There was a time, in the early years of the space race, when the moon seemed to be Soviet territory. The first man-made object to reach the moon was the Soviet Luna 2 probe, which struck the surface in September 1959. A month later Luna 3 gave humanity its first glimpse of the moon’s far side. In February and March 1966, Luna 9 transmitted the first pictures from the lunar surface and Luna 10 orbited the moon. And in September 1968 a handful of turtles and simpler organisms aboard the Soviets’ Zond 5 became the first living beings to make a circumlunar voyage. By then, planners within the USSR were hopeful that the first words spoken from the surface of the moon would be Russian.

But when a trio of U.S. astronauts orbited the moon in December 1968, that hope all but died. Apollo 8’s triumph sent a shock wave through the Soviet space hierarchy, which realized that the political victory of landing the first men on the moon would soon go to the Americans. Soviet leaders wondered what to do in response. Ultimately they focused on robotic missions, which were not only easier and cheaper than piloted lunar voyages but would also give them a chance to spin their space program as a scientific venture, rather than one conducted just for the sake of Cold War competition. The Luna missions were to include an automated sample-return probe; the government ordered that effort accelerated.

On a second attempt after a June 1969 launch failure, Luna 15 began circling the moon on July 17, 1969, two days before the Apollo 11 astronauts themselves entered lunar orbit for the first manned landing attempt. If all went according to plan, the Soviet craft could be back on Earth with a container of lunar soil a day after the astronauts returned—close enough to upstage the U.S. achievement, or, if Apollo 11 failed, to give the Soviets an outright triumph. But on July 21, as Neil Armstrong and Buzz Aldrin were preparing to lift off from the Sea of Tranquility, Luna 15, while making its descent into the Sea of Crises, smashed into a mountain. Not until September 20, 1970, did Luna 16 alight safely on the Sea of Fertility and carry out a sample-return mission.

Luna 16 was a dazzling technical achievement, but it was also clear that, compared with America’s manned lunar missions, it didn’t measure up scientifically. By this time, two teams of Apollo astronauts had brought back a total of over 120 pounds of rock and dust. Luna 16’s return was just 3.5 ounces. Still, geologist Alexander “Sasha” Basilevsky of the Vernadsky Institute for Geochemistry recalls that the sense of competition with the Americans was still very much alive. “These samples would be our samples,” Basilevsky says. “We would study them. If you don’t send anything [to the moon], you’re just defeated.” But Basilevsky was already looking forward to a very different kind of mission—one that would turn him into a virtual lunar explorer.

With the Soviet manned landing effort in limbo, a rover was slated to substitute for human explorers. Its name was Lunokhod, Russian for “moonwalker.” The first challenge chief designer Georgiy Babakin and his team at the Lavochkin Design Institute faced was protecting their machine from the temperature extremes it would encounter on the moon. Lunokhod would have to operate in the blistering heat of the two-week lunar day, up to 240 degrees Fahrenheit, and survive the frigid two-week lunar night, when temperatures plummeted to 290 degrees below zero. To control temperatures inside the rover, designers chose a tub-like pressurized shell, topped by a lid that could be opened and closed on command from Earth. The lid, which contained an array of solar cells for charging the rover’s batteries, would be kept open during the day so the cells could absorb solar energy. Before sunset the lid would be closed, and the rover would go into hibernation as radioactive polonium-210 warmed vital components inside. For locomotion, designers at the All Union Science and Research Institute of Transportation tested a variety of designs for the seven-foot-long rover, including tractors, walkers, and even jumpers, but in the end chose eight individually controlled wheels, each supported by spokes and covered with wire mesh to aid mobility in powdery soil.

Once Lunokhod was on the moon, the success of the mission would be in the hands of two five-man crews chosen from the military’s missile defense corps. In the spring of 1968, candidates were carefully screened for engineering expertise, capacity for prolonged mental focus and attention, quick reaction times, the ability to process information quickly, good long-term and short-term memory, and vision and hearing. So thorough was the selection process that some of the men thought they were being recruited for the cosmonaut corps, until they were told of their real mission: to operate the first wheeled vehicle on the surface of another world.

