

The launch of the world's first artificial satellite 50 years ago

Iskusstvennyy sputnik zemli

On the early morning of 20 September 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, climbing to an altitude never reached before by any manmade object, nearly 1,100 kilometres.

The payload itself travelled downrange about 5,400 kilometres from the launch site before burning up in the atmosphere. As radio systems beamed back information to the blockhouse on the record-breaking flight, von Braun "danced with joy". 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.

This somewhat obscure missile launch irrevocably changed the course of the 'Space Race', serving as one of the main catalysts for what eventually became the world's very 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 some time. These studies had begun in the early 1950s under the tutelage of rocket designer Mikhail Tikhonravov (1900-74) at a secret military organisation known as the Scientific-Research Institute No. 4 (NII-4 or "nee-4") based in the north-eastern Moscow suburb of Bolshevo.

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 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 50 years after he proposed the clustering concept, the R-7 continues to be used today, albeit in significantly updated versions.

The R-7 was designed at the famous Experimental Design Bureau No. 1 (OKB-1)

There are now many detailed histories of the origins of Sputnik. Yet, for being one of the most important (if not arguably the most important) event in the history of space exploration, few historians have tried to reconstruct the events of 1957, especially those leading up to the launch of Sputnik on 4 October 1957. We only have a few scattered anecdotal accounts, mostly from the height of the Communist era. The goal in this article is less on the political and institutional roots of Sputnik, which have been covered in many other places, but on the actual events of 1957. How was Sputnik designed? How was it built? Who tracked it? What happened during the launch? Who publicised it? The aim is to provide the very first fully fleshed out account of the 'opening shot' of the Space Age based on a vast array of original Russian-language sources collected over two decades of research by the author.

by
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based in the Moscow suburb of 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 post-war rise as one of the geniuses behind the Soviet missile and space programmes.

Yet, Korolev's early successes might not have been possible without the help of Tikhonravov. They had known each other 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 organisations, 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' of young scholars at NII-4 who, since September 1953, had been busily working on a concrete proposal for an artificial satellite of Earth. Korolev's projects were given an imprimatur of legitimacy by the involvement of Academician Mstislav Keldysh (1911-78), a brilliant applied mathematician who specialised 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. With his help, Korolev managed to get the sanction of the USSR Academy of Sciences for the satellite project and, after a little over a year of lobbying, the Soviet government approved a modest scientific satellite programme in August 1955.

Anxiety about Americans

Initially, the Soviet satellite project was a massive (1.3 tons) scientific observatory known as the 'Object D'. Building this complicated satellite on time, however, proved to be very challenging, especially since many of the scientific instruments had to be redesigned for 'space' conditions. In addition, ground tests showed that the launch vehicle for 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 launch served to guide the Soviet satellite project in an inexorably different direction. Although the Jupiter C launch 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 before 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 and 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 kilogrammes or so, even lighter?"

Korolev 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 Ryazanskiy (1909-87) of NII-885 to provide the radio equipment and Chief designer Nikolay Lidorenko (1916-) of the Scientific-



Chief designer Sergey Korolev shown here in a famous photograph taken at the Kapustin Year launch range in May 1953. *Asif Siddiqi*

Research Institute of Current Sources (NII IT) to supply the batteries.

Everything else would be built under his direct command in-house 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 (Prosteyshyy 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. Il'ya Lavrov, 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.

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 5 January 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 kilogrammes, between April and June 1957, just before the beginning of the International Geophysical Year (IGY). As is well-known, the IGY was sponsored by the International Council of Scientific Unions as a planned period of 18 months (1 July to 31 December 1958) during which scientists from all over the world would carry out an intense programme 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 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 prominently highlighted the possibility that the Americans might easily pre-empt the Soviets.

Top leaders in the Soviet government were convinced and, about a month later on 15 February, 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 re-tooled R-7 rockets. According to the government decision, the goals of the PS satellites would be rather simple: "Deliver the simplest unoriented Earth satellite (the object PS) into orbit, [and] verify the possibility of observing the PS in orbit and receive signals, transmitted from the object PS."

Cone or ball

Looking at the shape of Sputnik now, it seems obvious that the world's first artificial satellite should have 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 25 November 1956, Korolev had tasked a young antenna specialist in his design bureau, Nikolay Kutyrkin, to make initial drawings for the satellite.

Early on, the designers 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 Yevgeniy Ryazanov met with Korolev to show him some draft sketches of the satellite, Korolev flipped through all of them and didn't like any. Cautiously, Ryazanov asked "Why?" to which Korolev mysteriously answered: "Because it's not round."

As one designer later recalled: "There were weighty scientific considerations" in favour of a sphere and two factors were crucial. First, a sphere was an ideal geometric shape with maximum volume in ratio to minimum surface area, giving it a favourable trade-off between packing as much equipment into as possible versus 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 kilometre range (the distance of the satellite from an observer as the satellite was above the horizon) was practically impossible.

Initially, the sphere was quite small, weighing in at about 40-50 kg but at some point in January 1957, the satellite's design mass doubled to about 80 kg (although the mass margin was about 100 kg). Based on the new calculations, Korolev signed off on the specifications for the PS-1 satellite on 25 January.

Sputnik inside out

There were six major guidelines followed in the construction of PS-1 and, 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 the spacecraft 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 of sufficient power



Mikhail Tikhonravov, shown here in 1970, was one of the pioneers of Soviet rocketry and space exploration. His ground-breaking studies laid the groundwork for the R-7 ICBM, Sputnik, the early lunar and interplanetary probes, and the Vostok spacecraft. Boris Chertok

to be tracked by amateurs and 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 a life of two to three weeks, and
- the attachment of the satellite to the core stage would be designed in such a way as to minimise the possibility of a failure in separation or a failure in the deployment of antennae.

Tikhonravov also listed the five primary scientific objectives of the mission as:

- 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 which 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 pressurisation used on the satellite.

The satellite, as it eventually took shape, was a pressurised sphere, (see images of the satellite on the following pages), 58 cm in diameter made of a 2 mm thick aluminium alloy (a particular kind known as AMG6T in Russia). The sphere was constructed by combining two hemispherical casings together with a ring-like rubber seal. The

overall pressurised sphere was held together by 36 bolts. The front half-casing was smaller than the rear half-casing, although it was covered by a 1 mm thermal shield. It also had four fittings with support projections for inserting the long external antennae.

The pressurised internal volume of the sphere was filled with nitrogen (at 1.3 atmospheres) which maintained 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 mm by 270 mm) 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 pressurised 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 the ventilation fan which regulated the temperature within the satellite, and also 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 30C and turn off when values were between 20 and 23C.

The two D-200 type radio transmitters operated on frequencies of 20.005 and 40.003 megacycles at wavelengths of 15 and 7.5 m. These transmitters (which obviously used vacuum tubes) each had a power intake of 1 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 (>50C or <0C) and pressures (<0.35 atmospheres), thus changing the signals' parameters. The radio equipment package unit, shaped roughly like a rectangular block (100 X 130 X 390 mm), was hooked to a

joint on the front half-casing and cushioned by a shock-absorber.

The antennae system was situated outside of the main body of PS-1. The system comprised four metallic rods, two with a length of 2.4 m each and the remaining two with a length of 2.9 m each. All four would spring open into their unfurled position at separation from the launch vehicle, at an angle of 35 degrees 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 degrees angle) and held down by eight small latches. The total mass of the satellite was 83.6 kg, of which 51.0 kg was the power source.

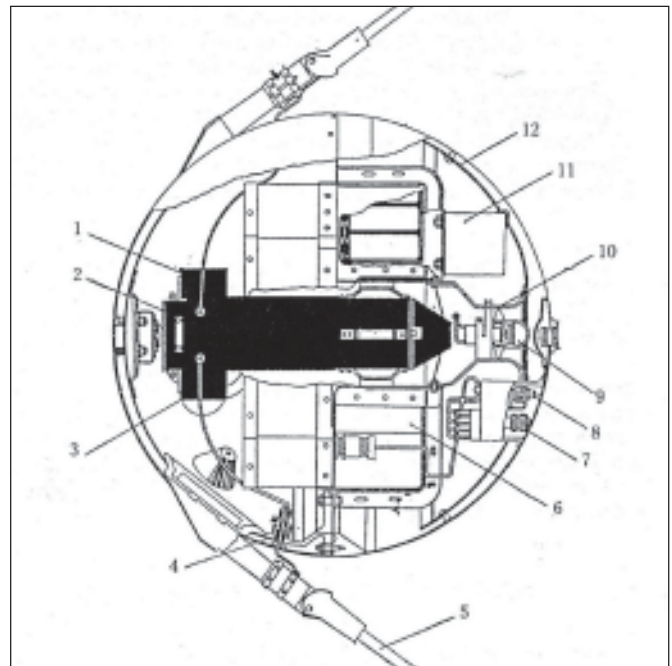
The PS-1 satellite was designed in OKB-1's Department No. 9 under Korolev and Tikhonravov's direct supervision. The core group who designed the world's first artificial satellite were V.I. Petrov and A.P. Frolov (design and layout), O.V. Surguchev (thermal mode support), M.V. Krayushkin and Yu.A. Bogdanovich (calculation on antennae systems), N.A. Kutykin (design of antennae systems), F.V. Kovalev, B.G. Shumakov, Yu.S. Karpov and V.K. Shevelev (the 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 nose cone 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).

Radio transmitters

The development of Sputnik's radio transmitter package was fraught with uncertainty. Korolev visited Ryazanskiy's institute several times in the late winter and early spring of 1957 to discuss the nature of the instrument and 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 behaviour of radio waves, let alone the lifetime of the satellite in orbit. Ryazanskiy 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,, Korolev and Ryazanskiy signed an agreement on 15 February 1957 (which included the technical specifications) for the latter to deliver a

A schematic side view of the PS-1 satellite. The legend for the diagram is: (1) Duplex thermal sensor of the DTK-34 temperature control system; (2) D-200 radio transmitter; (3) temperature and pressure sensors; (4) pressure seal intake; (5) antenna; (6) batteries; (7) socket junction point; (8) heel contact; (9) ventilator fan; (10) diffuser; (11) remote control switch; (12) screen.
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functioning radio transmitter unit for use on PS-1.

