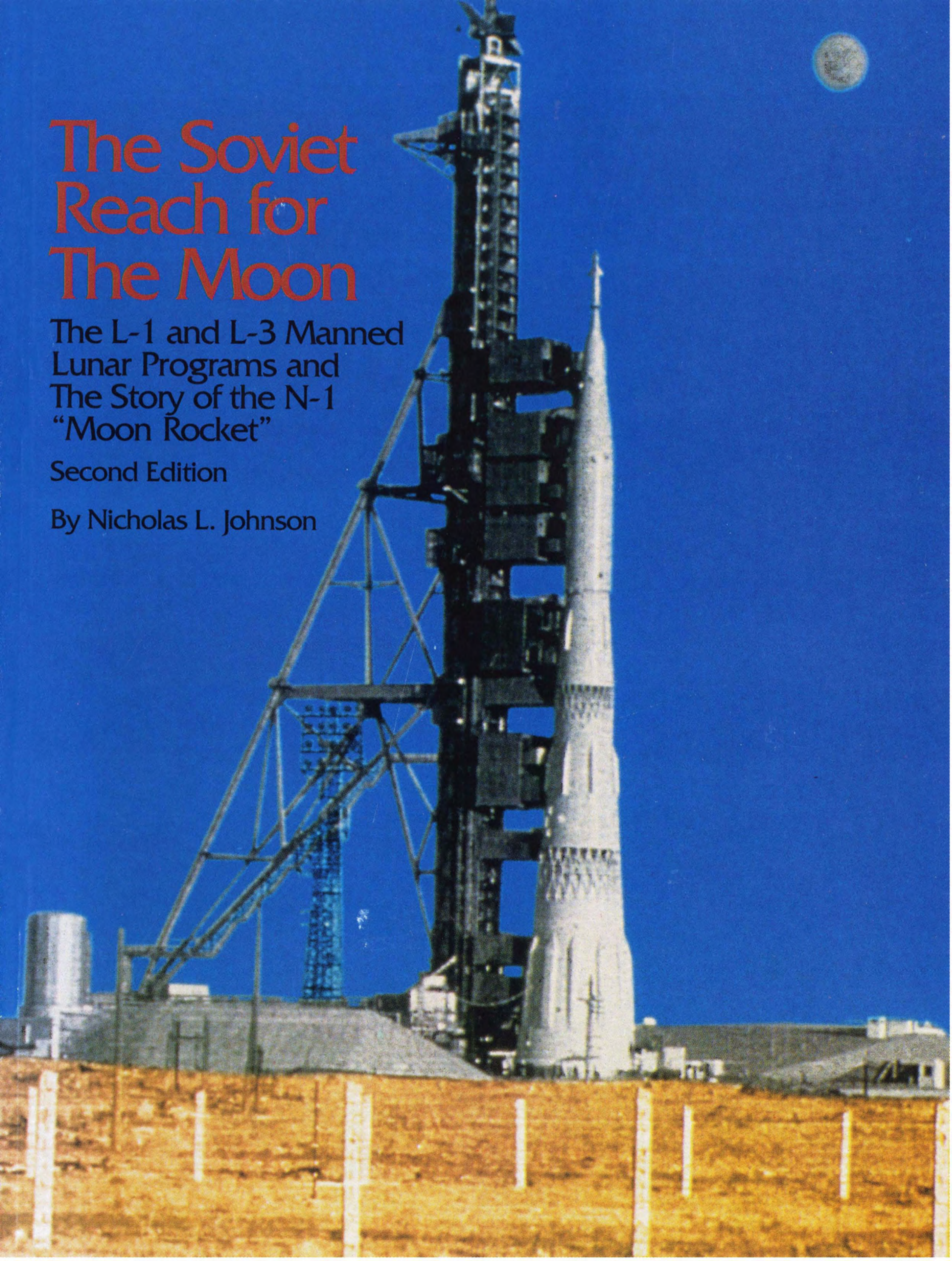
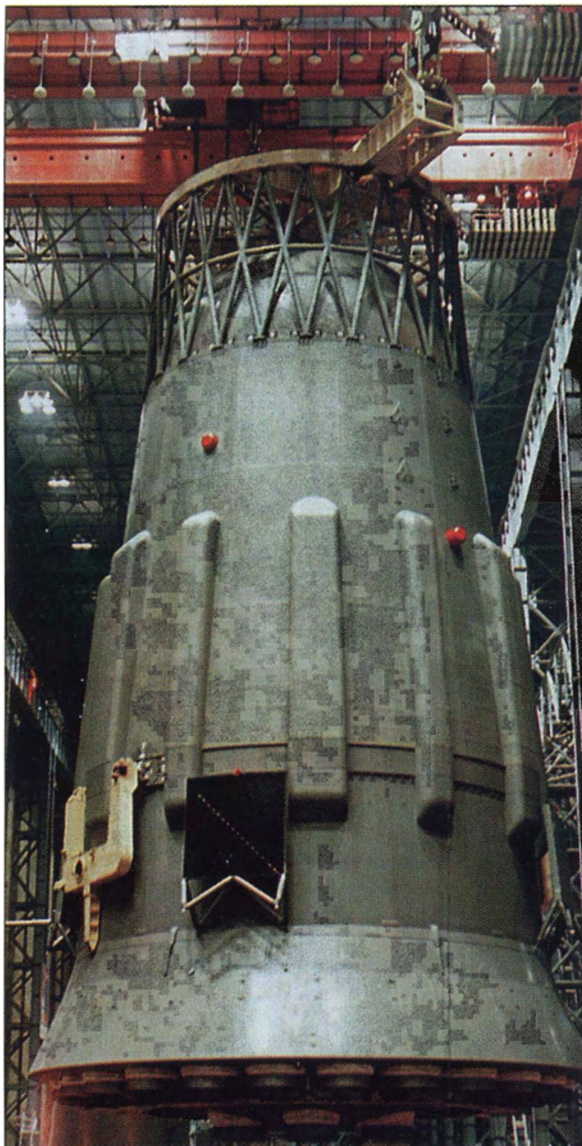


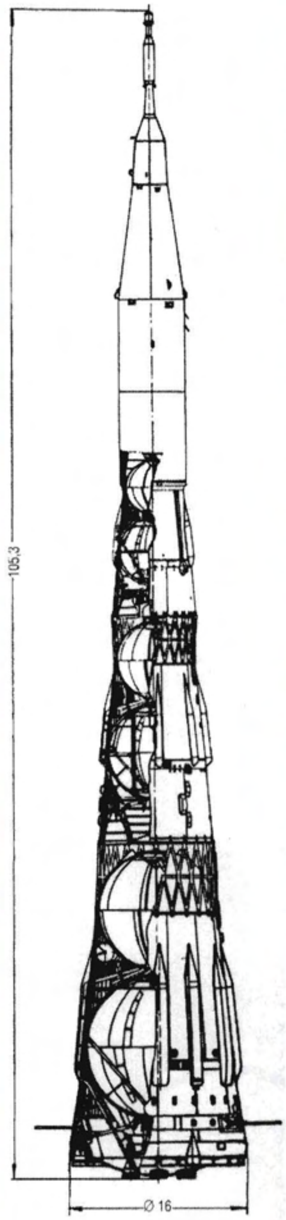
The Soviet Reach for The Moon

The L-1 and L-3 Manned Lunar Programs and The Story of the N-1 "Moon Rocket"

Second Edition

By Nicholas L. Johnson

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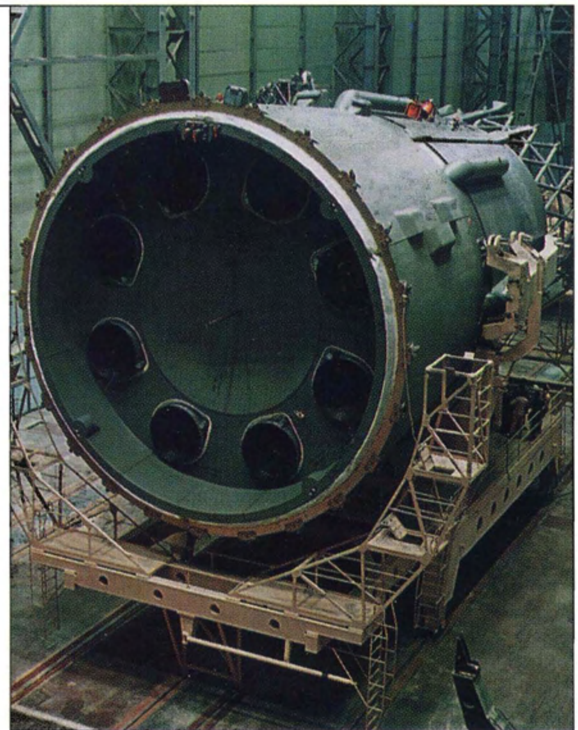

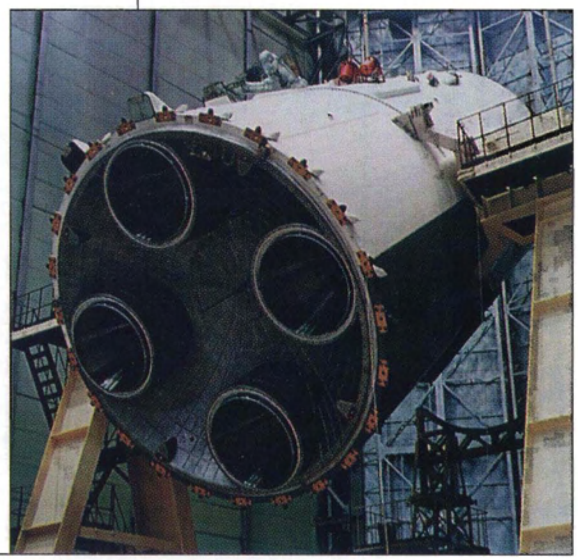

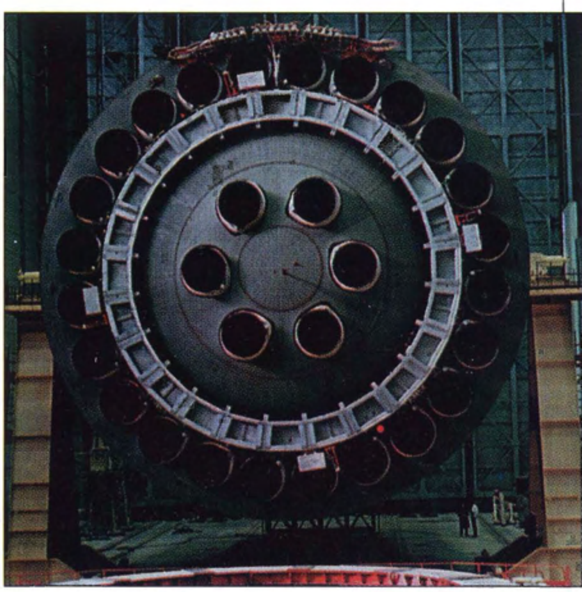

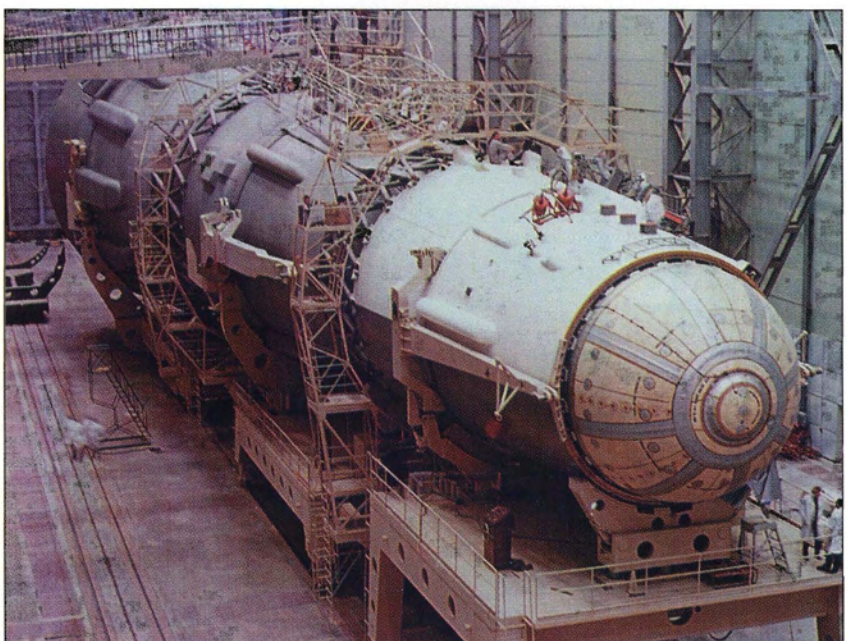

The Soviet Reach for The Moon

The L-1 and L-3 Manned Lunar Programs and The Story of the N-1 "Moon Rocket"

Author: Nicholas L. Johnson

Art Director: William A. Ford

Editor in Chief, Cosmos Books:
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Second Edition

The story of Soviet lunar exploration is one of three separate but complementary and contemporary programs:

- The Luna program utilized automated spacecraft representing three generations of space technology;
- The L-1 manned spacecraft of the Zond program were to circumnavigate the Moon;
- The L-3 manned lunar landing program envisioned sending a lone cosmonaut to the lunar surface.

Soviet lunar successes were many and historic:

- First unmanned flyby of the Moon;
- First impact of a man-made object on the Moon;
- First photograph of the Moon's far side;
- First soft-landing on the Moon;
- First lunar satellite;
- First automated return of lunar soil to Earth;
- First robotic lunar rover.

▶ ***On the Cover: The impressive 100-m tall N-1/L-3 lunar rocket was launched unmanned from its special pad at the Baikonur Cosmodrome in Kazakhstan but failed to reach orbit in all four attempts.***

▶ ***Inside front cover photos: (Clockwise from bottom left) the aft end of the N-1 first stage with 30 main engines; N-1 first stage being transported within the enormous vehicle assembly building at the Baikonur Cosmodrome; a cutaway of the 3-stage N-1 launch vehicle with its L-3 launch shroud; the third stage of the N-1 with its four main engines; the second stage of the N-1 with its eight main engines; the three N-1 stages are mated for preliminary chechouts before being mated with a payload and transported to the launch pad.***

Contents

CREDITS:

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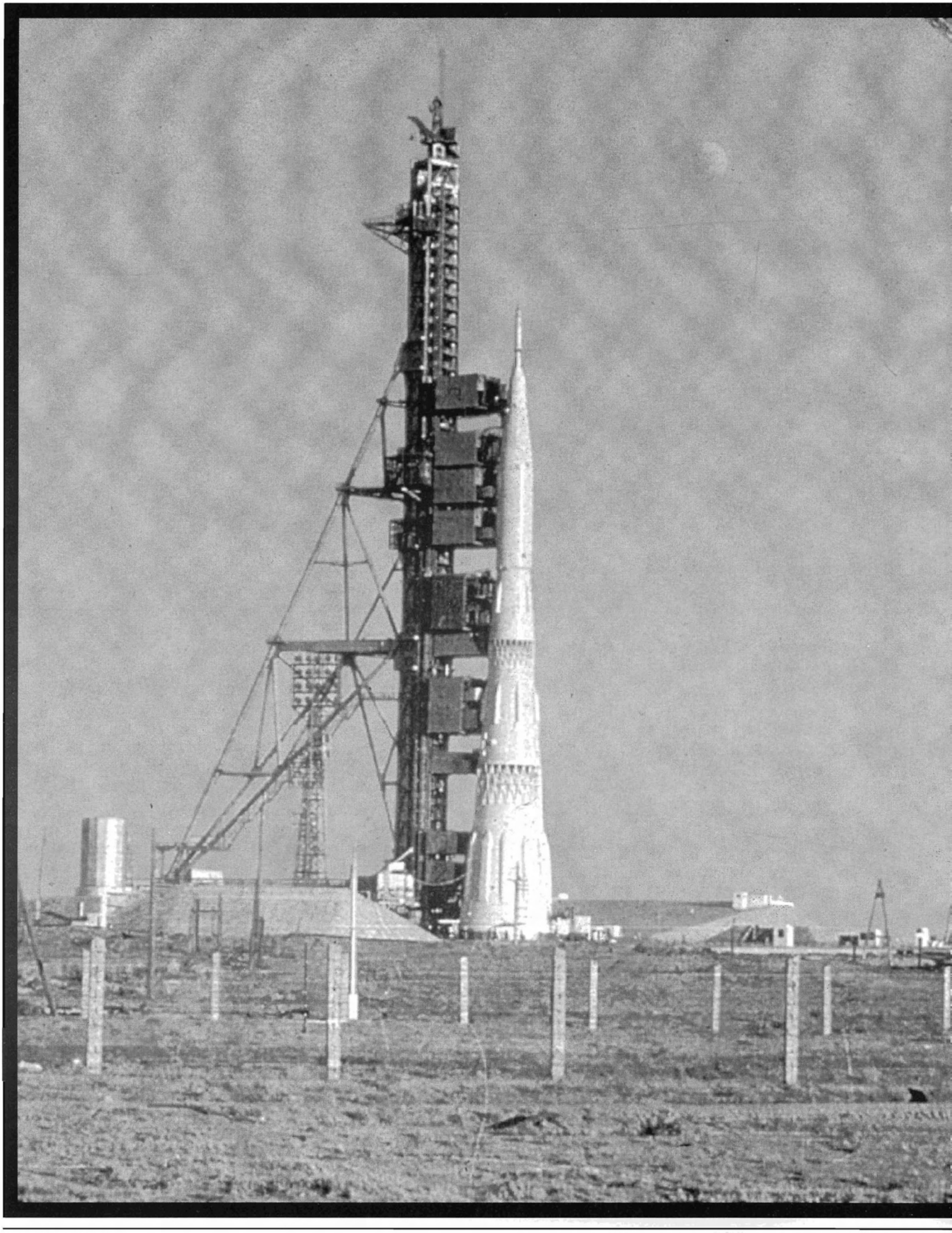
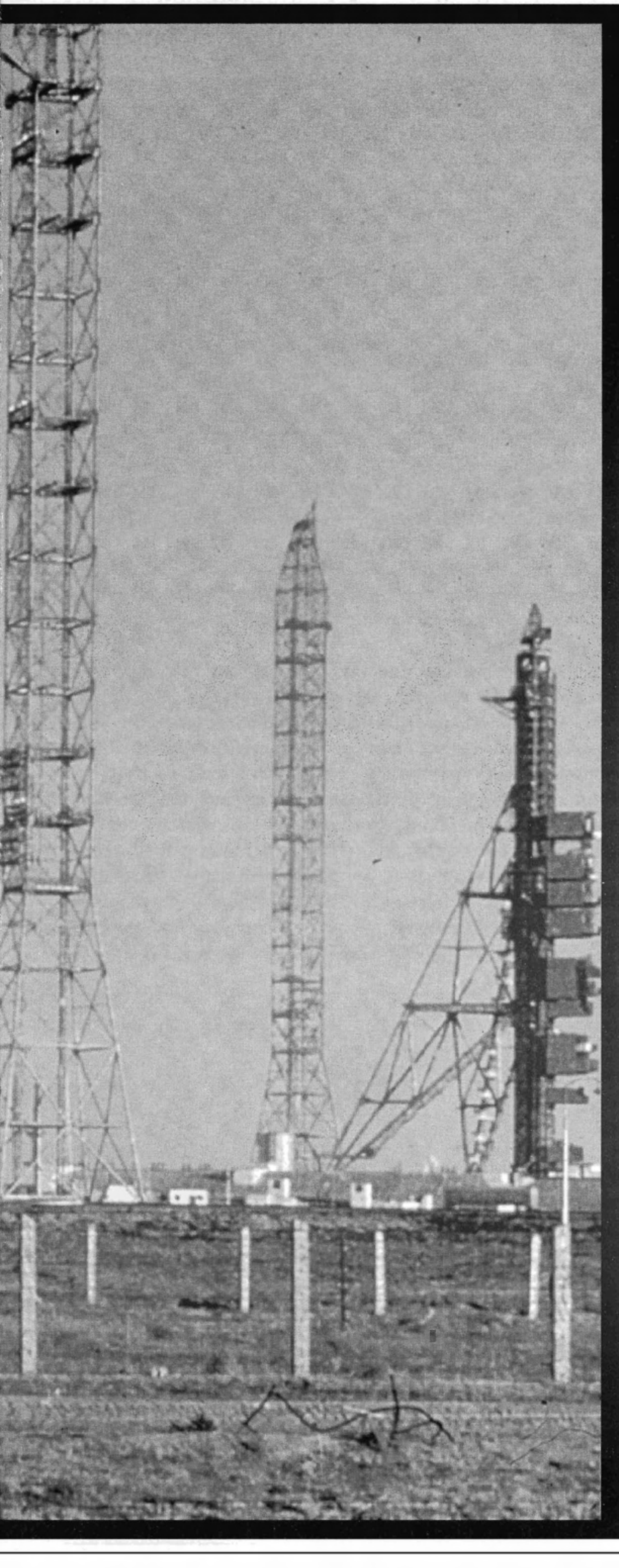




Introduction

Even before the launch of the first artificial Earth satellite by the Soviet Union shocked the world, the fundamental foundation for manned space flight, with its ultimate objective of leaving the confines of the Earth for the Moon and more distant celestial bodies, had been laid. In 1903 Konstantin E. Tsiolkovsky (1857-1935), the father of Russian cosmonautics, published his landmark treatise on the technical requirements for space flight, *Investigation of Cosmic Spaces by Reactive Devices*. His pioneering work was supplemented by Tsander (1887-1933) and Kondratyuk (1897-1942). A scant half century later, Russian scientists and engineers began turning Tsiolkovsky's dream into reality. By the time Yuri Gagarin marked a milestone of human evolution by becoming the first man in space, the seemingly impossible task of landing men on the Moon and returning them to Earth had been reduced to a technical and engineering challenge well within the grasp of the current generation.

The Soviet assault on the Moon spanned a period of 18 years and required over 60 rocket launchings. Although the Herculean effort fell short of its final objective of manned space flight to the Moon, Soviet successes were many and historic: the first unmanned fly-by of the Moon, the first impact of a man-made object on the Moon, the first photographs of the Moon's far side, the first soft-landing on the Moon, the first lunar satellite, the first automated return of lunar soil to Earth, and the first robotic lunar rover. In addition to greatly expanding man's knowledge about the Earth's long-time companion, these missions were critical in establishing the feasibility and technology of manned expeditions.

The story of Soviet lunar exploration is one of three separate, but complementary and contemporary, programs. The pathfinder Luna program utilized a wide variety of automated vehicles representing three generations of space technology to set the requirements of the manned missions to follow and to test the ability and ingenuity of Soviet spacecraft engineers. In their wake, L-1 manned spacecraft of the Zond program were to circumnavigate the Moon and thereby to perfect further the techniques and systems necessary for the next and final stage. Unlike its American counterpart, the Soviet L-3 manned lunar landing program, which envisioned sending a lone cosmonaut to the lunar surface, was distinct from the manned lunar precursor flights, relying instead on a dramatically different set of hardware.

A core cause of the Soviet loss of the Moon race was an inability to develop and to perfect the vital launch systems needed to place the spacecraft into Earth orbit: the Proton and the N-1 launch vehicles. Political intrigue and a failure to marshal the aerospace industry on a high priority national program clearly contributed to the extensive delays which were atypical of most Soviet space programs. In retrospect, a duplication of effort and the competition for resources were probably ultimately responsible for the eventual demise of both the L-1 and the L-3 programs. ●

▶ ***Two N-1 launch pads were constructed at Baikonur.***

1 The Initial Reconnaissance Of the Moon

▶ Immediately after the second World War, the Soviet Union consolidated its fledgling and disperse rocket development efforts into a centralized and coordinated program to develop military ballistic missiles. The Chief Designer of the ballistic missile program, Sergei Pavlovich Korolev, was a student of the works of Tsiolkovsky, Tsander, and Kondratyuk with his sights fixed on more ambitious goals. As head of the ballistic missile program, Korolev in 1946 established and chaired the Council of Chief Designers, a body of six talented engineers who would set the course of Soviet space technology for decades to come and guide the Soviet manned lunar programs. Korolev's council included Valentin Petrovich Glushko, Chief Designer of Rocket Engines; Nikolai Alekseyevich Pilyugin, Chief Designer of Autonomous Guidance Systems; Mikhail Sergeyevich Ryazanskiy, Chief Designer of Radio Control Systems; Viktor Ivanovich Kuznetsov, Chief Designer of Gyroscopes; and Vladimir Pavlovich Barmin, Chief Designer of Launch Complexes.

By 1948 this team had developed the Soviet R-1 short-range ballistic missile, based largely on the German V-2 rocket. Five years later the Council of Chief Designers had produced the more sophisticated R-5 with a wholly Soviet design. However, the debut of the R-7, the world's first intercontinental ballistic missile (known also as the SS-6 in the West), in 1957 enabled Korolev to begin his program of space exploration in earnest. Although the maiden flight of the R-7 on 15 May 1957 failed, by August of the same year the rocket had successfully flown a full range test. Korolev immediately petitioned government authorities to launch the first artificial satellite of the Earth, leading to the historic flight of the 84-kg Sputnik 1 on 4 October 1957 from the Baikonur Cosmodrome in Kazakhstan. On the first anniversary of the initial R-7 test flight, the Soviet Union pushed its orbital prowess to over 1,300 kg with the launch of Sputnik 3.

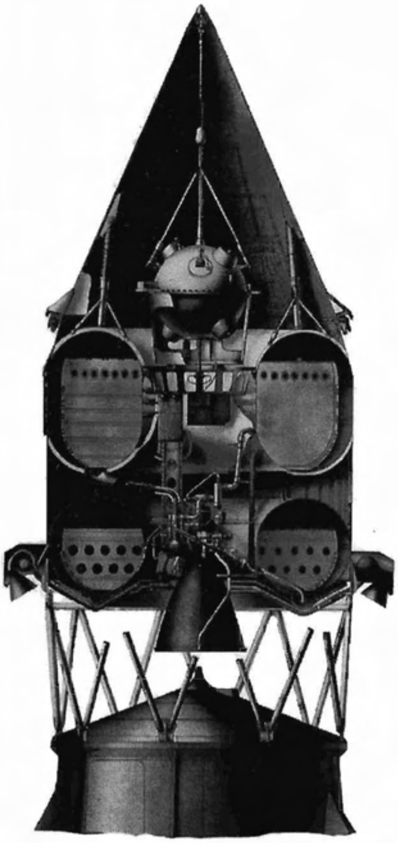
To reach the Moon with even the smallest payload, Korolev's Special Design Bureau (OKB-1) needed to add another stage to the R-7. Glushko's Gas Dynamics Laboratory (GDL-OKB, aka OKB-456) had designed and developed the large main engines (RD-107 and RD-108) for the R-7, but Korolev gave the task of creating a smaller engine (RO-5) with a 5 metric ton thrust for the upper stage of his lunar rocket to Semyen A. Kosberg's design bureau in late 1957. Less than a year after the flight of Sputnik 1, the new, more capable launch vehicle was ready to fly.

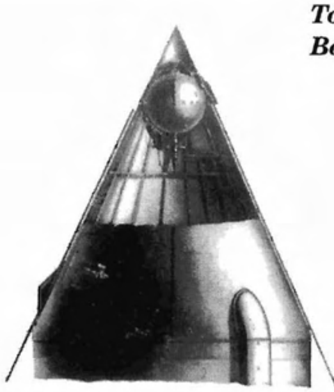
The first attempt to reach the Moon came on 23 September 1958 but ended 92 seconds after launch when the vehicle brokeup in flight before the new upper stage could be ignited. A second probe was quickly prepared as Korolev rushed to beat the launch of the first American lunar spacecraft, Pioneer 1. In the end, neither country was successful. Pioneer 1 was launched on 11 October but failed to attain the required velocity to reach the Moon and then fell back to Earth. Korolev's relief, however, was short-lived: his own rocket launched the next day exploded 100 seconds after lift-off. An investigation revealed that both Luna boosters had succumbed to resonant oscillations caused by a change in the rocket's center of mass when the upper stage was added.

A modification to the Luna launch vehicle was implemented in time for a third attempt on 4 December. This time the critical portion of the launch phase passed without incident; but 245 seconds into the flight an engine failed, once again thwarting all efforts to escape the pull of Earth's gravity. The next lunar launch window would arrive at the start of the new year, and Korolev was determined to try again.

During 1959 Korolev's efforts at lunar exploration were richly rewarded, at the same time setting the stage for serious consideration of manned lunar missions. On the other hand, the Soviet successes also led to more overt competition with the United States - a competition which would hinder rather than aid the Soviet program. On 2 January 1959 the new Luna vehicle functioned successfully for the first time, propelling a 361-kg capsule named Luna 1 and the booster's upper stage on a direct trajectory for the Moon. Half way to the Moon the upper stage, which carried its own set of scientific instruments, released a cloud of sodium vapor more than 100 km long to aid in tracking the two space objects. Approximately 34 hours after launch Luna 1 passed by the Moon at a distance of

▶ ***The Council of Chief Designers guided the initial Soviet space program; from left, M. S. Ryazanskiy, N. A. Pilyugin, S.P. Korolev, V. P. Glushko, V. P. Barmin, and V. I. Kuznetzov.***





Top: Luna final stage with Luna 1; Sputnik 1
Bottom: R-1, R-5, R-7 (Sputnik), R-7 (Luna)

5,000-6,000 km.

Although the probe had been intended to hit the Moon (a fact officially acknowledged only many years later), Luna 1 made history by becoming the first man-made satellite of the Sun and by continuing to operate to a distance of nearly 600,000 km. In addition to the political rewards bestowed upon the USSR as a consequence of the mission, the spacecraft and the upper stage returned valuable data on the translunar particulate and radiation environment as well as the Moon's magnetic fields: prerequisite information for the design of any future manned mission. Two months after Luna 1, on its fifth attempt, the US finally sent a spacecraft (Pioneer 4) to the vicinity of the Moon, although it passed more than 37,000 km away.

The next Soviet attempt to place a Luna spacecraft on the surface of the Moon occurred on 18 June 1959, two days later than scheduled. The initial portion of the flight was nominal, and the four strap-on boosters were released on time. However, the failure of a guidance unit in the core stage led to the self-destruction of the vehicle and its payload. Although discouraged, Korolev pressed ahead with his Luna program, knowing that the US was planning to place a satellite in orbit around the Moon in the second half of 1959 with a new larger booster. On 10 September the first Atlas-Able launch vehicle was destroyed during an on-pad test at Cape Canaveral.

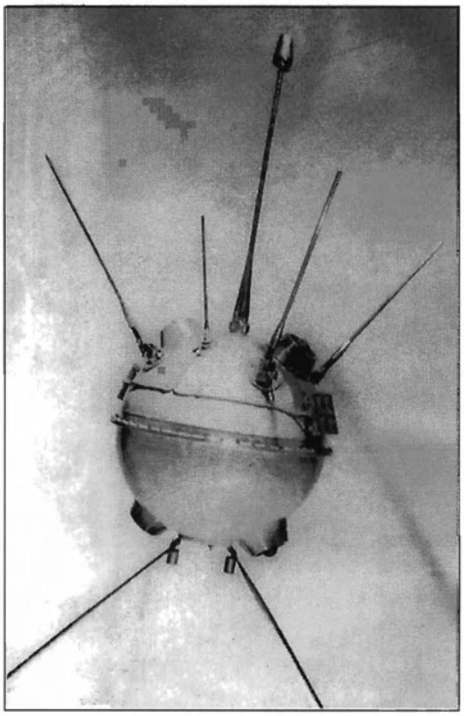
Two days later the Soviet Union successfully launched Luna 2. All three stages of the booster performed as designed, and the navigational accuracy was sufficient to ensure a lunar encounter. At two minutes past midnight on 14 September, Moscow time, Luna 2 slammed into the northern hemisphere of the Moon with a velocity of 3.3 km/s. The 390-kg probe was very similar to Luna 1 although the sensitivity and capacity of several of the scientific instruments had been improved.

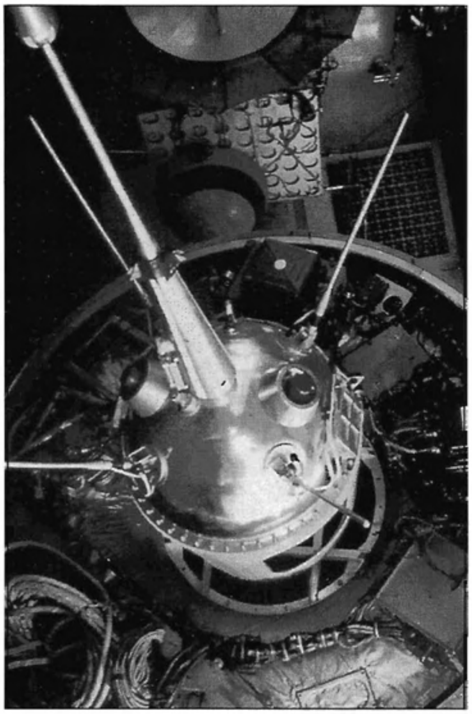
Even though the Soviet Union had beaten the US with the first lunar flyby and lunar impact, Korolev was not yet prepared to attempt placing a satellite into orbit about the Moon. However, he did have other plans which would be equally sensational and which could be implemented before the American lunar mission. On the second anniversary of the launching of Sputnik 1, the Luna 3 spacecraft was sent toward the Moon with the objective of returning the first photographs of the far side. The 279-kg Luna 3 weighed slightly less than its predecessors but was significantly more complex, while another 157 kg of scientific equipment was loaded on board the upper stage of the Luna launch vehicle.

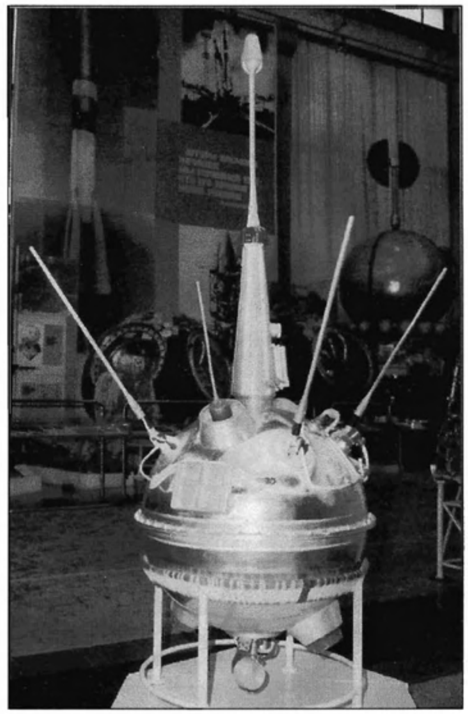
After passing by the Moon on 6 October at a distance of 6,000 km, the probe continued on, looping around the Moon on a trajectory which would send it back toward Earth. For 40 minutes on 7 October Luna 3 snapped 29 photographs of 70% of the Moon's hidden features with two lenses: one with a focal length of 200 mm to photograph the entire lunar disc and another with a focal length of 500 mm for more detailed views. The specially designed 35 mm isochrome film was later processed and scanned for transmission of the unique images back to Earth. Even these rudimentary glimpses immediately revealed a lunar terrain distinctly different from the familiar crater-pocked near side. Luna 3 continued to return new data on the Earth-Moon environment for several weeks.