Only one member of each crew would drive the rover. Behind him would sit the crew commander, who would oversee the driver’s handling of the rover. Joining them in the control room would be a navigator, a radio antenna operator, and the flight engineer, who would monitor the rover’s systems. Each crew would operate the rover for two hours; then the other crew would take control. At the Lavochkin plant the crew members familiarized themselves with every aspect of the craft and
A model of Lunokhod 1 on display in the 1970s. The real rover was a source of great pride for the Soviet people.
spent hours practicing with a mockup on a specially constructed "lunodrome" near the mission's control center, in the Crimean city of Simferopol.

An exploding booster doomed the initial launch attempt in February 1969, but the second try landed Lunokhod 1 at the western edge of the moon's Sea of Rains on November 17, 1970. Under driver Gabdulkhay Latypov's control, the rover descended one of the two ramps extended from the descent stage and stood on the moon's surface, ready to begin its expedition.

Gripping in his right hand a control stick that resembled a car's gearshift, Latypov could make the rover go forward at one of two speeds (0.5 or 1.2 mph) or go in reverse. He and Vycheslav Dovgan, the other crew's driver, turned the craft not by rotating the wheels, which were fixed, but by slowing down one side relative to the other, the way one steers a tank.

Latypov and Dovgan's only guidance came from a monitor, which displayed images from Lunokhod's two low-resolution television cameras. To any video game enthusiast it sounds simple—but this was nothing like a video game. The cameras did not send a continuous stream of images, but rather single frames, like a slide show, at intervals that varied from seven to 20 seconds. And because radio signals took three seconds to travel round trip between Earth and the moon, the driver didn't see the results of his actions for many long moments. For this reason, if crew commanders Nikolai Yeremenko and Igor Fyodorov saw Lunokhod heading toward catastrophe, they could push a button to halt the rover.

Dovgan, now 66, was well prepared by intensive training. "Driving on the moon felt even easier than it was in the lunodrome," he says, but his comment belies the difficulties of navigating the rover. The low resolution of the slide show made it difficult to spot craters and boulders, especially at high sun angles, and there was a "dead zone"—a three-foot-wide area immediately in front of the rover that Lunokhod's cameras could not see. The only solution, according to Dovgan, was to memorize the features in this area from the previous image, before the rover reached it. "When we were looking ahead and thinking of the obstacles that we did see, we also had to remember what was just behind," he says.

Dovgan also had to constantly verbalize what he saw to Fyodorov. "103," Dovgan would say, using the commander's call sign, "this is 101 reporting on the situation. Twenty degrees left of the course, a stone; distance, five meters; height, 35 [centimeters]; width, 50. Straight ahead, a crater, diameter, nine meters. To the right, 15 degrees, a gap. Decision: Will turn left 60 degrees to avoid both crater and stone, and then regain the straight-ahead direction." Although Fyodorov sometimes challenged Dovgan before approving his plans, he ultimately trusted his driver's judgment as if Dovgan were actually on the moon. And indeed, Dovgan sometimes felt as if he were. "Not that I forgot that I was on Earth, but it felt like I was so phased into my work that the only thing that wasn't part of me being on the moon was the constant, continuous reporting," he recalls. "It almost felt like I was talking to myself all the time, or that I was talking to Lunokhod."

Unlike cosmonauts of the day, Dovgan and crewmates were unknown to the Soviet public and under strict orders not to talk about their work. For Dovgan, who grew up in Simferopol, the secrecy was especially tough. "I couldn't even tell my friends," he recalls. "And you know, all my friends were there; I went to school there. It was particularly hard...for me to keep my mouth shut." For Basilevsky, there was an even more frustrating problem: The control room was off-limits to him and other scientists taking part in the mission. Relegated to another room in the Crimea complex, they could listen to the crew's workmenlike dialogue only over a loudspeaker. During mission operations, the researchers were expected to be passive consumers of data, not participants in the exploration. "Scientists were considered, in the beginning, as something unnecessary," Sasha Basilevsky explains.

