around the Earth. In May 1954, soon after the Soviet government formally approved development of the R-7 ICBM, Korolev began lobbying senior industrial leaders to sanction a satellite project. He depended to a great degree on the "Tikhonravov Group," a group of young scholars at NII-4 who, since September 1953, had been busily working on a concrete proposal for an artificial satellite of the Earth. Korolev's projects were given an imprimatur of legitimacy by the involvement of Academician Mstislav Keldysh (1911–78), a brilliant applied mathematician who specialized in a wide variety of phenomenon, including aerodynamics, hydrodynamics, and vibration theory. Keldysh was an extremely influential and highly respected scientist, particularly within the secret world of weapons development. These three men—Korolev, Keldysh, and Tikhonravov—formed a very effective lobby group that pushed the idea of a satellite to the Soviet Party and government leadership. The story of how they did this is stranger than one can imagine.

This much-reproduced photo of Sergei Korolev was taken in 1953 when he was at the Kapustin Iar launch site directing launches of the R-5 strategic missile. (credit: Asif Siddiqi)

One of the strategies that Korolev used to get support from the top was to flood the Soviet media with speculative articles about the future of space travel. One of these articles, a lengthy one, was published in the Soviet newspaper *Vecherniaia moskva* (Evening Moscow) on April 16, 1955. Among other things, it announced the formation of a Soviet commission to study interplanetary space, a commission that we now know was really nothing much but a front for Soviet scientists to write articles in the media on the topic of space exploration. Although the commission had no authority to develop a satellite (let alone a rocket to launch it), the announcement of its existence caused a flurry of attention in the American media, probably just as Korolev and Tikhonravov had intended. The *New York Times* and *Washington Post* wrote about it. Even the CIA took notice: in their next top-secret National Intelligence Estimate, there was talk of this article. All of this was taken as evidence that the Soviets were racing to launch a satellite. In fact, there was no such plan at the time. But the anxiety about a Soviet launch was one (although not the only or most important) factor that played into the decision of the Eisenhower Administration, announced with much fanfare on July 29, 1955, that a launch of an American satellite was planned for the so-called International Geophysical Year, in 1957–58.

The American announcement was reported back to Korolev. And almost immediately he wrote a letter (co-authored with some high-ranking Soviet industrial bureaucrats) to Nikita Khrushchev and Nikolai Bulganin, arguing that the Soviet Union needed to respond. To add power to his request, he added a folder containing a bunch of recent articles from the American media, all properly translated, all communicating that the United States was giving priority to its own satellite program. The attached folder clinched the deal: a little over a week after the American announcement, on August 8, 1955, the Soviet Politburo approved a satellite project under Korolev. A later government decision, from January 30, 1956. formally approved a firm program to launch what was known as "Object D," a massive 1.3-ton scientific observatory that would beat the Americans.[4]

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Anxiety about Americans

Building the complicated Object D satellite on time proved to be very challenging, especially since many of the scientific instruments had to be redesigned for Earth orbit, i.e., in conditions of near vacuum, weightlessness, and unknown radiation. In addition, ground tests showed that the launch vehicle slated to launch the Object D, known as the "article 8A91" (basically an R-7 ICBM with some improvements), would not have the necessary specific impulse required to launch the heavy satellite into orbit.

In this context, in late 1956, news of the American Jupiter C test provoked the Soviets in an inexorably different direction. Although the mission of the Jupiter C launch in September had nothing to do with a satellite launch, by the time news of the flight reached Korolev, it was reported as an "attempted launch of a satellite." This clearly garbled piece of information shook both Korolev and Tikhonravov. There were all the troubles with the Object D to contend with, and now this supposed American "space" launch. If they were concerned about losing first place to the Americans, they were now seriously anxious. Korolev had long complained about all the delays with the Object D to Tikhonravov; usually Tikhonravov remained quiet, pondering over all the problems. Korolev had often seen this as indifference on Tikhonravov's part but in fact, the latter had been devising an alternate plan, a "Plan B."

In mid-November 1956, Tikhonravov suddenly piped up to Korolev: "What if we make the satellite a little lighter and a little simpler? Thirty kilograms or so, even lighter?"[5] Korolev quickly pondered over the suggestion, weighing all the options carefully. One of the main problems with the development of the Object D had been the many delays in delivering its component scientific instruments. Having never designed instruments to operate in space, the subcontractors were facing many problems during production and testing. Instead of the complex Object D, Tikhonravov suggested reducing the satellite down to its most essential components: one or two radio transmitters and a power source to feed them. Finding this plan more and more attractive, Korolev decided to cut out almost all of the subcontractors and rely instead on two people he could count upon. He asked fellow Chief Designer Mikhail Riazanskii (1909–87) of NII-885 to provide the radio equipment and Chief Designer Nikolai Lidorenko (1916–2009) of the Scientific-Research Institute of Current Sources (NII IT) to supply the batteries to power the former. Everything else would be built in-house under his direct command at OKB-1's experimental plant located right next to the design bureau premises. True to its elementary nature, the new satellite was called PS-1 (*Prosteishyi sputnik-1*, Simplest Satellite-1). It was so simple, the idea went, that it could be built and tested in a month or two, time enough to beat the Americans to the launch pad. The satellite would not only be simple but also cheap—if it was destroyed on launch, they could quickly ready another one without much ado.