In conceiving the basic design of the transmitter, Korolev and Tikhonravov took the advice of many, including Academician Vladimir Kotel'nikov (1908-) 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 Ryazanskiy's NII-885 institute, the Laboratory for the Propagation of Radio Waves, headed by Konstantin Gringauz (1918-93). Already for a year, Gringauz had been developing a radio transmitter for the heavy Object D satellite, work that was suspended when Ryazanskiy ordered him to develop a transmitter for the smaller PS-1.

Despite objections from just about everyone (including Korolev), Gringauz insisted that PS-1 carry a high frequency transmitter (the 20.005 MHz 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.

The transmitter hardware was built by one of Gringauz' youngest engineers,

Vyacheslav Lappo, who spent day and night trying to make the deadline and later confided in Soviet journalist Yaroslav 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. As Korolev's deputy Konstantin Bushuyev (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."

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 which 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 m 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



This exploded view of the PS-1 satellite clearly shows its constituent parts. From the top: the thermal shield, the "front" half-casing, the batteries, radio transmitter system, and the "rear" half-casing. National Air & Space Museum

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, Sergey 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...?" Testing on the entire radio transmitter system was completed by 5 May 1957, ten days before the first attempted launch of the R-7 ICBM.

Sputnik's rocket

Much has been written about the R-7 (more commonly and affectionately known as the Semyorka or "the number seven"). Its basic conceptual design was derived from studies carried out in the early 1950s under Tikhonravov which indicated that it would be technically feasible to fashion a very long-range rocket by clustering stages in parallel rather than in tandem. In such a configuration, all the engines would fire simultaneously at lift-off. Thus, engineers could avoid the challenges of designing high

performance rocket engines for an upper stage (which would have to fire in near-vacuum conditions).

By the time the R-7 design was frozen in July 1954, the rocket was a one-and-a-half stage missile, composed of a core surrounded by four identical strap-on boosters, each powered by a similar rocket engine. The central hammerhead-shaped core (known as the Block A) was 26 m long while each of the conical strap-ons (known as Blocks B, V, G, and D) were each 19.2 m long. The strap-on boosters, each containing about 40 tons of propellant, tapered up to a point at the top and were connected to the core by ball-and-socket joints at the apex and by tension bands at the bottom. With the four strap-ons, the total base diameter was 10.3 m and total length of the missile (including the early nuclear warhead payload) was 34.22 m. The launch mass was 270 tons, of which about 253 tons (93.7 percent) was propellant. At lift-off, the five main engines (core + four strap-ons) would generate a total thrust of 403.4 tons.

After a typical launch, at an altitude of 50 km and about 100 km downrange from the launch site, pyrotechnical devices would loosen the tension bands at the base of the vehicle which connected the four exterior stages to the core. With the four strap-ons still firing, albeit at much lower thrust by then, the lateral boosters would, by their natural force, move away from the core, and rotate upwards and away from the base. At a certain angle, the mountings at the apex of the four boosters would automatically release. Oxygen valves would also automatically open to exert gentle pressure on the strap-ons to move them independently away from the core.

The core stage (called the "second stage" by the Soviets) would then continue to operate until reaching an altitude of 170 km and a range of 700 km, at which point engine cut-off would occur. For the remaining portion of the flight, the payload, a cone-shaped object weighing about 5.5 tons, would coast on a ballistic trajectory until re-entry. The maximum slated range for the early R&D versions of the R-7 was about 8,000 km and a total flight time to target was around 18 minutes.

The R-7 missile used a combination of an

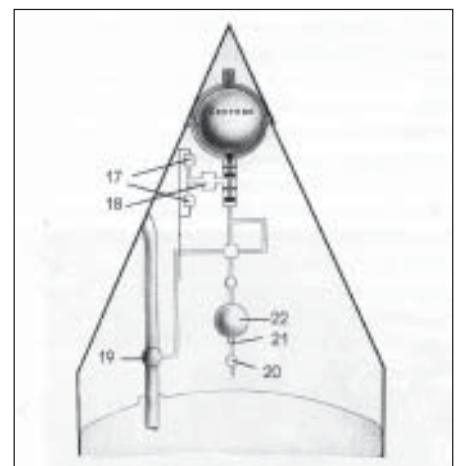
This schematic shows two systems to separate the PS-1 satellite from the launch vehicle, a pyrotechnical system and an oxygen jet system. The legend for the diagram is: (17) pyrotechnical cartridges; (18) igniter; (19) valve; (20) electro-pneumatic valve; (22) choke washer.

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autonomous inertial guidance and remote radio control for trajectory control, both developed at the NII-885 institute based in Monino. The former was designed under chief designer Nikolay Pilyugin (1908-82) and the latter under chief designer Ryazanskiy (also responsible for Sputnik's radio transmitters). The inertial system operated during the entire part of powered flight and ensured angular stabilisation (along the axes) and centre-of-gravity stability, using several different subsystems - for normal and lateral stabilisation, for adjusting apparent velocity (RKS), for the simultaneous depletion of tanks, and for synchronising the depletion rate of the tanks. The RKS was capable of throttling engine thrust up or down (within limits) as was needed.

The radio control package (which included a transponder) installed at the top of the core booster contained equipment for processing signals and control commands simultaneously from two ground stations located about 250 km to the 'left' and 'right' of the nominal trajectory. These electronic commands would be converted to firings of the verniers on the main engines to alter the trajectory as needed. In essence, during flight, ground control would monitor the actual trajectory of the rocket and compare it to planned parameters and issue commands with the goal of minimising the difference between nominal and actual values.

One major function of the radio control system was near the end of the powered segment. About 20 to 30 seconds prior to all engine burnout, the core's main engine would shut down, and the four verniers would continue to fire, adding a little bit more velocity to ensure that the missile reached its required speed and to further trim the direction of the rocket. At main core engine shutdown, the RKS from the inertial system would be switched off and the radio control



system would correct any major deviations of the core stage from the planned trajectory. When the desired velocity was reached, the radio control system would shut down the verniers, and the missile would continue on a ballistic trajectory.

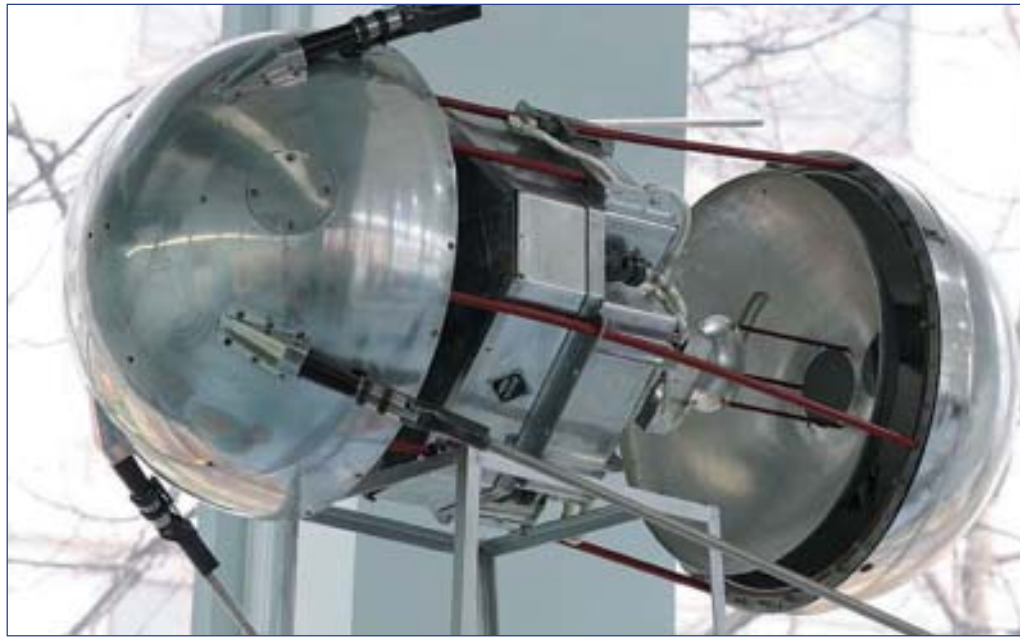
Three autonomous Tral telemetry systems (augmented by many subsystems) on each R-7 communicated information to the ground about more than 700 different parameters from the missile.

In all paperwork related to the new ICBM, bureaucrats simply used the term 'article 8K71' as a way to obfuscate the true nature of the system being described. The 8K71 was the basic ICBM version of the R-7, the most important priority weapon developed for the Soviet armed forces in the 1950s. Yet, the basic ICBM required some changes before it could be used to launch Sputnik into orbit. Besides removing the warhead container (about 5.5 tons) and associate cables connecting the warhead to the rocket, the missile's 300 kg radio control system installed on top of the core booster (which was necessary only for the final stage of powered flight on a normal ballistic flight) was removed and replaced by a set of systems designed to separate the constituent parts of the payload from the launch vehicle at orbital insertion. These included a mechanical 'pushing' system to impart a relative velocity of 2.73 m/second to the satellite.

As a backup, the rocket also included a pyrotechnical system (probably with a small amount of explosive) to separate the satellite at a relative velocity of 1.45 m/s. Finally, there was a spring-loaded mechanism that would separate the protective nosecone at a relatively velocity of 0.643 m/s, ie, about one-fourth of the velocity of ideal separation velocity of the satellite from the rocket. The protective nose fairing contained a heat shield to protect the payload against aerodynamic heating during the powered phase up to orbit.

The seriousness with which engineers took the issue of booster separation from the satellite is underscored by the use of yet another system that involved a nozzle installed on the upper surface of the oxidizer tank that would fire a jet of oxygen (venting gas from the oxidizer tank) at the moment of satellite separation, not only to slow down the core booster but also to change its attitude to prevent the core from colliding with the payload after separation.