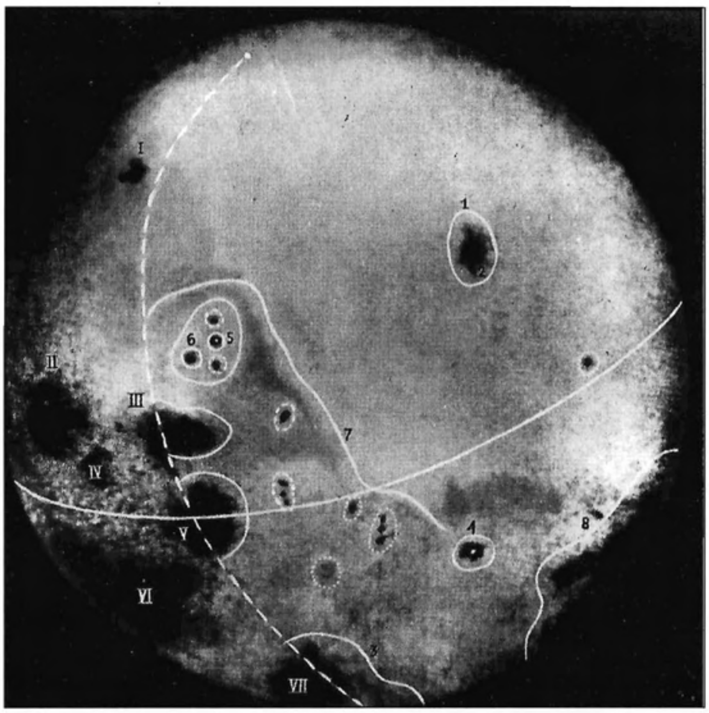
The US attempt to insert a satellite into lunar orbit failed less than a minute after launch in late November, providing Korolev with another opportunity to expand his lunar exploration lead. Two more spacecraft of the Luna 3 type were prepared with an objective of returning higher resolution photographs of the lunar surface. (Luna 3's photography session had taken place at more than 60,000 km above the Moon to permit broad coverage of the far side.) Unfortunately for Korolev, both probes were lost in April, 1960, as a result of launch vehicle malfunctions: the first did not achieve escape velocity and the second failed catastrophically only seconds after lift-off. ●

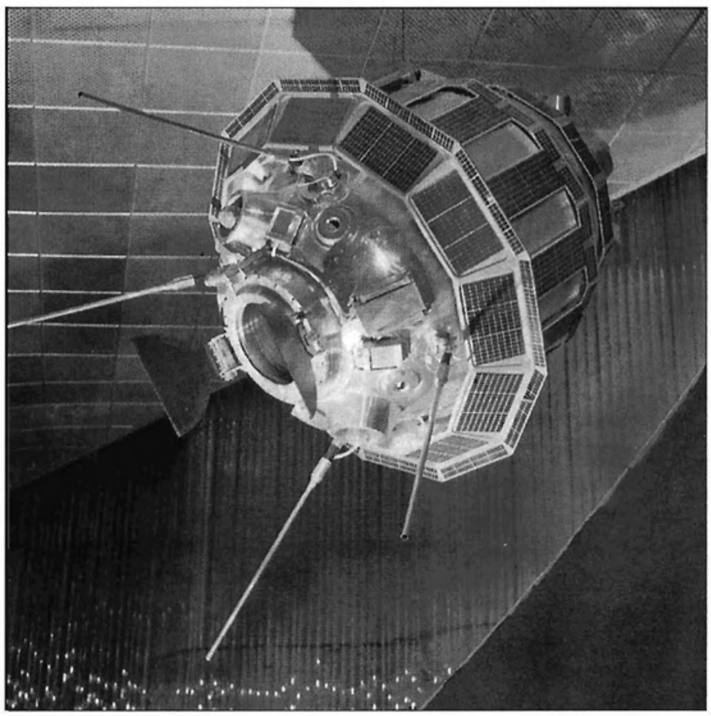
▶ ***Fifteen of the Soviet Union's foremost missile experts comprised the State Commission for the launch of Sputnik 1: (Top row, from left) M. S. Ryazanskiy, K. N. Rudnev, N. A. Pilyugin, S. M. Vladimirskiy, V. I. Kuznetsov; (bottom Row, from left) G. R. Udarov, I. T. Bulychev, A. G. Mrykin, M. V. Keldysh, S. P. Korolev, V.M. Rjabikov, M.I. Nedelin, G. N. Pashkov, V. P. Glushko, V.P. Barmin.***











▶ ***This historic first photograph of the lunar farside was returned by Luna 3 in October, 1959, and includes a portion of the Moon's visible face (left) to provide reference for the previously unseen farside features, which the Soviets quickly named.***
Farside: 1. Sea of Moscow, 2. Gulf of Cosmonauts, 3. Continuation of Mare Australe, 4. Tsiolkovsky Crater, 5. Lomonosov Crater, 6. Joliot-Curie Crater, 7. Sovietsky Mountain Range, 8. Sea of Dreams
Nearside: I. Mare Humboldt, II. Mare Crisium, III. Mare Marginis, IV. Mare Undarum, V. Mare Smythii, VI. Mare Foecunditatis, VII. Mare Australe

▶ ***Clockwise from top left: Luna 1 spacecraft, Luna 2 mated to last stage of Luna launch vehicle, Luna 2 spacecraft, Luna 3 spacecraft.***

2 Laying the Foundation for Manned Lunar Missions

The first stage of Soviet lunar exploration was at an end. In nineteen months only three of nine missions reached the Moon, but their successes far outweighed the more numerous failures. These Soviet achievements were highlighted against the background of a string of eight successive American failures during the same period. With Khrushchev's patronage, Korolev orchestrated three new, seemingly independent efforts which would develop the enabling technologies for manned missions to the Moon.

First, Korolev had to prove that human space flight was possible. The Vostok Earth orbital program would test both the man and the machines. Secondly, a new generation of automated lunar probes was needed to confirm that man could walk on the Moon without sinking into meters-deep dust and to survey the lunar surface for suitable landing sites. These new spacecraft would be 3-4 times heavier than the first generation Lunas, and, therefore, Korolev's R-7 launch vehicle would need to be uprated once again.

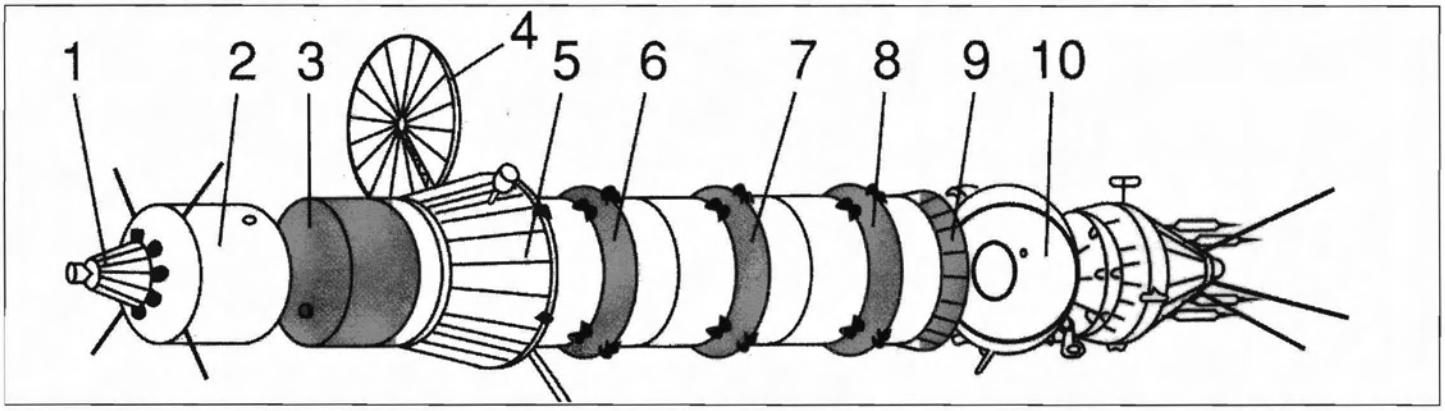
Korolev's third objective was to begin the design of the very large launch vehicle which would be required to support his long-range plans for exploration of the solar system. In 1960 the Earth orbital capacity of the Luna launch vehicle, the Soviet Union's most powerful booster, was limited to only a few metric tons. A payload 10-20 times heavier was seen as a likely requirement for a variety of future missions, including manned flights to the Moon. Hence, during 1960-1961 Korolev's OKB-1 design bureau began the preliminary designs of a family of heavy-lift boosters.

As originally conceived, a new launch vehicle, named N-1, with an orbital capacity of 40-50 metric tons would be developed during the period of 1962-1965. In concert, an N-2 rocket would be designed and tested during 1963-1970 for the purpose of lifting payloads of 60-80 metric tons into low Earth orbit. Neither of these projects were explicitly linked to manned lunar missions, although a proposal for utilizing an N-vehicle to send two cosmonauts on a circumlunar mission did appear early in the effort. On the other side of the Atlantic Ocean, President Kennedy had just (May, 1961) set a national goal of landing Americans on the Moon before 1970 and returning them safely to Earth.

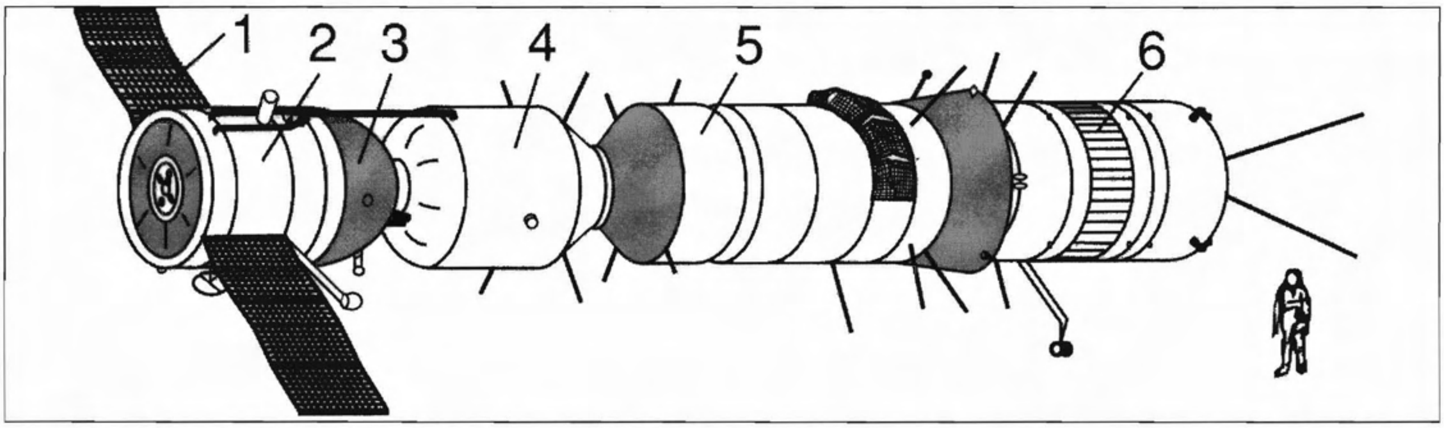
While Korolev's N-program was restricted to engineering studies only, the special design bureau OKB-52, formed in 1959 by Vladimir N. Chelomei, was given an assignment by Khrushchev in 1961 to develop a launch vehicle and manned spacecraft capable of carrying at least one cosmonaut around the Moon. The selection of Chelomei for this task instead of Korolev reflected a Soviet tradition, particularly in the defense and aerospace industries, of supporting competitive design bureaus to produce alternative concepts as well as to prevent a single organization from developing a monopoly and undue influence. Chelomei's group would bring to three the number of major design bureaus working on launch vehicles. In 1954 Mikhail K. Yangel established a rocket design bureau in the Ukraine, and by 1961 he was putting the finishing touches on what would become the USSR's second space launch vehicle: the original Kosmos booster, capable of placing a half-metric-ton payload into orbit about the Earth.

The heart of Chelomei's circumlunar mission was to be an entirely new 3-stage booster burning toxic but easily storable propellants: nitrogen tetroxide and unsymmetrical dimethylhydrazine. Glushko was tasked to develop the first stage main engines (RD-253), while Kosberg was tapped for the second and third stage engines (RD-465/RD-468 and RD-473, respectively). In the 3-stage variant, the booster, known as Proton or UR-500K, could place nearly

The original cosmonaut team posed for this photograph in front of their training facility: (bottom row, from left) Popovich, Gorbatko, Khrunov, Gagarin, Korolev and wife Nina with Popovich's daughter, Karpov (training director), Nikton (Parachute trainer), Federov (doctor); top row, from left) Leonov, Nikolayev, Rafikov, Filatev (behind), Zaikin, Anikeyev (behind), Volynov, Belyayev (behind), Titov, Nelyubov, Bykovsky, Shonin.



▶ ***ABOVE: 1962 proposal for a manned lunar flyby mission: 1. nose propulsion system of L-1 spacecraft; 2. living compartment; 3. reentry compartment; 4. solar panel; 5. instrument-equipment bay; 6.–8., rocket stages; 9. jettisonable section of lower rocket stage; 10. Vostok-7 spacecraft. BELOW: Advanced 1963 proposal for a manned lunar flyby mission: 1. solar panel; 2. instrument-equipment bay of Soyuz spacecraft; 3. reentry compartment; 4. living-working compartment; 5. upper rocket stage; 6. one of the spacecraft-tankers.***



20 metric tons into a low orbit. Chelomei's circumlunar spacecraft, later designated LK-1, was initially envisioned as a one-man vehicle.

The period 1960-1961 also witnessed the culmination of the Vostok manned spacecraft development program. Suborbital testing in January, 1960, was followed by three orbital flights between May and December of that year using the Luna launch vehicle. The second mission, launched on 19 August, circled the globe for more than a day and successfully brought back two dogs, the first living organisms to orbit the Earth and return. In March, 1961, two more, dress rehearsal orbital missions, employing a new Kosberg upper stage engine (RO-7) with a thrust of 5.6 metric tons, paved the way for Yuri Gagarin's historic 108-minute flight on 12 April. Four months later Soviet Cosmonaut Gherman Titov shattered Gagarin's mark by staying in space for more than 25 hours. Meanwhile, the US Mercury program had not yet attempted an orbital mission.

Flush with the successes of Vostok 1 and Vostok 2, Korolev moved quickly to maintain the momentum of the man-in-space program and to inch closer to his own lunar objectives. One of the first major - and in the end crucial - decisions to be made in designing the N-1 was the selection of the propellants which would be burned. Glushko was the preeminent rocket engine designer in the Soviet Union whose professional career predated Korolev's. Although Glushko had designed the liquid oxygen and kerosene engines for the R-7, he was now more interested in other propellants, like the ones which had just been chosen for Chelomei's Proton booster. Korolev objected to these hypergolic propellants in part due to their toxicity which raised serious safety issues in the event of a launch pad accident, particularly in the enormous quantities required for the N-1. On the other hand, liquid oxygen/kerosene or the alternative liquid oxygen/liquid hydrogen propellant combinations were less dense, requiring significantly larger launch vehicles which in turn led to additional unwanted weight.

The disagreement between Korolev and Glushko, which began when Korolev was designing the new R-9 ICBM, escalated into a full-blown feud. Glushko refused to participate in the N-1 program, not only setting back the N-1 design effort but also eroding needed political support at upper Soviet governmental levels. Chelomei and Glushko were especially aligned with the influential Ministry of Defense. As a last resort, Korolev turned to Nikolai D. Kuznetsov, then a General Designer of Aircraft Engines, who had come to his aid in developing engines for the R-9. Kuznetsov's design bureau was located in Kuybyshev, where Korolev operated major launch vehicle and spacecraft manufacturing plants, and could devote substantial resources to the program due to a downturn in the aircraft industry at the time.

Although Korolev may have preferred using the more energetic yet untested liquid oxygen and liquid hydrogen for the N-1, Kuznetsov's limited experience with rocket engines dictated that a less complicated design employing liquid oxygen and kerosene be adopted. Consequently, Kuznetsov was given an order to develop the main engines for the three stages of the basic N-1 vehicle. To accelerate the process, another decision was made to employ numerous engines of modest thrust (150 metric tons) instead of only a few, very powerful engines. The Kosberg design bureau had already been at work on the design of similar engines for the upper stage of the N-1.

In January, 1962, the N-1 design began to take shape. Early concepts proved unsuitable, so Korolev chose a simplified configuration, dubbed the SK-125, which would feature large spherical propellant tanks instead of the more common cylinders and toroids. The design was structurally less efficient and also necessitated the building of separate manufacturing rigs for each of the six propellant tanks (two per stage) which were of differing diameters.

On 10 March 1962 Korolev approved a technical prospectus which called for a manned circumlunar mission involving a Vostok spacecraft and a new L-1 spacecraft. The scenario began with the Vostok spacecraft assembling in Earth orbit a complex of three rocket stages which had been launched independently. The L-1 spacecraft with a crew of up to three cosmonauts would then be launched and docked with the complex. After the Vostok had withdrawn, the three rocket stages would be fired successively to send the L-1 spacecraft on a lunar flyby trajectory. The L-1 spacecraft, which included separate living and reentry compartments, was the predecessor to the Soyuz family of manned spacecraft which debuted in 1966 and are still in use today as crew ferries for the Mir space station.

While the feasibility of this near-term manned lunar mission was being evaluated, the preliminary N-1 concept underwent a rigorous review in July, 1962, by a special commission headed by Mstislav V. Keldysh, President of the USSR Academy of Sciences and the chief theoretician of cosmonautics. The Keldysh commission recommended several design changes which essentially merged the original N-1 and N-2 concepts. The N-1 design which emerged was a behemoth with a gross launch mass of 2,200 metric tons and a payload capacity to low Earth orbit of 75 metric tons. To lift the vehicle off the launch pad, the first stage would need 24 of Kuznetsov's main engines. A government decree on 24 September 1962 set a tentative schedule of 1965 as a target date for the first test flight, but concern was already rising about the ability to have the necessary ground support equipment in place by then. As expected, the task of designing the N-1 launch facilities fell to Chief Designer Barmin.

The N-1 concept was actually designed as a family of new launch vehicles which could also accommodate lesser payloads. A configuration called N-11 would consist of the second and third stages of the N-1 and an additional upper stage for a total mass of 700 metric tons and a payload capacity of 20 metric tons (equivalent to the later UR-500K Proton booster). An even smaller vehicle, dubbed N-111, would employ only the N-1 third stage and the new upper stage. Total payload capacity was calculated to be 5 metric tons with a lift-off mass of 200 metric tons.

Several new manned space flight milestones important to future lunar missions were already underway. On 11 August Cosmonaut Andriyan Nikolayev piloted the Vostok 3 spacecraft into Earth orbit, where he was followed 24 hours later by Pavel Popovich in Vostok 4. The dual mission caught the world by surprise and gave clear evidence of the Soviet Union's space launch expertise. Rapid, successive launches of this nature would be necessary if the Vostok/L-1 circumlunar mission was to be realized. Of equal importance was the duration of the missions: Nikolayev established a new space endurance record of nearly four days. The conditions of both cosmonauts upon landing suggested that a longer, 7-day flight to the Moon and back would probably pose no health problems.

With the start of the new year 1963, Korolev was engaged in a variety of activities: the continuation of manned flights on Vostok, the design of the successor Soyuz and L-1 spacecraft, the development of the N-1 booster, and the initiation of a new generation of unmanned Luna spacecraft. The last program required a new multistage version of the original R-7 launch vehicle, later called Molniya. The short upper stage developed for the earlier Luna missions was replaced by a new, longer upper stage with a Kosberg engine and yet another, final stage developed by Korolev's own design bureau. Unlike the original Luna missions, the Molniya/Luna flights used the first three stages to enter a temporary low Earth parking orbit. About an hour later, the fourth stage was to ignite to send the Luna probe toward the Moon.

Unfortunately for Korolev, the Molniya booster proved exceedingly difficult to perfect. During 1960-1962 the vehicle was used at least 10 times for flights to Mars and Venus, but on only two occasions did the launch vehicle perform satisfactorily. The primary problem lay with the operation of the fourth stage. When the first of the new Luna probes was launched on 4 January 1963, the fourth stage failed yet again, stranding the Luna spacecraft in low Earth orbit from where it quickly decayed and was destroyed the next day during reentry. At the time this short mission was not even acknowledged by the Soviet Union, a policy which changed two years later after pressure from the US to record all space missions which entered Earth orbit. Three months later, Luna 4 was successfully launched and inserted into a translunar trajectory. On 6 April the robot explorer passed the Moon at a distance of 8,500 km and continued on. The 1.4 metric ton Luna 4 represented the first of a new generation of spacecraft (designated Ye-6) designed to survive a landing on the Moon.

In late April Korolev made a presentation to the Presidium of the Interdepartmental Council on Space on the potential of the N-1 to support manned lunar missions and Earth orbital space stations as well as military space projects. The following month Korolev approved a revised prospectus for a manned circumlunar mission. Titled "Assembly of Space Vehicles in Earth Satellite Orbit" and signed by Korolev on 10 May 1963, the new mission plan completely eliminated the Vostok assembly spacecraft and reflected an updated Soyuz spacecraft design (designated 7K), which had been approved the previous March. A single, unfueled rocket stage would be placed in Earth orbit and then fueled by special tankers launched separately. When all was in order, a Soyuz spacecraft would be launched and then docked to the fueled rocket stage, which in turn would be ignited for translunar injection. The remainder of the mission was similar to that envisioned for the original Vostok/L-1 profile. Ultimately, the complexity of this scenario, the delay in the development of Soyuz, and the alternative circumlunar option using a single Proton booster led to the cancellation of Korolev's plan.

The Vostok program came to a successful conclusion in June, 1963, with the joint flights of Vostok 5 and Vostok 6. Valeri Bykovsky in Vostok 6 set a new space flight record with a mission just shy of five days in length, while Valentina Tereshkova piloted Vostok 6 to become the first woman in space. Although additional Vostok flights were considered, for example a week-long mission by a cosmonaut with medical training, the program was terminated in favor of progressing to more challenging tasks, including multi-man crews, maneuverable spacecraft, and extra-vehicular activity (EVA). By resolution of the Central Committee of the Communist Party of the Soviet Union (CPSU) on 3 December 1963, the Soyuz program was approved with an anticipated first test flight of the 7K spacecraft in 1964. Soyuz was optimistically assigned to support missions not only to the Moon but also to the planets. ●

3 Developing Technology For Lunar Exploration

▶ In late 1963 another enabling technology for the manned lunar mission was tested. On 1 November the USSR launched an experimental spacecraft called Polet 1 for the purpose of gaining experience with orbital maneuvers. Polet 1, developed by the Chelomei design bureau to support a military space weapons program, was the first Soviet satellite able to move from one orbit to another. Such maneuvers were essential for the Earth orbital rendezvous scenario under study by Korolev for a circumlunar mission or for a potential lunar landing profile requiring lunar orbital rendezvous. The successful Polet 1 flight was repeated on 12 April 1964 by Polet 2. These vehicles later evolved into the Soviet co-orbital anti-satellite system, operational from 1968 to 1993.

By February, 1964, the Central Committee of the CPSU had approved a plan for a manned lunar landing in the 1968-1970 time frame. The scenario envisioned three N-1 launches to assemble a 200 metric ton complex in Earth orbit. However, as the summer of 1964 arrived, the landing of a Soviet cosmonaut on the lunar surface was still not an official national goal.

Meanwhile, in the US the Saturn I had already flown with a boilerplate Apollo spacecraft, and the lunar program was on track for a landing on the Moon before the decade was out. Finally, Korolev succeeded in convincing the Soviet government that a Russian could still be the first man on the Moon only if an official program were initiated immediately. A decree entitled "On Work Involving the Study of the Moon and Outer Space" set 1967-1968 as the target date for a lunar landing. However, Korolev found his N-1 rocket competing with designs by Chelomei (UR-700) and by Yangel (R-56), both powered by Glushko engines.

At the same time a manned lunar landing objective was being set, the Central Committee of the CPSU and Council of Ministers on 3 August 1964 (Resolution 655-268) charged Chelomei with accomplishing a manned lunar fly-by with his LK-1 spacecraft in 1967. Launched by a 3-stage version of the Proton booster, the LK-1 vehicle consisted of three separate sections. The first was actually an upper stage used to propel manned spacecraft from Earth orbit toward the Moon. Next came an instrument-equipment compartment containing most of the spacecraft's major support systems and solar panels for generation of electricity. The third and final section was the return module, which was conical in shape and designed to carry one cosmonaut. LK-1 was covered at launch by a fairing with an emergency escape rocket capable of lifting the spacecraft away from the Proton booster in event of a launch accident.

With the Vostok man-in-space program concluded and the debut of Soyuz still two or more years in the future, Korolev assigned his spacecraft engineers the task of creating a gap-filler program which could test technologies important to both Earth orbit and lunar missions. Thus was born the short-lived and daring Voskhod program. Only two manned Voskhod flights were conducted (five months apart during 1964-1965), but the achievements were substantial - both politically and technically. For a short time, Korolev entertained the idea of using a Voskhod for a circumlunar mission and even proposed the project to the Communist Party Central Committee and the USSR Council of Ministers.

Designing an entirely new spacecraft was impossible during the brief period allowed, so the basic Vostok capsule was extensively modified. The cosmonaut's ejection seat, used either during a launch abort or during a normal reentry, was eliminated to make room for additional cosmonaut couches. In exchange, a new soft landing solid rocket system was added. Whereas in the event of a reentry system malfunction Vostok carried sufficient supplies to maintain a single cosmonaut until natural decay occurred, Voskhod was equipped with a back-up propulsion unit to ensure a timely return to Earth. Since Voskhod would initially carry crews of 2 or 3 men, the duration of early missions was restricted to one day due to a limited amount of consumables, e.g., air and water. Also, for the first time men would be sent into space with no protective pressure suits and no means of abandoning their carrier rocket should a failure occur during launch.

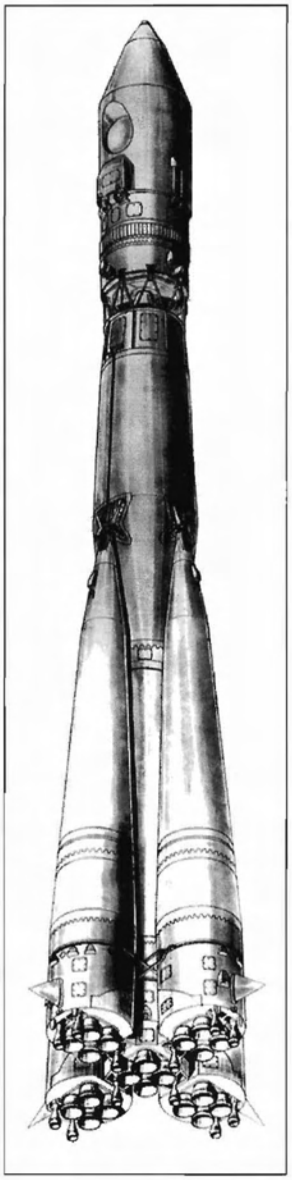
Following an unmanned test of Voskhod as Kosmos 47 on 6-7 October 1964, Voskhod 1 with three cosmonauts aboard was placed in Earth orbit on 12 October. Since Voskhod weighed up to one metric ton more than Vostok, a new variant of the R-7 launch vehicle, with an RO-9 upper stage engine (30 metric ton thrust) was developed. This engine had earlier seen service with the unmanned probes to Venus, Mars, and the Moon during 1961-1963 on the Molniya launch vehicle. One of the crew members of Voskhod 1, Konstantin Feoktistov, was a civilian engineer from Korolev's OKB-1. This precedent, designed to improve the chance of success of the rapidly prepared mission, set the stage for future confrontations between the design bureau and the Soviet Air Force in selecting crews for the L-1 and L-3 lunar missions.

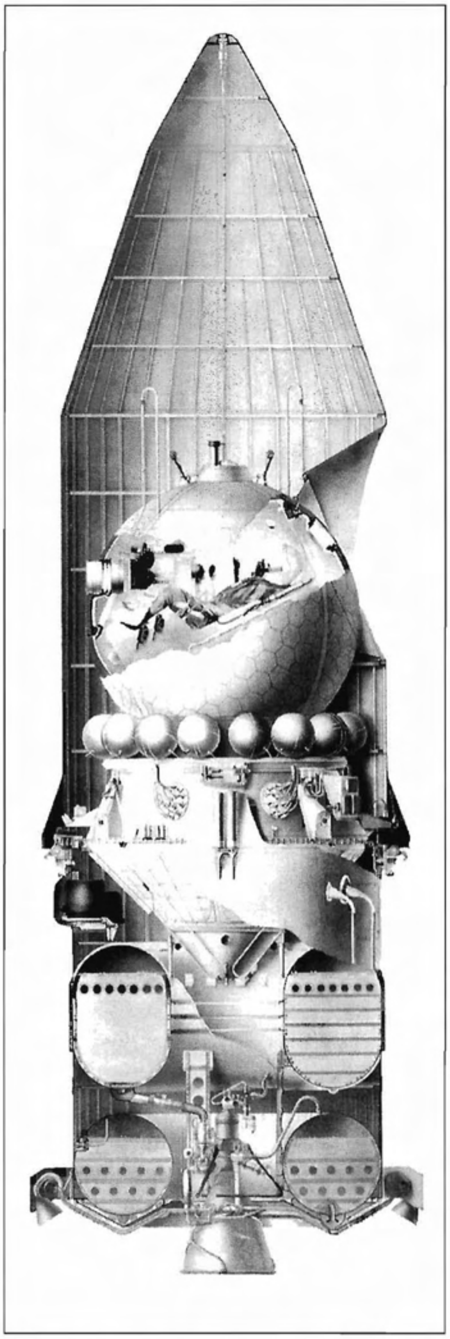
Although the scientific benefits of the Voskhod 1 mission were modest, the spacecraft was certified for the more challenging Voskhod 2 flight scheduled for early 1965. On the propaganda level, the idea that the Soviet Union could send three cosmonauts into space in a single craft before the US had begun its two-man Gemini program was very attractive to Khrushchev. Ironically, Khrushchev was suddenly removed from office in the midst of the short flight of Voskhod 1. With this departure Korolev lost a valuable ally at the highest decision-making levels of the Soviet government.

On Christmas Day, 1964, Korolev signed the preliminary design for his long-awaited lunar landing mission, although official government approval was still two years away. His N-1 launch vehicle had yet again been improved and was now capable of placing a payload of 92 metric tons into low Earth orbit. As a consequence, launch mass had grown to 2,700 metric tons and an additional six main engines were included in first stage, bringing the total to 30.

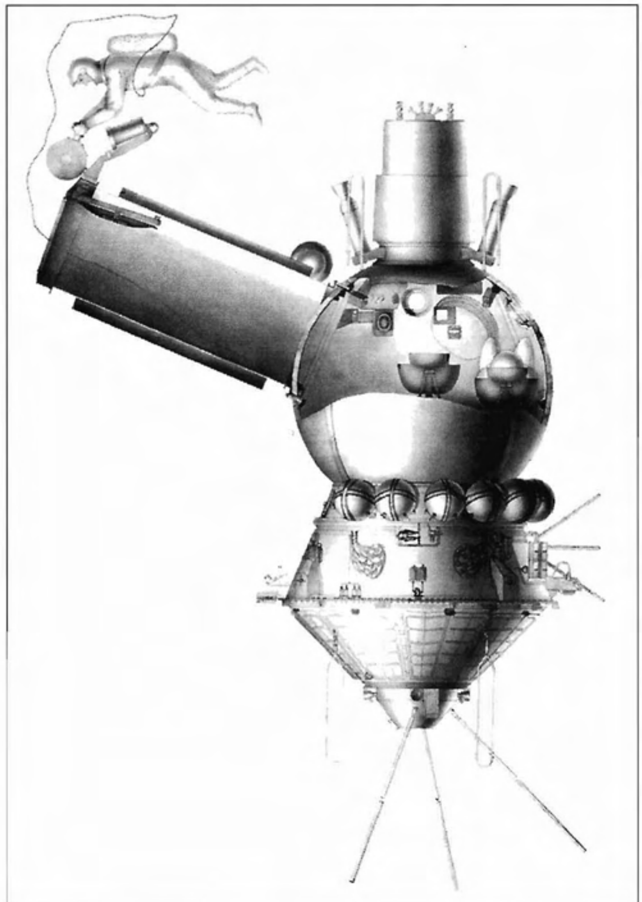
Atop the basic 3-stage N-1 would be the L-3 complex consisting of two rocket stages, a lunar orbiter and a lunar lander. Although earlier concepts had involved coordinated N-1 launches and subsequent Earth orbital assembly of the lunar complex, in the end Korolev had accepted the simplified single-launch, lunar-orbit-rendezvous profile already chosen by the US. However, since the N-1 payload capacity was less than that of the US Saturn V, Korolev could only send two cosmonauts to the Moon, and only one of those would actually set foot on the lunar surface.

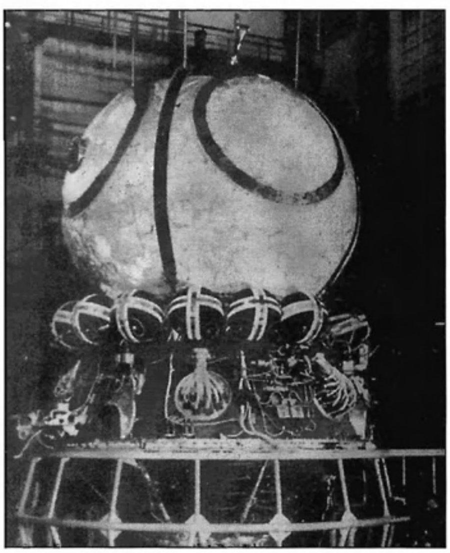
Always looking ahead, Korolev tasked the rocket design bureaus of A. M. Lyulka, A. M. Isayev, and N. D. Kuznetsov to begin development of new engines for N-1 which would burn liquid oxygen and liquid hydrogen (like second and third stages of US Saturn V) to increase further payload capacity of the N-1. During 1964 Korolev also proposed combining second and third stages of the N-1 with the first stage (Block G) of the L-3 complex as a booster for a manned circumlunar mission. However, the Chelomei UR-500K/LK-1 design remained the official Soviet circumlunar program. ●

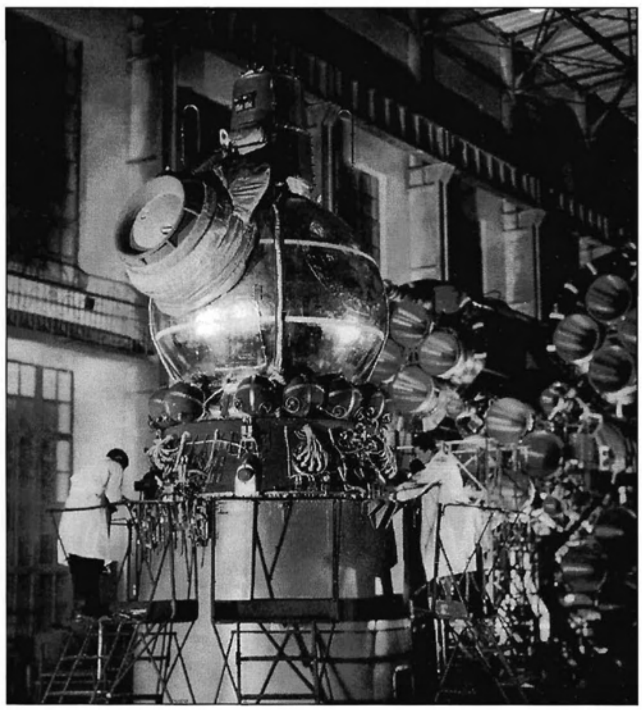




► ***Clockwise from top left: Vostok spacecraft with Vostok launch vehicle; cutaway of Vostok spacecraft and the upperstage of the Vostok launch vehicle; illustration of Voskhod 2 during Leonov's historic spacewalk; Voshkod 2 spacecraft (with stowed airlock) being readied for flight; Vostok spacecraft prior to mating with its launch vehicle.***







4 A New Stage of Robotic Lunar Exploration

▶ By the beginning of 1965 Korolev's design bureau was engaged in numerous space programs of both scientific and practical applications. When Korolev's workload had grown during the 1950's, he had established new independent design bureaus to assume responsibility for specific technologies and projects. The Yangel design bureau was created in this manner in 1954, followed by the design bureaus of Mikhail F. Reshetnev (communications and navigation satellites) and Dmitri I. Kozlov (manned and unmanned recoverable spacecraft and variants of the R-7 launch vehicle) in 1959. Korolev now decided that the important automatic lunar and planetary exploration programs warranted a dedicated developer. Georgiy N. Babakin had met Korolev after World War II, later becoming involved in spacecraft and impressing Korolev with his ingenuity. Thus, in 1965 the Babakin design bureau was established in the Khimky suburb of Moscow to manage the Luna, Venera, and Mars programs.