Not everyone supported the PS-1 plan. In fact, although Korolev and Tikhonravov firmly believed in the idea, the third man in the original satellite proposal, Academician Keldysh, strongly opposed it. Keldysh had good reason to do so: he was, after all, the scientific head of the original Object D project. He had also committed the resources of the Academy of Sciences into the massive scientific observatory and didn't want to have to tell his scientists that their beloved satellite would not be the first. Others in Korolev's design bureau also opposed the new plan. For example, Il'ia Lavrov (1920–1995), one of Korolev's engineers who had invested an enormous amount of energy into bringing the Object D satellite project to fruition vocally objected. Speaking of the "simplest satellite," he told his colleagues that "this sphere is nonsense and a disgrace to the design bureau," and that they should finish the original job that they set out to do on the Object D.[6]

More than internal dissension, Korolev also needed to convince the government that this was the right thing to do. He knew the military would be problematic. They had already committed to handing over a military weapon, the R-7 ICBM, to launch the "useless" Object D satellite. Now, Korolev wanted more ICBMs to launch another satellite. On January 5, 1957, he sent a letter to the government with his revised plan, asking for permission to launch two "simplest satellites," each weighing about 40–50 kilograms, between April and June 1957, i.e., *before* the beginning of the International Geophysical Year (IGY).[7] As is well-known, the IGY was sponsored by the International Council of Scientific Unions as a planned period of 18 months (July 1, 1957, to December 31, 1958), during which scientists from all over the world would carry out an intense program of research on geophysical phenomena. Korolev's thinking on scheduling the satellites was based on the premise that since the Americans were planning to launch a satellite during IGY, if the Soviets managed to launch *before* the IGY, they would probably come out ahead. Knowing that government leaders would respond more strongly to competition with Americans than any rationale of scientific research, Korolev, in his letter, prominently highlighted the possibility that the Americans might easily preempt the Soviets. In other words, this was an urgent situation. Perhaps the most important bit of text Korolev's somewhat disingenuous appeal was that, far from deleteriously affecting the ICBM test program, a satellite launch would actually help "solve a number of questions [related to] the launch, work of the engines, stage separation, etc.)."[8]

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Top leaders in the Soviet government were convinced, and about a month later, on February 15, the government issued a formal decree approving work on the new plan. Two identical satellites, PS-1 and PS-2, would be launched in April and May 1957 on retooled R-7 rockets.[9] Their orbits would range in altitude from 225 to 500 kilometers. According to the Politburo decision, the goals of the PS satellites would be rather simple: "prepare two R-7 [rockets] with an artificial Earth satellite and [associated] ground equipment for their launch in May or June 1957." These launches would be carried out only if "favorable results" were produced of "one or two R-7" rockets launched in the test series. While the Academy of Sciences was given permission to generally publicize the idea of satellites, there was to be no "disclosure of any information about the [launch vehicle] of the satellite."[10]

A cone or a ball?

Looking at the shape of Sputnik now, it seems obvious that the world's first artificial satellite should have had such an elegant design. In the beginning, however, designers were not sure of its form. Long before official approval of the PS-1 plan, on November 25, 1956, Korolev had tasked a young antenna specialist in his design bureau, Nikolai Kutyrkin, to make the initial drawings for the satellite.[11] Early on, the designers working on the satellite settled on a cone-shape for PS-1, echoing the cone chassis for the much larger Object D. They reasoned that a cone would fit well and naturally with the shape of the R-7 rocket's payload fairing.

But when Tikhonravov's deputy Evgenii Riazanov met with Korolev to show him some draft sketches of the satellite, Korolev flipped through all of them and didn't like any. Cautiously, Riazanov asked "Why?" to which Korolev mysteriously answered, "Because it's not round."[12] And as one designer later remembered, "there were weighty scientific considerations" in favor of a sphere.[13] Two factors were crucial for picking a sphere. First, a sphere was an ideal geometric shape with maximum volume in ratio to minimum surface area, giving it a favorable tradeoff between packing as much equipment into as possible vs. limiting surface area exposure to changes in temperature. Second, a spherical shape (as opposed to more irregularly shaped objects) was ideal for determining atmospheric density on its orbital path. Korolev also apparently believed that a shiny metal *spherical* object would better reflect light and thus have a better chance of visibility with telescopes. It was, however, clear that such a small object would not be visible to the naked eye. Visually tracking a moving object at about 1,700 kilometer range (the distance of the satellite from an observer as the satellite was above the horizon) was practically impossible.

The designer of Sputnik was Mikhail Tikhonravov, shown here in c. 1970. His career spanned over four decades during which he contributed to some of the greatest achievements of the Soviet rocket and space programs. (credit: Asif Siddiqi)

The technical stuff: Sputnik inside out

It's worth remembering here the exact design and construction of Sputnik, if only to admire the creativity of its designers as well as the way the urgency of its construction often affected its design. At its core, there were six major guidelines followed in the construction of the satellite.[14] According to Tikhonravov, Sputnik's primary designer, they included the following:

- The satellite would have to be of "maximum simplicity" and reliability while keeping in mind that methods used for this satellite would be used in future projects;
- The body of the satellite would be spherical in order to determine atmospheric density along its orbital trajectory;
- The satellite would be equipped with radio equipment working on at least two different wavelengths, with sufficient power to be tracked by amateurs as well as to obtain data on the propagation of radio waves through the ionosphere;
- The antennae would be designed so as not to affect the intensity of the radio signals if the satellite were to spin;
- The power sources would be onboard chemical batteries ensuring work for two to three weeks; and
- The attachment of the satellite to the core stage would be designed in such a way as to minimize the possibility of a failure in separation, or a failure in the deployment of antennae.

According to Tikhonravov, there were five primary scientific objectives of Sputnik:

- To test the method of placing an artificial satellite into Earth orbit and to verify its separation from the launch vehicle;
- To provide information on the density of the atmosphere that would be useful for calculating the orbital lifetime of future satellites;
- To test radio and optical methods of orbital tracking;

- To determine the effects of radio wave propagation through the ionosphere; and
- To check principles of pressurization used on the satellite.