Meanwhile, on the Sea of Rains, with its Earthbound masters ever mindful of its safety, Lunokhod made halting
In an image taken by side-mounted panoramic cameras, the tracks of a Lunokhod rover's eight wire-mesh wheels appear to run through its shadow.

Lunokhod 1 roamed 6.5 miles on the Sea of Rains before its radioactive heat source ran out and its instruments froze during the two-Earth-week-long lunar night.
Scientists used photometric targets (rectangle) painted with color squares of known intensities to identify the intensities of the materials seen in panoramas.

progress until, on November 22, having traveled some 646 feet, the rover was put to sleep for the approaching two-week night. During the hibernation, astronomers in Crimea and the French Alps bounced a laser beam off a French-built reflector mounted on the rover; these experiments were designed to provide ultra-accurate measurements of the moon's periodic wobbles, called librations, as well as the moon's distance from Earth. Some team members worried about whether Lunokhod could be revived, but after the sun had risen on the Sea of Rains, the rover was ready for its first full lunar day of work.

As the controllers gained more experience, they also gained confidence, until they were able to let the rover proceed as long as they could see no clear hazard on the monitors. Progress had to be halted for three days during the lunar noon, when the lack of shadows made driving too dangerous. Lunokhod logged almost an additional mile before night fell. And during the third workday, starting on January 17, navigators steered the rover back to its landing spot, where the landing stage stood like a tiny fortress.

It was around this time that Basilevsky ventured into the control room at last. "I came and brought a chair with me," he says. "Nobody allowed me, actually. I just did it. And I stayed. And they looked at me, and nobody said anything. The next day I came with my chair again, feeling I have a right to do this. And then, it was my place."

But Basilevsky soon realized that the very things he wanted to get close to and study—large rocks—were hazards the drivers and commanders wanted to avoid. Having learned (just as the Apollo astronauts had) that distances on the moon are difficult to perceive, and wary of the time delay, Lunokhod rarely ventured closer than about seven feet from a boulder. "They were cautious people," Basilevsky says about the crews, adding that he never saw them disagree about how to proceed, or any other breach of military discipline. And, having watched the controllers during their challenging pre-mission practice runs, Basilevsky didn't try to persuade them to do otherwise.

He did challenge the crews' supervisors, who equated the mission's success with the total distance logged by the rover. The only way to obtain panoramic images with Lunokhod's high-resolution cameras was to use the craft's narrow-beam antenna, which required the rover to be stationary. At one point, Basilevsky recalls, "We could see beautiful rock fragments. I was saying to Babakin, 'Let's stop here. We'll make good panoramas; we'll see something unusual here.' His deputies told me, 'Sasha, it is Lunokhod, not Lunostop.'"

It was even harder for Basilevsky to use Lunokhod to obtain stereo images, one of the geologists' key tools for studying lunar landforms. The easiest way was to take a panorama, have the rover turn in place for a few degrees, then stop and take a second panorama. But for the mission managers, taking a second panorama of "the same boring place" precluded the logging of more distance, which looked good in Pravda, the state newspaper. To publicists, "it was a serious indicator of our success: meters, meters, meters," Basilevsky says. In his frustration, Basilevsky took one of the few stereo panoramas he had acquired and spread it out, with a special stereo viewer, on a table in the control center. He then sought out the army colonel who was responsible for the Lunokhod crew and showed him the moon in 3-D. With the desolate beauty of the Sea of Rains spread out before him, the colonel registered his amazement; "This is why," Basilevsky told him. After that, Basilevsky says he "had a green light" to request panorama shots.

Even with these occasional victories, Basilevsky and the
other geologists still faced battles with scientific colleagues about how best to use the rover’s precious time on the moon, because Lunokhod was also constantly studying cosmic rays and X-rays and measuring the brightness of the lunar sky early and late in the lunar day. And the sheer length of the working day—a communications session with Lunokhod might last as long as 10 hours—could wear out everyone involved. The geologists could not afford the luxury of a full night’s sleep either, because they needed to wake up well in advance of the next communications session to review the latest data. Only during the three-day lunar night did the scientists get a break, with a visit to a seaside resort. During the two-week lunar night, the scientists returned to Moscow; then they headed back to the Crimea. “It was exhausting,” Basilevsky says. And this went on longer than anyone expected, because instead of lasting the four months planned, Lunokhod lasted almost 11 months.