Since the successes of 1959, the Luna program had progressed relatively slowly, in part due to the development of a new generation of spacecraft and needed modifications to the R-7 launch vehicle, i.e., the Molniya-class booster. In 1965 the program for unmanned exploration of the Moon was renewed in earnest, albeit with frustrating results. Between March and December six Luna probes were launched from the Baikonur Cosmodrome, but all failed. The first attempt on 12 March, later designated Kosmos 60, was left stranded in Earth orbit when the final rocket stage failed to fire, while a second Luna was lost on 10 April when a launch vehicle malfunction occurred early in flight.

The next four spacecraft were only marginally more successful, surviving the launch phase and being inserted into translunar trajectories. Luna 5, launched on 9 May, attempted to place a 100-kg capsule on the Moon to take detailed photographs of the lunar surface and to confirm that the strength of the lunar soil would support a manned vehicle. Unfortunately, Luna 5's retro rocket failed to fire at an altitude of 64 km, and the probe slammed into the southern hemisphere of the Moon on 12 May and was destroyed. The following month Luna 6 fared even less well, missing the Moon by more than 160,000 km due to a mid-course correction failure.

After a four-month lapse while the Luna program underwent a reevaluation, Luna 7 was launched toward the Moon on 4 October, the eighth anniversary of Sputnik 1 and the sixth anniversary of the Soviet Union's last successful lunar probe, Luna 3. Luna 7 reached the Moon on 8 October, but its retro rocket fired prematurely, causing the Luna 7 capsule to strike the lunar surface at a high velocity. The final attempt of the year to soft land on the Moon commenced on 3 December but once again ended three and one-half days later in failure. Whereas Luna 7's retro rocket had fired too soon, Luna 8's engine ignited too late, and the spacecraft crashed on the Moon west of the Kepler crater. Despite the failure of all six Ye-6 Luna missions in 1965, some valuable guidance data were acquired during the translunar portions of the flights of Lunas 5-8. Babakin could only hope that the new year would smile more favorably on his new design bureau.

While the Luna program suffered its string of failures, a few bright spots did appear elsewhere. The most dramatic event of the year was the flight of Voskhod 2 on 18-19 March. Less than two hours after launch, Cosmonaut Alexei Leonov became the first man to walk in space. He left his Voskhod capsule with Cosmonaut Pavel Belyayev inside via an inflatable airlock and floated beside the spacecraft for twelve minutes. The feat not only verified the design of the spacesuit to protect and to support men exposed to the harsh environment of space but also proved that men could function in orbital weightlessness without severe disorientation. (On all previous US and USSR manned spaceflights the crews were confined to their cramped seats throughout the mission.) The latter finding was crucial to plans which might require cosmonauts to transit from one spacecraft to another on lunar missions.

In July a major milestone in the manned circumlunar program was achieved with the maiden flight of Chelomei's Proton booster. The first launch on 16 July employed the UR-500 variant with only two rocket stages. A scientific payload of 12.2 metric tons - by far the heaviest Soviet satellite to that date - was placed in a low Earth orbit and named Proton 1. The mission was repeated, again successfully, on 2 November.

Although the Proton launch vehicle program was progressing satisfactorily, the Chelomei design bureau was encountering difficulties on the development of the LK-1 manned spacecraft. The rocket designer had increased the performance of the Proton booster, and OKB-52 spacecraft engineers had saved enough weight in the construction of the vehicle to permit a crew of two to make the lunar journey instead of the original concept with only a single cosmonaut. However, during the second half of 1965 the LK-1 program had fallen behind schedule. A total of twelve spacecraft were to be built by the second quarter of 1967. Part of the difficulty was attributed to Chelomei's lack of experience in developing recoverable and manned spacecraft.

Korolev, who had wanted to maintain his monopoly on manned spacecraft, was quick to seize this opportunity to wrest the manned circumlunar program away from his competitor.

On 15 December 1965 Korolev made a bold move to replace Chelomei's LK-1 spacecraft with his own L-1 spaceship and an upper stage (Block D) of the L-3 complex. The L-1 was similar to the designs for the Soyuz 7K spacecraft and the lunar orbiter which was being developed under the N-1/L-3 program. Korolev's plan was approved by the Council of Ministers' Military Industrial Commission, chaired by L. V. Smirnov, and by S. A. Afanasyev, Minister of General Machine Building. The Soviet manned circumlunar program was officially redesignated as the UR-500K/L-1, and Korolev was granted primary authority over the effort.

Korolev's victory in the years-long, hard-fought battle to run the manned circumlunar program was short-lived. On 14 January 1966, just one month after his L-1 proposal was adopted, Korolev died unexpectedly during a botched operation. The loss of Korolev at such a critical time in the L-1 and L-3 programs, as well as the Soyuz effort, was devastating. Despite his disputes with Chelomei and Glushko, Korolev's influence over the entire Soviet space program was unequaled. His technical and managerial skills had made him a virtual legend in his own time. Holding his empire together and maintaining the hectic pace of the manned lunar programs was going to be difficult. No less than 5-6 manned Earth orbital missions were planned for 1966, including the docking of two Soyuz spacecraft. The first manned L-1 flight was still scheduled for 1967 with an L-3 lunar landing during 1968-1969. Korolev's deputy, Vasiliy P. Mishin, who had worked with Korolev since 1945, was appointed Chief Designer of OKB-1, which was subsequently renamed TsKBEM, an abbreviation for Central Design Bureau of Experimental Machine Building.

After this disastrous start the year 1966 improved rapidly. Luna 9 was launched on 31 January, and by 3 February the vehicle was accelerating again toward the lunar surface. About one hour prior to touchdown and still 8,300 km away, Luna 9 reoriented itself, turning its powerful retro engine toward the Moon. A radio-altimeter carefully measured the distance to go, and at an altitude of 75 km the engine was ignited. In less than a minute a five-meter probe made contact with the lunar surface, triggering the release of the precious scientific cargo.

The egg-shaped capsule safely landed on the Moon intact while the rest of the vehicle slammed into the Moon at about 20 km per hour. Within four minutes of touchdown in the Oceanus Procellarum, the Luna 9 capsule had opened its stabilizing petals and had begun communications with Earth. More importantly, on the morning of 4 February the first panoramic view of the lunar surface was transmitted, revealing a rugged, rock-strewn landscape. Luna 9 continued to send back photographs and other data until its batteries were depleted on 7 February. In addition to beating the US with the first lunar station (the US Surveyor 1 did not land on the Moon until four months later), the success of Luna 9 left no doubt that the lunar surface was indeed capable of supporting man.

When the next lunar launch window arrived on 1 March, the Soviets sent out another probe. This time, however, the Molniya fourth stage failed to fire, and the spacecraft, now called Kosmos 111, fell back to Earth two days later. Unfazed, Babakin's design bureau readied yet another spacecraft for launch on 31 March. Luna 10 differed considerably from Luna 9 and was not intended to land on the Moon. Instead, on 3 April Luna 10 decelerated and entered an orbit around the Moon, coming as close as 350 km to the surface every 2 hours and 58 minutes. Twenty minutes after achieving orbit, the 245-kg Luna 10 satellite separated from its propulsion unit. By becoming the first artificial satellite of the Moon, Luna 10 had beaten the American Lunar Orbiter 1 by four months. To the rest of the world, Luna 9 and Luna 10 represented a comprehensive and vigorous Soviet lunar exploration program which continued to stay ahead of similar US efforts.

The value of the Luna 10 mission extended far beyond mere propaganda. Korolev had finally selected a lunar landing profile which required an initial insertion into lunar orbit and later a lunar orbit rendezvous between the L-3 lunar lander and lunar orbiter. The last procedure, in particular, required a thorough understanding of the Moon's gravitational field. Luna 10 and the subsequent Soviet and American lunar satellites discovered that the Moon possessed a much more complex gravitational field than expected. This was due to the presence of mass concentrations (mascons) in the lunar interior. An extensive mapping of gravitational perturbations was necessary to plan for a future manned landing. Luna 10 was also equipped with instruments to measure the lunar magnetic field and surface radiation levels and continued to return data for 56 days.

On 24 August Luna 10's sister spacecraft, Luna 11, was launched and became a satellite of the Moon on 28 August. Luna 11 entered a low inclination orbit of only 27 degrees (compared with the Luna 10 inclination of 72 degrees), which allowed the spacecraft to concentrate on analyzing the equatorial sectors of the Moon where the L-3 lander was likely to touchdown. Exactly three weeks after Luna 11 ceased functioning, the USSR launched a more sophisticated lunar satellite with a mission of photographic mapping of the lunar surface. Such surveys were essential to selecting potential landing sites for the L-3 mission. The 1.1 metric ton Luna 12 entered an elliptical, nearly equatorial lunar orbit of 100 km by 1740 km on 25 October. Near its closest approach to the Moon, Luna 12's camera system could view a region of 25 square kilometers with a resolution capable of detecting craters 15-20 m in diameter. Each Luna 12 photograph was taken by a conventional camera, then developed, and finally scanned by a television camera for transmission to Earth.

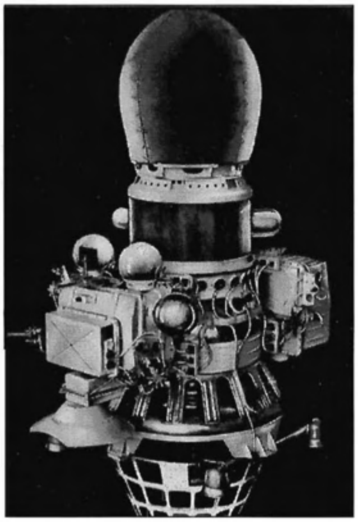
While Luna 12 was still operating in lunar orbit, the Soviet Union launched its final Luna probe of 1966 on 21 December. Three days later Luna 13 soft-landed on the Moon approximately 400 km from the now silent Luna 9. The new lander was quite similar to its predecessor, but two 1.5 m booms had been added to permit a more detailed analysis of the lunar soil. At the end of one boom was an explosively driven penetrometer to measure soil strength and density. A radiation densitometer was located on the other boom to provide a complementary analysis of the lunar soil. Luna 13 also carried a camera system virtually identical to that of Luna 9.

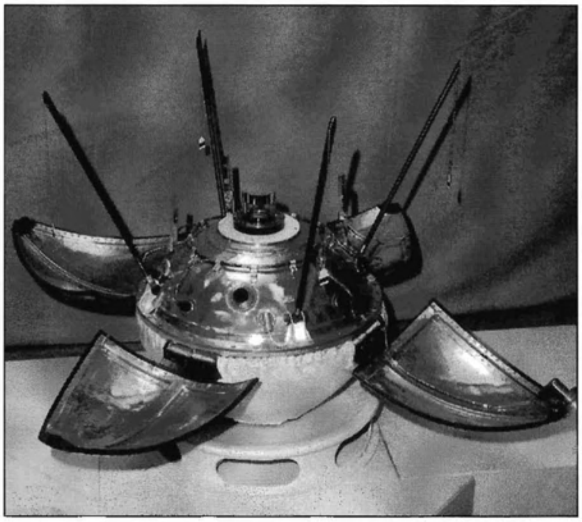
Following successes of Lunas 9–12 and establishment of a new government council (of Ministers, Deputy Ministers, Chief Designers, and academics) to examine problems in the conquest of the Moon, the Keldysh commission completed another review of Soviet manned lunar landing program. On 16 November Korolev's (now Mishin's) draft plan for the N-1/L-3 mission was approved. Officially, the first lunar landing was only two years away, but this schedule was becoming more unrealistic with each passing month.

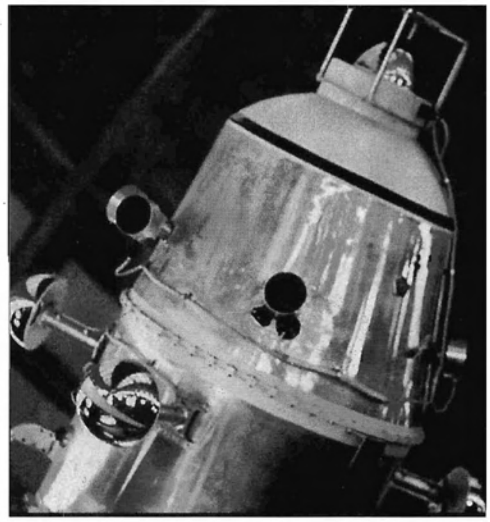
At the same Keldysh commission meeting, Chelomei presented his own manned lunar landing proposal. His design bureau had refined the concept of the heavy-lift UR-700 launch vehicle which was now expected to place a payload of up to 150 metric tons into low Earth orbit - more than half again as much as Mishin's N-1. With this advantage, Chelomei had designed the 45-metric-ton LK-700 spacecraft which was capable of landing its two-man crew on the Moon and returning directly to Earth without the need for lunar orbital rendezvous. The return vehicle would be based on the LK-1 spacecraft originally conceived by Chelomei's OKB-52 for manned circumlunar flights. All UR-700 and LK-700 rocket engines would burn nitrogen tetroxide and unsymmetrical dimethylhydrazine as propellants. Despite support from Glushko and other chief designers, the UR-700/LK-700 plan was not taken seriously by the Keldysh commission, although Chelomei was allowed to continue the preliminary design effort.

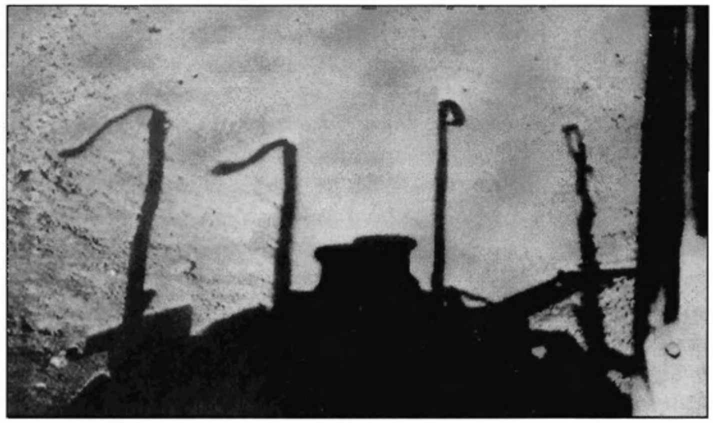
Two weeks after this important meeting, Mishin supervised the first orbital test of hardware related to the L-1 and L-3 programs. On 28 November the Soyuz prototype spacecraft was launched unmanned as Kosmos 133 using an upgraded 30.5-metric-ton thrust RO-9 engine (designated 11D55) for the upper stage. (This configuration was later christened the Soyuz launch vehicle.) A second, unmanned spacecraft was to be launched the next day followed by a demonstration of automated docking. However, early in flight Kosmos 133 experienced an attitude control failure, exhausted its propellant reserves, and was spinning at a rate of 2 rpm, causing the launch of the second Soyuz to be canceled. After two days in space and five attempts to correct the problem, the ion orientation system finally positioned the spacecraft for the return to Earth, but the vehicle was intentionally destroyed after reentry when it strayed off course.

The next attempt to launch a Soyuz spacecraft was even more disastrous. On 14 December 1966 the spacecraft and launch vehicle were prepared on launch pad no. 31. (Sputnik 1 and Yuri Gagarin had both been launched from pad no. 1.) At the designated time for launch, the core stage ignited, but the strap-on stages









▶ ***Above and center: The egg-shaped capsule atop the Luna 9 spacecraft unfurled its petals upon landing to become the first man-made object to return photographs and data from the lunar surface.***
▶ ***Above right: On the Luna 10 mission, the landing capsule of Luna 9 was replaced with a satellite designed to examine the Moon from lunar orbit.***
▶ ***Right: The Luna 13 landing station is silhouetted by the Sun after its successful touchdown on the Moon in December, 1966.***

did not due to a malfunctioning oxidizer by-pass valve. The vehicle was immediately shutdown, apparently averting a calamity. However, as the service truss was being re-erected around the launch vehicle, the rocket was struck, causing it to lean which in turn activated the Soyuz emergency escape system. This inadvertently ignited the third stage and the rest of the launch vehicle.

The ensuing explosions were horrendous, killing one person, injuring several others, and severely damaging the launch pad. Another launch was tentatively set for mid-January, 1967, but launch pad no. 1 was not yet ready for the new launch vehicle. The first two manned Soyuz missions were postponed until March, 1967. After such high expectations for Soyuz program early in 1966, the year ended with two successive failures and no manned missions.

Four versions of the manned spacecraft were under development: 7K-OK for standard Earth orbital missions, L-1 for circumlunar flights, L-3 for the lunar landing program, and 7K-VI for special military missions. In August, 1966, Lt. Gen. Nikolai Kamanin of the Soviet Air Force, with responsibilities for crew training at the TsPK (Center for Cosmonaut Training), became embroiled in an acrimonious debate with Mishin, Keldysh, and others, who wished to wrest cosmonaut training for the 7K-OK, L-1, and L-3 programs from the military. Mishin recommended a group of OKB-1 specialists be prepared for the 7K-OK program. Kamanin's rebuttal in September was to nominate Bykovsky, Gagarin, Gorbatko, Khrunov, Kolodin, Komarov, Nikolayev, and Voronov: all Air Force officers from the TsPK. Likewise, his list for L-1 missions included Bykovsky, Dobrovolsky, Kolodin, Komarov, Volynov, Voronov, and Zholobov, and his list for the planned L-3 flights included Gagarin, Gorbatko, Leonov, Khrunov, Nikolayev, and Shatalov.

By the end of the year a comprise had been reached on L-1 cosmonaut candidates. Nine military spacecraft commanders were selected (Beregovoy, Bykovsky, Gagarin, Khrunov, Komarov, Leonov, Nikolayev, Shatalov, and Volynov) along with five civilian crew members (Grechko, Kubasov, Makarov, V. Volkov, and Yeliseyev). The commanders had to be space veterans, but the crew members need not be. Training was set to start in January, 1967.

Other aspects of the L-1 program were also progressing. The first two L-1 spacecraft were already at the Baikonur Cosmodrome awaiting launch. However, these unmanned spacecraft were not designed to be recovered; instead the missions were to check out the numerous on-board systems. If all went well, flights no. 3 and no. 4 would fly-by the Moon in an automated mode and an attempt would be made to recover them on Earth. The first manned L-1 mission might be undertaken as early as June, 1967, according to the scenario dictated by Dmitri Ustinov, Secretary of the Central Committee of the CPSU, and Leonid Smirnov, Chairman of the Military-Industrial Commission and a deputy chairman of the Council of Ministers. G. A. Tyulin was chosen as Chairman of the State Commission for the launch of L-1.

Mishin, however, was concerned about the as yet untested 4-stage version of the UR-500K (UR-500K plus Block D stage). To date only the 2-stage UR-500 had been launched with three successes in four attempts. As an alternative to launching the UR-500K/L-1 with a crew on board, Mishin proposed launching L-1 unmanned. A manned Soyuz 7K-OK would then follow and dock with the L-1. After the crew transferred from Soyuz to the L-1, the Soyuz would return to Earth and L-1 would be launched on a fly-by of the Moon by Block D stage. Although this was a more expensive and complicated flight profile, it offered a potentially less hazardous mission for the crew. In the end, these debates became academic. ●

5 Preparing for the L-1 Circumlunar Missions

▶ At the start of 1967 the USSR was still optimistic about its chances of beating the US with a manned circumlunar flight before the 50th anniversary of the Communist state in November. Mishin also turned 50 in 1967 and desperately needed to overcome his faltering start as Korolev's successor. The landing of a Soviet cosmonaut on the Moon during the 1960's was also still possible. The maiden flight of the N-1 was now set for the third quarter of 1967 with a manned lunar landing no later than the third quarter of 1969. However, to meet these ambitious schedules, a series of critical milestones set for 1967 had to be achieved. Alternatively, the Soviets would benefit from a major disruption in the American Saturn/Apollo program. The year was destined to be a dark one for both nations.

The third attempt to test the Soyuz 7K-OK spacecraft commenced inauspiciously on 7 February. The vehicle, designated Kosmos 140, lifted-off 24 hours late and entered a lower than desired orbit. Like its Kosmos 133 predecessor, Kosmos 140 immediately experienced attitude control problems and excessive propellant expenditures. An orbital maneuver was performed on the 22nd revolution about the Earth, but the attitude control system still did not operate properly. Although the ion orientation system did permit the spacecraft to be positioned for the return to Earth, Kosmos 140's trials were far from over. During reentry a hole (~250 mm by 350 mm) was burned in the heat shield - an event which almost certainly would have doomed a human crew. Then, the capsule strayed off course and landed on the ice of the Aral Sea. With its high temperature and weight and its air-tightness now gone due to the hole in its base, the capsule broke through the ice and sank.

A review of the manned circumlunar program produced a new decree on 4 February 1967 entitled "On the Progress of the Work on the Development of the UR-500K/L-1". With the initial test mission only a month away, no serious difficulties were identified. By March the first UR-500K/L-1 vehicle was on a pad at the Baikonur Cosmodrome ready for launch.

The basic 3-stage UR-500K Proton vehicle stood 44.3 m tall. Six Glushko RD-253 engines powered the first stage and were attached to six cylindrical fuel tanks (each about 2 m in diameter) arranged around a 4-m diameter oxidizer tank. The overall diameter of the first stage was 7.4 m with a height of 20.7 m. On a nominal mission the six engines would burn for about 120 seconds with a total thrust of 894 metric tons.

The second stage employed three Kosberg RD-465 and one Kosberg RD-468 engines to develop a total thrust of 245 metric tons for 215 seconds. The stage was 17 m long with a diameter of 4.2 m. The shorter, 6.6-m-long third stage carried a single Kosberg RD-473 plus four small vernier engines for a total thrust of 64 metric tons. Its mission was to insert the Block D rocket stage and the L-1 spacecraft onto a ballistic trajectory, just shy of orbital velocity. A 3.7 m diameter fairing covered the L-1 during the initial launch phase and supported a powerful emergency escape system which could pull the L-1 command/descent module away from the Proton booster in the event of a serious launch malfunction.

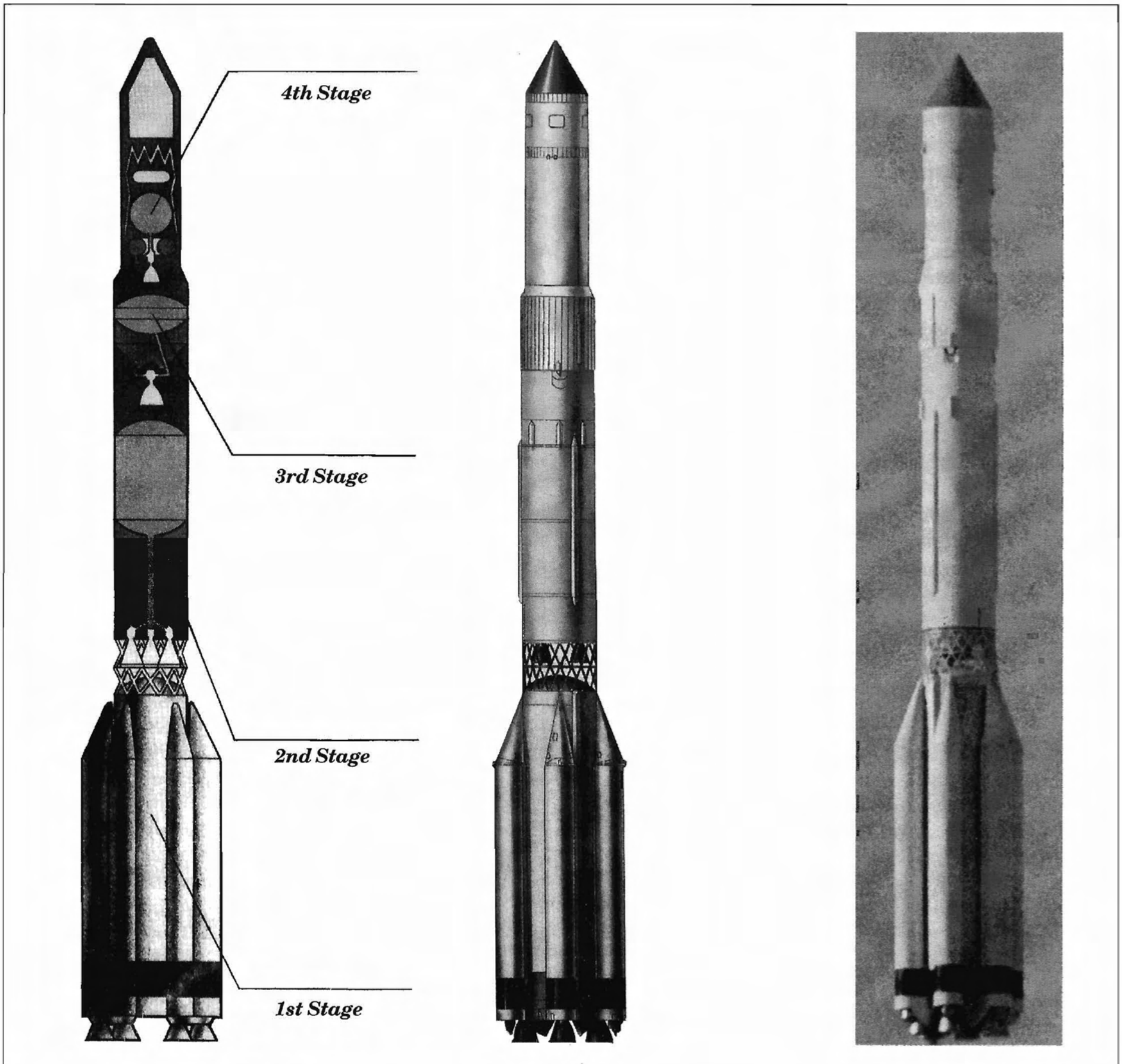
Unlike the first three stages which employed hypergolic propellants, the 3.7-m-diameter, 6.3-m-long Block D relied on simple liquid oxygen and kerosene. For the UR-500K/L-1 mission the Block D unit's single 11D58M engine developed 8.5 metric tons of thrust and was used to first place the L-1 spacecraft into a low Earth orbit and then to accelerate the L-1 spacecraft to a velocity of nearly 11 km/s (called the second cosmic velocity by the Soviets) to enter a translunar trajectory. This engine was developed in Korolev's own design bureau under the leadership of Mikhail Melinkov. The translunar injection burn was programmed to start slightly more than one hour after lift-off when the assembly made its first northbound pass over the Earth's equator.

The L-1 spacecraft was a two-piece vehicle with a total mass of 5,680 kg, a diameter of 2.7 m, and a height of 5 m. The lower half of the spacecraft was similar to the Soyuz instrument compartment and housed attitude control and mid-course correction engines as well as the primary spacecraft support systems, e.g., thermal control, life support, electrical. Two solar panels, each about 2 m wide and 3 m long, extended from the instrument compartment to produce electrical power.

The command/descent module was attached to the instrument compartment and was virtually identical to the Soyuz capsule in shape and basic instruments, although special navigation and related equipment were installed in the L-1. Both cosmonauts had to remain in the command/descent module for the entire week-long mission since the Soyuz orbital module was absent from the L-1. In its place was a large support cone used for entry into the spacecraft while on the launch pad and for securing the L-1 command/descent module to the emergency escape system. At the support cone-command/descent module interface, a special high gain antenna was attached to facilitate communications with Earth while at lunar distances. Finally, the thermal protection and attitude control jets of the command/descent module were upgraded as compared to the Soyuz capsule.

The UR-500K/L-1 complex was checked out for the first time as a unit in January, 1967. The flight-ready configuration was finally fueled and ready for launch on 10 March. The objectives of this maiden voyage were limited with primary emphasis on the performance of the Block D stage; the L-1 spacecraft was a simplified model. The 3-stage UR-500K flew flawlessly and the Block D and L-1 test article (7K-L1 no. 2P), now officially designated Kosmos 146, entered a low Earth orbit. The Block D maneuvered correctly, reaching the necessary velocity for a circumlunar mission, and the flight was declared successful. Exactly one lunar month later on 8 April, with the 10-strong L-1 cosmonaut corps in attendance, the mission was repeated as Kosmos 154 (7K-L1 no. 3P). The Block D stage operated satisfactorily to reach Earth orbit, but a malfunction prevented the second vital firing of the stage's propulsion system. Kosmos 154 reentered the Earth's atmosphere two days later. In retrospect, this mission foreshadowed the beginning of a long series of seemingly random flight failures that would ultimately doom the UR-500K/L-1 program.

Two weeks after the disappointing flight of Kosmos 154, the Soviet man-in-space program was dealt its severest blow when Cosmonaut Vladimir Komarov, a veteran of the Voskhod 1 mission, loss his life during the inaugural manned flight of the Soyuz spacecraft. (Yuri Gagarin was the backup for Komarov on the Soyuz 1 mission.) Launched on 23 April, Komarov experienced several difficulties with his Soyuz spacecraft soon after reaching orbit. The mission plan called for the launch of a second Soyuz the next day to rendezvous and dock with Soyuz 1. Due to the problems with Soyuz 1, the launch of Soyuz 2 was canceled, and Komarov was instructed to return to Earth on 24 April. The initial phase of reen-



PROTON CONSTRUCTION AND CHARACTERISTICS

	Block A (1st Stage)	Block B (2nd Stage)	Block V (3rd Stage)	Block D (4th Stage)
Stage Specification				
Primary diameter (m)	7.4	4.15	4.15	3.7
Height (m)	20.7	17	6.6	6.3
Fuel	UDMH	UDMH	UDMH	Kerosene
Oxidizer	N_2O_4	N_2O_4	N_2O_4	Liquid Oxygen
Stage thrust (metric tons)	894	245	64	8.7
Number of main engines	6	4	1	1
Main engine designator	RD-253	RD-465 (3), RD-468(1)	RD-473	11D58M
Specific impulse (seconds)	285	333	333	352
Nominal burn time (seconds)	120	215	255	up to 600

try was successful, but the Soyuz 1 capsule's parachute lines became tangled, preventing full deployment. Komarov was killed instantly as his capsule struck the ground at high speed. The seemingly simple parachute system had been a source of concern for spacecraft engineers, e.g., when a mockup 7K-OK had experienced a failure of its reserve parachute during a drop test the previous August, and perfecting the system would continue to prove difficult.

The death of Komarov had psychological as well as technical and political ramifications. The Soviet Earth orbital man-in-space program ground to a halt while an exhaustive accident investigation was conducted. A similar hiatus was underway in the US as a result of the Apollo 1 pad fire which claimed the lives of Astronauts Grissom, White, and Chaffee just three months earlier. The fatality not only threw the Soyuz program into disarray but also raised questions about the management of manned space flight in the post-Korolev era.

During the spring and summer of 1967 Soviet manned and lunar programs lay outwardly dormant. Difficulties with the N-1 suggested that the schedule for a third quarter test flight would not be met. The L-1 State Commission met on 5 June and decided to abandon Mishin's proposal for the dual-launch (Proton and Soyuz) L-1 scenario. Instead, four unmanned circumlunar missions with Earth recovery employing the original UR-500K/L-1 direct profile would be necessary before committing men to the flight. The parachute system which failed on Komarov's flight was to be modified for both Soyuz (7K-OK) and the L-1. However, an L-1 mission with the older design was contemplated for launch in July. Meanwhile, the trainer for the L-1 spacecraft was still not ready by August, leading to renewed tensions between Mishin and Kamanin. The more complex L-3 trainers were considerably less developed, in part since the design of the spacecraft was itself in a state of flux.

Finally, nearly six months after the Kosmos 154 failure, the UR-500K/L-1 (7K-L1 no. 4) was ready to resume space testing on 28 September. For the first time, a complete fly-by of the Moon and return to Earth would be attempted. The primary landing zone was near the Baikonur Cosmodrome with the backup target a 100 km by 2,000 km region in the Indian Ocean. Unfortunately, one of the six Proton first stage engines malfunctioned because of a rubber plug in the fuel line, and the booster was destroyed less than 100 sec after take-off. As a small consolation, the emergency escape system performed perfectly, pulling the L-1 spacecraft safely away from the ill-fated launch vehicle.

Two months later on 22 November, the fourth UR-500K/L-1 flight (7K-L1 no. 5) lifted-off a pad at the Baikonur Cosmodrome. This time the first stage performed nominally, but one of the second stage engines failed, resulting once again in a launch abort after a little more than two minutes. Although the emergency escape system operated as designed, the special solid-rocket engines at the base of the L-1 command/descent module, which are set to fire immediately before landing at an altitude of only one meter, ignited prematurely at a high altitude, adding further consternation to L-1 program managers. The capsule came to rest 80 km south of Dzhezkazgan near the normal recovery range, but the parachute failed to release and the cabin was dragged for 600 m.

Meanwhile, on 25 November at another Baikonur site east of the Proton facilities, the first full-scale mock-up of the N-1 launch vehicle was installed on a pad for compatibility testing while two flight models were in the vehicle integration and testing building (MIK). Unfortunately, this critical operation was already many months late, resulting in a rescheduling of the first N-1 test flight for the third quarter of 1968. Consequently, the possibility of a manned lunar landing by the end of 1969 seemed to be fading rapidly. Moreover, the L-3 lunar lander and lunar orbiter had still not been tested in space, and the spacesuit needed for the lunar excursion would probably not be ready for two more years due to requirements for operations exceeding three days and travel over five kilometers on the lunar surface. By early 1968 the 90-kg Krechet-94 suit (with only a 6-hour life support system) was the likely choice for the mission.