Initial conceptions of the satellite had the sphere as being quite small, weighing in at about 50 kilograms, with a diameter of 500 millimeters.[15] At some point in early 1957, the satellite's design mass doubled to about 80 kilograms (although the mass margin was about 100 kilograms.) The satellite, as it eventually took shape, was a pressurized sphere, 58 centimeters in diameter made of an aluminum alloy 2 millimeters thick (a particular kind known as "AMG6T" in Russia.) The sphere was constructed by combining two hemispherical casings ("front" and "rear" half-casings) together along a ring-like rubber seal. The overall pressurized sphere was held together by 36 bolts. The front half-casing was smaller than the rear half-casing, although it was covered by a one-millimeter thermal shield. It also had four fittings with support projections for inserting the long external antennae.

The pressurized internal volume of the sphere was filled with nitrogen (at 1.3 atmospheres) which maintained the following:

- An electro-chemical source of power (three silver-zinc batteries);
- Two D-200 type radio-transmitters;
- A DTK-34 type thermal regulation system;
- A ventilation (fan) system to regulate the temperature of the satellite;
- A commutator;
- Temperature and pressure sensors; and
- Associated wiring.

The power source unit was shaped like an octagonal prism (450 by 270 millimeters) attached to the "front" half-casing. The unit had a cavity into which the radio equipment was "embedded." An octagonal shape was chosen both to ensure symmetrical circulation of the nitrogen gas inside the pressurized sphere and to efficiently remove heat produced by the radio transmitters. Of the three batteries (each shaped like a rectangular block), two provided power to the radio equipment while the third supplied power to both the ventilation fan, which regulated the temperature within the satellite, and to the commutator. By means of a switch operated by a temperature sensor (a thermocouple), the fan was designed to operate when temperatures were higher than 30° C and turn off when values were between 20 and 23°C.

The two D-200 type radio transmitters operated on frequencies of 20.005 and 40.003 megacycles at wavelengths of 15 and 7.5 meters. These transmitters (which obviously used vacuum tubes) each had a power intake of one watt and provided the famous "beep-beep-beep" sound to Sputnik. The signals on both the frequencies were spurts lasting 0.2 to 0.6 seconds, and carried information on the pressure and temperature inside the satellite; one set would transmit during the "pauses" of the other. The frequency of the signal, as well as the relationship between the length of the signals and the pauses in between, would change according to changes in temperature and pressure within the satellite hull. The satellite had simple pressure and temperature pickups that would close a circuit, given certain ranges of temperatures (greater than 50°C or less than 0°C) and pressures (less than 0.35 atmospheres), thus changing the signals' parameters.[16] The radio equipment package unit, shaped roughly like a rectangular block (100 by 130 by 390 millimeters), was hooked to a joint on the "front" half-casing and cushioned by a shock absorber.

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A set of antennae was bolted outside of the main body of PS-1. The system comprised four metallic rods, two with a length of 2.4 meters each and the remaining two with a length of 2.9 meters each. All four would spring open into their unfurled position at separation from the launch vehicle, at an angle of 35° with the satellite's main axis. When the satellite was actually stacked on the launch vehicle, these antennae were folded inside a cone-shaped adaptor (46° angle) and held down by eight small latches. The total mass of the satellite was 83.6 kilograms, of which 51.0 kilograms was simply the power source.

It is worth remembering the names of the designers, engineers, and technicians who worked on this satellite. The object (officially known as "PS-1") was designed in OKB-1's Department No. 9 under Korolev and Tikhonravov's direct supervision. The core group included: V. I. Petrov and A. P. Frolov (design and layout); O. V. Surguchev (thermal mode support); M. V. Kraiushkin and Iu. A. Bogdanovich (calculations for antennae systems); N. A. Kutyrkin (design of antennae systems); F. V. Kovalev, B. G. Shumakov, Iu. S. Karpov, and V. K. Shevelev (power control system); B. M. Popov (pressure and temperature measurement systems); A. M. Sidorov (pressurization maintenance); V. V. Molodtsov (installation of PS-1 in the nosecone and conceptual drawings of the payload shroud); and V. P. Kuz'min (payload shroud jettisoning system and system for separating PS-1 from the launch vehicle).[17]

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This still from a film made post-Sputnik, gives a good sense of the size of the actual satellite. (credit: Don Mitchell)

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Sputnik's radio transmitters

The development of Sputnik's radio transmitter package was fraught with uncertainty. Korolev visited Riazanskii's institute several times in the late winter and early spring of 1957 to discuss the nature of the instrument. Korolev was adamant that signals from the transmitters should be picked up by "the most dilapidated receiver, [and] that the whole world should hear them!" Yet, Korolev was also well aware that there was really no way to predict the behavior of radio waves, let alone the lifetime of the satellite in orbit. Riazanskii resisted putting a firm limit on the working lifetime of the radio transmitter but eventually guaranteed that it would provide a "decent signal" for at least two weeks. Based on these discussions, on February 15, 1957, Korolev and Riazanskii signed an agreement (which included the technical specifications) for the latter to deliver a functioning radio transmitter unit for use on PS-1.[18]

Lappo later confided that he built the system without really knowing whether it would function in outer space. Since a radio transmitter had never been in space before, there was no hard data on what to protect against; there was only conjecture.