But there was compensation. After one particularly grueling session, Basilevsky emerged from the control center to see the moon hanging above the horizon in the early morning sky. It was a magically disorienting sight. “When you are involved in driving, psychologically you are on the moon,” he explains. “So [when I saw the moon] it was like, ‘Okay, but I was there!’ And it was some special moment in my life when I realized that through these devices, I was there. On that shining object in the sky.”

In the United States, that bright, cratered world had become a place for men, not machines, to explore. As it happened, the Soviet robotic successes came as NASA was recovering from the previous April’s Apollo 13 fiasco. At the same time, U.S. space budgets were in decline, forcing the cancellation of the last few Apollo landings. The Soviet robots’ success fueled a debate in the U.S. on whether sending people to the moon was worth the cost and the risk when machines could do the job—or so critics claimed. That point of view never held any sway with the scientists. Apollo 11 and 12 lunar sample co-investigator Bevan French recounts: “Anyone who...said that the Luna 16 and Lunokhod missions were so successful that we should have stopped doing manned lunar missions would’ve been laughed out of the room.”

No one needed to tell Basilevsky that. “It was obvious that the science we were doing [with Lunokhod] was much less important than what was obtained by Apollo,” he says. But to the Soviet people, the value of the Lunokhod and Luna robots had little to do with absolutes. In the USSR, where information about the Apollo landings was scarce, these machines were a source of enormous pride. Soviet scientists could now contribute...
lunar samples for research instead of merely borrowing; in 1971 NASA and the Soviet Academy of Sciences agreed to each exchange three grams of returned samples.

In January 1973, a month after Apollo 17, the final U.S. moonwalk, Lunokhod 2 landed at the Sea of Serenity’s eastern edge. By this time, the stature of Basilevsky and the other geologists had risen substantially—as had the confidence of the two crews—so much so that after four months on the moon Lunokhod 2 had driven more than 21 miles, three times as far as Lunokhod 1 had traveled in twice the time. (It helped that Lunokhod 2’s navigation cameras were improved, and sent an image every three seconds.) Near the end of its fourth lunar day, the rover approached a long, straight valley where the geologists could see boulders and even the rarest of features on the dust-covered moon: an outcropping of bedrock. Basilevsky was ecstatic. “He kept exclaiming, ‘Wonderful, this is it! Stop, look at this, show me that!’” says Dovgan.

Then, on May 9, 1973, the crew made a fatal mistake. “The sun was behind us,” Basilevsky says. “In the navigation camera we saw a beautiful smooth surface. But the pictures were deceiving. All shadows were hidden behind the objects casting them—including crater walls. Before anyone realized what had happened, Lunokhod descended into a crater some 15 feet across. What the crew should have done, Basilevsky says, was to stop, close the rover’s lid, then take a panorama to see where they were; instead, the controllers started maneuvering Lunokhod out of the crater. The lid touched the crater wall, resulting in part of the solar cells being covered with soil. “We immediately felt it, because the electric current dropped,” Basilevsky says. Within an hour of entering the crater, Lunokhod had re-emerged, and all seemed well—until everyone realized what would hap-

The nearly 300 panoramas transmitted during the two missions were produced by telephotometers mounted on the sides of the rovers. Panoramas were of higher quality than television images and were used to navigate. Scientists used vertically oriented telephotometers (seen protruding into images) to capture zenith-to-nadir panoramas. Then, by calculating the sun’s apparent position, crew members could calibrate the rovers’ gyroscopes. At the periphery are the rovers’ rod-like backups for more sophisticated antennas.

gen as night approached. The rover’s lid would have to be closed to keep it from freezing during the night. When the team closed the lid, they dumped lunar grime on the radiator, which was supposed to get rid of excess heat during the day. “We put on this radiator the best insulator—lunar soil,” Basilevsky laments.