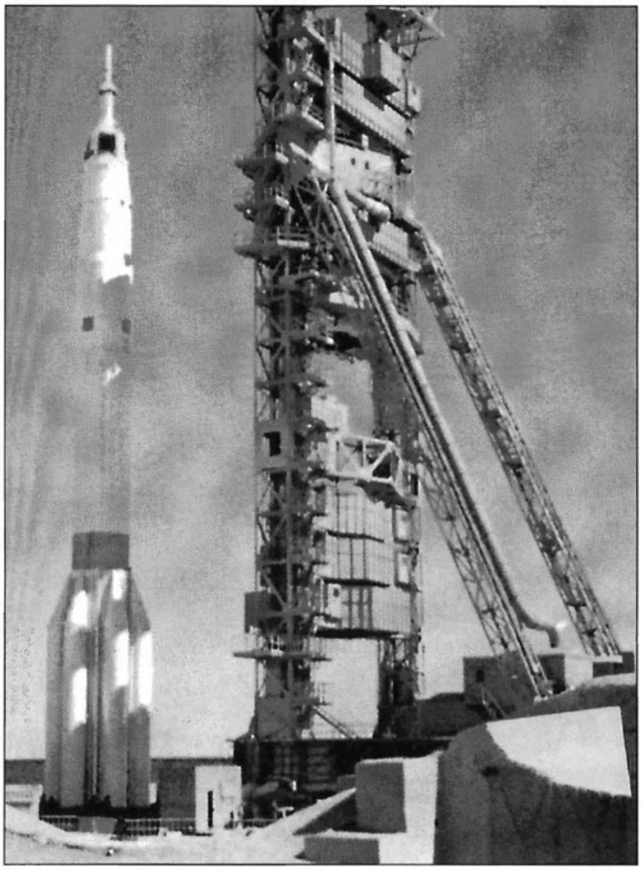
One bright spot in the fall of 1967 was the automatic rendezvous and docking of two unmanned Soyuz spacecraft. Although a resumption of manned Soyuz missions was still a year away due to the death of Komarov and continued problems with the parachute system, Mishin decided to move ahead with as much hardware testing as possible. Nearly a year after the first attempt to demonstrate an automated docking capability, on 27 October a Soyuz spacecraft, under the guise of Kosmos 186, was launched into a low Earth orbit. Two days later a second Soyuz, designated Kosmos 188, followed. As soon as Kosmos 188 reached orbit, Kosmos 186 assumed the active role in their rendezvous and docking experiment. This was precisely the manner in which the lunar orbiter would behave after the lift-off of the lunar lander from the Moon in the L-3 mission and how the Soyuz 1/Soyuz 2 mission in April was planned. Remarkably, the two spacecraft came together and docked, both mechanically and electrically, about two hours after the launch of Kosmos 188. The pair remained docked for three and a half hours before separating and pursuing independent flights.

The Kosmos 186 and Kosmos 188 mission not only demonstrated the feasibility of the Soyuz rendezvous and docking system, but by performing the feat in an automatic mode Soviet spacecraft engineers had tested the system under the most difficult conditions. Critics of Mishin had long asserted that his preoccupation with automatic systems (in preference to the crew) had led to the long delays and failures experienced in the Soyuz program. The mission also recertified the Soyuz command/descent modules when both Kosmos 186 and Kosmos 188 were safely recovered on Soviet territory.

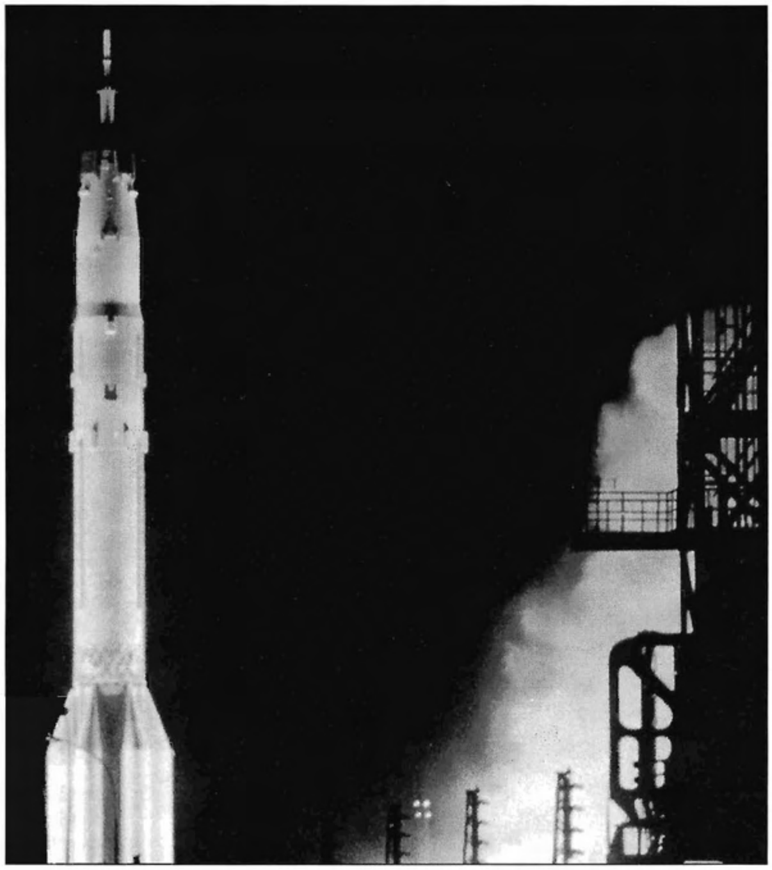
Despite the setbacks in the L-1 program during 1967, Mishin was optimistic that a Soviet manned circumlunar flight was still possible before the end of 1968. The US Apollo program was still grounded, and a lunar mission was not planned until 1969 at the earliest. Even if a Soviet cosmonaut could not be the first man on the Moon (a prospect becoming more and more unlikely), Soviet eyes might still be the first to view that ancient body up close. However, the L-1 trainer was still not ready.

In the lunar landing race the US appeared to be gaining speed. In November, 1967, the American Saturn/Apollo Moon rocket was flown for the first time on a nearly picture perfect mission. On 22 January 1968 an unmanned Apollo lunar excursion module (LEM) was launched by an uprated Saturn I. During the 6.5 hour test flight in low Earth orbit, both the LEM descent and ascent propulsion systems were fired several times with success.

Meanwhile, during the last few days of 1967 the Ministry of General Machine Building, the Soviet Air Force, and Mishin's TsKBEM finally agreed upon the pool of 20 cosmonauts to train for the L-3 mission. From the Air Force's TsPK were Bykovsky, Filipchenko, Gorbatko, Khrunov, Kuklin, Leonov, Nikolayev, Shonin, Voloshin, and Volynov. Representing TsKBEM were Feoktistov, Grechko, Kubasov, Makarov, Nikitski, Rukavishnikov, Sevast'yanov, Volkov, Yazdovski, and Yeliseyev. ●



▶ ***Preparation of UR-500K/L-1 at Baikonur.***



▶ ***Launch of the Proton launch vehicle with the L-1 complex.***

FLIGHT HISTORY OF THE UR-500K/L-1 PROGRAM

Year	Launch Date	Spacecraft	Mission Results
1967	10 March	Kosmos 146	Successful maiden flight of Proton UR-500K launch vehicle and Block D stage; A simplified L-1 capsule flown in Earth orbit
	8 April	Kosmos 154	A Proton control system failure prevented re-ignition of the Block D stage
	28 September	---	First stage of Proton malfunctioned, causing destruction of booster; Emergency rescue system activated to save L-1 capsule
	22 November	---	Second stage of Proton malfunctioned, causing destruction of booster; Emergency rescue system activated to save L-1 capsule
1968	2 March	Zond 4	L-1 spacecraft successfully flew to nearly lunar distance and returned but was intentionally destroyed during reentry after an attitude control system malfunction
	23 April	---	Second stage of Proton malfunctioned, accidentally triggering the emergency rescue system; vehicle failed to reach Earth orbt
	14 September	Zond 5	L-1 spacecraft successfully circumnavigated the Moon, but malfunctions led to a ballistic reentry and landing in the Indian Ocean.
	10 November	Zond 6	L-1 spacecraft successfully circumnavigated the Moon but suffered a depressurization on return trip; After a nominal reentry, a parachute malfunction caused the L-1 capsule to be destroyed during landing
1969	20 January	---	Second and third stages of Proton malfunctioned, causing destruction of booster; Emergency rescue system activated to save L-1 capsule
	8 August	Zond 7	First and only completely successful circumnavigation of the Moon and return to Earth
1970	20 October	Zond 8	L-1 spacecraft successfully circumnavigated the Moon, but an attitude control system malfunction led to a ballistic reentry and landing in the Indian Ocean

6 The Pivotal Year Of 1968

▶ After the two failures in late 1967, the Proton booster was cleared for renewed flights, but the L-1 parachute system was still experiencing difficulties. During a test on 26 January an L-1 capsule struck the ground at high velocity and exploded after the parachute folded prematurely. Less than two weeks later the primary L-1 crew commanders were selected: Bykovsky, Leonov, Popovich and Voloshin.

On 2 March 1968 the fifth UR-500K/L-1 launch was conducted, and a complete L-1 spacecraft (7K-L1 no. 6) was inserted into Earth orbit. The Block D stage re-fired successfully, sending the L-1 spacecraft, now called Zond 4, into a highly elliptical orbit with an apogee (330,000 km) shy of the orbit of the Moon (385,000 km). (Zonds 1-3 had been small - less than one metric ton - deep space probes which traveled out to the orbits of Venus and Mars.) Trajectory corrections failed on 4 and 5 March when the star sensor could not retain a lock on Sirius; but by 6 March the problem had been resolved, and Zond 4 was on course for its return to Earth.

To reduce the deceleration forces on cosmonauts returning from the Moon, the L-1 spacecraft was to perform a delicate reentry maneuver which called for an initial dip into the upper atmosphere at a low angle to within 45 km of the Earth's surface, followed by a brief exit back into space to a height of 145 km, and then a final reentry and landing. During the initial foray into the atmosphere, the spacecraft's velocity would drop from 11 km/s to less than 8 km/s. In the case of Zond 4, an on-board malfunction caused an attitude control error which in turn led to a simple ballistic reentry. Consequently, a self-destruct system on Zond 4 was activated, and the vehicle was intentionally destroyed over the Gulf of Guinea at an altitude of 10-15 km.

Tragedy struck again at the end of March when Yuri Gagarin, who had been part of the Zond 4 control team, was killed near Moscow when his MiG-15 aircraft crashed during a routine training flight. His death struck the cosmonaut corps hard. The faltering L-1 program had already begun affecting morale, and the prospect of beating the US to the Moon was fading. Earlier in the month the L-3 had been scheduled for its first Earth orbit mission before the end of the year, but the first lunar landing mission was unlikely until the 1970-1971 time frame.

April, 1968, was a busy month with the launch of four spacecraft of importance to the L-1 and L-3 programs. On the 7th of the month, Luna 14 was launched toward the Moon as the last of the second generation automatic lunar probes. Three days later the vehicle slipped into a lunar orbit of 160 km by 870 km, the fourth Soviet spacecraft in two years to accomplish this feat. The following week Soviet attention shifted back to Earth orbit with the launches of Kosmos 212 and Kosmos 213 on 14 and 15 April, respectively. The two spacecraft repeated the Kosmos 186 and Kosmos 188 automatic rendezvous and docking experiment. The exceptionally precise orbital insertion of Kosmos 213 left an initial separation of only a few kilometers between the two spacecraft. As in the previous mission, the older vehicle sought out the new spacecraft, this time with docking coming just 47 minutes after the lift-off of Kosmos 213. The pair remained docked for nearly four hours before ground controllers signaled for their uncoupling. Kosmos 212 and Kosmos 213 both completed five-day test programs before returning to Earth without incident.

While the two spacecraft were still in orbit, final preparations were underway for the next UR-500K/L1 mission. Unlike Zond 4, the objective of this shot was an actual circumlunar flight with a recovery in the Soviet Union. The launch with 7K-L1 no. 7 took place on 23 April and was nominal until maximum dynamic pressure was reached during the operation of the second stage of the Proton booster. A fault caused the emergency escape system to trigger accidentally, preventing the booster and payload from ever reaching Earth orbit. Once again the L-1 capsule was recovered near the town of Dzhezkazgan.

The next three months brought even more trials to the L-1 and L-3 programs. With much fanfare the first flight-worthy N-1 booster was brought to the pad at Baikonur in early May, only to have cracks discovered in the first stage. The vehicle was removed, and an investigation to determine their cause was begun. The maiden voyage of the N-1 was postponed indefinitely.

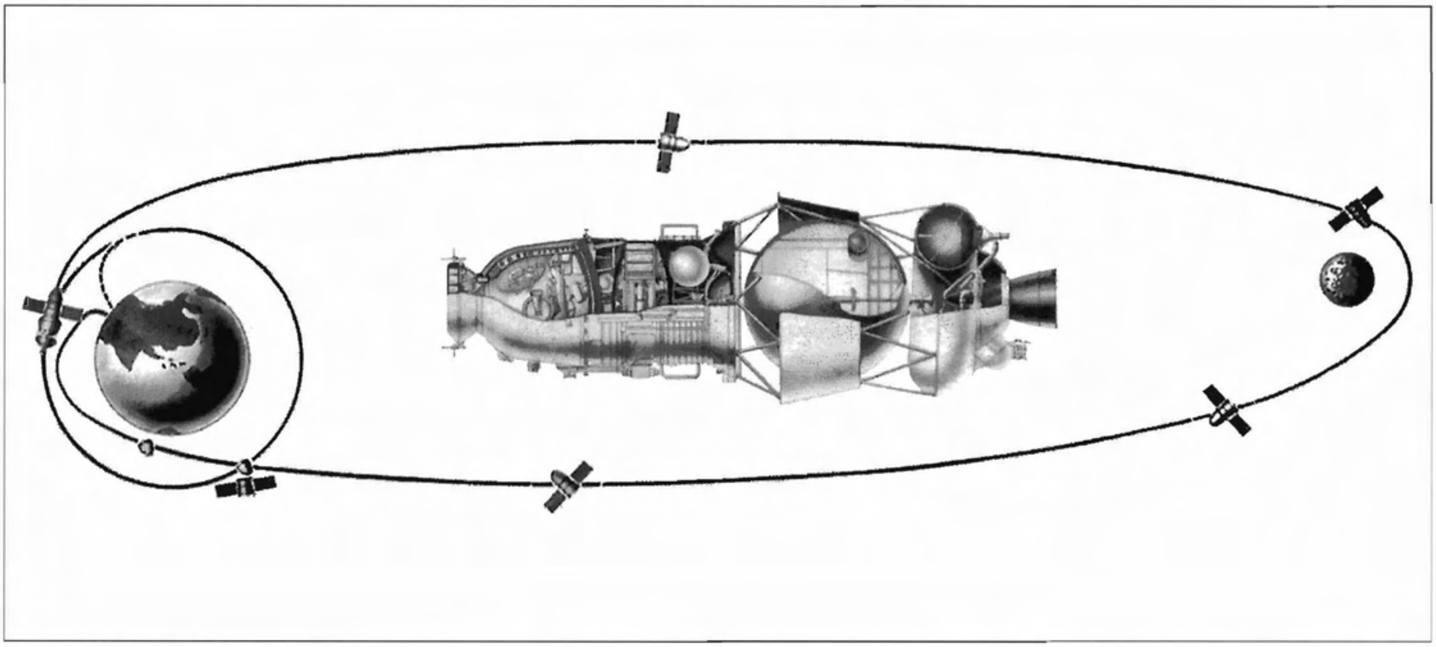
At a 26 June meting of the L-1 State Commission, a decision was reached to attempt the next circumlunar mission in July, followed by successive flights at intervals of one lunar month. If 3-4 missions were successful, a manned expedition was possible in November or December, before Apollo. This schedule, however, was quickly compromised. As the L-1 spacecraft (7K-L1 no. 8) and its UR-500K booster were being checked out on the pad in preparation for a 19 July launch, the fully fueled Block D stage exploded, killing three people. Remarkably, the L-1 spacecraft and the first two stages of the UR-500K were relatively undamaged. The accident, though, delayed the L-1 program for another two months, rendering a manned circumlunar flight in 1968 highly doubtful.

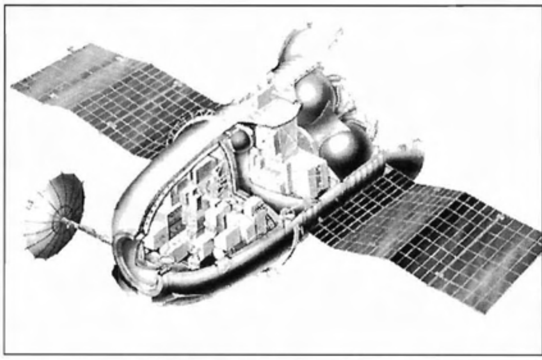
Finally, on 15 September, eighteen months after the mission of the first L-1-type spacecraft as Kosmos 146, Zond 5 (7K-L1 no. 9) was successfully launched into Earth orbit and then fired toward the Moon. A course correction planned for 16 September did not occur when the stellar orientation system malfunctioned as it had on Zond 4. The next day at a distance of 325,000 km from Earth, Zond 5 performed the first of two maneuvers to refine its trajectory, but the orientation system was still unreliable. On 18 September Zond 5 made its closest approach to the Moon at a distance of 1,950 km and continued on its loop around the Moon to return to Earth.

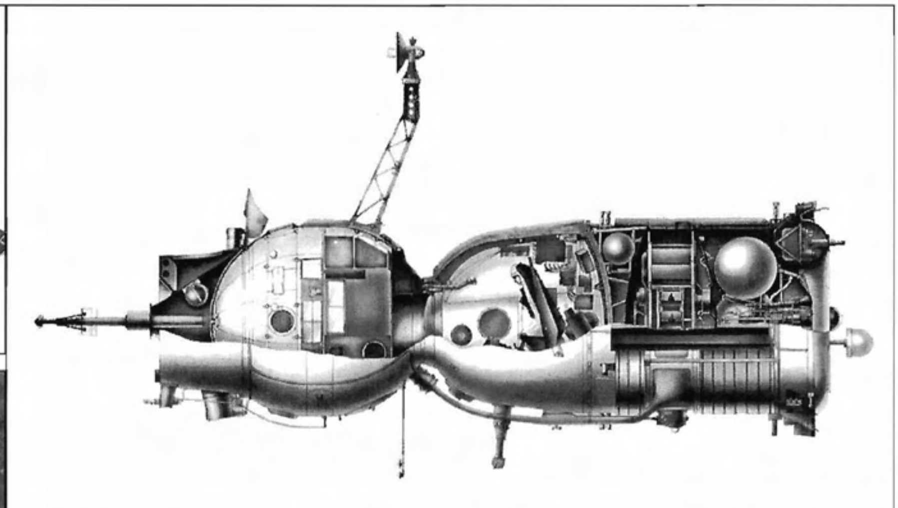
Still 143,000 km away, Zond 5 maneuvered again to ensure its arrival at the appropriate location for reentry into the Earth's atmosphere, although control of the spacecraft was becoming more difficult. One of the final mission objectives was accomplished at 1208 Moscow time on 21 September at a distance of 90,000 km when Zond 5 obtained a striking photograph of the nearly full Earth. Slightly less than seven hours later Zond 5 began the critical reentry phase.

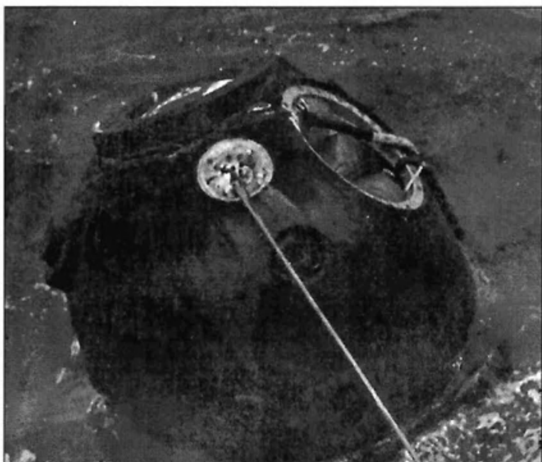
As noted earlier, the nominal reentry profile for the L-1 was to strike the atmosphere at a shallow angle, skip back into space, and then reenter the atmosphere at a lower velocity for the descent and landing. The alternative was to hit the atmosphere directly on a ballistic trajectory which would result in the crew being subjected to deceleration forces of up to 16-20 g's. (During the ballistic reentries of Vostok and Voskhod from low Earth orbit the g-forces did not exceed 8-10, while the Soyuz reentry was designed to keep g-forces below 4.) Unfortunately, Zond 5, like Zond 4, never got the chance to test the new procedure.

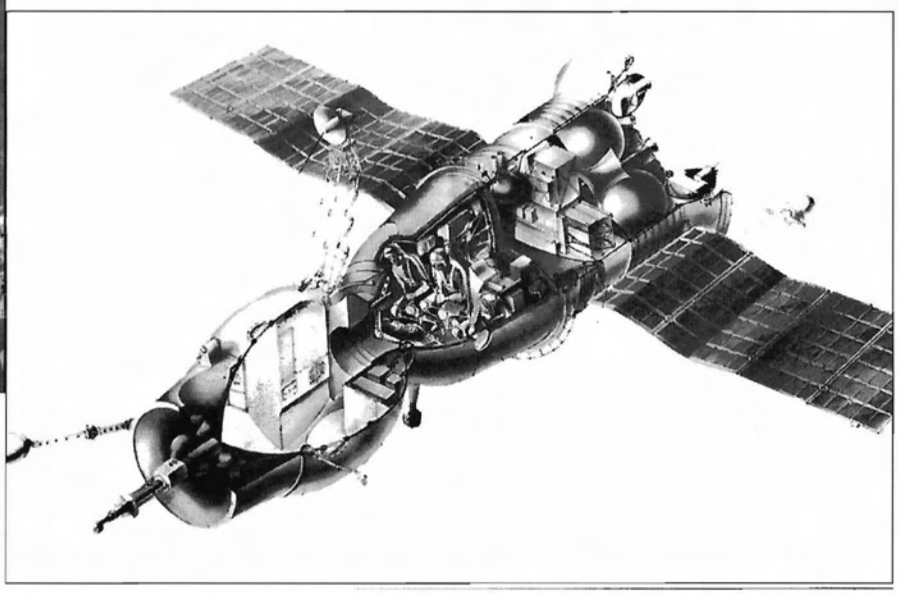
A series of malfunctions caused Zond 5 to follow a ballistic reentry trajectory toward the backup recovery region in the Indian Ocean, landing a little more than 100 km from a special naval task











▶ *Top: The L-1 (Zond) flight profile called for a simple loop around the Moon and return to Earth during the week-long journey▶ Cut-aways of the L-1 spacecraft and its Proton Block D final stage illustrate the cramped quarters provided for the two cosmonauts.* ▶ *The Zond 5 spacecraft was recovered in the Indian Ocean after it failed to land in its primary recovery region in the Soviet Union.* ▶ *The original Soyuz spacecraft was designed for Earth orbital missions and was vital for perfecting L-1 equipment and techniques.* ▶ *The Soyuz spacecraft could carry up to three cosmonauts for short duration missions in Earth orbit.*

force. A Soviet ship retrieved the vehicle the next day (22 September), and carried it back to Bombay, India, on 4 October to be airlifted to the Soviet Union. In addition to the photographic system, Zond 5 carried an assortment of plants and small animals and insects along with instruments designed to measure the radiation environment during the mission. Reportedly, Zond 5 also transmitted a recording of a cosmonaut's voice to test the long-distance communications system.

Only three months remained in 1968, and a completely successful circumlunar flight had still not been achieved. Mishin and Kamanin, however, did reach agreement in late September on the three prime L-1 crews: Bykovsky-Rukavishnikov, Leonov-Makarov, and Popovich-Sevast'yanov. The Bykovsky-Rukavishnikov team was considered the best bet for the historic first voyage.

Meanwhile, the possibility of beating the US with a manned lunar flight was diminishing. In August, NASA had begun consideration of a modified flight plan for the scheduled December Apollo 8 mission which would include a trip to the Moon as well as lunar orbit insertion and 10 circuits about the Moon before returning home. A month after the Zond 5 mission, the American man-in-space program had resumed with an 11-day maiden voyage of the manned Apollo spacecraft. In November NASA officials would make the final go/no-go decision regarding a Christmas-time lunar flight.

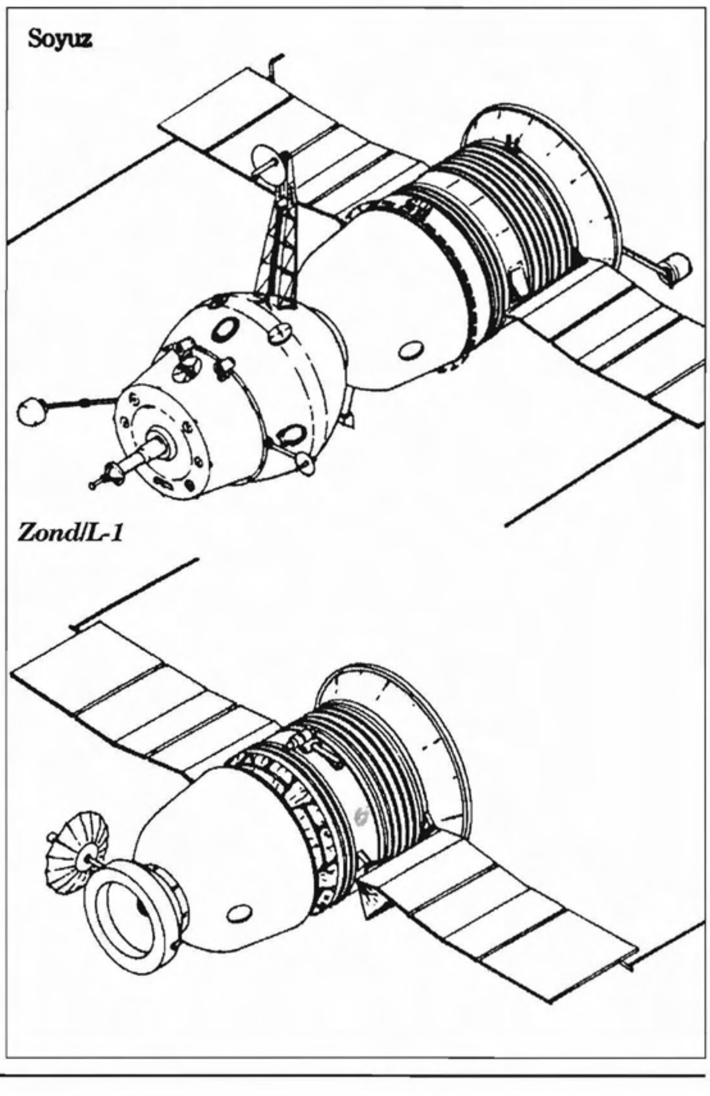
Three days after the conclusion of the Apollo 7 mission, the Soviet Union began its own return-to-flight program. On 25 October an unmanned Soyuz 2 spacecraft was launched, followed twenty-four hours later by Soyuz 3 with Georgiy Beregovoy at the controls. Beregovoy closed to within 200 m of Soyuz 2 during his first orbit about the Earth. Although Soyuz 3 was equipped with a docking mechanism similar to those of Kosmos 186 and Kosmos 212, no linkup of Soyuz 2 and Soyuz 3 ensued. After a flight of four days Beregovoy returned to Earth safely as did the unmanned Soyuz 2 capsule two days earlier. Although falling short of expectations, the flights of Soyuz 2 and Soyuz 3 lifted the weary spirits of the tens of thousands of workers struggling to send Soviet cosmonauts around the Moon before the Americans. Beregovoy's 4-day flight - the longest Soviet manned mission since Bykovsky flew Vostok 5 for nearly five days in 1963 - was still shy of the 6 to 7 days required for the L-1 journey. A plan to have Boris Volynov pilot a Voskhod 3 spacecraft for 18 days in 1965 was canceled by Ustinov and others to avoid diversions from the Soyuz and N-1 programs.

Eleven days after the end of the Soyuz 3 mission, Mishin supervised the launch of yet another UR-500K/L-1 circumlunar attempt. Late on 10 November Zond 6 (7K-L1 no. 12) successfully completed first Earth orbit insertion and a short while later translunar injection. Following a mid-course correction on 12 November at a distance of 230,000 km, Zond 6 flew within 2,420 km of the Moon on 14 November. During the swing-by Zond 6's photographic system captured a dramatic view of the lunar horizon with a half-full Earth floating overhead. On the return leg Zond 6 made minor maneuvers on 16 and 17 November, the last about eight hours before reentry. However, during the second half of the journey, a rubber gasket in the command/ descent module failed, leading to a potentially fatal depressurization of the cabin.

Despite the serious failure, control of the spacecraft was unaffected, and the complex reentry process was initiated. Zond 6 hit its 10-km-wide atmospheric corridor at an altitude of 45 km above the Southern Hemisphere. The vehicle rapidly decelerated from 11 km/s to 7.6 km/s and then briefly returned to space before making the final plunge over the Soviet Union. Zond 6 survived the fiery reentry, but the parachute deployed prematurely and the command/descent module crashed with such violence that a human crew would have perished. Photographic film was salvaged from the crumpled metal cassettes, permitting the aforementioned picture of the Earth and the Moon to be developed and published without comment about the fate of the Zond 6 capsule.

One more circumlunar launch window would arise in early December before the planned launch of the American Apollo 8. Any thought of utilizing this opportunity to send a manned L-1 spacecraft around the Moon evaporated quickly in the aftermath of the Zond 6 disaster. Mishin's only hope to beat the US to the Moon was for a delay or an early failure in the Apollo 8 mission which might prevent it from leaving Earth orbit. Although another UR-500K/L-1 vehicle was ordered prepared for launch in January, 1969, the subsequent historic flight of Apollo 8 in late December signaled the death knell of the manned L-1 circumlunar program.

Even though no future Zond flights would be piloted, the program did not end abruptly. On 20 January 1969 what was to have been Zond 7 (7K-L1 no. 13) was launched from the Baikonur Cosmodrome. Due to an engine failure in the second stage of the Proton booster, the L-1 could not reach Earth orbit. Consequently, the emergency escape system was drafted into action once more, at least permitting the safe return of the L-1 command/descent module to Earth, albeit in Mongolia. After seven successive failures in 16 months, the UR-500K/L-1 program stood down for half a year. ●



7 Focusing on the L-3 Lunar Landing Program

▶ Despite the acute disappointment in losing the manned circumlunar race to the US, the USSR pressed on with its manned lunar landing program. Throughout 1968 Soviet engineers worked feverishly to prepare both the N-1/L-3 vehicle and its ground support equipment. The first test flight with a modified L-1 spacecraft called 7K-L1S and a dummy lunar lander was slated for early 1969.

Two weeks into the new year an important demonstration with great significance to the L-3 program was conducted in Earth orbit. Soyuz 4 with a single cosmonaut (Vladimir Shatalov) on board was launched on 14 January, followed the next day by Soyuz 5 with a crew of three (Boris Volynov, Aleksei Yeliseyev, and Yevgeni Khrunov). Instead of immediately attempting to dock, the rendezvous activities were postponed until the following day. Taking the active role in Soyuz 4, Shatalov successfully linked the two spacecraft on the morning of 16 January.

Almost immediately, Yeliseyev and Khrunov began preparing for the most dangerous portion of the mission: a transfer from one spacecraft to the other via a walk in space. This action would simulate the movement of an L-3 cosmonaut from the lunar orbiter to the lunar lander and back again. (The American Apollo program permitted an internal transfer between the Apollo command module and the LEM.) Yeliseyev and Khrunov moved into the Soyuz 5 orbital module and donned special EVA suits. After closing the hatch to command capsule and depressurizing orbital module, the pair opened an exit in side of the orbital module and stepped into space.

Thirty-seven minutes later Yeliseyev and Khrunov had pulled themselves along guiderails and reached the orbital module of Soyuz 4. One by one the cosmonauts entered the already depressurized compartment, sealed the orbital module, and repressurized the vehicle. With transfer a complete success, the two spacecraft were undocked a few hours later. Soyuz 4 and Soyuz 5 returned safely to Earth on 17, 18 January, respectively, after flights of only three days.

Just one month later the fruits of many years labor were standing on a Baikonur launch pad undergoing final preparations. The N-1/L-3 system had evolved into a true giant with a base diameter of 17 m and a height of 105 m. Gross weight at lift-off was more than 2,700 metric tons. The vehicle was clearly distinguished by its two main sections: the 3-stage, 60-m-tall N-1 booster and the 43-m, tapered fairing (max diameter of 6 m) containing the L-3 complex.

The first stage (Block A) of the N-1 booster was conical in shape with a base diameter of 16.8 m (22.3 m with the four stabilizers extended) and an upper diameter of 11 m. The 30-m-tall stage contained two primary propellant tanks: one 10.5 m in diameter for the kerosene fuel and one 12.8 m in diameter for the liquid oxygen oxidizer. The upper half of the fuel tank was surrounded not by a solid wall but by a lattice-type structure which served as an interstage coupler with the N-1 second stage (similar to that used by Korolev's R-7). Twelve distinct conduits, which encircled the exterior of the lower part of the first stage, carried fuel from the upper propellant tank to the engines at the base of the stage. At launch the stage weighed nearly 1,900 metric tons.

The heart of the first stage was the thirty Kuznetsov NK-33 engines. Each engine developed a maximum thrust of 154 metric tons with a specific impulse of 331 seconds. (For comparison, the main engines of Korolev's R-7 were rated at 305-308 seconds, whereas the specific impulse of Chelomei's UR-500K first stage engines was only 316 seconds.) Twenty-four engines were deployed around the periphery of the base of the stage on a 14-m-diameter structure, while the remaining six engines were mounted on a central 6-m-diameter ring. Together, the engines developed a total thrust of 4,620 metric tons and on a nominal flight burned for about two minutes. During the flight, the pitch and yaw of the N-1/L-3 were controlled by varying the thrust of opposing engines. Roll control was effected by four independent engines with a thrust of 7 metric tons each.

The basic design of the second stage (Block B) was quite similar to that of the first stage with a height of 20.5 m and a gradual taper from the 10.3-m-diameter base to the 7.6-m-diameter top. Again, two large propellant tanks, one 7.0 m wide and one 8.5 m wide, occupied the majority of the stage's internal volume. Eight conduits lined the side of the stage to carry fuel to the engines. Also like stage one, the upper portion of stage two was characterized by a girder-type interstage coupler. The total mass of the fueled stage was 540 metric tons.