In conceiving the basic design of the transmitter, Korolev and Tikhonravov took the advice of many, including Academician Vladimir Kotel'nikov (1908–2005), who was the director of the Academy of Sciences' Institute of Radiotechnology and Electronics, as well as scientists from other Academy institutes, such as the Institute of Earth Magnetism and Propagation of Radio Waves and the P. N. Lebedev Physical Institute. The actual hardware was built in a subdivision of Riazanskii's NII-885 institute, the

Laboratory for the Propagation of Radio Waves, headed by one Konstantin Gringauz (1918–93). Gringauz had already been developing a radio transmitter for the heavy Object D satellite for a year, work that was suspended when Riazanskii ordered him to develop a transmitter for the smaller PS-1. Not everyone agreed with Gringauz' vision of the instrument: despite objections from everyone (including Korolev), Gringauz insisted that PS-1 carry a high frequency transmitter (i.e., the 20.005 megahertz transmitter operating in the decameter waveband) in addition to the VHF transmitter (which had been commonly used on Soviet ballistic missiles.) Many believed that having a high-frequency transmitter would delay the satellite launch since it would have to be much larger than its twin. In the end, Gringauz won over his opponents, partly because everyone agreed that a high-frequency transmitter would ensure that the radio transmissions would be heard around the world.[19]

The transmitter hardware was built by one of Gringauz' youngest engineers, Viacheslav Lappo, who spent day and night trying to make the deadline. Lappo later confided in Soviet journalist Iaroslav Golovanov that he built the system without really knowing whether it would function in outer space. Since a radio transmitter had never been in space before, there was no hard data on what to protect against; there was only conjecture. As Korolev's deputy Konstantin Bushuev (1914–78), who was closely involved in the satellite's development, later recalled, "in developing and preparing the satellite for launch, we were faced with many questions which remained unclear. The level of our knowledge about the physical conditions of the upper atmosphere and the space around Earth was totally insufficient."[20] Lappo tried to account for sharp temperature fluctuations, cosmic radiation, even meteorites, but not with much confidence. In the end, PS-1's designers under Tikhonravov decided to sheath the radio transmitter within the battery system, almost as if to "protect" it from the elements.

Overall, Lappo made six transmitter units, the extra ones for testing. One was used on a Tupolev Tu-16 aircraft that flew over ground-based tracking stations so the controllers could get familiar with PS-1's transmissions. A second was suspended from a helicopter on a 200-meter-long cable to verify the operation of the long antennas (they worked excellently, and tracking stations in the Far East were able to pick signals up.) Of the remaining transmitter sets, two were for "reserve" and two were prepared for the launch. Lappo later recalled a humorous incident when Korolev showed up suddenly at his laboratory late at night and asked to listen to the signals from the satellite. The young designer described the operation of the transmitter to Korolev, explaining how the "beep-beeps" would change in frequency and length according to the internal pressure and temperature of the satellite. Lappo told Korolev, "You understand, Sergei Pavlovich, that in the hour of its death, it will squeak differently." Korolev seemed very pleased with this, and afterwards, almost bashfully added, "Couldn't you make it squeak a word of some kind...?"[21] Testing on the entire radio transmitter system was completed by May 5, 1957, ten days before the first attempted launch of the R-7 ICBM.

Computing Sputnik's trajectory

In March 1957, Korolev asked a young engineer at his design bureau, future cosmonaut Georgii Grechko (1931–2017), to calculate the trajectory for injecting PS-1 into orbit around the Earth using an R-7 missile. These enormously complicated computations were initially done by hand using six-digit trigonometric tables. Later, Keldysh arranged for Grechko to get a few hours of nighttime access to the latest computer, a large-scale behemoth capable of 10,000 operations per second, kept at Keldysh's Department of Applied Mathematics at the Academy of Sciences. Unlike machines in the West, this computer was programmed using tapes rather than punch cards. Because the machine worked on vacuum tubes, it heated up fairly rapidly, which forced the users to keep the windows open to generate cold draughts in the room. Grechko remembers he and his colleagues turning blue from the bitter cold. He later added:

> Our allotted time as a rule ended at three or four o'clock in the morning. Shoving the tape with the flight trajectory of the first artificial Earth satellite into a shopping bag—it didn't fit into one's pocket, and we had not yet bought any fancy briefcases—we headed home to Podlipki [or Kaliningrad]. We went to sleep on the commuter train (*elektrichka*) and were happy.[22]

Because of the peculiar configuration of Sputnik's launch vehicle (which had no *Fakel* trajectory monitoring package), there would be no way to precisely measure and verify the satellite's actual orbit using radio instrumentation. In this case, there were only two ways to do this: by telemetry signals (from the rocket's *Tral* system) indicating the actual moment of main engine cutoff of the core booster of the R-7, and by noting the moment that the satellite started its signal transmission.[23] The orbital trajectory calculations were carried out and completed in two separate phases, in March and August 1957.[24] Based on their results, the original plan was to deliver PS-1 into an orbit with parameters of 223 by 1,450 kilometers and an orbital period of 101.5 minutes.[25]

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A disassembled model of the PS-1 satellite on display at the Memorial Museum of Cosmonautics in Moscow. (credit: Asif Siddiqi)

Manufacturing Sputnik

Through the first half of 1957, the PS-1 satellite's form changed quite a bit from the early design that Korolev had approved in January. On June 24, Korolev's deputy Bushuev called the Chief Designer—who was at Tiura-Tam launch site (now known as Baikonur) overseeing continuing launches of the R-7 ICBM—to tell him that he had just signed off on the new and final configuration of PS-1.[26] It was now time to manufacture all the parts and assemble them into one flightworthy unit.

For every project at Korolev's design bureau, there two major phases: design and production. For PS-1, Tikhonravov had led the design phase (although many others had participated.) In terms of transitioning from design to experimental production, Korolev usually appointed a "lead designer," a mid-level engineer who would be responsible for converting the designers' drawings into metal. They would also be Korolev's "eyes and ears" in the production shop, reporting back any glitches to the Chief Designer himself. In the case of PS-1, Korolev appointed Mikhail Khomiakov (1921–?) to be lead designer of PS-1; Khomiakov, on his initiative, asked another man, Oleg Ivanovskii (1922–2014), to serve as his deputy.