The R-7's engines were created by the design bureau named OKB-456 headed by the powerful Chief Designer Valentin



These images show an exploded view of the PS-1 satellite on display at the RKK Energiya Museum in Korolev outside of Moscow. Clearly visible in these images are the two casings of the satellite, the large battery package, and components of the radio transmitter. Seiji Yoshimoto/NPO InterCoS

Glushko (1908-89), a colleague of Korolev's from the 1930s. For the satellite launch vehicle, Glushko's engineers altered the firing regimes of the main engines of the R-7. In the original ICBM, the core used one RD-108 (or 8D75) while the strap-ons each used a single RD-107 (or 8D74).

With slightly altered firing regimes, these engines were renamed the 8D75PS and 8D74PS respectively. In particular, the thrust of the engines of the core booster was reduced to 60 tons (from 74 tons). Because such a change might result in the separating strap-ons and the booster colliding with each other due to smaller relative velocities, engineers decided to increase the altitude of separation of the strap-ons and the core by programming a throttle down of strap-on

engine thrust to 75 percent of nominal values at 17 seconds prior to strap-on separation. (The lower thrust would ensure less propellant consumption and therefore a longer burn time and a higher altitude). The high altitude of separation - with its thinner atmosphere - would put less dynamic pressure on the stack, reducing the risk of collisions.

A propellant sensor on the core would monitor propellant levels in the tanks through powered ascent. When the sensor detected propellant levels in the core stage were down to 50 percent of the 'guaranteed propellant reserve' the sensor would issue a command to shut down the engine. The desired orbital velocity determined the level of nominal propellant consumption. According to initial

projections, the booster was also designed to orbit the payload even if the sensor failed and the engines burned to propellant depletion.

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 Tral) indicating the actual moment of main engine cut-off of the core booster of the R-7, and by noting the moment that the satellite started its signal transmission. The orbital trajectory calculations were carried out and completed in two separate phases, in March and August 1957. Based on their results, the original plan was to deliver PS-1 into an orbit with parameters of 223 X 1,450 km and an orbital period of 101.5 minutes.

There were three other changes to the launch vehicle from the ICBM version - the number of onboard batteries was reduced, the launch vehicle carried no sensors to monitor vibration measurement (the RTS-5), and the missile's engines used a more potent mixture of hydrogen peroxide to drive the turbopumps.

The new PS-1 version of the R-7 ICBM, now named 'article 8K71PS', had a length of 29.17 m (almost 4 m shorter than the early version of the ICBM) and a fully loaded mass of 272.83, over seven tons less than a regular R-7. The whole cluster would generate a total lift-off thrust of 398 tons. These days, the Russians officially call this launch vehicle 'Sputnik', a name that westerners typically reserve for the satellite and not the launcher.

Manufacturing Sputnik

Through the first half of 1957, the PS-1 satellite's form changed significantly from the early design that Korolev had approved in January. On 24 June, Korolev's deputy Bushuyev called the chief designer - who was at Tyura-Tam 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. It was now time to manufacture all the parts and assemble them into one flight-worthy unit.

For every project at Korolev's design bureau, there were 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 Khomyakov (1921-) to be lead designer of PS-1. Khomyakov, on his initiative, asked another man, Oleg Ivanovskiy (1922-), to serve as his deputy.

Unlike Khomyakov, who has remained largely silent, Ivanovskiy has written a memoir of his time as a designer, which has been published in many editions in Russian. Yet, strangely, Ivanovskiy's memoirs provide only glimmers of the development of Sputnik - a few random details and generalised descriptions that say little. Vagueness seems to characterise the recollections of many with regard to the world's first artificial satellite.

Famous Soviet space historian Golovanov wrote: "I have had occasion to speak about our first satellite with many of the assistants at S.P. 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 rocket [the R-7 ICBM] was so voluminous and intensive that in people's memory, it overshadowed the little sphere with the 'feeler' antennas."

The basic details do, however, provide a fairly colourful picture of the preparations leading up to the launch of Sputnik, and a number involve Korolev himself.

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 m! Evidently, he was 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 Sergey Okhapkin (1901-80), was the most perturbed 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.

PS-1 was assembled at Factory No. 88

located right next to Korolev's design bureau in Kaliningrad (or Podlipki). 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 Klyucharev, 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 fulfill particular coefficients of absorption and reflection (to make it as visible as possible). Shop workers spent a lot of time 'finishing' the aluminium outer shell of the satellite. In the summer of 1957, Korolev and Academician Kotelnikov 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.

Kotelnikov, 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, making 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. Khomyakov later recalled that Korolev "demanded that everything, beginning with the atmosphere in the building ... and ending with quality of manufacture be changed".

Korolev was particularly aghast that workers were trying to weld the satellite's casings by hand. Emphasising the importance of full internal pressurisation, 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."

After Korolev's visit things changed.

Klyucharev recalled: "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.

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. Ivanovskiy 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.

Before launch, engineers thoroughly tested the satellite and its associated systems. Full, dry run static tests of PS-1 in conjunction with an R-7 booster were carried out at the factory in Kaliningrad on 31 August 1957 ten days after the first successful long-range flight of the R-7 ICBM.

The following week, there was a full course of testing of PS-1 in a thermal chamber and vibration stand. The total set of tests conducted in August and early September were challenging, partly because it was very difficult to simulate particular conditions, such as increasing g-loads, vibration and weightlessness in the experimental factory at Kaliningrad. Engineers devised some "special attachments and equipment" to repeatedly subject a mock-up of PS-1 to docking and separation from the R-7 launch vehicle. Khomyakov recalled: "The pneumatic locks operated reliably, the nose fairing separated, the antennae came out, and, after separation [of the nose fairing], the mechanical [separation system] moved the satellite in a forward direction."

Other post-assembly tests included installing the internal equipment, cabling, and mechanisms in mock-ups, verifying the pressurisation of the flight model using leak detectors, investigating the thermal conditions of the satellite to project actual temperatures during flight, and checking the simultaneous process of both fairing separation and satellite ejection from the core booster of the launch vehicle.

In early September 1957, once all the assembly and testing operations on PS-1 had been finished, 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.

Khomyakov 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 Sergey Pavlovich). Korolev interrupted Khomyakov, saying: "I know that many of you call me 'SP' but this is not our ... simplest satellite, that's 'PS'! Don't confuse the two."

In September, the PS-1 was finally delivered to the launch range at Tyura-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, a group of the main production personnel, including both Khomyakov and Ivanovskiy, left Kaliningrad on Korolev's orders.

Pre-launch publicity

Korolev and Tikhonravov disseminated information about the planned satellite launch to the general Soviet public via indirect links. In one particular case, they managed to galvanise 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. Beyond its public relations dimension, such a campaign could also support the Sputnik designers' own hopes of tracking the satellite 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 defence forces or a few scattered astronomical observatories. Making use of amateurs was a clever and effective way to "fill in the blanks".

Here, Academician Kotel'nikov, who had counselled 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 organisation, 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. 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.

Nikolay Kazanskiy, president of the

Soviet Amateur Radio Federation, remembers that he actually attended a meeting at which 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. Kazanskiy assured them that he could get news from any of the outlying clubs to the central location at Rastorguyevy (in Moscow) within 15 minutes.

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 MHz).

DOSAAF also funded test runs on the equipment delivered from Kotel'nikov's institute. At the Central Club they used a Yakovlev Yak-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.

Success with the R-7

Although Korolev had obtained permission to launch PS-1 back in February, the launch was not a foregone event. In his letter to the government in January, he had noted that "two rockets upgraded for [satellite] launches could be ready in April-June 1957 and launched immediately after the first successful launches of the intercontinental missile".

More precisely, the military had agreed to allow Korolev to indulge his fantasies only after two successful launches of the R-7 ICBM. As is well-known, there were several consecutive failures of the missile in the summer of 1957 - one missile on May 15 exploded 104 seconds into its ascent, a second rocket never left the pad despite three consecutive attempts on 9, 10, and 11 June, and a third R-7 was destroyed 33 seconds after launch on July 12.

If there had been hope of launching two PS-1-type satellites in the summer, that hope was lost. The mood at Tyura-Tam was hitting rock bottom by the time that a fourth R-7 was brought out to the pad. Engineers, soldiers, and even government bureaucrats

were all desperate for a success. One of Korolev's principal deputies, Anatoly Abramov (1919-98), later remembered: "Now, if ever, was the time to despair, to lose faith in the whole programme." However, S.P. Korolev's composure and the absence of any attempt to find scapegoats made people realise that we had embarked on a new level of scientific-technical complexity where no one had gone before. To have fallen into confusion or become mired in apportioning blame would have destroyed the team, its unity and self-confidence. The weight of responsibility resting on Korolev's shoulders was enormous, especially when you consider that he had still not been formally rehabilitated [after his imprisonment]. Arrest, prison and exile were still fresh in his mind.

Luck favoured them in this dark hour. An R-7 lifted off on its first (relatively) successful flight on 21 August. To the delight of thousands of engineers, the R-7's engines, combustion chambers, strap-on boosters, hybrid guidance system and launch complex worked with clockwork precision. The missile flew 6,500 km, and its warhead entered the atmosphere over the Kamchatka peninsula in the far-eastern coast of the Soviet landmass. Although the actual warhead container disintegrated about 10 km above the target, the flight was considered a major step forward in the R-7 programme. Korolev was so animated by the event that he kept his deputies awake until three in the morning, talking without end about all the doors opened by this success.

As for the missile, a quickly dispatched search party of about 500 men spent almost a whole week gathering the remains of the dummy warhead and its thermal coating. It was only after the search party returned that the State Commission wrote up an official communique on the launch, a statement which was published in the Soviet media on August 27.

"A few days ago a super-long-range, intercontinental multi-stage ballistic missile was launched. The tests of the missile were successful; they fully confirmed the correctness of the calculations and the selected design. The flight of the missile took place at a very great, hitherto unattained, altitude.