With the arrival of a new day, the lid was opened, and soon afterward, as the rover began its work, sensors showed the temperature aboard Lunokhod 2 increasing. Everyone knew it was only a matter of time before the rover would die. Before that happened, Basilevsky realized, Lunokhod could make a risky but potentially rewarding venture to some nearby, geologically intriguing mountains. He told the controllers, “Go to that place; we will die like heroes. If we just go stupidly in some safe direction, we will die anyway.”
But mission managers were unwilling to risk it, and once the temperatures aboard Lunokhod climbed above 150 degrees Fahrenheit, Basilevsky says, "That was the end."

A third Lunokhod was planned, and there was talk of a mission more ambitious and potentially much more rewarding than Lunokhod. Named Sparka, from the Russian word for "pair," the mission would team a Lunokhod-style rover with a Luna sample-return craft. Roaming the moon, the Sparka rover would pick up samples with a robotic arm, effectively dooming any hope of a Soviet manned landing.

Like so much about the Soviet space program, many details about the robotic lunar missions remained secret for decades. Lunokhod's crews were not publicly acknowledged for their work until 1990, and today, Lunokhod's forgotten images seem like postcards from a parallel history just coming to light. Basilevsky and his colleagues had a bittersweet flash of recognition in 1997, when NASA's Pathfinder Lander delivered a diminutive rover called Sojourner to Mars. Although Sojourner did most of its exploring within about 35 feet of its lander, Dovgan and his fellow controllers were so impressed that they wrote a letter of admiration to NASA (which, according to Dovgan, the agency did not answer).

Among the creators of Pathfinder and Sojourner, the reviews of Lunokhod are mixed. According to Don Bickler of NASA's Jet Propulsion Laboratory in Pasadena, California, one of the engineers who directed Sojourner's design, technology has changed so much since the early 1970s that the Mars rover bore little resemblance to its lunar predecessor. Bickler says that during his work on Sojourner he briefly took pictures, and carry its geologic treasures to a waiting sample-return vehicle. With a well-chosen, well-documented collection of samples, Sparka promised a scientific return equaling that of the Apollo landings.

It was not to be. Support for more robotic missions to the moon evaporated as interest shifted to a more distant and mysterious goal: Mars. Already, the Soviets had tried two times to land instruments on the Red Planet without success, and it was public knowledge that the United States was planning its own Mars landings, in a program called Viking. Lunokhod 3 never went to the moon—the rover now sits on display at the Lavochkin Museum in Moscow—and Sparka never made it past the conceptual stage. Meanwhile, the giant N-1 booster, designed to put humans on the lunar surface, had exploded in four separate test launches, studied the Lunokhod design, but he wasn't influenced by it. "There was nothing we could use there," he says flatly.

Down the hall from Bickler, Tom Rivellini offers a kinder perspective. Rivellini, who helped create the airbags that got Pathfinder and Sojourner safely to the Martian surface, is now working on a proposed robotic mission to retrieve samples from the moon's south polar region. He says of the Soviet missions, "When you go back and look at this stuff, it's impressive.... They were inventing the wheel; nobody had done this." Rivellini points out that unlike the Soviets, whose big Proton boosters could carry heavy payloads, he and his colleagues have to design for smaller launchers, a limitation that can make spacecraft design and production more difficult and expensive. Still, Rivellini says, future robotic explorers that roam the planets will owe a debt to Lunokhod. "Personally, the way I view the work the Soviets did back in those days is as a proof of concept that it could be done," Rivellini says.

It's an attitude Dovgan would appreciate. He still looks back on the Lunokhod missions with pride, and is grateful he was a part of them. Whatever worlds rovers might someday explore, his favorite destination is still the one he got to know so intimately three decades ago. "The moon is special," he says. "She's such a beauty. I come outside sometimes and look at it. And it seems to me sometimes that it winks at me."