Ivanovskii had an unusual background: after fighting in World War II, he worked as an electrician at the famous NII-88 institute, the heart of the Soviet postwar missile program. It was there that he first met Korolev. In 1952, he decided to get a higher education and joined the Moscow Power Institute (MEI), where he did his diploma work with Academician Kotel'nikov, the scientist who later contributed to the Sputnik transmitter design. After graduation as an engineer, Ivanovskii worked briefly at NII-88 before being tapped in 1955 to become the

Production culture changed quite a bit after Korolev's first visit to the assembly shop. Khomiakov later recalled that Korolev "demanded that everything, beginning with the atmosphere in the building... and ending with quality of manufacture be changed."

secretary of the local Communist Party bureau (*partbiuro*) of Korolev's design bureau. In a society where Party credentials were crucial to upward mobility, Ivanovskii's Party work gave him a high profile. Two years later, when the *partbiuro* was dissolved during an organizational restructuring, Ivanovskii decided to return to engineering work. Khomiakov, with the approval of Korolev, invited Ivanovskii to help him out in fabricating the first Sputnik.

Unlike Khomaiakov who remained largely silent, Ivanovskii wrote a memoir of his time as a designer, which has been published in many editions in Russian.[27] Yet, strangely, Ivanovskii's memoirs provide only glimmers of the development of Sputnik: a few random details and generalized descriptions that say little. Vagueness seems to characterize the recollections of many with regard to the world's first artificial satellite. Famous Soviet space historian Iaroslav Golovanov wrote:

> I have had occasion to speak about our first satellite with many of the assistants at... Korolev's experimental design bureau, and also with specialists from the factories that were producing accessory components. It is strange but they don't remember it clearly. The work on the [R-7] rocket was so voluminous and intensive that in people's memory, it overshadowed the little sphere with the "feeler" antennas.[28]

The few extant details do, however, provide a fairly colorful picture of the preparations leading up to the launch of Sputnik. A number involve Korolev. At some point, probably in the late summer of 1957, when many of the satellite components had been manufactured and tested, Korolev convened a meeting of the leading Sputnik designers and announced that the satellite must be larger—that the diameter be increased from 0.6 to 1 meters! He was suddenly concerned that the satellite would not be visible with the naked eye. Naturally, many designers were upset, not the least because they had spent months bringing the project to fruition. One of Korolev's senior aides, Deputy Chief Designer Sergei Okhapkin (1901–80), was the most upset since he was afraid that a change in the design so late would mean they would miss the launch date. A bigger satellite would also mean a more powerful launch vehicle, meaning more changes and more time. Eventually, even the mighty Korolev was convinced that this was a bad idea.[29]

Production culture changed quite a bit after Korolev's first visit to the assembly shop. Khomiakov later recalled that Korolev "demanded that everything, beginning with the atmosphere in the building... and ending with quality of manufacture be changed."

PS-1 was assembled at Factory No. 88 located right next to Korolev's design bureau in Kaliningrad (now called Korolev.) Most factory engineers involved in the creation of Sputnik did not perceive it as anything more or less important than any other object created at the plant. The factory's chief engineer, Viktor Kliucharev, later recalled that constructing PS-1, especially in comparison to the immensely complicated R-7 ICBM, was a relatively painless job for the workers. For the factory foremen, the most challenging job proved to be manufacturing and assembling the hemispherical casings of the hull of Sputnik. These half shells were made by "stamping," which produced many defects (or folds) typical of "deep drawing" which took great skill to eliminate from the final operational models. Technologists also had to ensure that the satellite was as shiny as possible to maintain coefficients of absorption and reflection to make it as visible as possible. Shop workers spent a lot of time "finishing" the aluminum outer shell of the satellite.

In the summer of 1957, Korolev and Academician Kotel'nikov had discussed ways to increase the reflectivity not only of the satellite payload but also the core booster, which would also be inserted into orbit with PS-1. Kotel'nikov, the director of the Academy of Sciences' Institute of Radiotechnology and Electronics, assigned one of his scientists, V. M. Vakhnin, to develop a deployable angular reflector that would later be installed on the core.[30] The use of this reflector made it possible for Soviet ground-based radar stations to track the core for several weeks after launch.

Production culture changed quite a bit after Korolev's first visit to the assembly shop. Khomiakov later recalled that Korolev "demanded that everything, beginning with the atmosphere in the building... and ending with quality of manufacture be changed."[31] Korolev was particularly aghast that workers were trying to weld the satellite's casings by hand. Emphasizing the importance of full internal pressurization, he insisted on automatic welding, as well as recommending new methods to check the air tightness of the hull. Factory workers eventually used a special helium leak detector (known as the PTI-4) to test the integrity of the satellite. But most important for Korolev was a clean environment. He told his foremen: "In three days everything here must shine. Hang white gloves on the windows, dress everyone who works here in white coats and gloves. Paint the stand under the satellite white and line the pedestal in velvet."[32] After Korolev's visit, things changed. Kliucharev remembers that:

> All of those who came into contact with the "little ball" literally carried it in their arms. They worked in white gloves, and the rigging on which the satellite was assembled was covered in velvet. Korolev kept track of all the operations involving the satellite, and he demanded that this article be given special treatment.[33]

Flight and test models of the PS-1 were manufactured in August 1957 in parallel with assembly of the R-7 rocket that would deliver it into orbit. Ivanovskii recalls that because the two systems were manufactured in adjacent halls, PS-1 workers would frequently run over to see the R-7 being assembled to make sure that they were not lagging behind, since they did not want to be the source of any delays.