"Covering an enormous distance in a short time, the missile hit the assigned region. The results obtained show that there is the possibility of launching missiles into any region of the terrestrial globe. The solution of the problem of creating intercontinental ballistic missiles will make it



Mikhail Khomyakov was the lead designer of the PS-1 satellite. Barring a few short essays, he has kept relatively silent about his experiences as the head of the team that manufactured, tested, and delivered Sputnik for launch. By the 1970s, he had risen to a senior position at RKK Energiya before retiring.

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possible to reach remote regions without resorting to strategic aviation, which at the present time is vulnerable to modern means of anti-aircraft defence."

It was extremely unusual for Soviet authorities to publicise successes in any military field at any point during the Cold War, let alone in the 1950s. But without access to archival source material, it is difficult to speculate on the rationale behind disseminating this particular statement which publicly announced the possession of an ICBM.

Some Western analysts reflexively assumed that the statement was intended for a foreign (ie, American) audience, especially since there were armaments reductions talks on-going in London at the time, focusing especially on means of verification. It is as likely that Khrushchev orchestrated the release of the communique for domestic reasons, aimed at officials high up in the Communist Party, the government and the military, who had strongly expressed doubt about the massive amounts of resources that Khrushchev diverted from conventional forces to strategic (particularly missile) weapons.

The announcement was picked up and discussed widely in the West although opinion was divided as to its veracity. Many were sceptical. British defence officials - including the Royal Air Force chief - were openly doubtful that the Soviet Union was capable of mastering the sophisticated technology required for intercontinental flight. Similarly, in the United States, the secretary of the Army, Wilber E. Brucker, echoed these comments, no doubt partly to buttress criticism of the Army's own missile programme.

Yet others saw the Soviet announcement as worrisome if not outright ominous.

Secretary of State John Foster Dulles "had no reason to doubt the veracity" of the Soviet claim but cautioned that the test did not fundamentally alter the balance of power between the two Cold War enemies.

Between the August announcement and the October launch of Sputnik, a number of major media speculations on the state of Soviet missile power were published. Some suggested that the Soviet success was entirely due to German technical know-how while others argued that a totalitarian system could galvanise a lot of resources to achieve singular goals such as missile development. Some of these pieces peripherally touched on the various and vague Soviet announcements on satellites.

The public announcement of the R-7 success certainly helped Korolev's reputation, which had come under attack with the repeated failures in the summer. With one R-7 success under his belt, Korolev now needed final permission from a body known as the 'State Commission' to proceed with an orbital launch.

In the Byzantine organisational world of the Soviet missile programme, these commissions were another layer of bureaucracy to deal with. State commissions had been a standard tradition in the Soviet defence industry since the 1930s. In principle, the idea was organisationally innovative - when a new weapons system needed to be tested and certified for adoption as a mass produced weapon, it made sense to organise a commission to oversee the process of testing and acceptance.

Members on these state commissions had regular jobs and usually represented a diverse array of interests - senior military officials, chief designers (or their deputies), ministers, deputy ministers and, often, respected scientists. A particular state commission ceased to exist once the weapon was declared operational.

In the case of the R-7, the Soviet government had organised a state commission on 31 August 1956 comprising 14 highly placed individuals, including the six chief designers who represented the major systems on the ICBM. The composition of the commission changed over time but it was expected that the core group of members would remain to supervise the launch of PS-1 if and when it happened.

The chairman of the State Commission for both the R-7 and PS-1 was Vasily Ryabikov (1907-74), who arguably played as important a role in the birth of Sputnik as Korolev, Tikhonravov and Keldysh - the other



Vasily Ryabikov was chairman of the State Commission for the launch of Sputnik. Ryabikov not only approved the Soviet satellite programme in 1955 but also oversaw the launch in 1957. He died in 1974.

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three big players. Yet ironically, Ryabikov is almost absent from the many stories on the history of the world's first satellite.

Ryabikov was originally a protégé of the famous armaments minister Dmitriy Ustinov (1908-84), the powerful defence industrialist who would go on to reign over the Soviet space programme for a quarter of a century. Although Ryabikov began his political career in 1939 working under Ustinov, after the war in 1951, he was abruptly promoted to a highly sensitive and powerful position as the manager of the massive Moscow air defence project where he worked closely with the dreaded Soviet security services chief Lavrentiy Beriya. Ryabikov reached the apex of his career on 14 April 1955 when Nikita Khrushchev appointed him to head a supervisory body that would hitherto manage all long-range missile development (including, of course, the ICBM programme) in the Soviet Union. As head of this body, Ryabikov not only out-ranked Ustinov but became the man who reported directly to Khrushchev on all matters related to long-range and strategic missiles.

According to one reliable source, back in February 1957 it was Ryabikov who supported Korolev's argument to switch the satellites from the big Object D to the small PS-1. On behalf of Korolev, he lobbied for the new plan with top Soviet leaders. As it got closer to commit to a satellite launch, it may have been Ryabikov who played the deciding role to push ahead.

Soon after the first ICBM launch success, the State Commission convened at Tyura-Tam to review the state of the R-7 test series. After a discussion of the results of the 21 August launch, Korolev - to everyone's surprise - proposed that they should immediately start preparations for the launch of an artificial satellite of the Earth, the PS-1.

He claimed that he would require a month-and-a-half to two months to get everything ready for the launch. The Tyura-Tam launch range's chief of staff at the time, Konstantin Gerchik (1918-2001), later

recalled that for many members of the Commission, this was a total surprise. Several had not even heard of the PS-1 option; they had assumed that the plan was still to wait for the Object D satellite to be ready before attempting an orbital launch.

The response to Korolev's request was "uproarious". Some members objected to the new plan, citing the more compressed and intense regime of work that many industrial enterprises were about to transition to because of numerous planned rocket launches - there would hardly be time to work as well on a satellite launch. Korolev persistently continued to press his case, but there was no unanimous support at the meeting. Perhaps sensing that he needed to try a different approach, he switched gears.

Gerchik recalled: "The fate of the launch of the [satellite] was determined by S.P. Korolev's second suggestion, 'I propose sending the question of national priority in the launch of the world's first [satellite] up to a meeting of the Presidium [the Politburo] of the Communist Party's Central Committee. Let them settle it'."

The notion that Korolev's idea be sent up to the Presidium completely changed the tenor of the meeting. No one on the Commission wanted this question to be passed up that high, and certainly no member wanted to be the one whose stubbornness had dragged the Presidium into this discussion. But for Korolev, the most powerful argument was the spectre of "national priority" - what bureaucrat would want to take a misstep and end up undercutting "national priority"? Perhaps Korolev was right? Maybe there was something to this satellite

One of the last photos of Sergey Korolev and Mikhail Tikhonravov before the launch of Sputnik. The photo dates from 15 September 1957 when the two men visited Kaluga, the hometown of Russian space patriarch Konstantin Tsiolkovskiy to celebrate his one hundredth birth anniversary. Pictured are (from left): Mikhail Ryazanskiy (designer of Sputnik's radio transmitters), Mikhail Tikhonravov, Sergey Korolev, Nina Koroleva (Korolev's second wife), and Konstantin Trunov (a colleague of Korolev's from his Gulag days).

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The famous Council of Chief Designers on the day of the Sputnik-2 launch on 3 November 1957. Pictured are (from left): Aleksey Bogomolov (telemetry systems), Mikhail Ryazanskiy (guidance systems), Nikolay Pilyugin (guidance systems), Sergey Korolev (missile and satellite), Valentin Glushko (rocket engines), Vladimir Barmin (launch complex), and Viktor Kuznetsov (gyroscopes).

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launch? In the end, the Commission unanimously approved Korolev's proposal, with the caveat that there be a second R-7 success first. The satellite launch was on.

Korolev returned briefly to Moscow on 31 August before heading back to Tyura-Tam on 5 September for his fourth trip that year to the launch range. The subsequent launch of the R-7 two days later was as successful as its predecessor, and the missile flew across the Soviet Union before depositing its dummy warhead over the skies of Kamchatka. Like the previous time, the warhead container disintegrated. It was clear that while the rocket itself was performing without fault, it could still not effectively deliver a warhead to any target. The problem required some serious research on the dynamics (shape, angle of entry, materials, aerodynamic quality) of the warhead container. Yet, the second failure of the warhead container actually helped Korolev's case in launching a satellite.

Korolev's first deputy Vasily Mishin (1917-2001) later wrote:

"To determine the reasons for the destruction [of the warhead containers] required time and, on S.P. Korolev's suggestion, a decision was taken on launching [PS-1] in the course of flight-design testing of the R-7 missile and gather statistical data on the flight of this rocket on the powered portion of its trajectory."

In other words, it would take weeks, perhaps months, to determine the precise cause for the destruction of the warhead containers. Engineers might have to produce an entirely new container (which is what they did). In the meantime, might not Korolev and his engineers continue flying R-7 missiles to

gain more data on its other systems?

Launching a satellite would be an ideal test in that sense, for the warhead would be replaced by the satellite, but everything else would largely be the same. For this reason, military representatives allowed Korolev to indulge his space dreams and handed over a perfectly "good" ICBM to launch a space satellite.

Tsiolkovskiy interlude

Korolev flew back to Moscow on 10 September. A major anniversary was approaching, the one hundredth birthday of Russian cosmonautics pioneer Konstantin Tsiolkovskiy, who was born on 17 September 1857. In the postwar years, Tsiolkovskiy had been canonised by the Soviet scientific community even though, during his lifetime the Academy of Sciences had patently ignored him. The tributes to Tsiolkovskiy attained a natural crescendo around the time of his centennial.

On 15 September Korolev and a number of major designers and scientists (including Glushko, Tikhonravov, Ryazanskiy, and Blagonravov) travelled by train to Kaluga, the town south of Moscow where Tsiolkovskiy lived in the last decades of his life. In the regional (oblast') theatre there was a function and later the guests all made their way to Peace Square (Mirnyy ploshchad') where a stone was laid for a future monument to Tsiolkovskiy. Finally, the procession walked to School No. 9 where Tsiolkovskiy had taught for many years. One striking photograph from the day shows Korolev and Tikhonravov uncharacteristically smiling, almost happy. They, the two primary authors of Sputnik, knew what few of their colleagues in attendance knew - that the space age would begin within a few weeks.