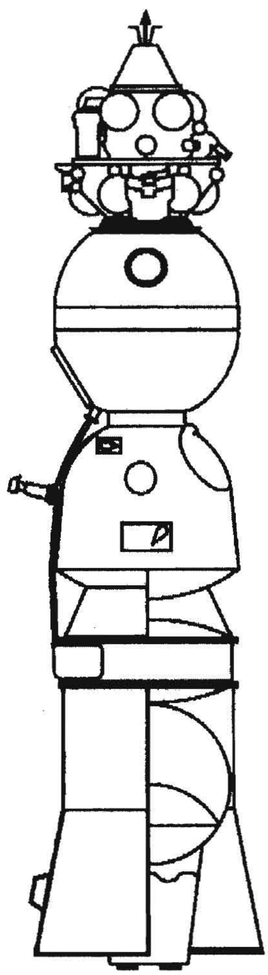
For the second stage Kuznetsov modified the first stage engines slightly, including larger nozzles to take advantage of their higher altitude operating environment. These changes increased the thrust of each NK-43 engine to 179 metric tons with a specific impulse of 346 seconds. In all, eight such engines provided a total stage thrust of 1,432 metric tons for 130 seconds on a typical mission. Stage two attitude control was similar to that of stage one, but only three separate roll control engines of 6 metric tons thrust each were needed.

The third and last stage (Block V) of the basic N-1 booster was 11.5 m high with lower and upper diameters of 7.6 m and 6.0 m, respectively. The kerosene tank was 4.9 m wide while that of the oxidizer tank was 5.9 m. Only four external conduits were required to connect the fuel tank to the main engines. Total stage weight at launch was approximately 185 metric tons.

Four Kuznetsov NK-39 engines were employed to power the third stage. These engines were descendants of the NK-19 which Kuznetsov had developed for a proposed ICBM which was not chosen for production. Each engine was rated at a maximum thrust of 41 metric tons with a specific impulse of 353 seconds. The third stage was designed for a nominal operating time of 400 seconds, at the conclusion of which the third stage and the entire L-3 complex would be in a low Earth orbit of about 220 km. Pitch and yaw control were again provided by altering the thrust of opposite engines, and roll control was made possible by four independent thrusters, each with a thrust of 200 kg.

The use of so many individual engines, particularly in first and second stages, raised serious concerns about total stage reliability. Korolev and Mishin had to ensure that failure of a single engine would not doom the entire mission. Consequently, an engine operation control system (KORD) was developed. If KORD system detected an engine malfunction, it would automatically shut-down the bad engine as well as the good engine diametrically opposed to the failing engine. This would preserve thrust symmetry and allow flight to continue. To compensate for reduced thrust, KORD would also extend the programmed burn time of the remaining engines.

In this way, the L-3 complex could still reach its planned low Earth orbit if two first stage engines failed (4 engines shutdown) or if one second stage engine failed (2 engines shutdown). For the third stage, only the malfunctioning engine was turned off since these engines were gimbal-mounted and the three remaining good engines could swivel their nozzles to compensate for the otherwise unbalanced thrust. While in theory the KORD system appeared to

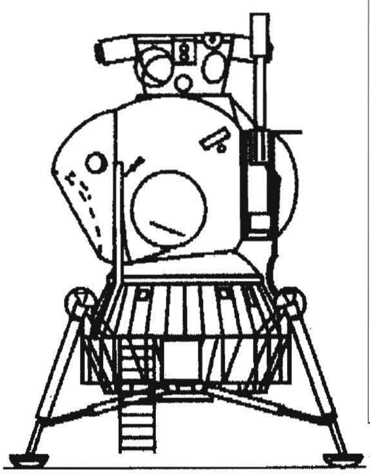


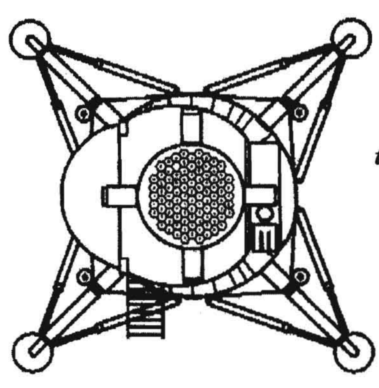
Primary Propulsion of the L-3 Complex

	Block G	Block D	Block E (Lunar Lander)	Block I (Lunar Orbiter)
Primary maneuvers	Trans-Lunar Injection	Lunar Orbit Insertion	Lunar Landing	Lunar Orbit Rendezvous
		Lunar Orbit De-orbit	Lunar Lift-off	Trans-Earth Injection
Fuel	Kerosene	Kerosene	UDMH	UDMH
Oxidizer	Liquid Oxygen	Liquid Oxygen	N_2O_4	N_2O_4
Main engine thrust (metric tons)	41	8.5	2.1	3.3
Backup engine	No	No	Yes	Yes

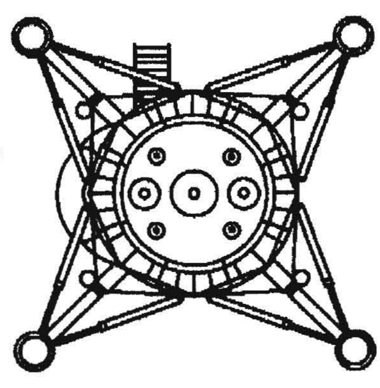
N-1 Construction and Characteristics

	Block A (1st Stage)	Block B (2nd Stage)	Block V (3rd Stage)
Stage Specifications			
Lower diameter (m)	16.8	10.3	7.6
Upper diameter (m)	11	7.6	6.0
Height (m)	30	20.5	11.5
Total stage mass (metric tons)	1870	540	185
Fuel tank diameter (m)	10.5	7.0	4.9
Oxidizer tank diameter (m)	12.8	8.5	5.9
Number of main engines	30	8	4
Total thrust (metric tons)	4620	1432	164
Nominal burn time (seconds)	110	130	400
Number of roll control engines	4	3	4
Roll control engine thrust (metric tons)	7	6	.2
Main Engine Specifications			
Engine designator	NK-33	NK-43	NK-39
Fuel	Kerosene	Kerosene	Kerosense
Oxidizer	Liquid Oxygen	Liquid Oxygen	Liquid Oxygen
Thrust (metric tons)	154	179	41
Specific Impulse (seconds)	331	346	353



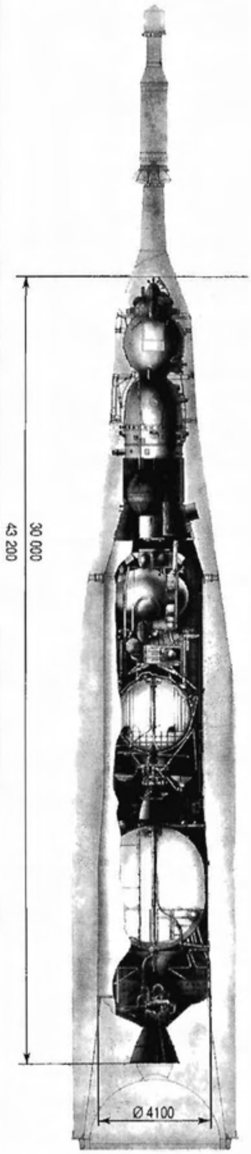


LK top view (left) Bottom view (right)



▶ This page: The L-3 complex included the LOK lunar orbiter (top left) and the LK lunar lander (bottom). Like the American Apollo program, a single cosmonaut would remain in lunar orbit while the manned exploration of the Moon took place below.

▶ Facing page: The N-1/L-3 launch vehicle and spacecraft weighed more then 2,700 metric tone and required five separate stages to place the LOK and LK spacecraft into lunar orbit.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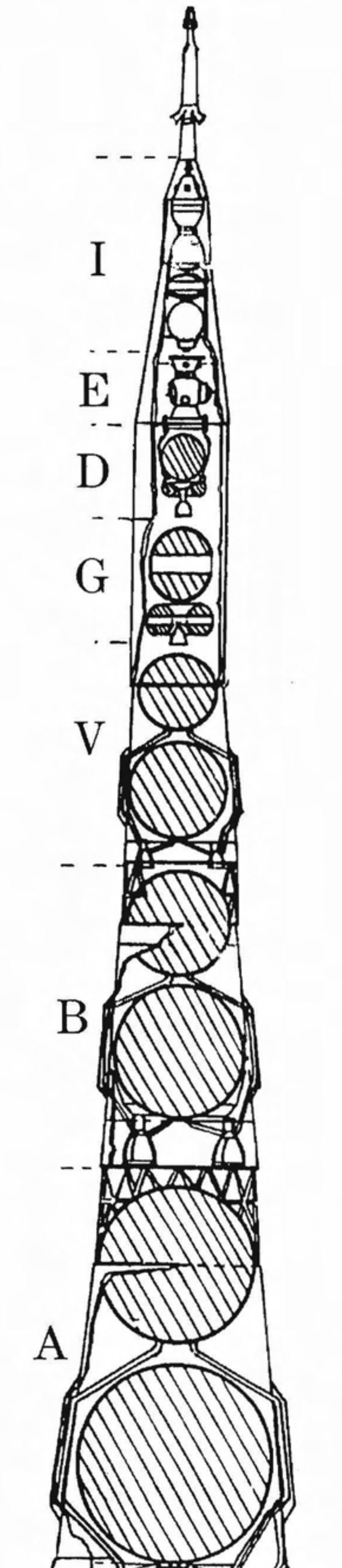
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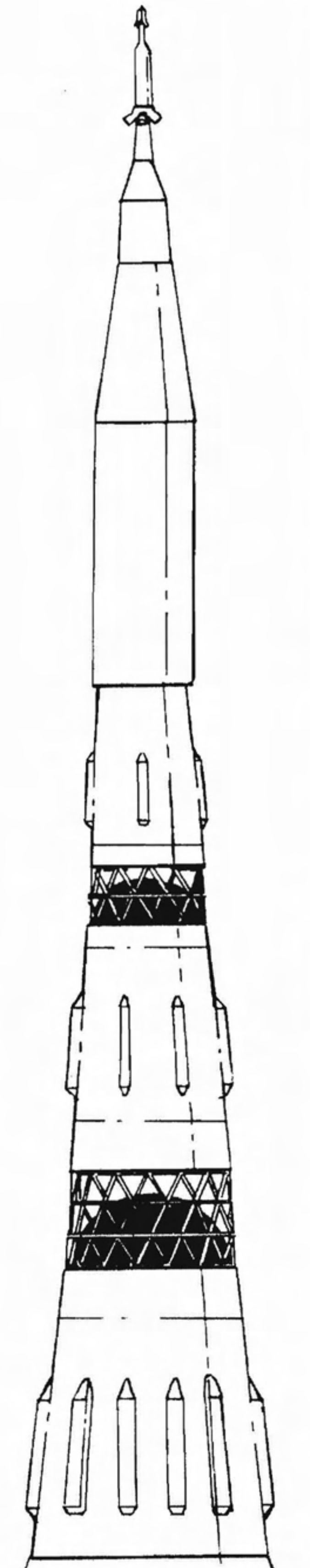
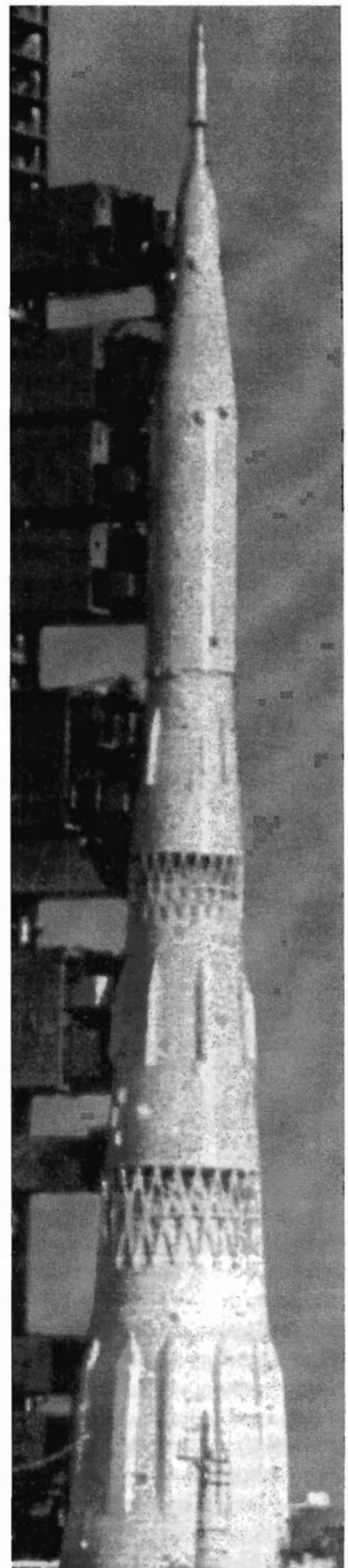




solve the problem of multi-engine reliability, in practice the system could not detect malfunctions and react quickly enough before catastrophic damage had occurred.

Resting atop the massive N-1 booster was the equally impressive L-3 complex. Inside the 43.2-m-tall (including the emergency escape system) protective fairing, which was to be jettisoned during the operation of the N-1 second stage, stood the 30-m-long L-3 complex, consisting of four major units: two rocket stages, the lunar lander, and the lunar orbiter. The purpose of the first rocket stage (Block G) was to propel the complex out of Earth orbit and onto a translunar trajectory, just as the Block D stage had done for the L-1 circumlunar missions. Block G was powered by a single Kuznetsov NK-31 liquid oxygen/kerosene engine, which was virtually identical to the NK-39 engines of the N-1 third stage. Shortly after completing the 480 second translunar injection burn, the Block G unit was to be discarded.

For the rest of the flight to the Moon, the previously described (Chapter 5) Block D stage would perform any necessary mid-course corrections. Upon arriving at the Moon, the Block D main engine would be fired to place the complex into an initial low lunar orbit of 110 km. Later, the altitude was to be reduced to 16 km, again by means of the Block D stage.

From launch until lunar orbit the cosmonauts would be confined to the lunar orbiter. Since an internal transfer between the lunar orbiter and the lunar lander was not possible, Soviet mission planners saw no need to perform a separation and docking of the orbiter and lander before the lunar landing operation as was done in the Apollo program. Once safely in the staging lunar orbit, one cosmonaut would don a Krechet semi-rigid space suit and exit the lunar orbiter, in much the same way as the Soyuz 5 cosmonauts had demonstrated in January, 1969. With the aid of a special mechanical arm, he would make his way to the lunar lander and enter it.

The lunar lander rested, with legs retracted, on top of Block D stage, and both were encased in a protective shroud. If all systems checked out, the lunar orbiter would separate from the lunar lander/Block D assembly, whereupon the protective shroud was discarded and lunar lander's legs extended. The Block D main engine would then fire for the final time, sending the assembly toward the lunar surface. At an altitude of 1.5-2 km the Block D stage and the lunar lander would separate, allowing the Block D to crash onto the Moon while the lunar lander attempted to settle more gently nearby.

The 5.5-metric-ton lunar lander, also known as the Luna Korabl (Lunar Spacecraft) or LK (not to be confused with Chelomei's LK-1 circumlunar spacecraft), stood a little more than 5 m high and was comprised of two basic units, a landing platform and the cosmonaut cabin which also contained the vital propulsion systems. Unlike the American LEM design, the Soviet lunar lander contained a single propulsion system (Block E) used for both the final landing phase and lunar lift-off. Designed by the Yangel organization, the single-chamber, throttlable, 2.05-metric-ton thrust primary engine burned nitrogen tetroxide and unsymmetrical dimethylhydrazine like the Glushko and Kosberg engines used by the Proton booster. A dual-nozzle back-up engine with a slightly reduced maximum thrust was also available in an emergency. In fact, to ensure further a successful return to lunar orbit, at lift-off both lunar lander engines would initially be ignited. If both were operational, the back-up engine would immediately be shutdown.

The lunar lander was also outfitted with a complex, redundant attitude control system. Two independent circuits each contained eight low-thrust engines developed by an aviation bureau headed by V. Stepanov: four 40-kg-thrust engines provided pitch and yaw control (two for each direction) and four 10-kg-thrust engines maintained roll. Both systems were fed by a common reserve of approximately 100 kg of propellants. Impulses lasting as briefly as 9 milliseconds were possible with this carefully designed system.

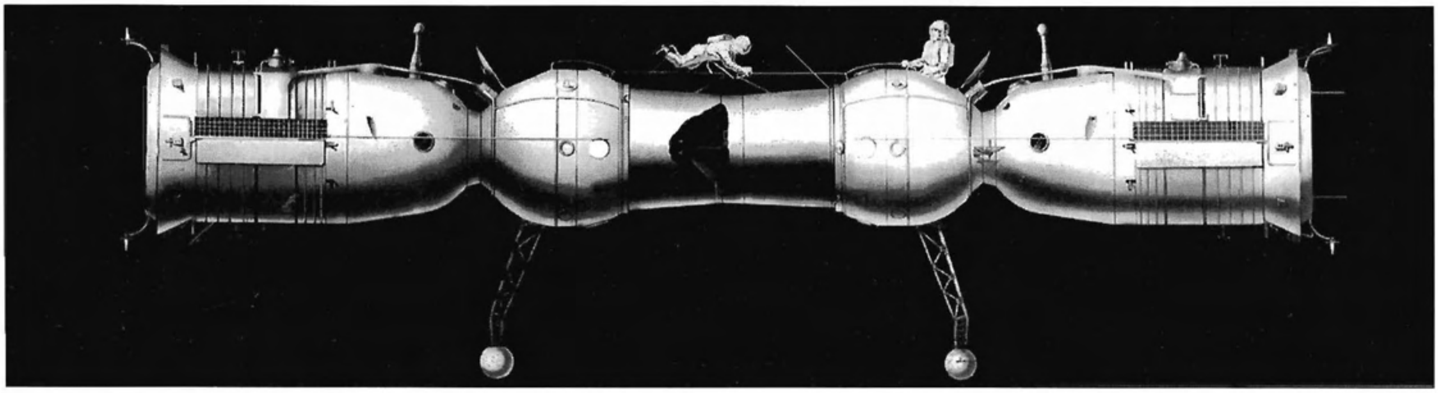
A roughly spherical, pressurized cabin housed the solitary cosmonaut. During descent and ascent the cosmonaut remained standing both for a better view around him and to save weight. Before him was a collimating sight to survey the lunar terrain and a stick to control his attitude and rate of descent. A circular hatch and ladder permitted egress and a safe means to the lunar surface. Located at the top of the cabin was the passive assembly needed for docking with the lunar orbiter after lift-off. Inside were all the necessary support systems and multi-frequency communications equipment for contact with the lunar orbiter or directly to Earth.

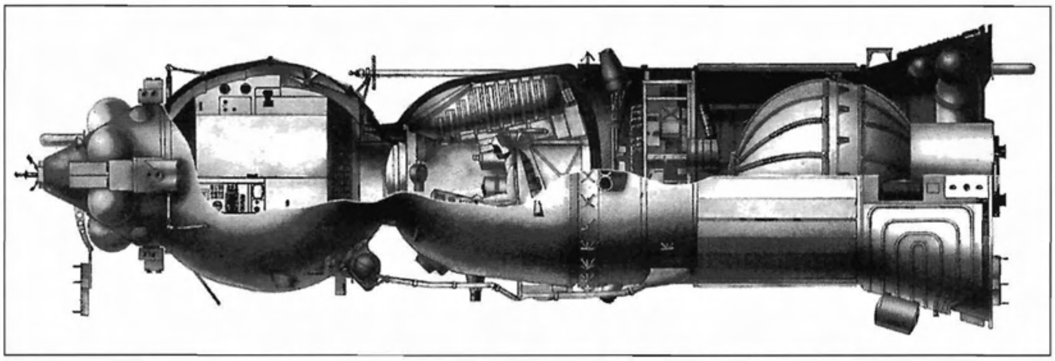
The landing platform was a relatively simple frame on which the pressurized cabin rested and to which the four landing legs were affixed. Numerous designs were considered before the four-leg option was selected. This ensured stability on lunar slopes up to 20 degrees. To prevent the lunar lander from bouncing after touchdown, four solid-propellant hold-down rockets were ignited at the first indication of contact with the lunar surface. These small-thrust engines were pointed upward to keep the lunar lander firmly on the Moon. Several hundred drop tests were performed on Earth to verify the energy absorbing capability of the titanium foil honeycomb dampers. The landing platform also carried a television camera to monitor the ascent of the lunar cabin.

The lunar lander was rated for 72 hours of independent flight of which 48 hours could be spent on the Moon. However, on first missions the planned stay time was only a few hours. The cosmonaut's EVA suit could support excursions outside the vehicle for only about an hour and a half. During this period the cosmonaut would collect soil samples, photograph terrain, deploy a suite of scientific instruments, and erect the Soviet flag. To assist the cosmonaut in the event that he accidentally fell on the lunar surface, a hoop was attached to the EVA suit with the protrusion primarily extending from his back to allow the cosmonaut to roll over more easily onto his front in the cumbersome EVA suit.

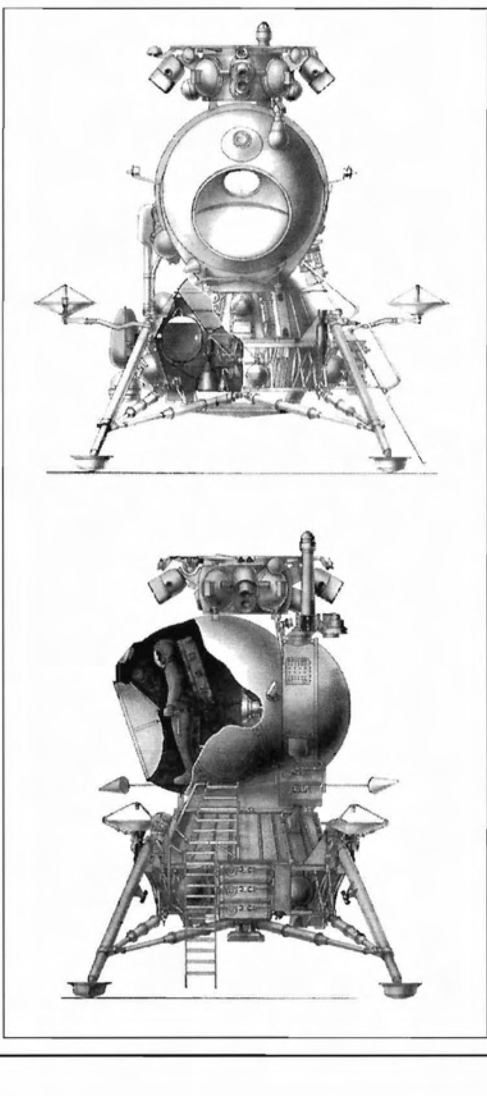
Following lift-off of the lunar cabin, the cosmonaut in the lunar orbiter would conduct the rendezvous and docking procedure already tested in Earth orbit during 1967-1969. To ensure the reliability of the docking operation, the lunar orbiter carried a simple hook-type extension which would catch onto a honeycomb receptacle atop the lunar lander. Then the cosmonaut in the lunar lander would have to perform a third EVA to transit from the lander to the orbiter. Once both cosmonauts were safely aboard the lunar orbiter, the lunar cabin would be cast off.

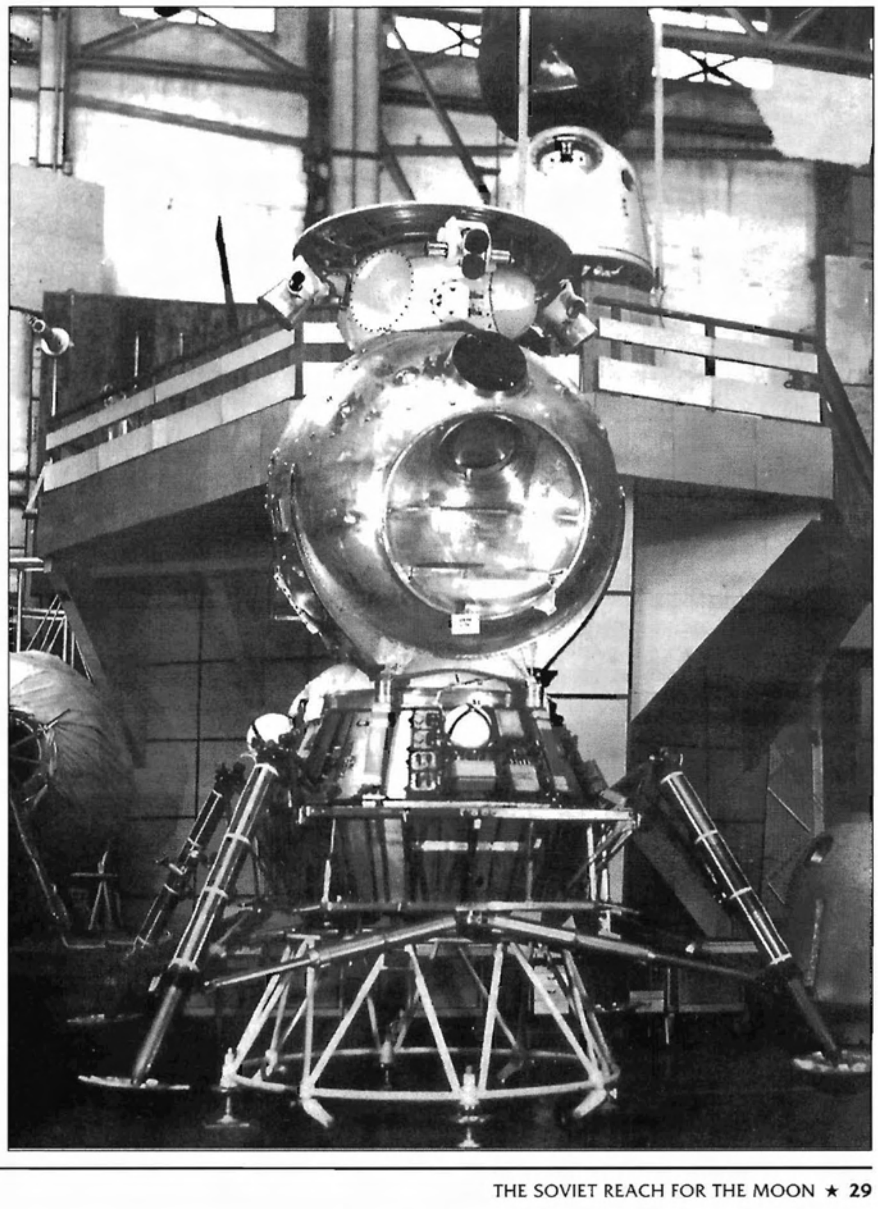
The lunar orbiter, also known as the LOK or Luna Orbitalny Korabl (Lunar Orbital Spacecraft), was very similar to the Soyuz and L-1 spacecraft but differed in several respects. The total mass was 9,850 kg with a length of 10 m and a maximum diameter of 2.9 m. Instead of solar panels the lunar orbiter relied on sophisticated fuel cells for electrical power generation. Orbital maneuvers would be carried out by a restartable, single-chamber 417-kg-thrust engine burning the same propellants as the lunar lander. To leave lunar orbit for the return to Earth, a separate, more powerful two-nozzle engine would develop 3.3 metric tons of thrust. The trans-Earth and reentry profile was then to be virtually identical to that tested on the UR-500K/L-1 missions. The entire propulsion unit was also referred to as Block I. ●

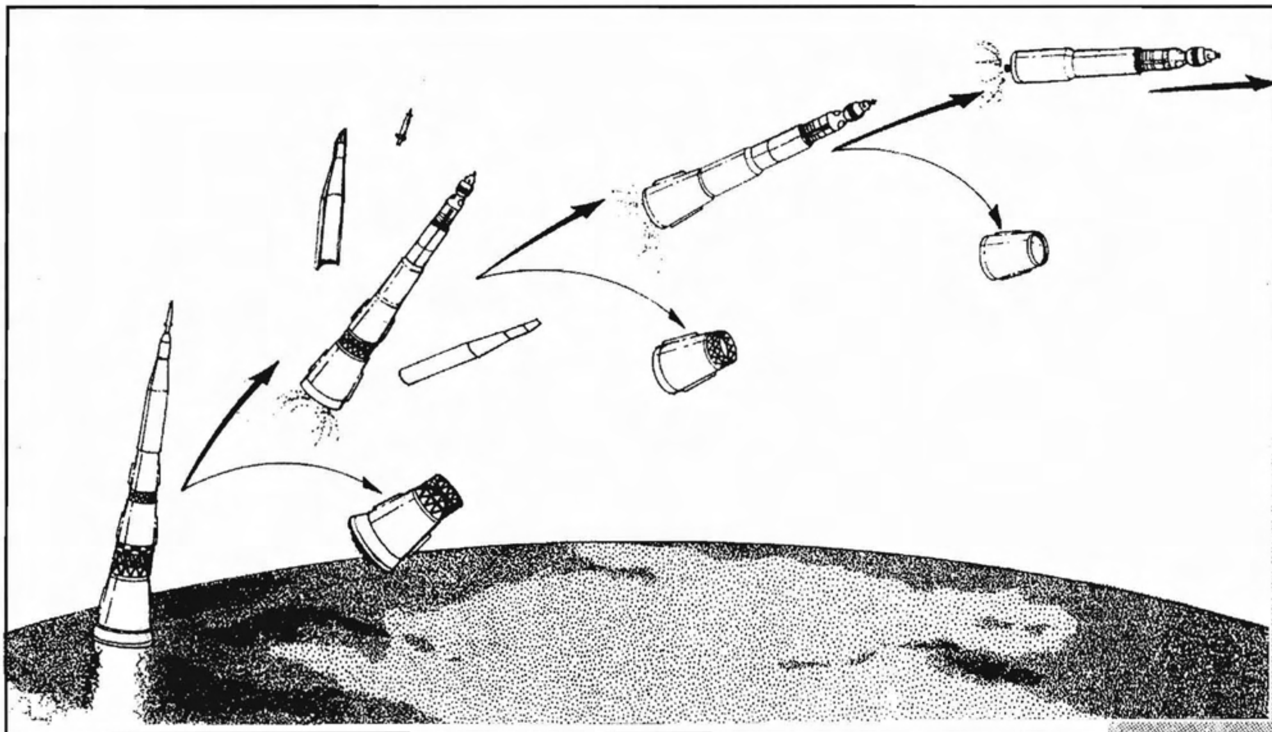


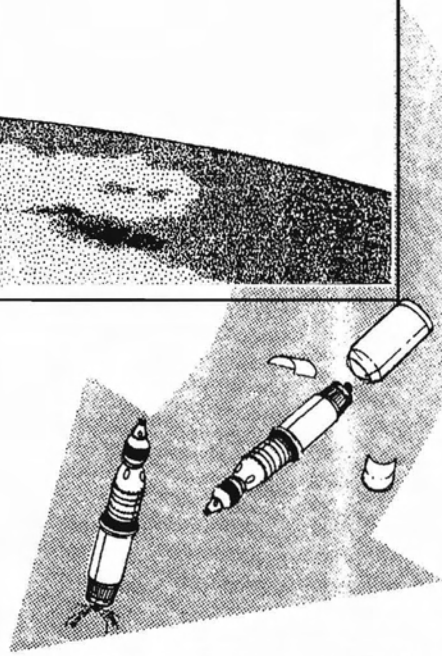


▶ *Top: The Soyuz 4/5 crew transfer in Earth orbit during January, 1969, was necessary to demonstrate the technique which the LK cosmonaut would employ twice in lunar orbit. Right: The LOK lunar orbiter. Bottom: The LK lunar lander weighed 5.5 metric tons.*