Once all the assembly and testing operations on PS-1 had been finished, in early September 1957, Korolev invited all those involved in the satellite's assembly and testing—about 40 people, including his deputies, department chief, and factory shop foremen—to discuss the status of the satellite. He asked Khomiakov to give a report, who provided a detailed status summary, but twice mistakenly referred to "PS" as "SP." The latter was the nickname many at Korolev's bureau used to informally refer to the Chief Designer ("SP" for "Sergei Pavlovich.") Korolev interrupted Khomiakov, asking people angrily "not to confuse the two."[34]

In late September, the PS-1 was finally delivered to the launch range at Tiura-Tam. The satellite was shipped in two separate containers, one containing the main body and the other carrying the four long antennae. (The launch vehicle had already arrived earlier.) Soon after, on Korolev's orders, a group of the main production personnel, including both Khomiakov and Ivanovskii, left Kaliningrad for the launch site on Korolev's orders.[35]

Publicizing Sputnik before launch

As many have noted over the years, the Soviets were not shy about announcing the fact they would launch a satellite during the IGY. Between 1953 and 1957—peaking especially in the latter years—several hundred articles on space travel flooded the popular Soviet media. Most appeared in popular science journals such as *Nauka i zhizn'* (Science and Life), *Kryl'ia rodiny* (Wings of the Motherland), *Tekhnika-molodezhi* (Technology for Youth), and *Priroda* (Nature); others appeared in popular general issue journals such as *Ogonek* (Zest) or daily papers such as *Pravda*, *Izvestiia*, and *Krasnaia zvezda* (Red Star). Although none of these articles contained any specific details about Sputnik, its launch vehicle, its designers, or indeed its schedule of launch, the prolific nature of these articles suggested a deep and persistent interest in spaceflight in the Soviet Union. Recent information now indicates that designers in the "secret world" of the Soviet military-industrial complex (such as Korolev and Tikhonravov) directly and indirectly passed information to public writers for public consumption.[36] Korolev was explicit about the need to publicize the impending Soviet space program. At a meeting in July 1956, he had told fellow chief designers that "the results of the true situation [with the satellite project] needs to be communicated at [international] conferences not by direct participants of the work but by major scientists, [who are] able to understand what they're talking about."[37] Korolev specifically singled out the upcoming IGY conferences in Barcelona and Rome.

All this publicity certainly made a difference in the West. In 1957 alone, as the months counted down to the launch of Sputnik, there were a number of important signs that something big was imminent.

Less than two months later, Academician Ivan Bardin (1883–1960), a reputable Soviet metallurgist who was chairman of the Soviet IGY committee, officially confirmed at Barcelona that the Soviet Union would launch a satellite during the IGY. Bardin, like Korolev, had long complained to the Soviet government of being hobbled by secrecy rules. After he wrote a letter to the Politburo, the Soviet government reluctantly agreed to let Bardin and others talk very generally about an impending satellite.[38] As a result, four months before the launch of the satellite, in June 1957, Bardin provided more information to CSAGI although he did not elaborate on a timing for the launch.[39]

Korolev and Tikhonravov also disseminated information about the planned satellite to the general Soviet populace through other conduits. In one particular case, they managed to galvanize the energies of thousands of young amateur radio enthusiasts all across the Soviet Union to help the engineers track the satellite once it was in orbit. At the time, there were few professional observation posts spread across the Soviet landmass—the few existing ones belonged either to the Air Defense Forces or a few scattered astronomical observatories, so making use of amateurs was a clever and effective way to "fill in the blanks."

Here, Academician Kotel'nikov, who had counseled Korolev's engineers in the creation of PS-1's radio transmitters, played a key role. On Korolev's instructions, some of Kotel'nikov's scientists at his institute passed on details of the satellite's radio transmitters, including its transmission frequencies, to the Central Radio Club of the major Soviet paramilitary youth organization, DOSAAF. Soon, DOSAAF, in coordination with Kotel'nikov's scientists, delivered special tracking instruments (tape recorders, signal generators, etc.) to 28 separate amateur radio clubs across the country, who all reported to the central club back in Moscow.[40] The particular clubs were chosen according to their location, spread along a line from the Baltic states all the way to Chukotka in eastern Siberia. Nikolai Kazanskii, president of the Soviet Amateur Radio Federation, remembers that he actually attended a meeting where Korolev was present where they asked him how many minutes it would take for the DOSAAF people to relay information on positive identification of the satellite to Moscow. Kazanskii assured them that he could get news from any of the outlying clubs to the central location at Rastorguevo (in Moscow) within 15 minutes.[41]

Simultaneously, in the summer of 1957, DOSAAF published information about the satellite in its amateur ham journal, *Radio*, which had a circulation of about 200,000. There was no information on the actual satellite nor about when or how it would be launched, but there was data useful to amateur radio enthusiasts: how the satellite might fly, how its signals might transmit through the ionosphere, and of course, the transmission frequencies (20 and 40 megahertz!) DOSAAF also funded test runs on the equipment delivered from Kotel'nikov's institute: at the Central Club, they used a Iakovlev Iak-12 airplane, a tiny single propeller vehicle capable of carrying one or two extra passengers, to send out signals from a makeshift transmitter which radio hams tracked from the ground. By October, there were many thousands of young Soviet citizens who were ready for the "real" thing.[42]

Evgenii Riabchikov, a journalist for the popular Soviet journal *Ogonek* who was one of the few in his profession with access to the "secret" world, also contributed to public anticipation for Sputnik. Riabchikov, who had spent time in Antarctica with the Soviet expedition working under the auspices of impending the International Geophysical Year, wanted to do a series of articles on space exploration. He met with PS-1 designer Tikhonravov, who eventually arranged for Riabchikov to talk directly to Korolev. As a result of these discussions, Riabchikov published two major *Ogonek* articles in the summer of 1957 that included very general details about Sputnik without mentioning either Korolev or Tikhonravov. Official state censors allowed such articles to be published once they were approved for public consumption by Academy of Sciences Corresponding Member Evgenii Fedorov (1910–1981), a meteorologist charged with approving the dissemination of scientific information to the public.[43] Fedorov, like Academician Bardin, was another "public" member of the Soviet IGY committee who actually knew very little about the satellite effort.