The ceremonies in Kaluga were merely a prelude to a major event in Moscow two days later, on Tsiolkovskiy's actual birthday. At 7 pm, in the Hall of Columns at Union House in Moscow, hundreds of eminent scientists and designers arrived to pay tribute to Tsiolkovskiy. Both Korolev and Glushko gave prominent speeches, hailing Tsiolkovskiy as not only one of the greats of Russian science but as a luminary on par with the greatest names in the history of science.

In his lecture, Korolev noted pointedly that "in the near future, for scientific purposes, the first trial launches of artificial satellites of the Earth will take place in the USSR and the USA". Only a few in the audience really knew that these words, far from being bluff and bluster, represented

hard cold facts.

Perhaps Korolev relished alarming the censors. In his paper, he noted that Soviet scientists were currently working on problems of sending probes to the Moon, circling the Moon, and even human spaceflight. The presentation ended with a slide show that began with photographs of Tsiolkovskiy and ended with rare pictures of recent Soviet suborbital flights that carried dogs to altitudes of 100 and 200 km. Few who attended the function knew the true jobs of Korolev and Glushko - they were simply introduced as 'Corresponding Members of the Academy'. Yet, their speeches were given widespread publicity. On the morning of the anniversary, Pravda published a full-page spread dedicated to Tsiolkovskiy that included an abridged version of Korolev's speech. It was the only article he published under his own name during the last three decades of his life. Soon an even darker shroud of secrecy would descend over his life.

Preparing for launch

Having made their connection to the past, Korolev, Tikhonravov, and Glushko returned to their jobs, now looking to the future. On 20 September Korolev attended a meeting of the State Commission for the launch of PS-1. Based on the current rate of preparations of the launch vehicle and the satellite, the attendees set the provisional date for the launch of the satellite as 7 October. They decided that the Soviet press would be officially informed about the launch of PS-1 only after it had completed its first orbit. The members also agreed to have ready within three days a draft of the announcement that would be sent to TASS.

On 24 September, Tikhonravov finally readied the internal design bureau document detailing all aspects of the launch and mission of PS-1. It was modestly titled 'Technical Account on the Possibility of Launching PS-1'. Korolev signed the cover and scribbled in bold 'Keep Forever!'

A more general document for the core State Commission members was also drawn up for everybody to sign. In the typical bureaucratic and dry language of the Soviet era, reading the title, one would never know that the five men who put their signatures to it had basically signed one of the most historic documents of the space age - 'The programme for carrying out a test launch of a simple unoriented ISZ (the object PS) using the article 8K71PS'.

On 26 September, Korolev flew to Tyura-Tam via Tashkent to supervise the launch of Sputnik. Once there, he stayed in a small

cottage close to the main area of activity at the range, Site 2. Activity at the assembly-testing building nearby was quickly accelerating as a mere 11 days remained until the planned launch. All operations with PS-1 were carried out in a hall room on the second floor adjacent to the main (and massive) assembly hall for R-7. This room later became the testing station for future spacecraft payloads, including the Vostoks that carried cosmonauts into orbit.

Sputnik's deputy lead designer Ivanovskiy remembers a few glitches in the preparations. Before stacking the PS-1 with the R-7 booster, the designers carried out a final test of all of the satellite's systems.

Vyacheslav Lappo, the young designer of the radio transmitter repeatedly - and some would say obsessively - checked and re-checked his handiwork, making sure that the transmissions correctly communicated information about internal temperature and pressure. Others verified "their" systems.

The last separate item to be checked was the heavy battery installed in the metal ball. The flight model was brought in and hooked up to a voltmeter. There was dead silence when it showed zero volts. There was clearly a problem since electrolyte was apparently leaking, yet no one could immediately figure out the precise source. Everyone present knew that the stakes were high since not only Korolev but State Commission chairman Ryabikov were already at Tyura-Tam.

Quickly, the testers formed a group to debug the problem. They put the battery on a work station, and "with the gravitas of doctors doing a heart operation", technicians began dismantling the battery under the supervision of Vladimir Bogotskiy, the man responsible for the system, who currently looked like his world had caved in.

Finally, a technician found that some wires had come off due to bad soldering. A plug socket had come undone. Rimmochka Kolomenskaya, a young mechanic, quickly repaired it on the spot. By this time, Ryabikov had apparently showed up wanting accountability. He railed at Bogotskiy who desperately tried to defend himself by explaining that the problem would not occur again, that they had applied a new coating of epoxy. Korolev, standing next to Ryabikov, kept silent the whole time.

After the debacle with the battery, all the systems were re-tested, the satellite components were reintegrated into a whole and, using pulleys and cranes, the payload was attached to the top of the horizontally stacked launch vehicle.

The 'long moustaches' - as the engineers called Sputnik's four aerals - were fixed adjacent to the payload fairing atop the rocket. Once the satellite was stacked completely, Korolev insisted on a final test of the radio transmitter. All the members of the State Commission were there to witness this. Lappo gingerly turned on the switch to the transmitter, and the "beep-beep-beep" of Sputnik eerily echoed throughout the big hall room of the assembly building. Once the transmitter was switched off, Ivanovsky climbed up a step ladder to the satellite and removed a protective plate from the contact point that would supply power to the transmitter. According to the flight programme, at the moment of separation from the launch vehicle, the commutator (basically an electrical switch) would switch on the power in the satellite.

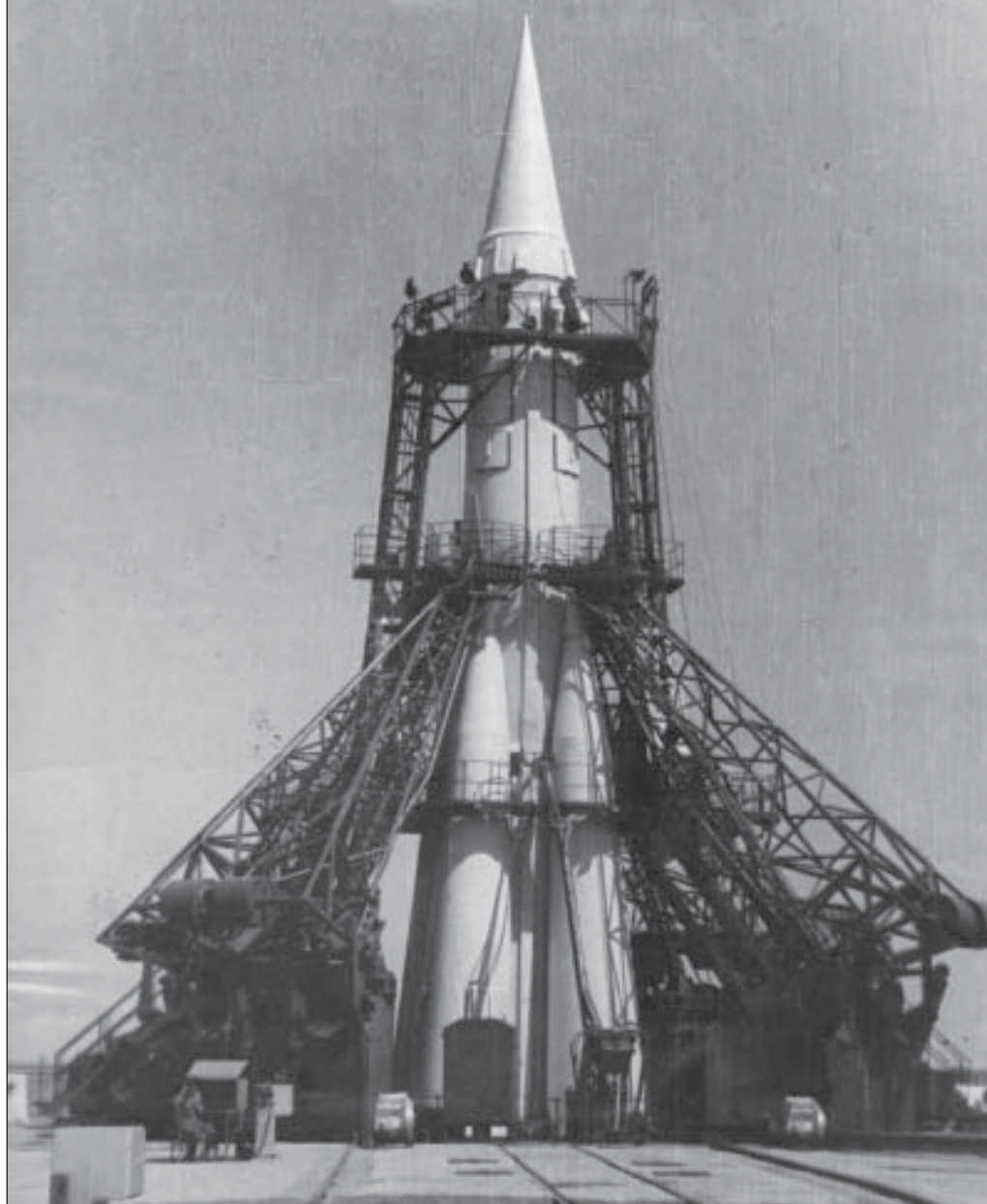
The launch

On 30 September a six day conference opened at the National Academy of Sciences in Washington DC focusing on rocket and satellite research during IGY. Representatives from six countries, including the Soviet Union, attended.

Korolev kept tabs on the proceedings via cables from the Soviet embassy in Washington. Seeing that the title of one of the papers was 'A Satellite Over the Planet [sic]', he concluded that this meant only one thing - that the Americans were timing a secret launch during the conference and that the paper would essentially be an announcement of the event. The fact that the paper was by John P. Hagen, the Vanguard satellite programme's manager, seemed to confirm his fears. Hagen was apparently familiar to Korolev.