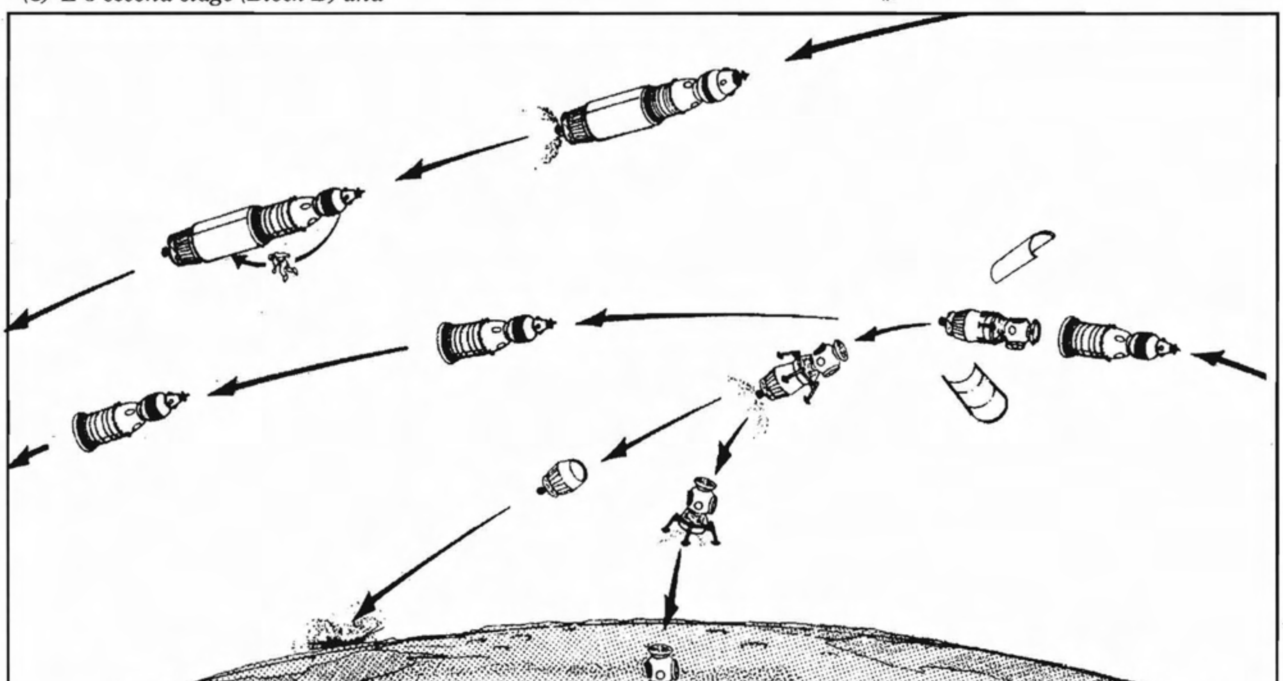


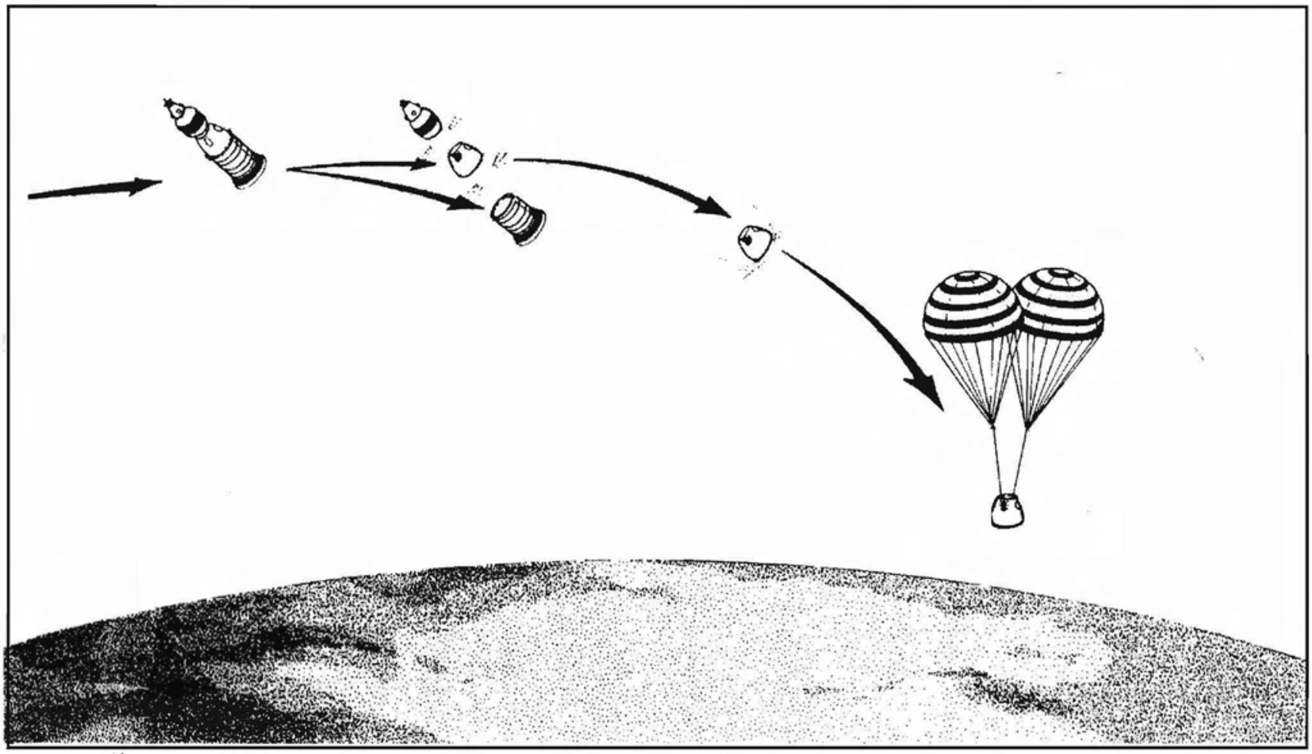




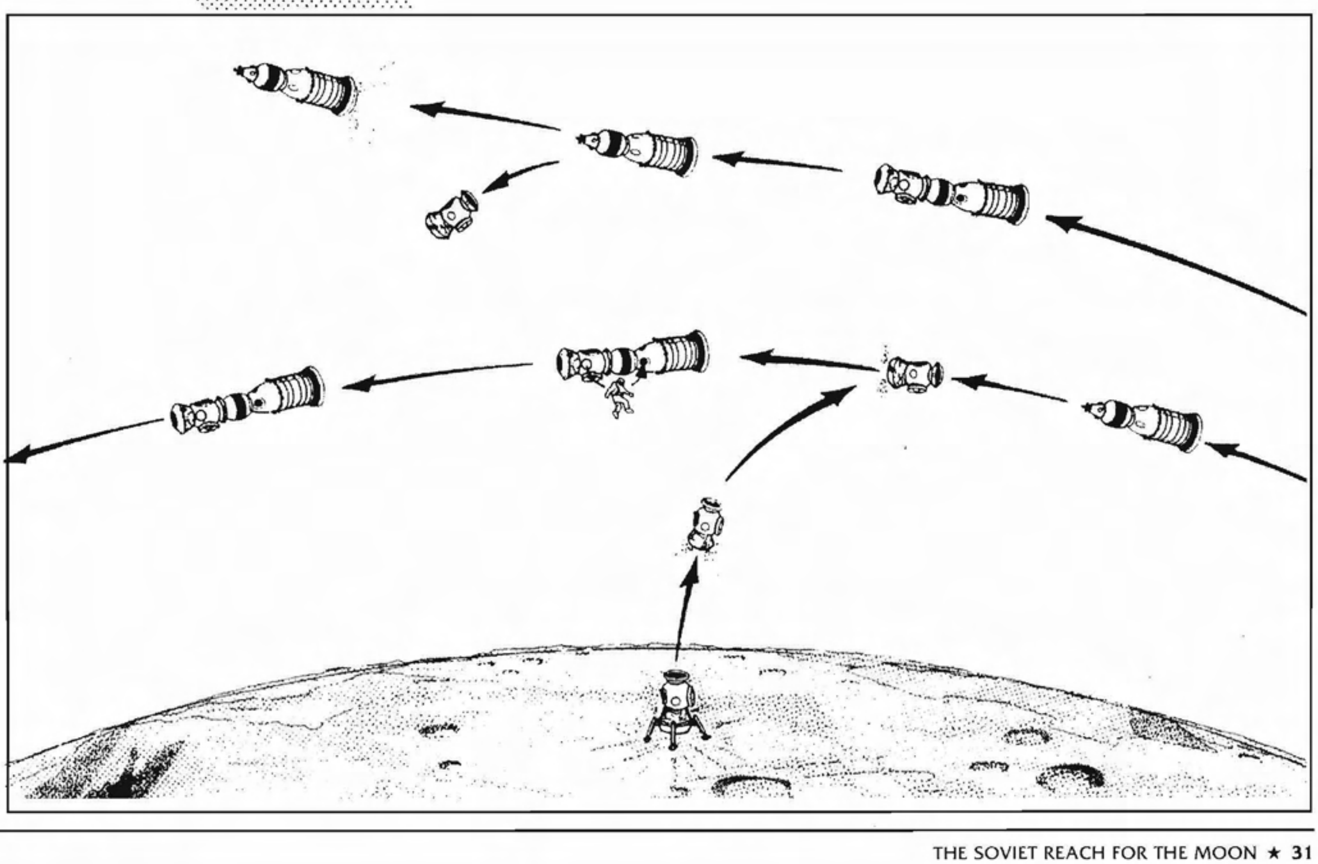
▶ ***The N-1/L-3 Flight Profile(s) From Earth to the Moon:***

(1) The N-1 / L-3 "complex" lifts off from Baikonur;
(2) N-1 first stage (Block A) separates;
(3) Escape tower and protective fairings separate;
(4) N-1 second stage (Block B) separates;
(5) N-1 third stage (Block V) separates;
(6) L-3 "complex" leaves Earth orbit onto a translunar trajectory;
(7) L-3 first stage (Block G) separates;
(8) L-3 second stage (Block D) and Lunar Lander and Lunar Orbiter enter Lunar orbit;
(9) Cosmonaut transfers from Orbiter (LOK) to Lander (LK);
(10) Lander / Block D separate from Orbiter (LOK);
(11) Block D fires, separates and crashes into Moon;
(12) Lunar Lander (LK) lands on the Moon.





▶ ***From Moon to the Earth:***
(1) Lunar Cabin (LK) separates / lifts-off from the Moon;
(2) Cabin (LK) rendevous and docks with orbiter (LOK);
(3) Cosmonaut transfers from cabin (LK) to orbiter (LOK);
(4) LOK leaves Moon orbit for trans-Earth and reentry profile;
(5) LOK "complex" separates and the return capsule (with cosmonauts) lands by parachute.



8 The N-1 Flight Tests Begin

▶ Back at Baikonur, as the N-1 was undergoing its last two days of preparation, another new space system was about to be launched. On 8 January 1969 the Central Committee of the CPSU and the Council of Ministers had approved a new resolution (no. 19-10), entitled "About the Work Plans for Research of the Moon, Venus, and Mars by Automatic Stations". A new generation of large, sophisticated solar system probes had been developed by the Babakin design bureau to continue the Soviet Union's pioneering extra-terrestrial exploration. The first of this breed, the Ye-8, was designed to soft-land on the Moon and deposit a 750-kg, remotely-controlled lunar rover. Although far from the grandiose manned missions of L-3 or Apollo, a successful automated exploration of the lunar surface early in 1969 would help dampen the disappointment later if the US reached the Moon ahead of the USSR. Moreover, the lunar rover could actually return data over a much wider area than manned missions could hope to do for many years to come.

Resting atop a UR-500K launch vehicle, the 5.7-metric-ton Ye-8 consisted of two principal modules. The descent stage was a versatile propulsion unit designed to effect course corrections on the way to the Moon, to slow the spacecraft into lunar orbit, and later to land softly on the Moon in a manner similar to the L-3 lunar lander. Above this stage was the lunar rover, standing 1.35 m tall and 2.15 m across. The comically looking vehicle resembled a small bath tub on wheels with two protruding eyes (cameras). Eight independent, electrically powered wheels would enable the rover to overcome a variety of obstacles and small craters. The inside of the hinged lid of the rover was covered with solar cells to provide electrical power to the little Moon car. Along its travels about the Moon during the lunar day (about two Earth weeks), the rover would perform a number of experiments, analyzing the lunar soil and sending back thousands of photographs to Earth. During the lunar night, the rover was parked with its lid closed in hibernation. A radio-isotopic source (Polonium-210) provided heat throughout the cold two-week-long night.

The first Ye-8 was launched on the morning of 19 February 1969 but fell victim to yet another malfunctioning Proton booster. This time the launcher failed after only 40 seconds, causing the valuable payload to fall and be destroyed just 15 km away. With two successive UR-500K failures so early in the year (carrying the L-1 in January and the Ye-8 in February), personnel at the cosmodrome turned toward the imminent launch of the gigantic N-1 with more than a little trepidation.

On 21 February 1969, the 2,735-metric-ton N-1/L-3 vehicle was fully fueled and ready for launch. Actually the payload was designated L-3S to denote a dummy lunar lander and an L-1S spacecraft in place of the lunar orbiter. The L-1S differed from its predecessor primarily in the addition of a forward maneuvering unit similar to that designed for the lunar orbiter. The unfueled booster with the L-3S payload had been transported to the pad horizontally by an enormous carrier powered by locomotives on parallel tracks. At the pad the entire complex was hydraulically erected in a manner similar to that used by virtually all Soviet launch vehicles. Surrounding the pad for protection were a pair of 130-m tall lightning towers.

Finally, at 1218 Moscow time the N-1 first stage ignited and the vehicle began to rise. Within seconds two of the 30 main engines (no.s 12 and 24) were shutdown erroneously by the KORD system, but the flight continued within acceptable parameters and passed through the maximum dynamic pressure regime at reduced engine thrust. Sixty-six seconds into the flight an oxidizer line to one of the NK-33 engines ruptured from excessive vibrations as the main engines resumed full power. The leaking liquid oxygen ignited and a fire developed in the aft end of the first stage. At 70 seconds after lift-off, the KORD system shutdown all engines, and the emergency escape system was activated. The N-1 booster and the L-3 propulsion stages were destroyed, but the L-1S spacecraft landed safely several dozen kilometers from the launch facility.

One of the strongest criticisms of the N-1 development program concerned the decision to not build a first-stage test stand with which to verify the operation of 30 engines firing simultaneously. (Test stands were built for the smaller second and third stages.) Korolev's judgment in this matter, later followed by Mishin, was that the expense and the resultant program delay that such tests would cause were unacceptable. Instead, tests were only conducted with individual engines. In a typical batch of six engines, two would be test-fired, and, if no problems arose, the remaining four engines were approved for flight. The multiple failures and the poor performance of the KORD system during the maiden N-1 flight reinforced the short-sightedness of the decision to by-pass large unit testing. Moreover, the design philosophy of the KORD system should have been more predictive rather than reactive.

Whatever small hope that the Soviet Union had of beating the US with a lunar landing evaporated in March and May of 1969 as a result of the highly successful Apollo 9 and Apollo 10 missions. The first thoroughly tested the LEM in Earth orbit with men on board, whereas the second witnessed a return to the Moon in a full dress-rehearsal of a lunar landing. With the Apollo 11 mission set for mid-July, the USSR pressed on hoping to score two more significant achievements before losing the Moon race.

The second variant of the new Ye-8 series spacecraft was poised for launch on 14 June. This time the Proton would carry a Ye-8-5, designed to soft-land on the Moon, drill into the lunar surface, extract a small soil sample, and return it to Earth. The 5.7-metric-ton, 4-m-high spacecraft used a descent stage virtually identical to its February predecessor, but the lunar rover was replaced with an ascent stage equipped with a drilling mechanism and a 50-cm-diameter, 39-kg reentry capsule capable of withstanding the intense heat of a ballistic reentry into the Earth's atmosphere. Unfortunately, the spacecraft was never given the opportunity to prove itself. The UR-500K Block D stage malfunctioned before the Ye-8-5 could reach Earth orbit, and the sophisticated probe fell into the Pacific Ocean.

Four days after this latest disappointment, Mishin and Kamanin agreed upon a reduced list of eight cosmonauts who would train for the L-3 mission: Bykovsky, Khrunov, Leonov, Makarov, Patsayev, Rukavishnikov, Voronov, and Yeliseyev. The next order of business was a successful flight of the N-1/L-3S.

On 3 July 1969 at 2318 Moscow time (4 July Baikonur time), the second N-1/L-3S mission with a payload like that carried the previous February was underway. Almost immediately a fatal chain reaction of malfunctions began. A metallic object fell into the oxidizer pump for engine no. 8, causing it to explode. The explosion disabled not only adjacent engines but also vital control cables. The remaining engines of the first stage, which was already on fire, were shutdown, and the vehicle fell back onto the pad, completely destroying both. The L-1S spacecraft was saved once again by the emergency escape system and landed nearby.

In the aftermath of this most recent disaster, several major modifications were implemented. The KORD system was redesigned, and a new freon fire-extinguishing system was added. Kuznetsov made changes to the main engines, including the installation of filters in the propellant lines. A second launch pad already under construction was completed, and the original launch pad was rebuilt. However, two years would elapse before the N-1 was ready to fly again.

The world-at-large knew nothing about the N-1 failures of February and July, 1969, since they were not revealed by the USSR or by US intelligence agencies. Knowledge of the July accident would have been especially embarrassing to the Soviet Union, coming only two weeks before the scheduled launch of Apollo 11. However, the Babakin design bureau had been working diligently to prepare a final robot spacecraft and to permit the Soviet Union to save some face.

On 13 July, three days before Apollo 11 was due to be launched, another lunar sample return spacecraft lifted-off one of the well-used Proton pads at Baikonur. This time the launch worked perfectly, and Luna 15 entered a temporary Earth orbit before speeding away toward the Moon. Two days later the probe performed a mid-course maneuver to refine its lunar aim. At 1300 on 17 July, with Apollo 11 already on its way to Moon, Luna 15 decelerated and slipped into a lunar orbit of 55 km by 203 km.

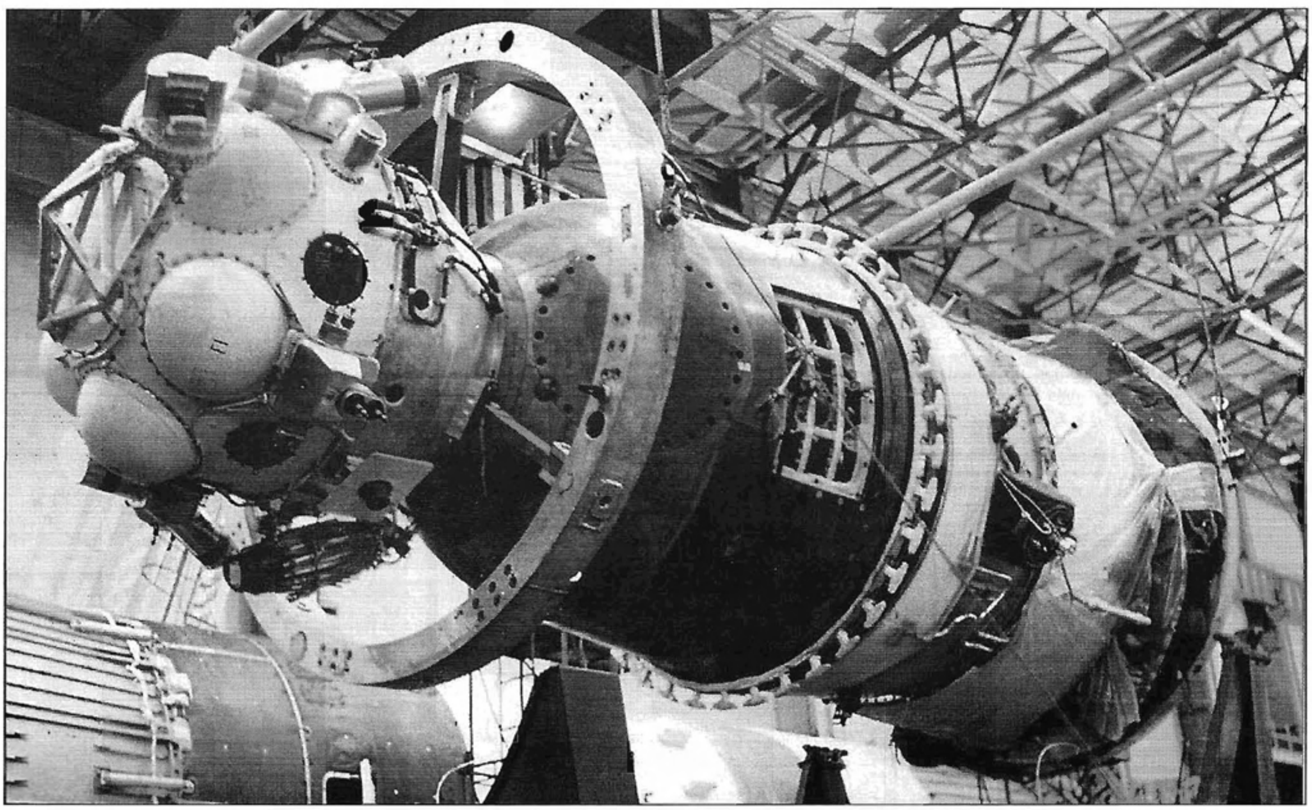
A second maneuver on 19 July dropped the low point of Luna 15's orbit to only 9 km above the lunar surface, followed by yet another orbit adjustment the next day. Not until the evening of 21 July, after Apollo 11's Eagle module had already landed safely on the Moon, did Luna 15 attempt to duplicate the feat. However, the Soviet craft crashed into Mare Crisium at a velocity of approximately 480 km/hr. Only many years later did the Soviet Union acknowledge that Luna 15's objective was the automated collection of lunar soil and its return to Earth.

Just two weeks after the return of the triumphant Apollo 11 astronauts, the Soviet Union launched yet another in its long series of UR-500K/L-1 missions. Ironically, after more than two years of failure after failure, this flight was destined to be successful. Launched on 8 August, Zond 7 looped around the Moon at a distance of 1,230 km and then accurately reentered the atmosphere with a soft-landing near the USSR town of Kustanai (about 50 km from the designated landing area) on 14 August. The flight did also benefit the N-1/L-3 program, particularly in confirming the ability of returning cosmonauts to land safely in the Soviet Union.

The nearly flawless mission was bittersweet to the cosmonauts who had trained for the mission and now were unlikely to fly. Technically, if Zond 8 was successful in December, a manned L-1 mission might follow in April, 1970. However, only 3 of the 15 L-1 spacecraft remained.

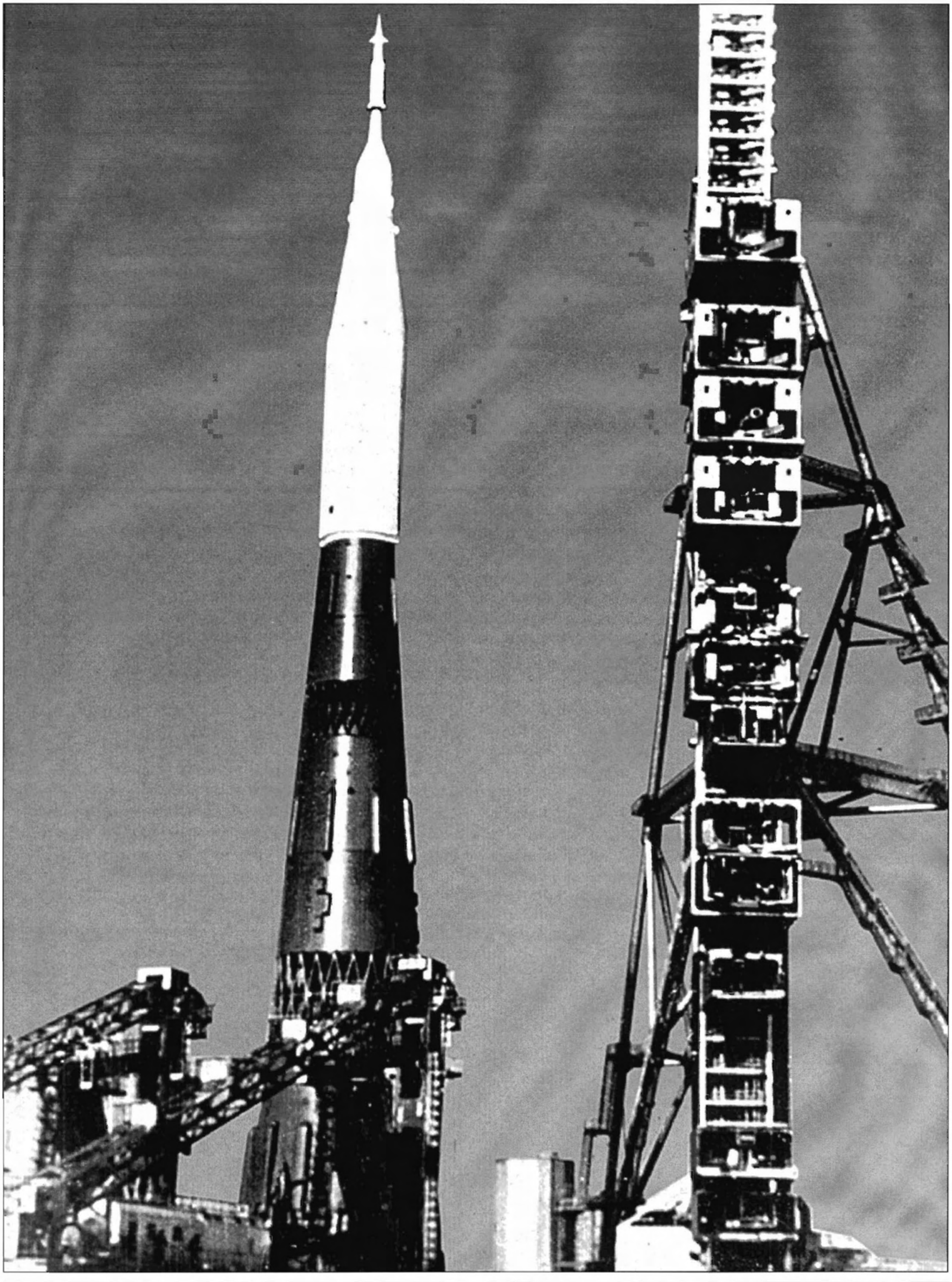
During September and October the Babakin design bureau tried twice more to send their newest creations to explore the Moon. On 23 September and again on 22 October (one lunar month later), third generation Luna payloads (the first a soil sample retriever and the second another lunar rover) were placed into low Earth orbits, but malfunctions of the Block D stage prevented translunar injection. Both expensive spacecraft decayed from orbit soon after launch.

Unbelievably, fate would strike yet another blow to Soviet lunar dreams before the year was out. On 28 November a Proton booster carrying a variant of the L-1 spacecraft on an Earth orbital mission failed when a third stage engine exploded. These last three failures also handed the bad-luck L-1 program the inevitable verdict: a manned circumlunar flight would not be permitted. ●



► ***The first N-1 flight on 21 February 1969 carried a simple L-1S spacecraft (above) and a dummy lunar landing to simulate the complete L-3 complex.***

▶ *This page: Like all Soviet launch vehicles, the N-1/L-3 was transported to the pad horizontally and then erected. The immense transporter was later modified to carry the Energia-Buran launch vehicle.*
▶ *Facing page: Once the N-1/L-3 was seated on its launch pad, a rotating gantry was moved into position for the final check outs and crew ingress.*



9 Defining the Advanced N-1/L-3M Program

▶ The year 1969 had been extremely disappointing to Mishin and the Soviet leadership. Both N-1 launch attempts had failed, none of the five Luna probes were successful, and the UR-500K/L-1 program was prohibited from ever sending a man to the vicinity of the Moon. A ray of hope for the future, however, emanated from the Soviet Academy of Sciences. Mishin was tasked to develop a new, more capable manned lunar exploration program to fulfill specific scientific objectives. Longer stays on the Moon and larger crews would almost certainly be needed.

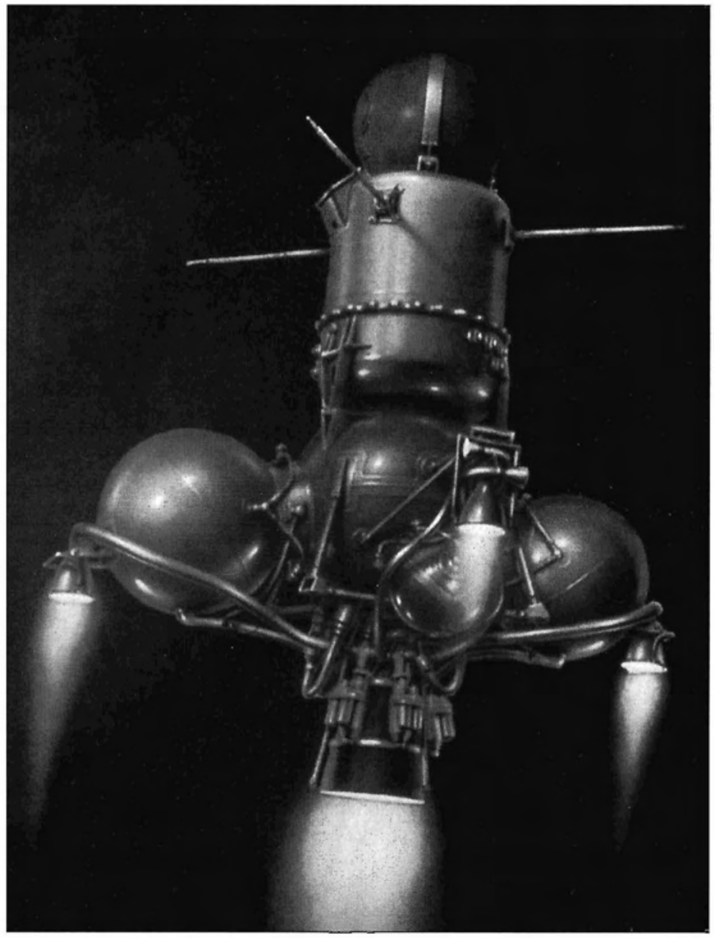
Two new concepts now emerged from Mishin's design bureau, although they evolved from studies underway since 1967. One scenario envisioned an uprated N-1 booster with improved (170-metric-ton thrust) first stage engines and liquid oxygen and liquid hydrogen upper stages to increase its lifting capability. In response to Korolev's 1964 directive, Isayev's design bureau had indeed been working on the development of such an engine, designated KVD-1. This improved N-1 would have a payload capacity of up to 105 metric tons, enough to place two men on the Moon, like Apollo.

In the second scenario Mishin reverted to Korolev's original idea for dual N-1 launches. Under Mishin's new plan, called N-1/L-3M, one N-1 would place an unmanned 104 metric ton assembly named GB-1 into low Earth orbit, followed by a second N-1 with the manned GB-2 complex weighing 103 metric tons. Each assembly would leave Earth orbit and travel independently to the Moon and there enter lunar orbit.

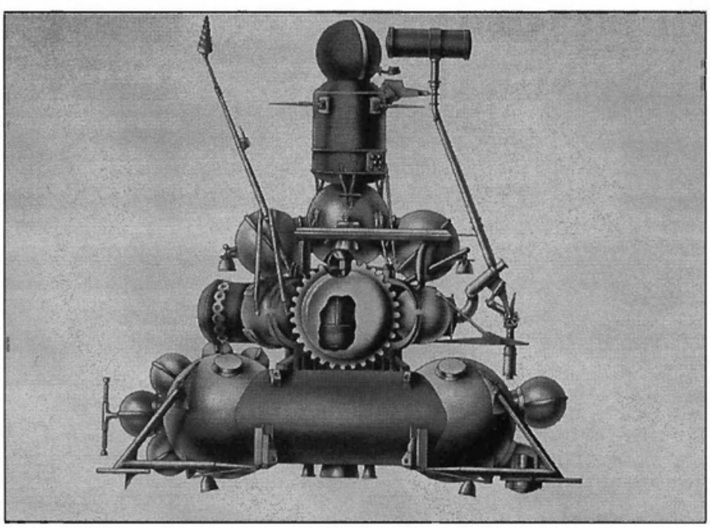
The GB-2 assembly would deliver a large, multi-man lunar lander and return module which was to be joined in lunar orbit with a powerful descent stage carried as part of GB-1. From this point on the landing profile was similar to that anticipated for the N-1/L-3. After performing the de-orbit maneuver, the descent stage would be jettisoned, and the lunar lander would perform the final deceleration for a soft touchdown. On the Moon, the mass of the lunar lander would be nearly 24 metric tons.

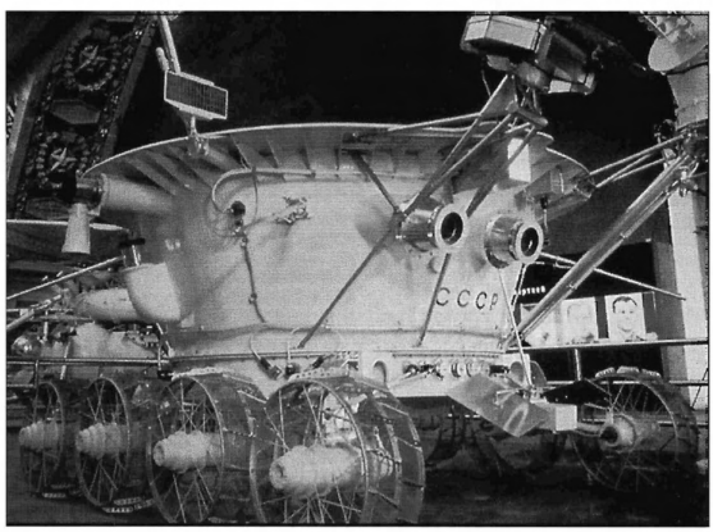
Early stays on the Moon might be restricted to 5-14 days, but longer expeditions were planned on later flights. The duration of the mission would be tied to the number of cosmonauts on board, e.g., 5 days for three cosmonauts and 14 days for two cosmonauts. At the end of the exploration program, the lunar lander's 19.5 metric ton ascent stage would blast-off the Moon for a direct return to Earth. Mishin believed that this type of mission was possible in the 1978-1980 time frame if the N-1 first and second stages could be perfected.

The unmanned Luna program finally was rewarded in 1970 with two outstanding missions, but not without another false start. On 6



▶ ***Clockwise from left: The Luna 16 spacecraft was the first vehicle to land on the Moon, collect a soil sample, and return to Earth; an artist's impression of Luna 16 lifting off the lunar surface with its precious cargo; Lunokhod 1 was driven around the lunar landscape for 11 months by Earth-based controllers.***





February the next attempt to launch a heavy Luna probe failed to even reach Earth orbit. Seven months later the Ye-8-5 Luna 16 was finally on its way. Launched on 12 September, Luna 16 entered lunar orbit (110 km altitude, 70 deg inclination) on the 17th of the month, where it remained for three days, slowly adjusting its orbit to 15 km by 106 km with an inclination of 61 deg. On 20 September the craft dropped out of lunar orbit and landed softly near the lunar equator and not far from the Moon's eastern edge. The total mass of Luna 16 on the Moon was 1.88 metric tons.

Less than an hour after landing, an automatic drill was lowered to the surface and a 101-gm, 35-cm-long soil sample was extracted. The precious cargo was raised and placed into the special reentry capsule which was then hermetically sealed. Approximately twenty-six and a half hours after landing on the Moon, Luna 16's ascent stage was fired, hurling the reentry capsule on a ballistic trajectory back to Earth. By 24 September the Luna 16 reentry capsule had successfully landed in the Soviet Union 80 km southeast of Dzhezkazgan (only 30 km from the planned site) and been recovered. Although the USSR had not landed men on the Moon, they had achieved one of the primary objectives of such a flight - and at a fraction of the cost.

The following month the last of the UR-500K/L-1 missions was conducted. Mishin linked this final flight to preparations for a resumption of the N-1/L-3 program scheduled for 1971. Zond 8 was launched on 20 October, flew by the Moon at a distance of 1,120 km on the 24th, and returned to Earth on the 27th. Although the flight was largely successful, an attitude control sensor malfunction caused the L-1 spacecraft to return over the North Pole on a ballistic trajectory, splashing down in the Indian Ocean. Thus ended the 10-year-old Soviet program to send men around the Moon. The two remaining L-1 spacecraft were never used.

Two weeks later the third lunar mission in three months was begun with the launch of Luna 17 on 10 November. Soviet press releases were silent on the objective of the mission, and the West could only speculate that the USSR would attempt to retrieve a soil sample from a different region of the Moon. After a flight of five days, Luna 17 entered lunar orbit, where it remained for two additional days before landing safely in the northern hemisphere of the Moon 2,500 km from the Luna 16 landing site.

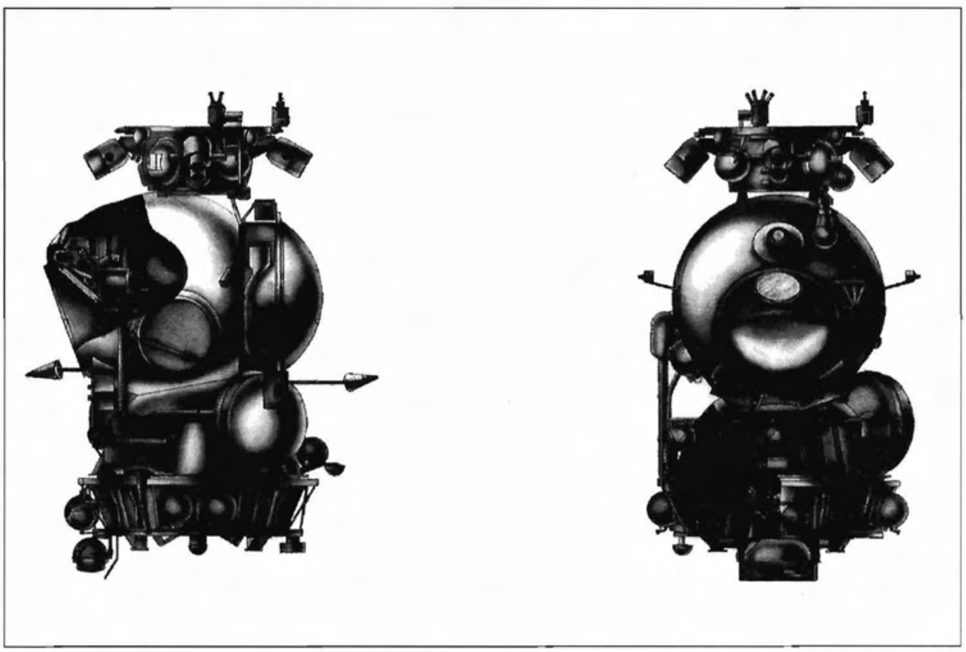
Only then was it revealed that Luna 17 was the Ye-8 lunar rover variant. Two ramps were extended on either side of the descent stage (in case one side was blocked by a boulder or crater), and the 756-kg rover, called Lunokhod 1, was driven onto the lunar surface. Equipped with television cameras to assist Earth-bound drivers and with soil testers, the eight-wheeled rover began an 11-month journey about the Moon which took it on a course more than 10 km long. In all, 25,000 photographs were beamed back to Earth, and the lunar soil was tested at more than 500 locations. In addition to providing a wealth of scientific data, the experience with Lunokhod 1 gave Soviet engineers valuable insight into the requirements and design of future manned rovers.