All this publicity certainly made a difference in the West. In 1957 alone, as the months counted down to the launch of Sputnik, there were a number of important signs that something big was imminent. The various statements of Academy of Sciences President Aleksandr Nesmeianov (1899–1980) on a future satellite launch were prominently featured in major American newspapers such as the *New York Times*. In a page one story on June 2, 1957, the paper reported (quoting Nesmeianov) that the Soviets had completed work on the rockets and instruments necessary to launch a satellite into an orbit a few hundred kilometers above the Earth; the *Times* helpfully added that “a kilometer is roughly five eighths of a mile.”[44] Riabchikov’s *Ogonek* article was also picked up in the same paper a few days later, with the additional information that the satellite would be launched by a multi-stage rocket and that the orbital period of the satellite would be 90 minutes. Nesmeianov added that “soon, literally within the next few months, our planet will acquire another satellite, a man-made satellite at that.”[45] A few days later, the *Times* quoted Academician Fedorov, the chief censor of the Soviet scientific community, as claiming that a satellite launch would happen before the end of 1958. He also provided more details on orbital parameters (190 by 480 kilometers) and launch time (early morning)—which were strangely far different from real plans.[46]

Endnotes

1. Michael J. Neufeld, *Von Braun: Dreamer of Space, Engineer of War* (New York: Alfred A. Knopf, 2007), 304.
2. See for example, “Army Test Reported on ‘Jupiter’ Missile,” *New York Times*, September 27, 1956, 31.
3. For the early history of Soviet satellite research (i.e., pre-1954), see Asif A. Siddiqi, *Challenge to Apollo: The Soviet Union and the Space Race, 1945-1974* (Washington, DC: NASA, 2000), 84-92, 139-144.
4. For a detailed account of this whole process, see Asif Siddiqi, “Sputnik 50 years later: New evidence on its origins,” *Acta Astronautica* 63 (2008): 529-539. For a much more detailed exposition of Soviet space thinking in the 1950s, see Asif Siddiqi, T*he Red Rockets' Glare: Spaceflight and the Soviet Imagination, 1857-1957* (New York: Cambridge University Press, 2010).
5. Iaroslav Golovanov, *Korolev: fakty i mify* (Moscow: Nauka, 1994), 532.
6. Golovanov, *Korolev*, 533.
7. S. P. Korolev, “Predlozheniia o pervykh zapuskakh iskusstvennykh sputnikoi zemli do nachala mezhdunarodnogo geofizicheskogo goda” in *Tvorcheskoe nasledie Akademika Sergeia Pavlovicha Koroleva: izbrannye trudy i dokumenty*, ed. M. V. Keldysh (Moscow: Nauka, 1980), 369-370.
8. This is from a joint letter authored by Korolev and others to the Presidium (or Politburo) sent on January 28, 1957. See “Dokladnaia zapiska o gotovnosti k zapusku uproshchennogo iskusstvennogo sputnika zemli....” in *Pervyi pilotiruemyi polet: sbornik dokumentov v dvukh knigakh, kn. 1-ia*, ed. V. A. Davydova (Moscow: Rodina MEDIA, 2011), 85-86.
9. “Postanovlenie prezidiuma TsK KPSS o zapuske ISZ s pomoshch’iu rakety R-7 v nachale mezhdunarodnogo geofizicheskogo goda” in *Pervyi pilotiruemyi polet*, 87-88.
10. Ibid.
11. Golovanov, *Korolev*, 532.
12. Memoirs of M. L. Gallai in *Akademik S. P. Korolev: uchenii, inzhener, chelovek*, ed. A. Iu. Ishlinskii (Moscow: Nauka, 1986), 63.
13. I. Miniuk, “Fantastika i real’nost’,” *Aviatsiia i kosmonavtika* no. 9 (1987): 46-47.
14. The technical details of Sputnik presented here are based on the following sources: “Pervyi iskusstvennyi sputnik zemli” in *S. P. Korolev i ego delo: svet i teni v istorii kosmonavtiki: izbrannye trudy i dokumenty*, ed. B. V. Raushenbakh (Moscow: Nauka, 1998), 574-575; M. K. Tikhonravov, "Provozvestnik kosmicheskoi ery: iz istorii sozdaniia pervogo sputnika,” *Aviatsiia i kosmonavtika* no. 10 (1974): 40-41; Iu. P. Semenov, ed., *Raketno-Kosmicheskaia Korporatsiia "Energiia" imeni S. P. Koroleva* (Korolev: RKK Energiia named after S. P. Korolev, 1996), 89-90.
15. These figures are from the January 28, 1957 letter to the government. See document cited in Ref. 8. Korolev apparently signed off on this early design on January 25, 1957. See Memoirs of Tikhonravov in *Akademik S. P. Korolev*, 447; V. Poroshkov, “Sozdanie i zapusk pervogo sputnika zemli,” *Novosti kosmonavtiki* no. 10 (2002): 56-60.
16. Tikhonravov notes that the signals were between 0.2 and 0.6 seconds long but doesn’t specify if these were nominal or off-nominal values. Poroshkov notes that the original beeps were 0.3 seconds in length while the beeps would “change from 0.2 to 0.4 seconds” when temperature or pressure parameters were out of range. See Tikhonravov, “Provozvestnik kosmicheskoi ery”; Poroshkov, “Sozdanie i zapusk pervogo sputnika zemli.”
17. V. V. Molodtsov, “Kosmos. Pervye shagi. Pervye itogi”.
18. Memoirs of Tikhonravov in *Akademik S. P. Korolev*, 447.
19. Mikhail I. Verigin and Norman F. Ness, “Konstantin Iosifovich Gringauz, 1918-1993,” *Space Science Reviews* 64 (1994): 1-3; Golovanov, *Korolev*, 536.
20. Memoirs of K. D. Bushuev in *Akademik S. P. Korolev*, 463.
21. Golovanov, *Korolev*, 536.
22. Golovanov, *Korolev*, 533.
23. N. L. Semenov, “Kak zapuskali pervyi sputnik,” *Zemlia i vselennaia* no. 5 (2002):49-55.
24. Memoirs of Tikhonravov in *Akademik S. P. Korolev*, 447.