Golovanov notes that Korolev "read [Hagen's papers] attentively". Korolev contacted KGB representatives to verify if the Americans were planning a launch but the security agency reported back that there was no evidence to suggest a launch was in the offing. Stubborn to the core, Korolev refused to take a chance. Now panicked about being pre-empted by Americans at the last minute, he insisted that the PS-1 launch be brought forward by two days, from early morning October 7 to late night October 4.

As a result, at 4 pm on the afternoon of 2 October, he signed an order for the new launch date and sent it to Moscow for final approval. Launch would be in two days. True to Korolev's headstrong character, he didn't bother to wait for official confirmation to start the ball rolling. In the pre-dawn twilight of 3 October, a diesel train carrying the rocket



An early version of the R-7 on the pad at Tyura-Tam (later Baikonur) in 1957.

Boris Chertok

and its delicate payload emerged out of the assembly building and slowly headed for the launch pad at Site 1. Witnesses remember Korolev saying, "Well, have a good trip ... let's accompany our first-born".

Scores of people lined the railway track all the way to the pad. With Korolev at the front, everybody slowly escorted the vehicle all the way to its launch site. (The signed document from Moscow approving the launch was returned on the morning of 4 October, launch day).

It was warm at the time, unusual for October at Tyura-Tam. On the morning of the launch, a Friday, testers at the pad were concerned that the high temperatures might overheat the tiny satellite, rendering its systems useless. A quick test seemed to indicate that temperatures were in fact rising underneath the payload fairing. A young military officer, Vladimir Kobelev, assigned to work with the designers at the firing range, took the initiative to go up the service platform and cover the payload fairing with a large white fabric while other tests were

going on. This proved ineffective. Eventually, Kobelev set up a hose that released cold air into the fairing, which evidently reduced temperatures to tolerable levels.

Fuelling of the rocket had already begun at 0545 hours local time. Korolev, although under pressure, remained cautious throughout the proceedings. He told his engineers: "Nobody will hurry us. If you have even the tiniest doubt, we will stop the testing and make the corrections on the satellite. There is still time..."

Yevgeniy Shabarov (1922-2003), one of Korolev's deputies in charge of flight-testing, later remembered that the launch preparations for the satellite were conducted at "a slower pace" than was usual. Most personnel at the launch range, understandably enough, did not have time to ponder over the historical value or importance of the upcoming event.

Ivanovskiy later wrote: "Nobody back then was thinking about the magnitude of what was going on, everyone did his own job, living through its disappointments and joys."

Although many people from Korolev's design bureau were on hand at Tyura-Tam, most of the personnel involved in carrying out the launch were young men from various rocket and artillery divisions of the Soviet armed forces. On behalf of Korolev, the launch preparations were directed by his deputy, Leonid Voskresenskiy (1913-65), a legend already in his own time, known for his fearlessness and colourful personality.

For most of Korolev's time as chief designer, he relied on the trustworthy Voskresenskiy to fix any situation at the pad, who sometimes disregarded even Korolev's own rules. Commanding the launch with Voskresenskiy was Lieutenant Colonel Aleksandr Nosov (1913-60), the same age as his colleague, whose official title was deputy commander of the launch range, which in effect meant that he was personally responsible for all missiles that took off from any pad. A World War II veteran, Nosov had gained considerable experience with firing rockets during long tours of duty at Kapustin Yar near the Volga river where the Soviets had tested their first German V-2s back in the late 1940s.

For the satellite launch, a young artillery captain, Vladimir Nikulin, was put in charge of maintaining the paperwork - filling out the mission goals and flight logs. Unsure of what to fill in for "goal of the launch", Nikulin turned to Korolev's first deputy Vasilii Mishin who told him to dispense with such entries as "target", and instead write out the launch azimuth (the angle between true north and the direction of the launch) as 34 degrees 37' 59.2". The launch azimuth was calculated based on the desired orbital inclination of 65.1 degrees, which would ensure that the satellite would pass over almost all inhabited areas of the globe, including, most importantly, both the eastern portion of the Soviet Union and the United States.

Nikulin's job was to get the key military testers responsible for each system of the launch vehicle and the satellite to sign off that 'their' system was ready for launch. This was a long tradition with military rocket launches in the Soviet Union, made doubly important with the test flights of the R-7 earlier in the year. Unlike all earlier missiles, the R-7 was an expensive and massive piece of machinery. To lose one of these due to a junior army officer's negligence was unacceptable. There was one novelty with the launch of Sputnik — there was an individual responsible for signing off for the satellite, a tradition that became established thereafter.

One-by-one, Nikulin got his signatures - Senior Lieutenant Yuriy Chalykh in charge of programming the rocket's launch azimuth, Lieutenant Colonel Aleksey Dolinin on the readiness of all the engines of the rocket, and Captain Semyon Grafskiy and Lieutenant Vladimir Ganushkin for the propellants.

All the chief designers involved in the operation — in particular, the 'big six' from the famed Council of Chief Designers of the 1940s, signed off on the launch: Korolev, Glushko, Pilyugin, Ryazanskiy, Barmin and Kuznetsov. The latter two, Vladimir Barmin (1909-93) and Viktor Kuznetsov (1913-91) were in charge of the launch complex and the rocket's gyroscope systems respectively. Another chief designer, Aleksey Bogomolov (1913-) - responsible for the R-7's telemetry systems - was listed as a 'technical supervisor' rather than a chief designer since historically he had not been part of the original 'big six' but was a new entrant to the big leagues. Nikulin remembers finding Korolev very close to the rocket. He signed off on the launch log pensively, in silence.

On the night of the fourth, huge floodlights illuminated the launch pad as servicemen crowded around the rocket completing their various tasks. Korolev was clearly anxious. About an hour before launch, he abruptly ordered PS-1 lead designer Khomyakov and a military tester from the launch team to go up to the very top platform and check everything out. This was highly unusual and probably quite dangerous, but Khomyakov obliged without resistance.

Khomyakov had been preceded up to the top earlier in the day by Konstantin Gringauz, the designer of the satellite's radio transmitter system. He later recalled: "I had to do the final check to make sure that the transmitter was going to work ... there was a special cover [hatch] in the nosecone, so I reached inside, checked the 'beep... beep... beep' signal, and I knew everything was all right... Then the cone was sealed for the last time." By his own admission, Gringauz was the last person to "touch" Sputnik.

Ivanovskiy, in his memoirs and in various interviews, has described an anonymous serviceman stepping out into the launch area after dusk and blowing a bugle, as if to mark the solemnity of the event. "The name of this solder remains unknown to history," according to Ivanovskiy. Yet, no other witnesses of the launch preparations have spoken of this lone bugler and, as good a story as it sounds, it may be closer to myth than memory in the history of Sputnik.

Back in the bunker there were six command and control panels, each manned by one or two individuals responsible for a particular aspect of the rocket: two panels, each controlling two of the strap-ons, a control panel for the core booster, a panel for charging the onboard batteries of the rocket, a panel controlling fire extinguishing systems on the pad, and a control panel for monitoring the 'launch' of PS-1 at the end of the R-7's trajectory.

At T-50 minutes, ground operators gave the order to spin up the gyroscopes for the launch. Commands were issued to disconnect various junction boxes from the rocket. The last servicemen around the missile left the area and made their way to the safety of the bunker where they occupied their respective posts. At this point, the last pre-launch command was issued to "charge the batteries to flight time" which lit up the battery panel in the bunker. The inertial guidance system of the rocket was now ready.

At T-15 minutes, the whole area around the pad was evacuated. Five minutes later and, finally, Korolev, Voskresenskiy, Nosov and a few others joined the rest of the command crew in the bunker. Voskresenskiy and Nosov, in charge of the launch, took their places at periscopic sights. A loud speaker echoed the announcements in the now deserted and dark area around the launch pad: "T-10 minutes!"

Voskresenskiy's deputy Shabarov, also in the bunker, had a vivid memory: "With the exception of the operators, everybody was standing. Only N.A. Pilyugin and S.P. Korolev were allowed to sit down. The launch director [Nosov] began issuing commands. I kept an eye on S.P. Korolev. He seemed nervous although he tried to conceal it. He was carefully examining the readings of the various instruments without missing any nuance of our body language and tone of voice. If anybody raised their voice or showed signs of nervousness, Korolev was instantly on the alert to see what was going on."

At T-5 minutes, the 'auxiliary system' indicator suddenly turned on in the control room, indicating that a system was not ready. A sensor was showing an instability in the level of liquid oxygen, apparently due to natural evaporation. Operators quickly concluded that this was not a serious problem and blocked the sensor signal manually by turning a key on a panel, and the launch continued.

Boris Chekunov, the 24-year-old lieutenant in charge of pushing the ignition

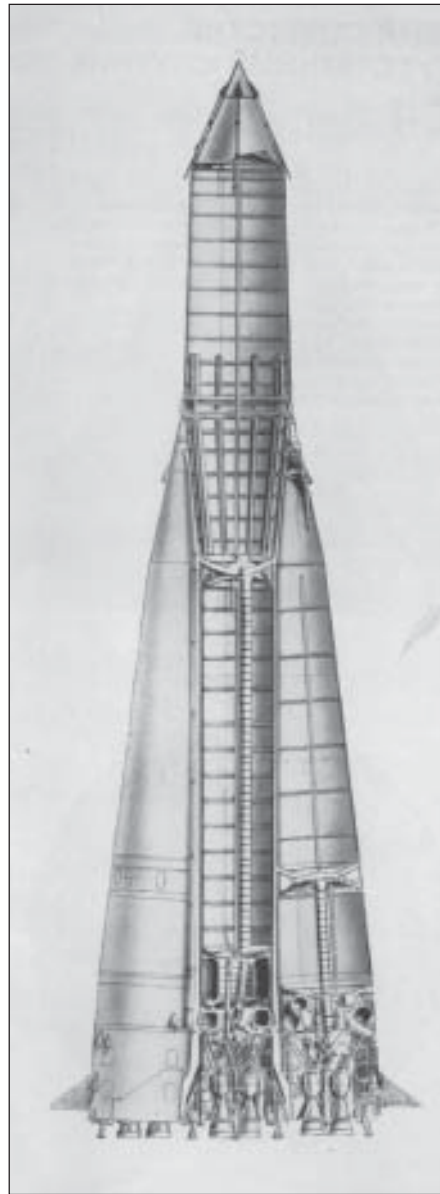
button for the central core booster, later described the final moments as the clock ticked down to lift-off: "When only a few minutes remained until lift-off, Korolev nodded to his deputy Voskresenskiy. The operators froze, awaiting the final order. Aleksandr Nosov, the chief of the launch control team, stood at the periscope. He could see the whole pad. 'One minute to go!,' he called." As the seconds counted down to zero, an operator announced, "Key to launch!" (Klyuch na start!). Chekunov turned a key on his panel clockwise from left to right, a task he would repeat nearly 600 times in a career spread over 30 years - but this was the very first time for a launch into space.