Lunokhod 1 was just beginning its drive about the Moon when the Soviet manned lunar landing program got a shot in the arm. Although the next N-1 launch was still many months away, a critical space test of the L-3 lunar lander was finally ready. Yangel had insisted on testing the lunar lander in Earth orbit several times before the vehicle could be certified for a manned L-3 mission. The orbital tests involved a lunar lander without landing legs, called T2K, placed into Earth orbit by a Soyuz launch vehicle with an enlarged payload shroud.

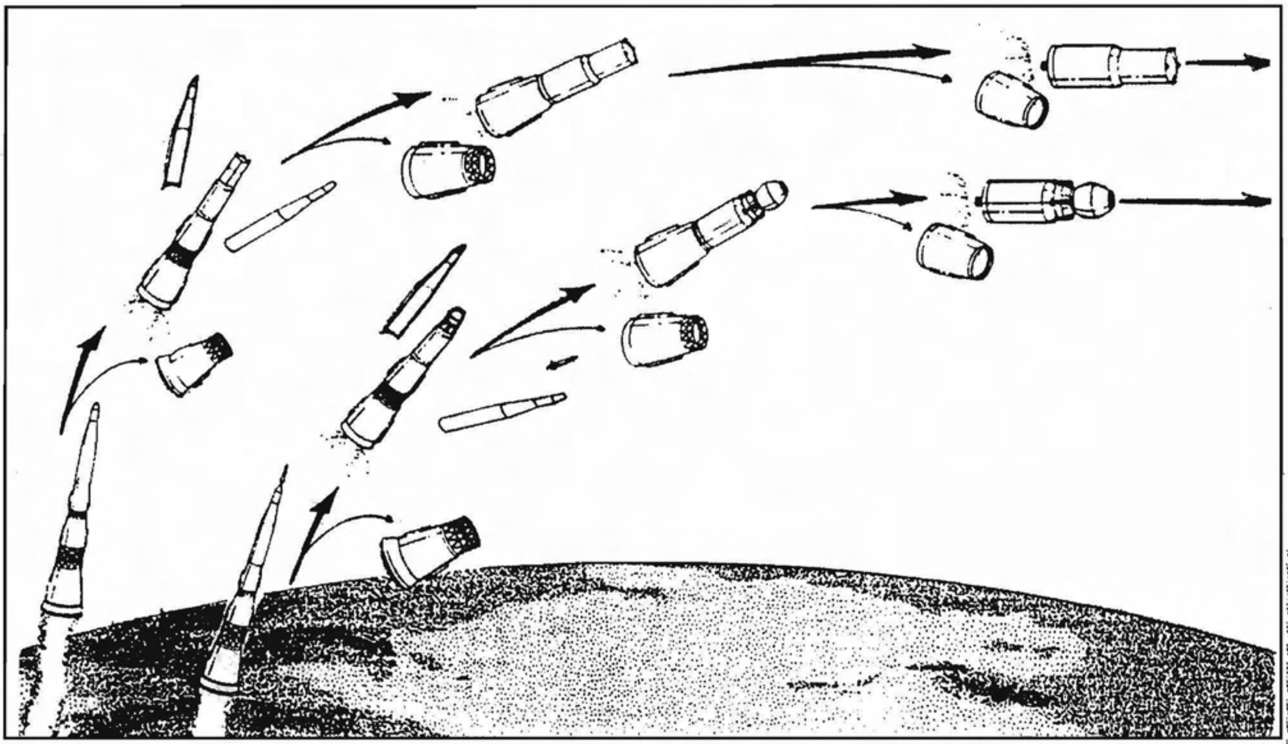
T2K no. 1 was successfully launched on 24 November 1970 under the name Kosmos 379. Three and a half days after entering space (flight time to the Moon), the T2K fired its main propulsion system for the first time with variable throttling to simulate the lunar landing. For the sake of the test, the T2K was oriented in such a fashion that the spacecraft actually moved into a higher orbit. The next day (simulated lunar stay time), the landing platform was jettisoned and the main engine restarted, mimicking the lunar ascent burn. Throughout the test, Kosmos 379 behaved as expected.

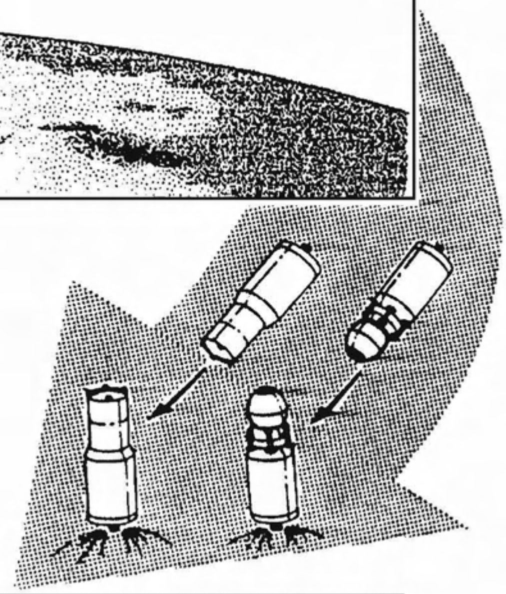
In addition to the lunar lander propulsion system, the lunar orbiter engines needed to be space-qualified. Despite the substantial similarity between the lunar orbiter and Soyuz return modules, the lunar orbiter high-thrust propulsion system had not been tested under the Soyuz program. The greater weight of the lunar orbiter also dictated that any Earth orbital test would require the lifting capability of the Proton booster. In a repeat of the failed 28 November 1969 mission, on 2 December 1970 Kosmos 382 was successfully launched by a Proton rocket into Earth orbit. Kosmos 382 then performed three major maneuvers over a period of four days which may have simulated lunar orbiter maneuvers, including trans-Earth injection.

The Soviet manned lunar landing program appeared to be picking up speed again during the winter of 1970-1971. A second and successful T2K test flight was conducted in late February 1971 by Kosmos 398 (launched 26 February). Kosmos 398 differed from its predecessor by testing various contingency firing modes rather than the nominal one. ●

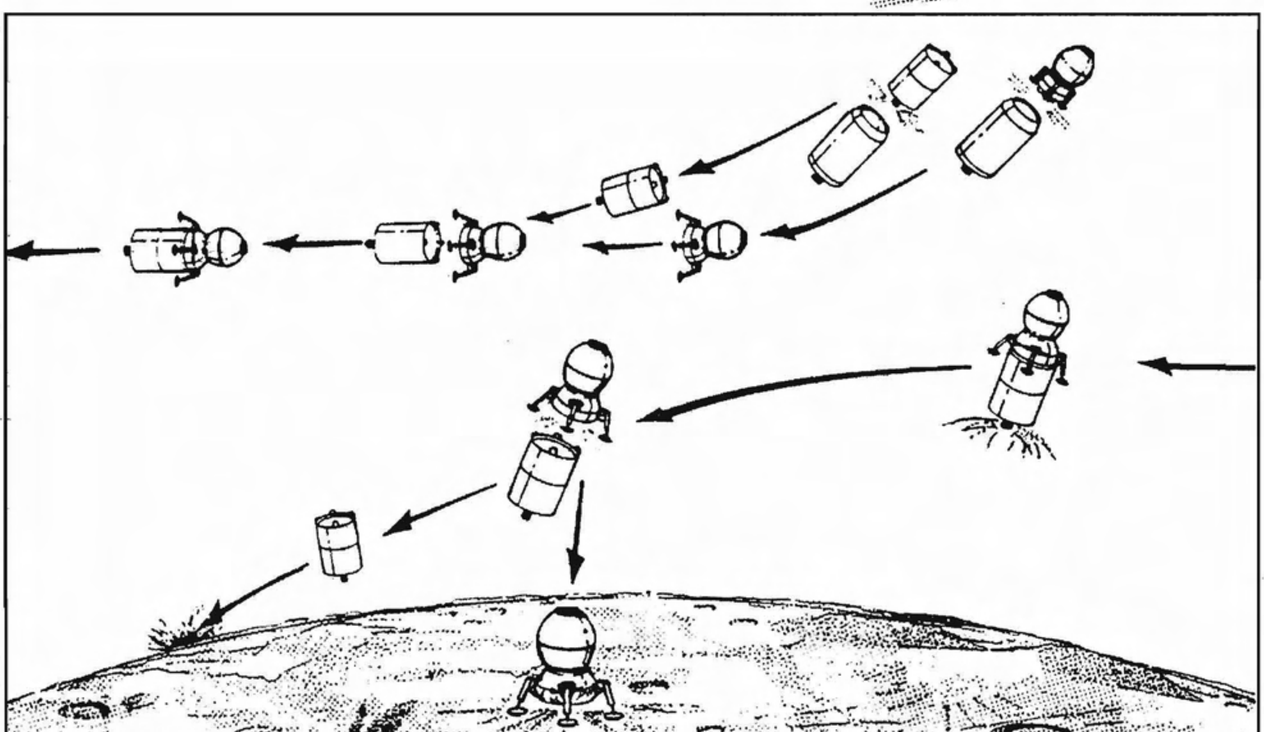


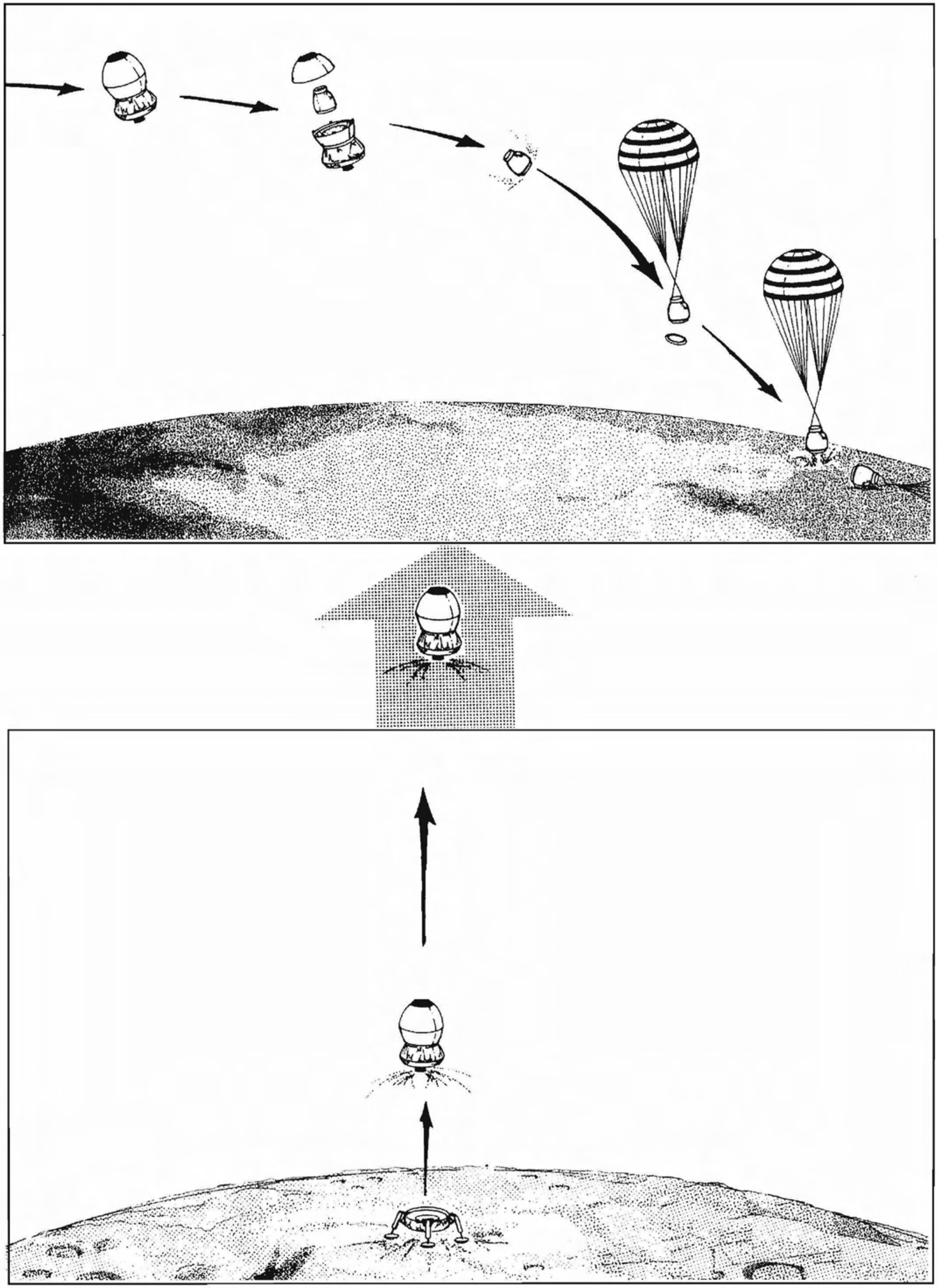
▶ ***The T2K spacecraft, a prototype of the LK lunar lander, was tested successfully in Earth orbit on three occassions during 1970–1971.***





▶ *The proposed flight profile of the L-3M mission required two coordinated launches of the N-1 booster to place the GB-1 lunar orbit descent stage and the GB-2 manned lunar lander into lunar orbit. After rendezvous and docking of the GB-1 and GB-2 in lunar orbit, the landing sequence would be similar to that envisioned for the L-3 missions. The return to Earth, however, would be direct.*





10 The Final Days of the N-1 Program

▶ Encouraged by the flights of Kosmos 379 and Kosmos 382, at the beginning of 1971 Mishin devised a new program plan for the N-1 and L-3. During 1971-1972 the N-1 would be perfected with 4-5 unmanned missions, and its payload capacity would be verified to 95-105 metric tons. By the end of 1972 the first Soviet manned lunar mission would be undertaken with a simple fly-by objective. If successful, a manned lunar landing was anticipated in March, 1973, as the Apollo program was winding down. By March, 1971, the Central Committee of the CPSU and the Council of Ministers had directed Keldysh to review the entire N-1/L-3 program and to recommend a new course of action by 1 May. In particular, Keldysh was asked whether the enormous project should be continued.

Mishin meanwhile focused again on preparing for the third N-1 launch attempt. In June, 1971, the improved and somewhat heavier booster had been placed on the second N-1 launch pad at Baikonur, about half a kilometer from the first. The modest goal for this mission was limited to achieving Earth orbit; thus, the payload consisted of only mockups of both the lunar orbiter and the lunar lander. Launch was scheduled for 20 June but was first delayed to 22 June and then to 27 June. Almost immediately after lift-off, the N-1 experienced severe roll control problems. By 39 seconds into flight the rate and angle of roll of the 100-m-plus vehicle exceeded the limits of the gyroscopic stabilizer. Nine seconds later the second stage started to fail due to high torques. At 51 seconds inputs into the KORD system indicated that the flight could no longer be salvaged, leading the KORD system to shutdown all first stage engines. Since payloads had been mockups, so, too, was the emergency escape system; the entire vehicle fell back to Earth and was destroyed.

The failure of the third N-1 was all the more disappointing since the troublesome first stage main engines were performing satisfactorily until the shutdown command. In the earlier days of rocket development, three losses of an entirely new launch vehicle were not uncommon and were considered the price which occasionally had to be paid for advancements in such a highly technical field. In fact, Korolev's famous R-7 did not fly successfully until the fourth attempt. In Mishin's case, however, economic pressures and an eroding political base (the US had already landed men on the Moon three times) created an unfavorable environment for failure. Conditions worsened considerably three days after this N-1 failure when three Soyuz 11 cosmonauts, returning from a record space flight on Salyut 1 space station, perished during a reentry accident. As head of Soviet man-in-space program, Mishin was held responsible.

While Soviet engineers poured over the data from the latest N-1 launch to determine the cause of the malfunction, the third and last Earth orbital test of the lunar lander was conducted. Kosmos 434, as T2K no. 3 was called, was launched on 12 August and followed a program quite similar to the previous missions. The first main engine firing, simulating the lunar descent and hover phase, was the longest to date. The second, lift-off burn was also within specifications. The lunar lander systems were now certified for a complete N-1/L-3 mission. Yangel died two months later, satisfied that his design bureau had performed its task well.

The Babakin design bureau had also lost its leader in the summer of 1971, but under the direction of S. S. Kryukov two more Luna probes were readied for launch in September. Luna 18, launched on the second day of the month, was intended to repeat Luna 16's mission and automatically return a small sample of lunar soil from a region not far to the north of the Luna 16 site. Luna 18 arrived at the Moon on 7 September and prepared to land four days later. According to a Soviet press release on the fate of Luna 18, the landing "under complex conditions of the lunar continent was unfavorable" - in other words, the spacecraft had crashed.

Less than three weeks after Luna 18's demise, a new Luna probe was launched with a different objective. Luna 19 left Earth on 28 September and arrived in lunar orbit on 3 October. Resembling a Lunokhod without wheels, Luna 19 represented a new generation of lunar orbiter and the third variant of the Ye-8 series. The spacecraft was equipped with a suite of scientific instruments for photographing and remotely analyzing the lunar surface and nearby environment. In particular, Luna 19's image-scanning television cameras provided higher resolution pictures (compared with Luna 12) of potential landing sites. Luna 19 functioned for more than a year in lunar orbit, also permitting a more detailed mapping of the unusual lunar gravitational field.

The next lunar mission began on 14 February 1972 with the launch of Luna 20, which was sent to the rough lunar terrain less than 2 km from where Luna 18 had been destroyed. After becoming a temporary lunar satellite on 18 February, Luna 20 made its descent to the surface three days later. This time the landing was successful. With the aid of television cameras, controllers on Earth directed the drilling operation and found the lunar crust to be much harder than at the Luna 16 site. Twenty-eight hours after landing, with soil samples safely stored in the reentry capsule, Luna 20 ascent stage was launched from the Moon, arriving back on Earth on 25 February.

In early 1972 as the preparations were underway for the fourth N-1 launch attempt, Mishin formally proposed his new N-1/L-3M plan. The Council of Chief Designers, including Glushko, approved the more advanced program. The US Apollo program would end in 1972 after canceling some planned missions due to budgetary and political influences. Moreover, the Americans had no plans to return to the Moon for at least 10 years. Although the Soviet Union was not first to land men on the Moon, it could surpass the limited Apollo explorations and perhaps establish a modest lunar base.

All of this, of course, still depended on the N-1. When the time came for the next N-1 launch, Mishin was in the hospital. Rather than delay the program further, his deputy, Boris Ye. Chertok, was designated the Technical Director for the flight. With an augmented roll control system in the first two stages, the new N-1 carried a payload of a complete lunar orbiter and a lunar lander mockup. Lift-off came on 23 November 1973, and at 90 seconds into the flight the six central NK-33 engines were shutdown as planned. However, the abrupt stoppage of the propellant flow to these engines caused a pressure overload which ruptured the lines. A fire ensued and within 20 seconds after the malfunction the first stage exploded. The emergency escape system did succeed in extracting the lunar orbiter descent module from the disintegrating booster.

Soviet engineers developed new fixes for N-1. On the next launch vehicle oscillation dampers were to be installed in propellant lines and normal engine shutdowns were to be carried out more smoothly. In analyzing the last failure, designers pinpointed another deficiency. Malfunction had occurred with only a few seconds remaining in the operation of the first stage. If the stage had been separated immediately, the remaining stages of N-1 could have compensated for the slight velocity loss and still placed the payload into an acceptable Earth orbit. It was decided that future N-1's should be capable of responding to such situations. By the end of 1973 improved first stage engines were ready for the next N-1 mission.

The only Moon-related space mission conducted in 1973 was Luna 21 which carried a second, improved robot rover. Launched on 8 January, the Lunokhod 2 vehicle was safely deposited inside the crater LeMonnier on 16 January. For five months the little Moon car explored a variety of terrain between the Mare Serenitatis and the Taurus Mountains. With the experience gained in the operation of Lunokhod 1, its successor was able to travel over 3.5 times farther during a mission which lasted less than half as long.

As 1974 dawned, Mishin was under considerable government scrutiny. The N-1 program had been expensive and to date totally unsuccessful. The rationale for the L-3 lunar landing program had significantly diminished, and the risk of losing a Soviet crew on the Moon after the historic Apollo program was becoming politically unacceptable. Mishin's management of the Soyuz and Salyut programs was also under fire. Whereas Mishin had avoided serious criticism following the Soyuz 1 disaster, the deaths of three cosmonauts on Soyuz 11 were clearly his responsibility. Furthermore, the Salyut space station program, now the centerpiece of the Soviet man-in-space program, had not met expectations. Mishin's Soyuz 10 mission had failed in its attempt to enter Salyut 1, and the Soyuz 11 flight had ended in tragedy. Two more TsKBEM space stations, one in 1972 and one in 1973, were lost before they could be manned due to launch vehicle and spacecraft malfunctions. Also, by 1973 the US Skylab space station, much larger and more capable than Salyut, had been orbited.

By May, 1974, the ambitious and powerful Central Committee Secretary, Dmitri Ustinov, had decided Mishin should be replaced. Such a move would be unprecedented for a major Chief Designer of the Soviet space program. Ustinov first obtained the support of General Machine Building Minister Sergei Afanasyev to whom Mishin reported. Finally, Leonid Brezhnev's approval was received. Mishin's replacement was to be long-time rival Valentin Glushko.

When Mishin was dismissed in May, two N-1 launch vehicles were being prepared for launches later that year and were nearly completed. The first launch was tentatively set for August, followed by the other late in the year. If successful, the N-1 may have been operational by 1976, but Glushko's first act as head of the former OKB-1 was to suspend the N-1 program. This decision was followed two years later (March, 1976) by an official termination of the program and an order to destroy all remaining N-1 hardware, including the two largely finished N-1's and components of several others.

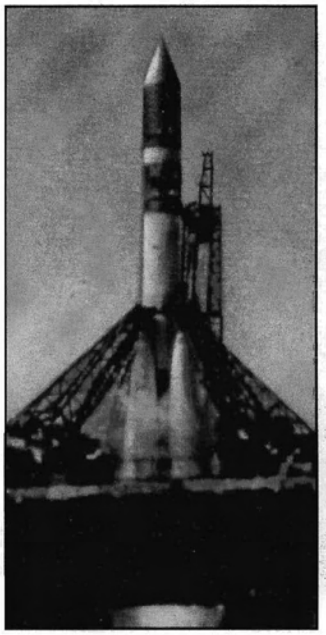
With the end of the N-1 program also came the end of the L-3 manned lunar landing program. However, Glushko was not yet prepared to abandon the Moon entirely. In October, 1974, Glushko proposed a new, larger scale program for manned lunar exploration. A new Vulkan booster, relying on liquid oxygen and liquid hydrogen propellants to place a 200-metric-ton payload into Earth orbit, would permit the creation of a new direct landing mission profile. Glushko envisioned the establishment of lunar bases and the use of manned lunar rovers. However, Glushko's primary objective was the development of the Energiya-Buran space transportation system, and the expensive lunar exploration program was deferred indefinitely.

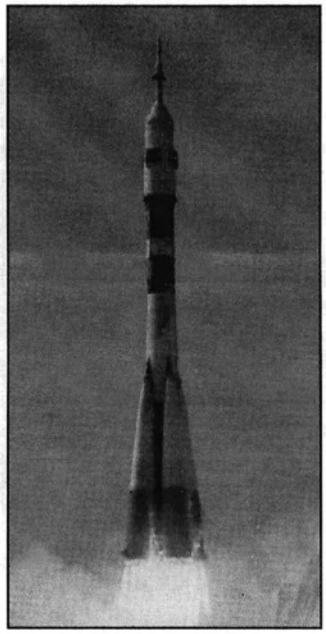
Interest in unmanned lunar exploration also waned, particularly in light of the absence of similar American activity. During 1974-1976 four more Luna probes were prepared and launched before this program, too, ended. In early June, 1974, Luna 22 became the last of the dedicated lunar orbiters - surveys of the Moon were no longer needed to plan for manned landings. Luna 23 landed on the Moon on 6 November of the same year to retrieve a soil sample from the southernmost part of Mare Crisium. Unfortunately, the drilling mechanism was found to be damaged after landing, and the probe never returned to Earth. The next Luna spacecraft was lost in a launch vehicle accident on 16 October 1975. Finally, during 9-23 August 1976 Luna 24, the last of the Luna probes, traveled to the Moon, bored into the lunar surface near the Luna 23 landing site, and brought back the final soil sample of man's first lunar exploration era (1969-1976).

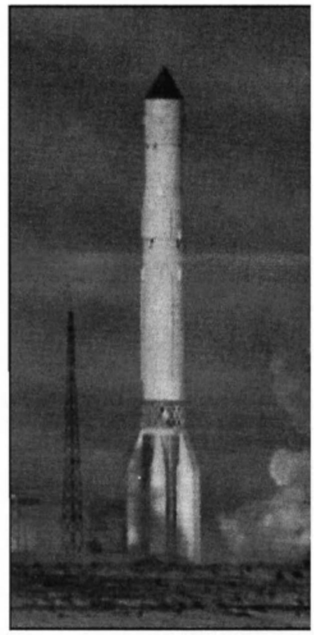
The failure of the Soviet programs to send men around the Moon and to land on its surface cannot be placed on any one individual. In the end, a confluence of technical, political, and economic factors prevented the consummation of both projects. Born out of fierce US-Soviet competition, the L-1 and the L-3 programs expired when that competition ended. ●

FLIGHT HISTORY OF THE N-1/L-3 PROGRAM

Year	Launch Date	Launcher	Spacecraft	Missions Results
1969	21 February	N-1	L-3S	First stage of N-1 terminated after 70 sec; launch vehicle destroyed; L-1S and mockup of lunar lander carried instead of L-3
	3 July	N-1	L-3S	First stage of N-1 terminated within seconds of lift-off; launch vehicle and launch pad destroyed; L-1S and mockup of lunar lander carried instead of L-3
	28 November	Proton	L-1E	Third stage of Proton malfunctioned; planned test of lunar orbiter systems
1970	24 November	Soyuz	T2K	Prototype of lunar lander successfully tested as Komos 379; lunar landing and take-off maneuvers simulated in Earth orbit
	2 December	Proton	L-1E	Lunar orbiter systems successfully tested as Komos 382; lunar rendezvous and trans-Earth injection maneuvers simulated in Earth orbit
1971	26 February	Soyuz	T2K	Prototype of lunar lander successfully tested in Earth orbit for second time as Kosmos 398
	27 June	N-1	---	First stage of N-1 terminated after 51 sec; launch vehicle and L-3 mockup destroyed
	12 August	Soyuz	T2K	Prototype of lunar lander successfully tested in Earth orbit for third and final time as Kosmos 434
1972	23 November	N-1	LOK	First stage of N-1 terminated after 107 sec; launch vehicle destroyed; lunar orbiter and mockup of lunar lander carried instead of complete L-3



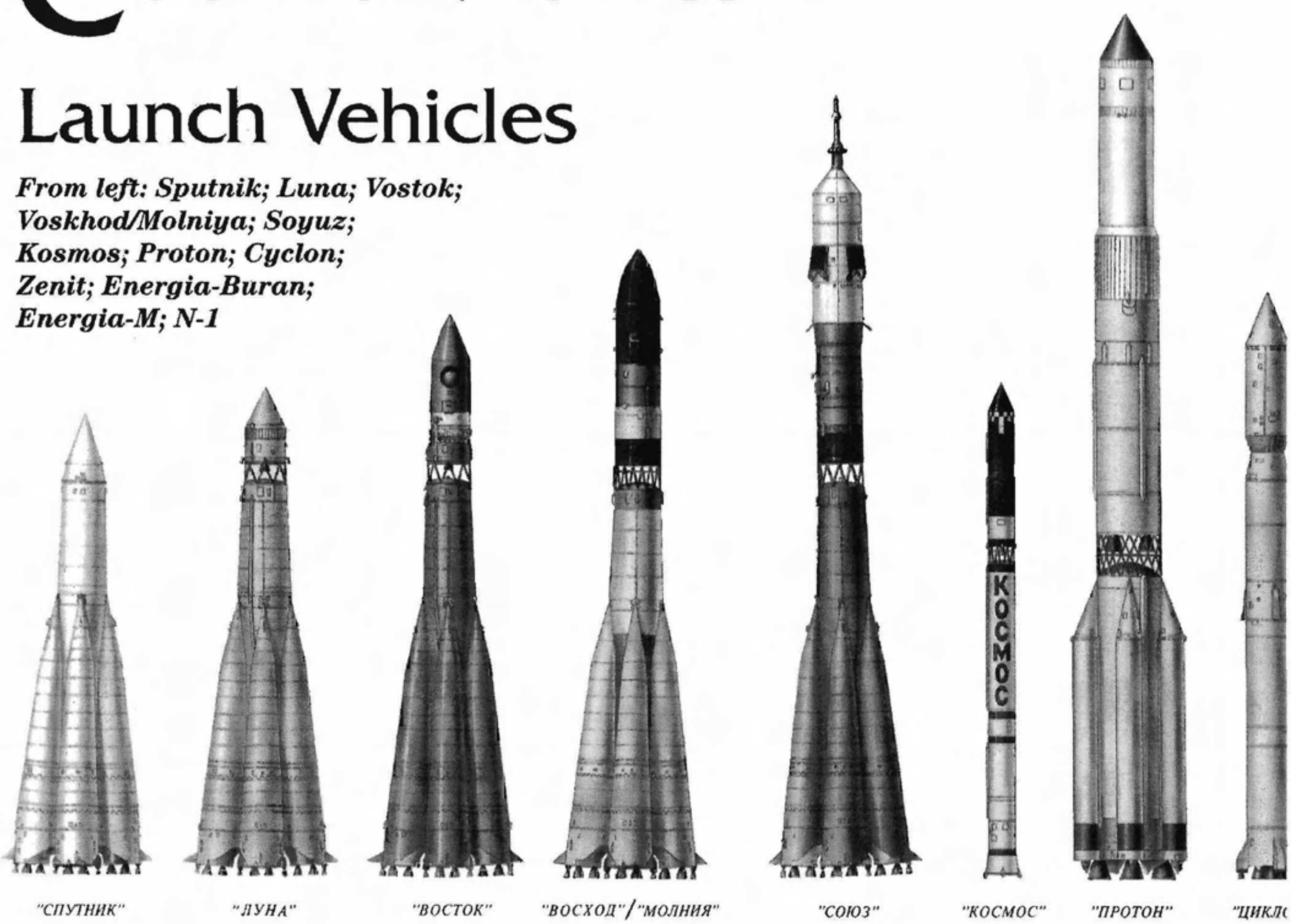


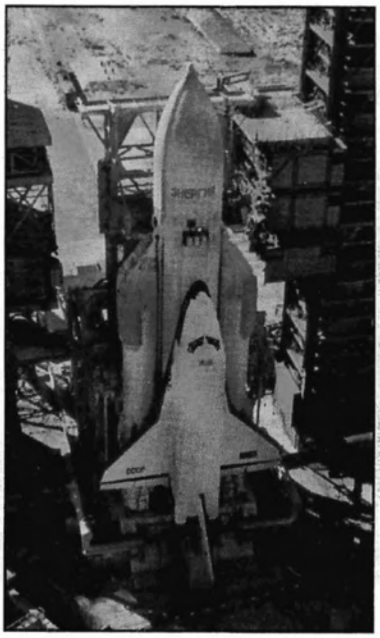


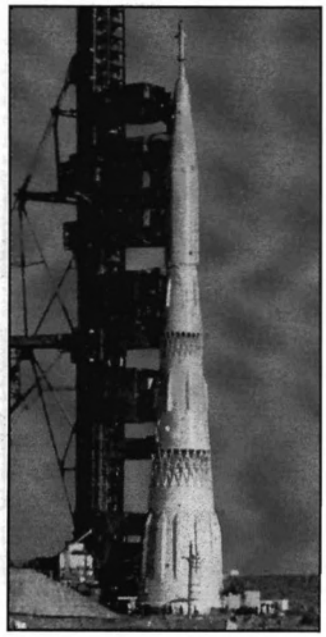
COSMONAUTICS

Launch Vehicles

From left: Sputnik; Luna; Vostok; Voskhod/Molniya; Soyuz; Kosmos; Proton; Cyclon; Zenit; Energia-Buran; Energia-M; N-1







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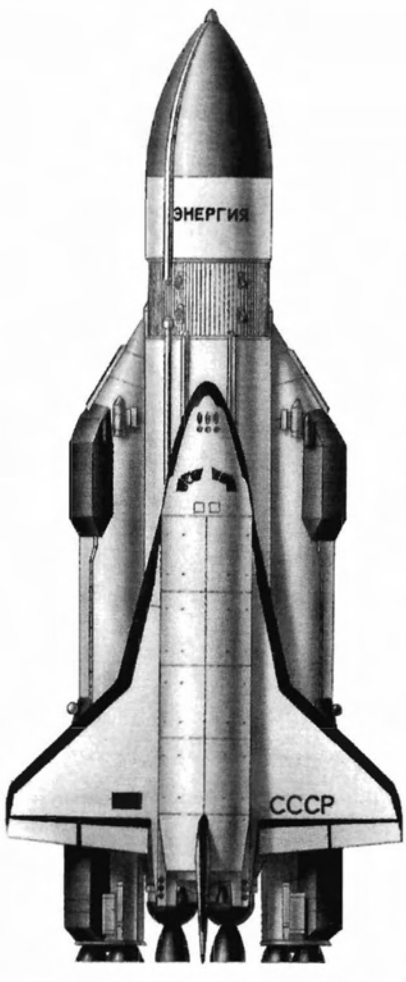

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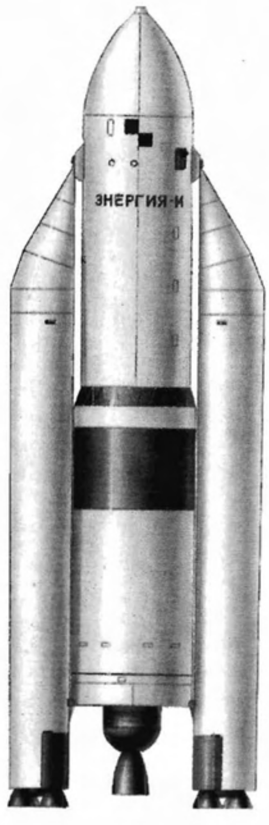