25. “Osnovne rezul’taty puska rakety-nositelia s pervym isz 4 oktiabria 1957 [1957 g.]” in *S. P. Korolev i ego delo*, 239-242. There is some confusion on this issue, since the final report to the government from Korolev and others before the launch (dated September 24, 1957), states that the orbit would be 225 X 1,000 kilometers. See “Zapiska V. M. Riabikov....” in *Sovetskaia kosmicheskaia initsiativa v gosudarstvennykh dokumentakh, 1946-1964 gg.*, ed. Iu. M. Baturin (Moscow: RTSoft, 2008), 72-74.
26. Iaroslav Golovanov, "Start kosmicheskoi ery,” *Pravda*, October 4, 1987, 3.
27. During the Soviet era, Ivanovskii wrote under the pen name “Aleksei Ivanov.” His memoirs were published as Aleskei Ivanov, *Pervye stupeni* (Moscow: Molodaia gvardiia, 1970). Subsequent updated editions were published in 1975 and 1982. An unexpurgated version of his memoirs appeared in 2005 as *O. G. Ivanovskii, Rakety i kosmos v sssr: zapiski sekretnogo konstruktora* (Moscow: Molodaia gvardiia, 2005).
28. Golovanov, *Korolev*, 534-535.
29. Miniuk, “Fantastika i real’nost’,”; Golovanov, *Korolev*, 533-534.
30. Memoirs of G. A. Skuridin in *Akademik S. P. Korolev*, 459.
31. Memoirs of M. S. Kavyzin [pseudonym for M. S. Khomiakov] in *Akademik S. P. Korolev*, 449.
32. Memoirs of Kavyzin [Khomiakov] in *Akademik S. P. Korolev*, 449.
33. Golovanov, *Korolev*, 537.
34. Ivanovskii, *Rakety i kosmos v sssr*, 30.
35. Ivanovskii dates their departure to Tiura-Tam as “early September” in one of his many memoirs. See O. G. Ivanovskii, *Naperekor zemnomu pritiazhen’iu* (Moscow: Politizdat, 1988), 175.
36. For a deeper look at this material and the connections between the open and secret worlds, see Siddiqi, *The Red Rockets’ Glare*, Chapter 8.
37. G. S. Vetrov, “Pervyi sputnik: istoricheskii rubezh,” *Novosti kosmonavtiki*, no. 16 (1997): 2-8.
38. “Zapiska akademika I. P. Bardin N. S. Khrushchevu o pozitsii sovetskikh predstavitelei na soveshchanii Mezhdunarodnogo o spetsial’nogo komiteta po provedeniiu Mezhdunarodnogo geofizicheskogo goda” (July 4, 1956) in *Sovetskaia kosmicheskaia initsiativa v gosudarstvennykh dokumentakh*, 70-71.
39. “The USSR Rocket and Satellite Program,” in *Annals of the International Geophysical Year, Vol. IIA: The International Geophysical Year Meetings*, ed. M. Nicolet (London: Pergamon Press, 1959), 310-311; “USSR Rocket and Earth-Satellite Program for the IGY,” June 10, 1957, U.S. National Academy of Sciences, IGY Archives, Drawer 19, File: TPESP Sat. Corr. June 1957.
40. Some sources say 26 clubs. See for example, A. A. Maksimov, “Iz istorii sozdaniia komandno-izmeritel’nogo kompleksa,” *Iz istorii aviatsii i kosmonavtiki* no. 60 (1990): 12-19.
41. N. Grigor’ev, “Radioliubiteli i kosmos,” *Radio*, no. 10 (1982): 5-7.
42. Grigor’ev, “Radioliubiteli i kosmos.” For the 1957 articles in *Radio*, see issue nos. 6, 7, and 8. For an analysis of Soviet amateur radio preparations for Sputnik, see Rip Bulkeley, “Harbingers of Sputnik: The Amateur Radio Preparations in the Soviet Union,” *History and Technology* 16 (1999): 67-102. Most notably, the scientist in charge of installing the angular reflector on the R-7 ICBM, V. M. Vakhnin, wrote one of the *Radio* articles in 1957 for DOSAAF members.
43. E. Riabchikov, “Shturm kosmosa,” *Ogonek*, no. 23 (1957): 6-7; E. Riabchikov, “Sputnik zemli,” *Ogonek*, no. 24 (1957): 25-26. For Riabchikov’s recollections, see “Zaria kosmicheskoi ery,” *Ogonek*, no. 40 (1987): 1-3. Fedorov’s main claim to fame was arctic and polar research and the publication of his diary of an arctic expedition. E. K. Fedorov, *Polar Diaries* (Moscow: Progress, 1983); E. K. Fedorov, *Ekspeditsiia ‘Severnyi polius’* (1937) (Leningrad: Izd-vo glavsevmorputi, 1940-45).
44. “Soviet Reports gain on an Earth Satellite,” *New York Times*, June 2, 1957, 1, 39.
45. “Russian Gives News of Space Satellite,” *New York Times*, June 11, 1957, 2.
46. Max Frankel, “Soviet to Launch First ‘Moon’ in ’58,” *New York Times*, June 20, 1957, 31; “Soviet Stressing 2 I.G.Y. Projects,” *New York Times*, August 4, 1957, 19.

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Asif Siddiqi is Professor of History at Fordham University. He can be reached at siddiqi@fordham.edu.