For Soviet launches, there was no countdown, only an occasional voice announcing "X minutes readiness" punctuated by the announcement of sudden commands. The next command - "Key to drainage!" (Klyuch na drenazh!) - meant that the drainage valves were closed after disconnecting from the rocket's propellant tanks.

Operators then waited the few seconds until the second hand of the clock approached the precise time for engine ignition indicated on their launch cards. As the word "Launch!" (Pusk!) rang out, Chekunov decisively pressed the launch button on his panel (known as V-347) to begin the engine firing cyclogram. There was a little over a minute now left to the actual departure of the rocket from the pad, perhaps the most anxiety-inducing seconds of the whole launch. Voskresenskiy and Nosov's eyes were glued to their periscopes as they watched the launch vehicle vent steam around it. A panel indicator lit up: "Preliminary" (Predvaritel'naya), meaning that the engines had ignited and were revving up to their preliminary thrust regime. All in the bunker began to sense the growing rumbling vibrations. An operator yelled: "Main!" (Yest' glavnaya!) and almost immediately "Contact of lift-off! (Yest' kontakt pod'yema!), Lift-off!"

It was exactly 2228 hours and 34 seconds Moscow Time, about an hour-and-a-half after midnight local time. One participant remembered: "At the moment [of lift-off] it seemed to onlookers that the rocket would burn where it was, on the launch pad, without taking off."

Flames from the base of the rocket cut through the darkness of the Kazakhstan desert steppes as the arms of the launch complex pulled back, allowing the rocket to lift off gracefully from its pad. First slowly,



A schematic of the 8K71PS launch vehicle that delivered Sputnik into orbit. This configuration was only used twice, for the first and second Sputniks. Sputnik-2 also had a slightly different payload shroud.

but then quickly, almost too quickly, the nearly 273 ton mass of metal, oxygen and kerosene, gathered speed and shot up into the warm night sky. The five engines, the children of Glushko's genius, generated a total of nearly 400 tons of thrust.

There were problems on the outbound flight, in both the engines and in the inertial guidance system. At lift-off, telemetry noted that the engine in one of the strap-on boosters (Block G) reached its intermediate stage late, ie, it took longer than usual to reach the desired level of thrust. Because of this, there was a brief threat of the rocket flying off-kilter at a dangerous angle since there was unequal thrust spread across the bottom, but fortunately, at the very last minute, the engine completed its thrust

build-up and the rocket returned to its correct attitude within 18 to 20 seconds.

A more serious problem occurred soon after, at T+16 seconds, when the Tank Depletion System, which regulated how much propellant was being used for each engine, failed. The malfunction led to a higher consumption of kerosene than planned and, as a result, the booster did not have enough propellant to reach the original burnout point (at T+296.4 seconds). The main core engine, in fact, shut down one second earlier than planned, at T+295.4 seconds.

These details were not known at the time of the launch. In the bunker, only the major events were reported back. At T+116.38 seconds, the four strap-on boosters separated as planned, as the rocket made its way across the Soviet landmass, gaining altitude and velocity. At main core engine burnout - which was reported back in the bunker with an exclamation of "main command!" - the core and its satellite payload were travelling at 7,780 km/s at a height of 228.6 km above Earth.

As planned, 19.9 seconds later (at T+314.5 seconds), the PS-1 satellite successfully separated from the core booster. The separation was effected by mechanical pressure at a speed of 2.73 m/s. Simultaneously, the nose fairing over the satellite was discarded (using the spring system) at a relative speed of 0.643 m/s. At the moment of separation, PS-1's commutator switched on the satellite's power supply system and pressurisation system. Less than 11 seconds later, the angular reflectors on the core deployed.

From the data streaming into the bunker - principally a signal that was received by IP-1 at Tyura-Tam from the booster core's Tral telemetry system that indicated engine shutdown — it seemed that Earth orbit had been achieved. Shabarov recalled: "Everyone breathed a sigh of relief, and there was [finally] a minute of silence. And suddenly, everyone began talking to each other, and people began to go up. The launch chief and I were even allowed to smoke inside the bunker."

While Korolev was in the bunker, another group of people had begun crowding around a van stationed near a house at Site 2, the main living area of the launch range. Inside, Vyacheslav Lappo and Konstantin Gringauz, the men who had built the radio transmitters, were sitting with headphones to their ears, waiting for a sign from the heavens. People were constantly trying to shove their way into

the van, to the irritation of the two, who had to repeatedly tell people to be quiet. Suddenly, there was weak “beep-beep-beep” which slowly grew in volume, becoming louder and louder each second. There was a round of “hurrahs” outside the van.

Ryazanskiy, Lappo and Gringauz' boss, immediately got on the phone and called Korolev, who was still back at the bunker: “There it is! There's a signal!” This was apparently a tape recording, evidently transmitted from one of the Kamchatka tracking stations. Korolev was not impressed. He dryly commented, “This could be a mistake. Until we hear the signals after the satellite comes back after its first orbit ... it's too early to celebrate.”

In general, people urged caution. There was, after all, a chance that the satellite was heading on a ballistic trajectory into the Pacific Ocean, helplessly transmitting its beep-beep-beeps for all to hear. There was only one thing to do now - wait an hour or so for the satellite to come around again. Korolev, Ryabikov, Keldysh, Glushko, Barmin, Voskresenskiy and Nosov all made their way out of the bunker and headed to the radio operator's van.

It took a little over an hour for the satellite to return back around the Earth. Once again, Lappo picked up the signals, the insistent “beep-beep-beep”. He screamed: “It's there! It's there! Turn on the tape recorders!”

Ballistics experts brought in their data. According to their calculations, the satellite was in an orbit with an apogee (high point above the Earth) of 939 km and a perigee (low point) of 215 km. These figures would be adjusted later, but at the time, the numbers must have seemed like a revelation - even if the apogee was much lower than expected.

According to the memoirs of Korolev's deputy Boris Chertok (1912-), the high point was about 80-90 km too low. Compared with the original planned apogee of 1,450 km, however, the apogee appears to have been far below its target range - by as much as 500 km. These were minor considerations, since the first object made by humans was in a freefall trajectory, an orbit-around Earth. The space age had arrived.

According to calculations revised over the night - sharpened by scientists back at the Computation Center at the NII-4 institute near Moscow - PS-1 was in a 947 X 228 km orbit. The orbital period (the time it took to make one complete circuit around Earth) was a little over an hour-and-a-half, more precisely, 96 minutes



A documentary still showing the launch of the very first R-7 on 15 May 1957. Asif Siddiqi

10.2 seconds. The satellite was circling at an angle of 65.1 degrees to the equator, giving it surface coverage over an enormous portion of Earth's inhabited surface.

Earlier the State Commission had planned to inform Khrushchev after the first orbit, but exercising more than usual caution, Commission chairman Ryabikov waited until the second orbit before calling the Soviet leader. According to conventional wisdom, Khrushchev's reaction to the launch was unusually subdued for an event of such magnitude, indicating that he, like many others, did not immediately grasp the true propaganda effect of such a historic moment.

He told the press at the time: “When the satellite was launched they phoned me that the rocket had taken the right course and that the satellite was already revolving around Earth. I congratulated the entire group of engineers and technicians on this outstanding achievement and calmly went to bed.”

Khrushchev's son, Sergey, however, recalls his father's reaction was a little more enthused. The older Khrushchev at the time was on visit to Kiev to discuss economic issues with the Ukrainian Party leadership. Around 11 pm - it was already past 2 am at Tyura-Tam - these negotiations were interrupted by a telephone call. Khrushchev left the meeting room to take the call, then returned without saying anything - at least at first.

His son described the scene: “He finally couldn't resist saying [to the Ukrainian officials], ‘I can tell you some very pleasant and important news’. Korolev [sic] just called

(at this point he acquired a secretive look). He's one of our missile designers. Remember not to mention his name - it's classified. Korolev has just reported that today, a little while ago, an artificial satellite of the Earth was launched.”

The Ukrainian Party leaders were a little bewildered as Khrushchev continued to ramble on about the satellite. They, after all, had important economic issues to discuss. Yet, the Soviet leader was animated the rest of the evening, speaking in glowing terms about the new era of missiles which could “demonstrate the advantages of socialism in actual practice” to the Americans.

For the engineers, scientists, soldiers, and bureaucrats responsible for the achievement - in Moscow, in Bolshevo, at Kaliningrad, at Tyura-Tam and at tracking stations all over the country, the feeling was one of elation and exhaustion. As night turned to day - the first daylight of the space age - people arranged an impromptu meeting where Korolev climbed onto an improvised rostrum and gave a speech that was unusually flowery, even for him.

“Dear comrades! Today, that which the best human minds have dreamed of has taken place! The prophetic words of Konstantin Eduardovich Tsiolkovskiy that mankind would not always remain on the Earth have come to pass. Today the first artificial satellite in the world has been injected into circumterrestrial orbit. With its injection into orbit, the conquest of space has begun. And the first country to open the road to outer space has been our country - the land of the Soviets! Allow me to congratulate all of you on this historic occasion. And allow me to especially thank all the junior specialists, technicians, engineers and designers who took part in the preparation of the [rocket] and the satellite, for their titanic labour.... Once more I give to you a hearty Russian thanks!”

Soon, Voskresenskiy's deputy Shabarov ordered the chief of the mission at Tyura-Tam to express thanks in a different way by handing out alcohol. So that people would not come back for more, he stipulated that each man would get a whole teapot of spirits.

Meanwhile, radio transmitter designer Lappo extended one of his speakers right out into the street and set it at full volume; all over Site 2, one could hear the enigmatic beep-beep-beep - a tape that ran over and over again. Later in the day, there was a celebration in a small movie theatre at Site 10, the main living area at the launch range.

Ryabikov made a speech congratulating all, followed by Korolev and Keldysh.

After nightfall, Korolev and a small group of his co-workers took off in an Il'yushin Il-14 aircraft from Tyura-Tam to head for Moscow. Despite the two massive piston engines that roared through the flight, most were exhausted and slept through the trip - some, after all, were sleeping the alcohol off.

Soon after takeoff, the pilot of the airplane, Tolya Yesenin, came out of the cockpit and bent over Korolev's seat to tell him that "the whole world was abuzz" with the launch - "in all languages you can hear, 'Russia' and 'satellite'."

Korolev quickly got up and went into the pilot's cabin. Returning back to the passenger's area, he announced gleefully to everybody: "Well comrades, you can't imagine - the whole world is talking about our satellite," adding with a huge smile, "It seems that we have caused quite a stir..."

At about 1:30 am Moscow Time on the early morning of 5 October 5 - just after 7:30 pm in Washington DC, the night before - the official Soviet news agency TASS released the communique on the launch that the State Commission had authored in late September. Published in the morning edition of Pravda, it was exceptionally low-key and was not even the headline of the day - the main headline 'above the fold' was 'Preparation for winter is an urgent task'. Even the text of the satellite launch was understated.

When the authors wrote the original text, they clearly did not play up the event: "For several years scientific research and experimental design work have been conducted in the Soviet Union on the creation of artificial satellites. As has already been reported in the press, the first launching of the satellites in the USSR were planned for realisation in accordance with the scientific research programme of the International Geophysical Year. As a result of very intensive work by scientific research institutes and design bureaus the first artificial satellite in the world has been created. On 4 October 1957, this first satellite was successfully launched in the USSR. According to preliminary data, the carrier rocket has imparted to the satellite the required orbital velocity of about 8,000 m/s. At the present time the satellite is describing elliptical trajectories around the Earth, and its flight can be observed in the rays of the rising and setting Sun with the aid of very simple optical instruments (binoculars, telescopes, etc)."

In the announcement, there was no detail

on the actual orbit of the satellite, just a general comment that it was travelling at "altitudes of up to 900 km above Earth's surface".

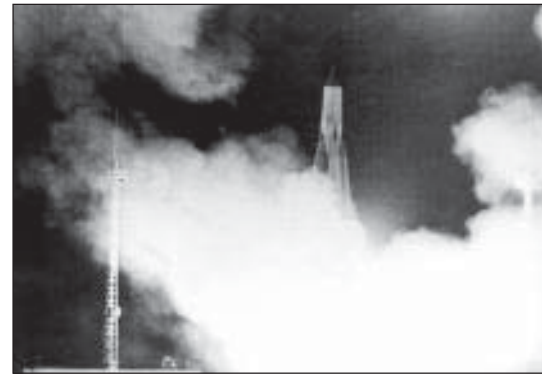
The communique nor the Soviet media ascribed a specific name for the satellite (like the Americans would with Explorer-1), but generically and simply called it "the artificial satellite of the Earth" (*iskusstvennyy sputnik zemli*). Since the word for satellite in Russian was *sputnik*, that word acquired a greater resonance than perhaps intended. In the West, Sputnik became a synonym for the satellite although in Russia, even to this day, the satellite is still simply called "the first Soviet artificial satellite of the Earth" (*Pervyy sovetskiy iskusstvennyy sputnik zemli* or *Pervyy sovetskiy ISZ*).

As the media tumult over Sputnik began to mount in the West, the Soviet leadership began to capitalise on the utter pandemonium surrounding the event in the United States. After everybody's return to Moscow, on 6 October, one of Keldysh's assistants at the Academy of Sciences, Gennadiy Skuridin (1926-91), met with a small group to hammer out a more dramatic and informative announcement. They included the young scientists led by Dmitriy Okhotsimskiy (1921-2005) from the Department of Applied Mathematics who had developed the basic equations for orbital flight earlier in the decade and a number of Korolev's representatives. Their draft was passed around to Korolev, Glushko, Keldysh and others before being sent to Pravda where Skuridin and Pravda's science editor A.G. Azizyan smoothed out any sensitive information. The article was typeset and then published as a major page one story in Pravda on the morning of 9 October. Given the constraints that its authors were working with, the article was actually rather informative, especially about the satellite itself, and included figures of the satellite as well as its ground track. The parties responsible for this great deed were, of course, not named.

Sputnik in orbit

Hundreds of thousands of people all over the world visually saw Sputnik (or more likely, the core stage of the R-7 which was more reflective) in orbit. Many heard the famous beep-beep-beeps. The duo of orbital payloads was tracked relatively easily through mid-November.

After 15 November, according to Tikhonravov, it became much harder to identify the payloads, apparently due to



A film still shows the actual launch of the first Sputnik on the night of 4 October 1957. Unfortunately, there are no high quality still photographs of the launch. As a result, all the existing images are poor quality stills from a single black-and-white film clip. Asif Siddiqi

"destruction of [material on the] angular reflector" on the core. For a while ionized trails from the core (from venting residual propellants) was visible in the night sky. Newspapers all over the world published the ground track of the satellites so that people could plan optical observations.

Although the Sputnik launch had no scientific goals per se, it did contribute to certain fields. Soviet scientists used observational data to try and determine the coefficient of absorption of radio waves in the ionosphere and to develop a model of the ionosphere's effect on the diffusion of radio waves. There were also attempts to develop methods to determine electron concentrations above the maximum layer F2 (the F layer has the highest concentration of electrons and ions in the atmosphere).

The satellite's radio transmitters provided useful information during the three weeks that they successfully sent out their beep-beep-beeps. According to the 'data' that they transmitted, it was determined that while the radio transmitters were working, the temperature and pressure inside the satellite remained within design limits. Engineers could confidently say that there had been no damage due to micro-meteoroids. According to Tikhonravov, Sputnik's radio beeps were tracked at distances of six to eight thousand kilometres and at some points as far as 16,000 to 17,000 km from the source.

The satellite was not the only object transmitting information. There was a working telemetry system known as Tral onboard the orbiting core booster. Tral was originally designed for monitoring various systems of the rocket during ballistic flight,



A still from a documentary on Sputnik shows a technician working on PS-1. More than likely this was a "re-enactment" staged soon after the Sputnik launch rather than the actual flight-model.

Don Mitchell

but was included on this launch, partly to verify whether it could be used on future orbital missions. (It was later used on Sputnik-2). Concern that Tral's operation would interfere with the radio transmitters on Sputnik proved unfounded.

Observations from the dozens of

A full-sized model of the PS-1 satellite shown hanging in the main hall of the Tsiolkovskiy Museum of Cosmonautics in Kaluga.

Asif Siddiqi



DOSA AF amateur radio clubs were useful. Their monitoring equipment had two antennas - when the satellite entered or exited the zone of radio visibility, the signal received on one of the antennas was more powerful than the other. When the satellite was equidistant from the two antennas, then the signals were of equal strength. By knowing the exact time of the signal reception, amateurs were able to very roughly map the location of the satellite.

Besides radio reception, optical observations were carried out not only by DOSAAF clubs all but also by other amateurs, university students, and lay people. Because the core was the brighter of the two objects - it was at magnitude two while the satellite was at magnitude 5 to 6 - it was more likely to be visible by the naked eye. Soviet AT-1 telescopes were made available at select urban settings for regular people to observe the satellites.

The Sputnik core booster, given its larger dimensions, had a faster rate of orbital decay. On 2 December, the booster was tracked slowly falling over a trajectory that took it over Irkutsk (in western Siberia north of Mongolia), the Chukotka peninsula, Alaska, and then down the western coast of the North America. According to Soviet information, the core circled the Earth 882 times before its untimely demise. The Sputnik satellite meanwhile circled the Earth for 1,440 orbits before re-

entering the Earth's atmosphere on 4 January 1958. Thus ended the life of the world's first artificial satellite.

The impact of Sputnik

PS-1's lead designer Mikhail Khomyakov underscored that "frankly speaking, many of us did not understand the full significance of this event". Not one of the Soviet engineers, scientists or politicians truly anticipated the global response. They had expected something but not on the scale they saw.

There was, of course, the political and economic dimensions to be considered, which journalists wrote widely about in the days after the launch. Sputnik punctuated the Cold War in a way that was not unlike another earlier strike to American self-confidence - some called it a "technological Pearl Harbour".

Historians have written many volumes about the effect Sputnik had upon the American psyche, how it led to the formation of NASA, how it increased funding for scientific research and education, and even how it led to the creation of the organisation (ARPA) that would later create the seed of the internet.

But there was also a philosophical import to Sputnik. It was the first time in the history of the human race that our handiwork had managed to breach the heavens around us and stay there. Golovanov eloquently summed up this notion in his biography of Korolev: "For the first time on Earth something that had been thrown upwards had not come down again."

Before Korolev left Tyura-Tam, he had asked Khomyakov to pack up and bring back the entire set of the spare PS-1 model, "an exact copy of the one which was now in orbit around the Earth". When Khomyakov returned to the design bureau near Moscow, he checked in with Korolev, saying that he was back from his "business trip". This was the usual way engineers spoke about going to the launch range - an assignment to Tyura-Tam was a "business trip", a strange euphemism that was accepted as part of the culture of intense secrecy around the missile industry.

Korolev confused Khomyakov with his response: "What business trip?". The chief designer raised his voice: "What's this you say, a business trip, a business trip... Tell your comrades that you have participated in the preparation and launch of the world's first artificial satellite of the Earth."

Acknowledgement

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