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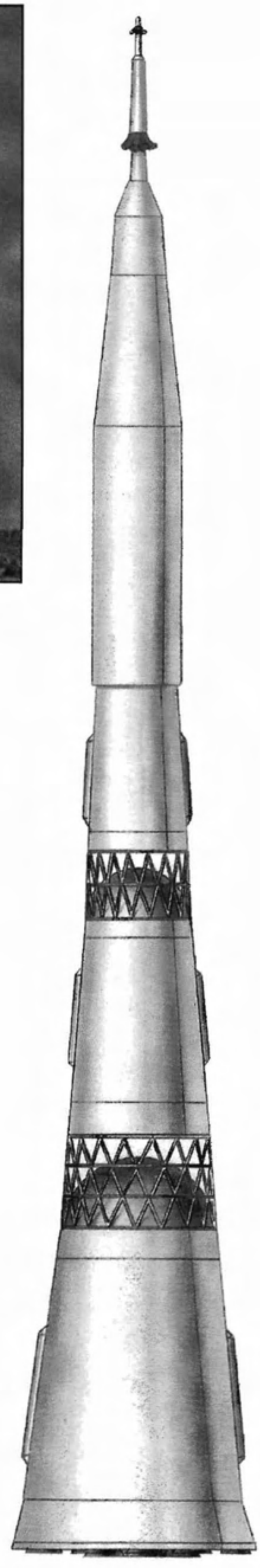
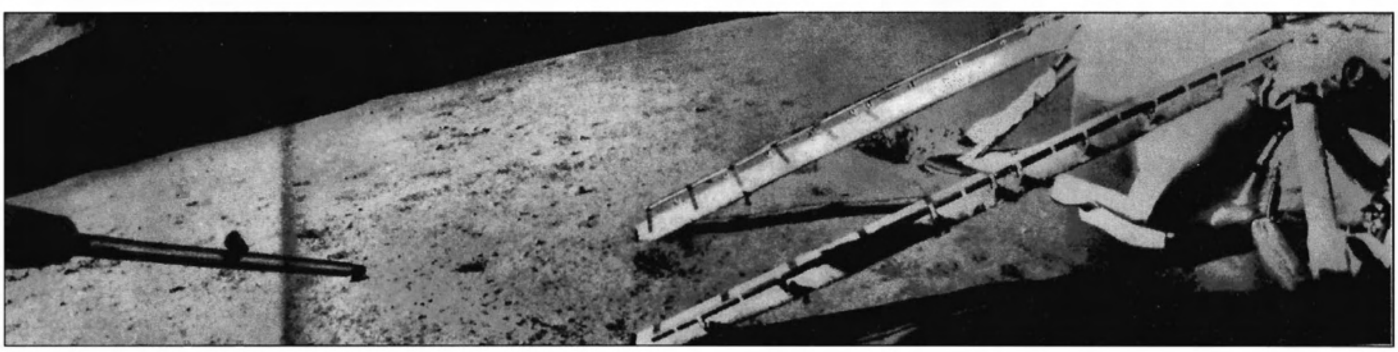


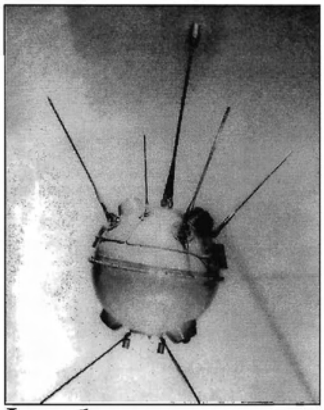
"Н-1"

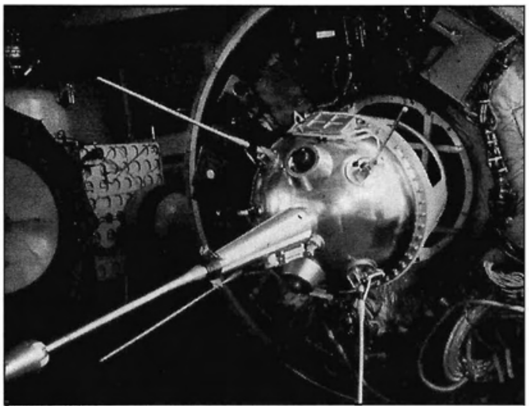
ROBOTIC SPACECRAFT OF THE LUNA PROGRAM

Launch Date		Spacecraft	Launcher	Mission Results
1958	23 September	---	Luna	Launch failure
	12 October	---	Luna	Launch failure
	4 December	---	Luna	Launch failure
1959	2 January	Luna 1	Luna	Missed Moon by 5,000-6,000 km on 4 Jan
	18 June	---	Luna	Launch failure
	12 September	Luna 2	Luna	Impacted Moon on 14 Sep; first man-made object on Moon
	4 October	Luna 3	Luna	Flew around Moon 7 Oct; returned first photos of lunar farside
1960	15 April	---	Luna	Launch failure
	16 April	---	Luna	Launch failure
1963	4 January	---	Molniya	Launch failure; stranded in Earth orbit
	2 April	Luna 4	Molniya	Missed Moon by 8,500 km on 6 Apr
1965	12 March	Kosmos 60	Molniya	Launch failure; stranded in Earth orbit
	10 April	---	Molniya	Launch failure; did not reach Earth orbit
	9 May	Luna 5	Molniya	Crashed on Moon 12 May
	8 June	Luna 6	Molniya	Missed Moon by 161,000 km on 11 Jun
	4 October	Luna 7	Molniya	Crashed on Moon 8 Oct
	3 December	Luna 8	Molniya	Crashed on Moon 7 Dec
1966	31 January	Luna 9	Molniya	Landed on Moon 3 Feb; returned first photos from lunar surface
	1 March	Kosmos 111	Molniya	Launch failure; stranded in Earth orbit
	31 March	Luna 10	Molniya	Entered lunar orbit on 3 Apr; first lunar satellite
	24 August	Luna 11	Molniya	Entered lunar orbit on 28 Aug
	22 October	Luna 12	Molniya	Entered lunar orbit on 25 Oct; returned photos
	21 December	Luna 13	Molniya	Landed on Moon 24 Dec; returned photos and analyzed soil
1968	7 April	Luna 14	Molniya	Entered lunar orbit on 10 Apr
1969	19 February	---	Proton	Launch failure; did not reach Earth orbit
	14 June	---	Proton	Launch failure; did not reach Earth orbit
	13 July	Luna 15	Proton	Crashed on Moon 21 Jul; first attempt to return soil automatically
	23 September	Kosmos 300	Proton	Launch failure; stranded in Earth orbit
	22 October	Kosmos 305	Proton	Launch failure; stranded in Earth orbit
1970	6 February	---	Proton	Launch failure; did not reach Earth orbit
	12 September	Luna 16	Proton	Landed on Moon 20 Sep; returned soil sample to Earth 24 Sep
	10 November	Luna 17	Proton	Landed on Moon 15 Nov; lunar rover operated for 11 months
1971	2 September	Luna 18	Proton	Crashed on Moon 11 Sep; soil sample retriever
	28 September	Luna 19	Proton	Entered lunar orbit 3 Oct; returned photos
1972	14 February	Luna 20	Proton	Landed on Moon 21 Feb; returned soil sample to Earth 25 Feb
1973	8 January	Luna 21	Proton	Landed on Moon 16 Jan; lunar rover operated for 5 months
1974	29 May	Luna 22	Proton	Entered lunar orbit 3 Jun; returned photos
	28 October	Luna 23	Proton	Landed on Moon 6 Nov; failed to leave Moon with soil sample
1975	16 October	---	Proton	Launch failure; did not reach Earth orbit
1976	9 August	Luna 24	Proton	Landed on Moon 18 Aug; returned soil sample to Earth 23 Aug



▶ ***A Lunokhod rover looks back at the ramp it used to move onto the lunar surface from its landing vehivle.***


Luna 1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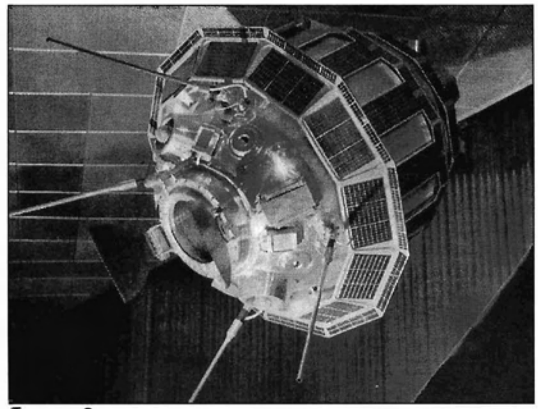
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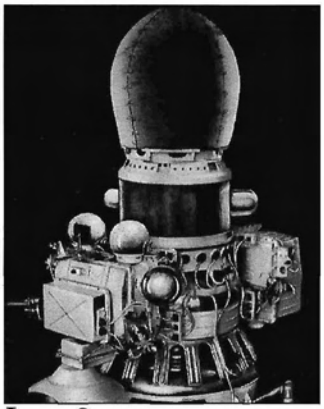
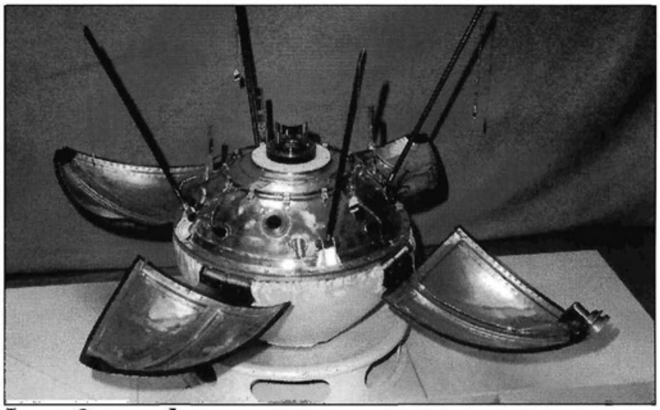
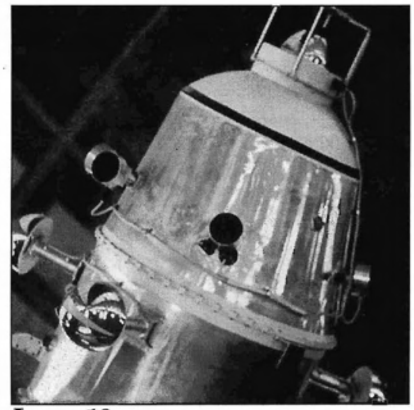
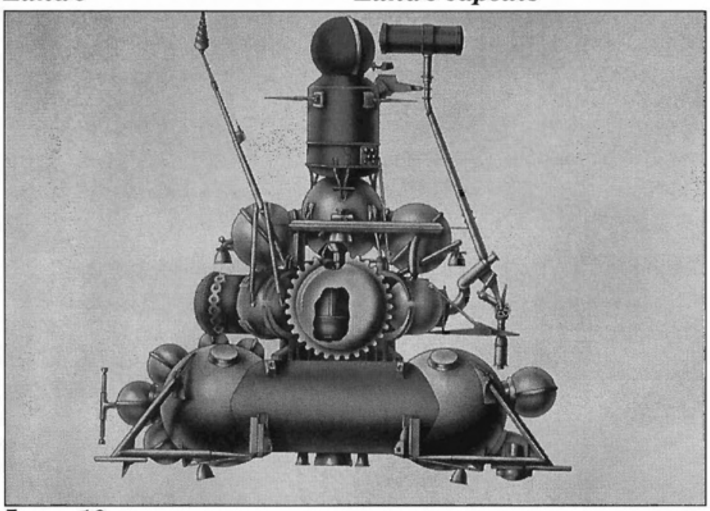
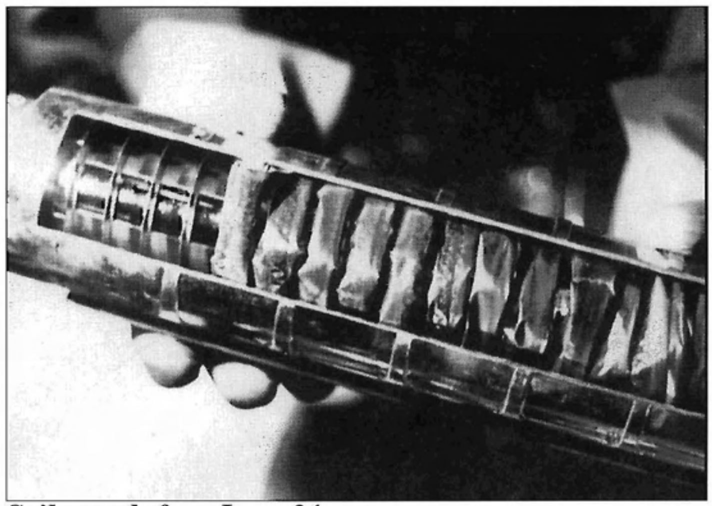
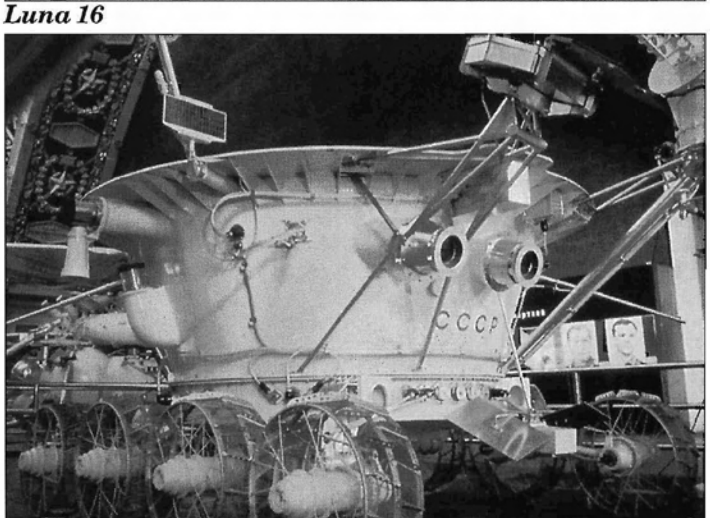

Luna 9


Luna 9 capsule

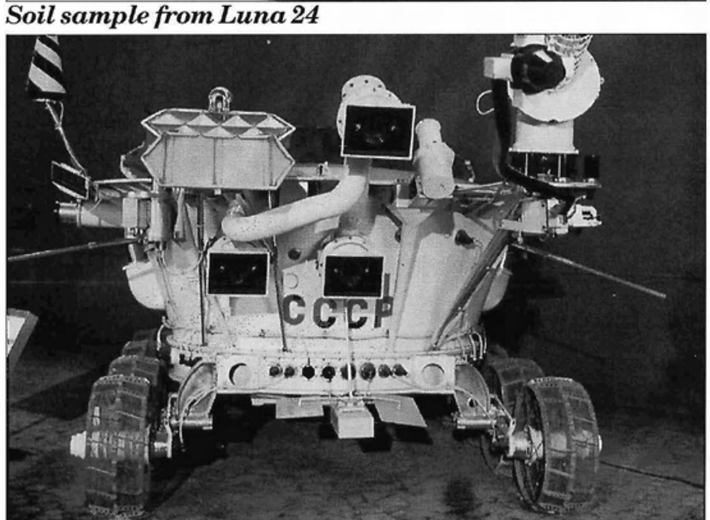

Luna 10


Luna 16


Soil sample from Luna 24



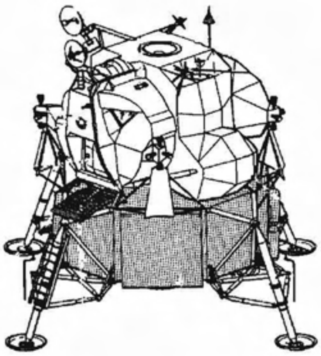
Luna 17/Lunokhod 1



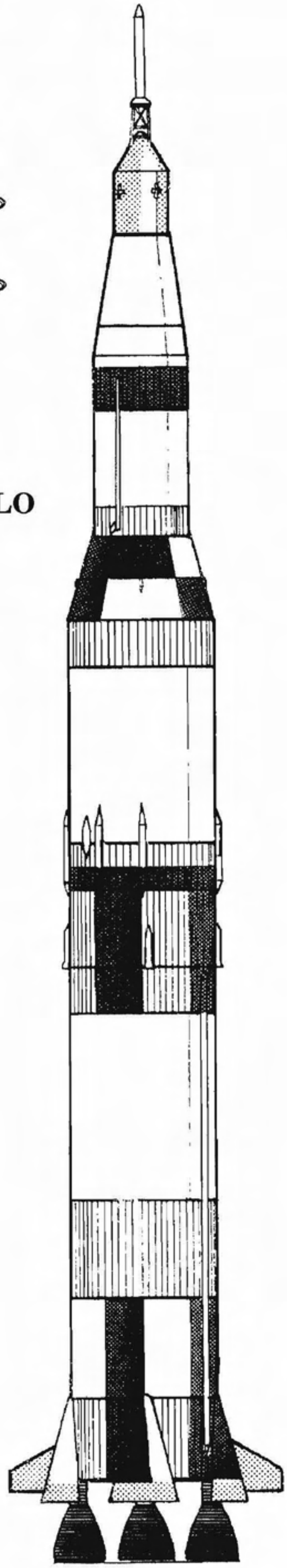
Luna 21/Lunokhod 2

US-USSR MANNED LUNAR PROGRAM HIGHLIGHTS

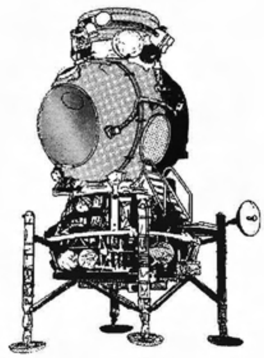
	UNITED STATES	UNION OF SOVIET SOCIALIST REPUBLICS	
	Apollo Lunar Program (Saturn V/Apollo)	Zond Circumlunar Program (UR-500/L-1)	L-3 Lunar Landing Program (N-1/L-3)
1961	US committed to a manned lunar landing before 1970 by President Kennedy	3-stage Proton booster (in development) designated for circumlunar flight	Original N-1 and N-2 launch vehicle programs officially approved
1962	Prelininary Apollo mission profile, including lunar orbit rendevous, approved		
1963			
1964	Boilerplate Apollo spacecraft launched by Saturn I	3-stage Proton/LK-1 design and mission profile adopted. nned lunar fly-by scheduled for 1967	Lunar landing mission adopted; Preliminary N-1/L-3 mission profile established; Lunar landing target date 1967-1968
1965		Maiden flight of 2-stage Proton; Circumlunar mission modified to 4-stage Proton with Korolev L-1 spacecraft	
1966	Manned spacecraft docking demonstrated in Earth orbit		Korolev dies; N-1/L-3 program officially adopted; Lunar landing set third quarter 1968
1967	Grissom, White, and Chaffee killed in Apollo 1 fire; Maiden flight of Saturn V with unmanned Apollo spacecraft successful	Maiden flight of 4-stage Proton and L-1 in Earth orbit successful but followed by three failures; Cosmonaut training begun	Komarov killed during flight of Soyuz 1; Initial N-1 flight tests delayed; Automatic spacecraft docking demonstrated in Earth orbit
1968	First manned flight of Apollo spacecraft; Unmanned lunar module tested in Earth orbit; First manned Apollo around the Moon	Four unmanned Zond circumlunar missions all end in failure (3 total, 1 partial)	Cosmonaut training for lunar landing begun
1969	First manned flight of lunar module in Earth orbit; Three manned missions to Moon, including two lunar landings	After another Zond failure in January, August mission successful but program canceled	Maiden flight of N-1 failed after 70 seconds; Second flight of N-1 failed immediately after launch — vehicle and launch pad destroyed
1970	Apollo 13 aborted lunar landing mission	Final unmanned Zond circumlunar mission only partially successful	Prototype of lunar lander (T2K) tested in Earth orbit
1971	Third and fourth Apollo lunar landings		Third N-1 flight failed after 7 seconds; Advanced N-1/L-3M program proposed
1972	Fifth and sixth Apollo lunar landings; Apollo program concluded		Fourth N-1 flight failed after 107 seconds
1973			
1974			Mishin replaced by Glushko; N-1 and N-1/L-3 programs cancelled



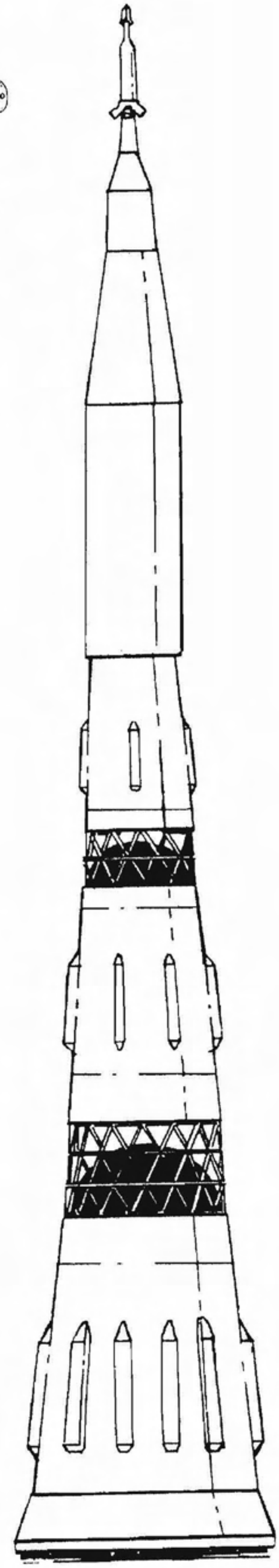
US Lunar Module



UNITED STATES - SATURN 5/APOLLO



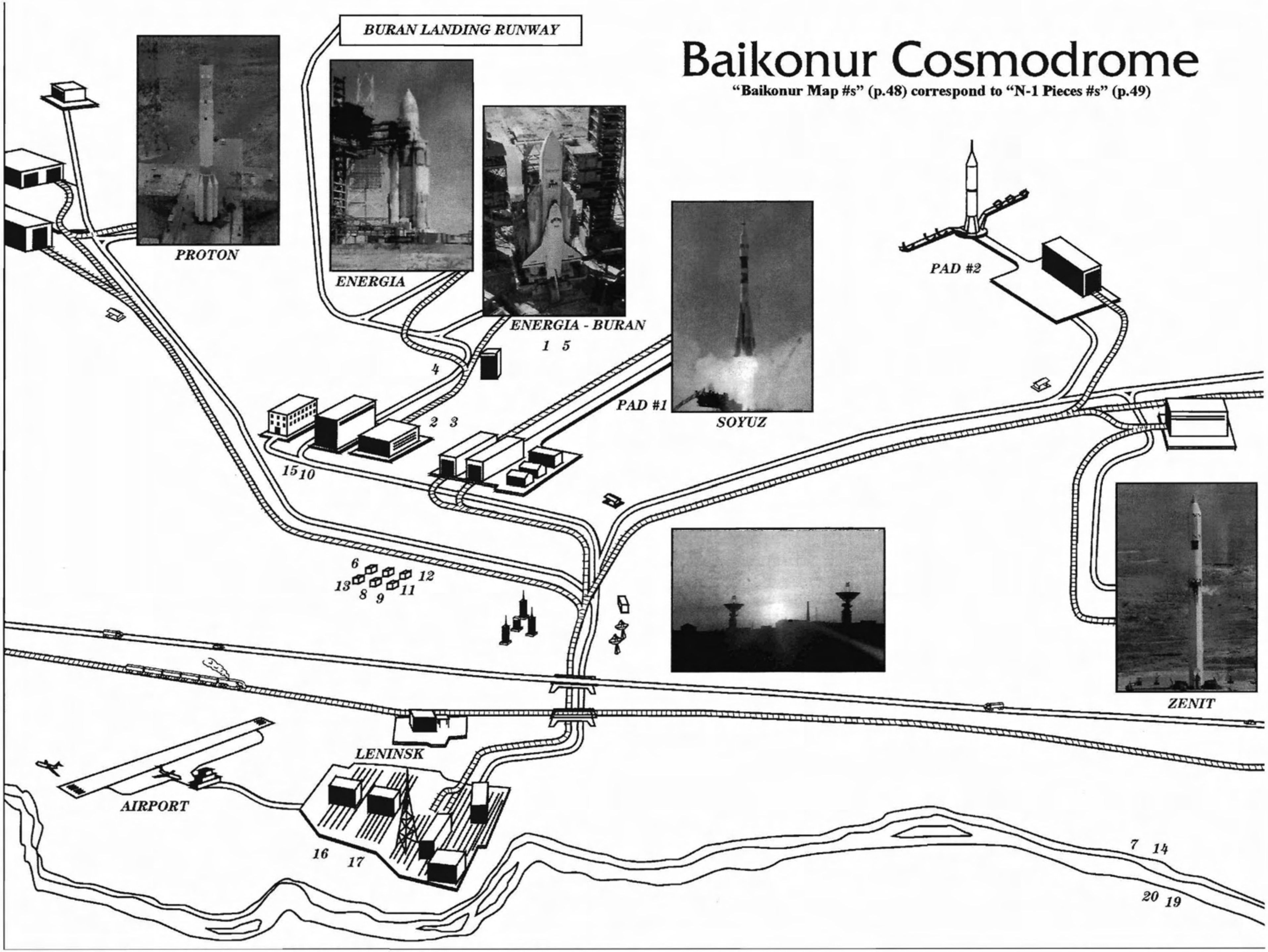
USSR Lunar Module



SOVIET UNION - N-1/L-3

Baikonur Cosmodrome

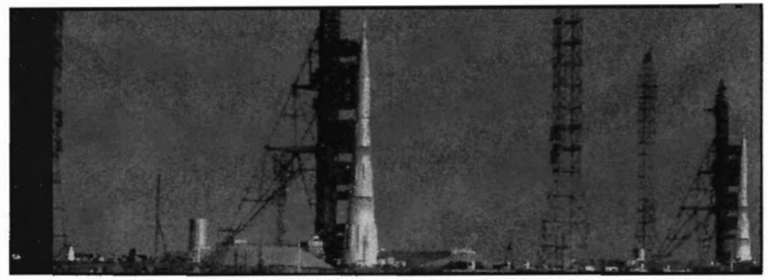
"Baikonur Map #s" (p.48) correspond to "N-1 Pieces #s" (p.49)



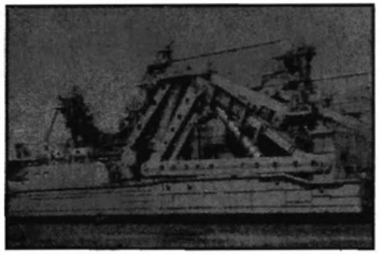
The N-1 "Moon Rocket" - today.

"Baikonur Map #s" (p.48) correspond to "N-1 Pieces #s" (p.49)

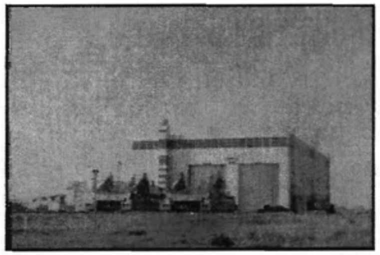
Those interested in the story of N-1 frequently ask - what happened to the N-1 vehicles? After the program was cancelled the vehicles were "cut-up." Pieces are scattered around the Baikonur Cosmodrome. Probably no outsider has visited Baikonur more than Dr. Matson. In the summer of 1992 he and his friends, Boris and Valentin (who live at Baikonur), visited the various locations (numbered on the map above) where pieces of the N-1 are now located. Their photos are presented (below). The old N-1 launch pads are now the Energia-Buran launch pads. [Compare photos #1 and #5].



(1) N-1 "Moon Rocket(s): on launch complex(s) - then



(2) Launcher transport

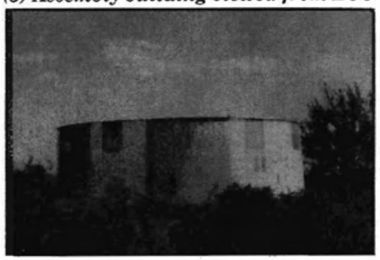


(3) Assembly building viewed from LCC

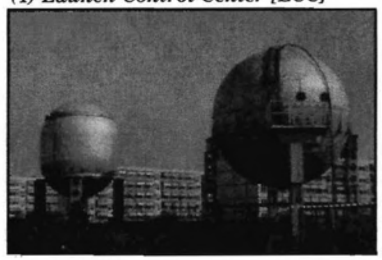
(4) Launch Control Center [LCC]

(5) Energia-Buran complex(s) - today

(6) Car port

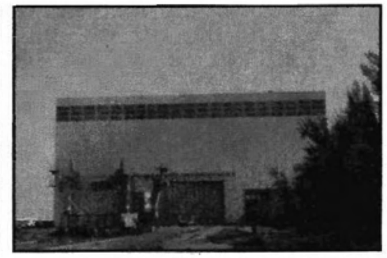


(7) Shroud from 1st tail section

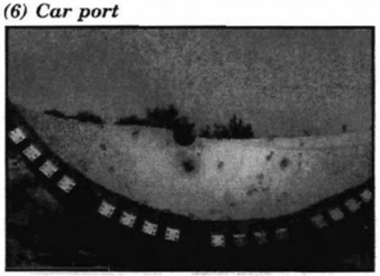


(8) Showers

(9) Solarium for sun tanning

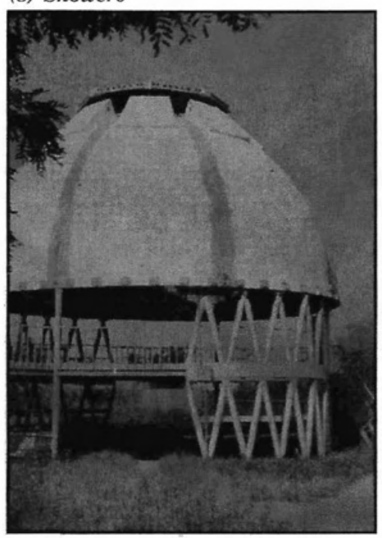


(10) Assembly building & transporter



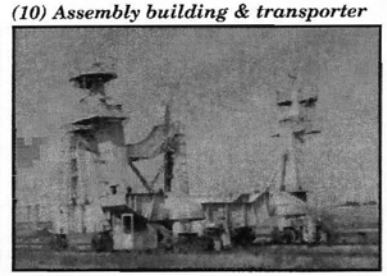
(11) Semi-tank of first stage

(12) Garage



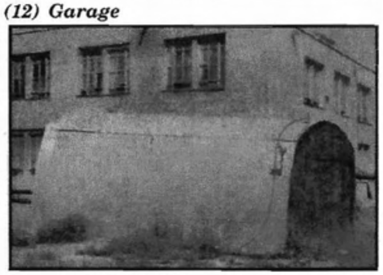
(13) Gazebo for relaxation

(14) Rec-center/Semi-tank first stage



(15) Transporter for head of launcher

(16) Children's playground



(17) Storage building

(19) Gazebo. Lattice from N-1 stabilizers

(20) first stage protection coverings

Principal Personnel of the Soviet Manned Lunar Program Era

• **Sergei A. Afanasyev**, Minister of General Machine Building. As head of the Soviet aerospace industry, Afanasyev was a prominent figure in virtually all government decisions regarding manned lunar programs. After repeated delays and failures in the Proton/Zond and the N-1/L-3 programs, he supported their termination and the appointment in 1974 of Glushko to replace Mishin.

• **Vladimir P. Barmin**, Chief Designer of Launch Complexes. Barmin was a founding member of Korolev's Council of Chief Designers, formed in 1946. He was responsible for the development of all three Soviet cosmodromes: Kapustin Yar, Baikonur (Tyuratam), and Plesetsk. Barmin supervised the design and construction of the N-1 launch pads at Baikonur, which were later modified to support Energiya-Buran launches.

• **Leonid I. Brezhnev**, First Secretary of the Communist Party of the USSR (1964-1982) and the Soviet leader during the entire official manned lunar program period. Despite authorizing considerable resources for the Proton/Zond and the N-1/L-3 lunar missions, Brezhnev exhibited little enthusiasm for space activities. At Ustinov's urging, Brezhnev retired Mishin in 1974, leading to the immediate cancellation of all N-1 and manned lunar exploration programs.

• **Vladimir N. Chelomei**, Chief Designer of Spacecraft and Rockets. The Chelomei Special Design Bureau (OKB-52) was formed in 1959 and was responsible for the development of the Proton launch vehicle as well as numerous military space systems. Four years before its first flight, the Proton booster was selected for the Soviet manned circumlunar program. The original LK-1 spacecraft design by Chelomei was replaced by Korolev's L-1 in 1965 to become the UR-500K/L-1 (Proton/Zond) program. Repeated failures of the Proton and unmanned Zond vehicles during 1967-1969 and the success of the Apollo missions led to the termination of the manned Zond program in 1969. A 1966 Chelomei manned lunar landing design for a complex (UR-700/LK-700) capable of direct ascent/direct return (i.e., no Earth orbit or lunar orbit rendezvous) was never adopted.

• **Boris Ye. Chertok**, Deputy Chief Designer of Spacecraft. A specialist in control systems, Chertok played leading roles in the Vostok and Voskhod manned spacecraft programs and was principal designer for the Molniya communications satellite. He was a principal designer on the N-1/L-3 program and became Mishin's deputy for the project after the death of Korolev. Chertok was Technical Director for the fourth and last N-1 launch (November, 1972) due to the hospitalization of Mishin.

• **Yuri A. Gagarin**, Cosmonaut and first man to orbit the Earth in 1961. Due to his extremely respected position within the Soviet cosmonaut corps, Gagarin was considered a likely candidate for a manned lunar mission. In 1967 he was the backup commander for the Soyuz 1 spacecraft, which closely resembled the lunar orbiter of the N-1/L-3 program. Gagarin was closely involved in the L-1 circumlunar program up to the time of his untimely death in March, 1968, in an aircraft accident. He was a principal candidate for these missions as well as under consideration for a lunar landing flight.

• **Valentin P. Glushko**, Chief Designer of Rocket Engines. Glushko was the principal designer and developer of rocket engines for Soviet ballistic missiles and space boosters, including the Sputnik/Luna/Vostok/Soyuz/Molniya and Proton launch vehicle families. His preference for hypergolic and exotic propellants led to a falling-out with Korolev, who preferred simple kerosene or hydrogen as fuels. Glushko refused to support Korolev's N-1 program and consistently lobbied against it. Moreover, Glushko designed the engines for the competing Chelomei (UR-700) and Yangel (R-56) heavy-lift launch vehicles. Consequently, Korolev was forced to enlist the aid of Kuznetsov in developing the rocket engines for the N-1. Glushko succeeded Mishin in 1974, terminated the N-1 program, and initiated the Energiya-Buran project.

• **Mstislav V. Keldysh**, Chief Theoretician of Cosmonautics and President of the USSR Academy of Sciences (1961-1975). Keldysh was named an Academician in 1946 and was a member of the Soviet space program's State Commission until 1961. As head of the Academy of Sciences and a peer of Korolev, Keldysh supported the manned lunar landing program. Keldysh led an expert commission which periodically reviewed the N-1 program and in the late 1960's tasked Mishin to design a new program (N-1/L-3M) for more extensive manned lunar exploration.

• **Nikita S. Khrushchev**, Premier of the USSR and First Secretary of the Communist Party of the USSR (1958-1964). Khrushchev was a strong advocate of the space program as a showpiece of Soviet technological achievement. He was a principal benefactor for Korolev but never formally approved a man-on-the-Moon program. Khrushchev was removed from office on 15 October 1964, two months before Korolev established the preliminary N-1/L-3 mission profile.

• **Sergei P. Korolev**, Chief Designer of Spacecraft and Rockets, Chairman of the Council of Chief Designers, and Father of the Soviet space program. Following his success with the R-7 (SS-6) ICBM and Sputnik, Korolev began designing a family of heavy-lift boosters in 1960. He led the development efforts for the manned Vostok, Voskhod, and Soyuz programs as well as the L-1 and L-3 lunar spacecraft. His dispute with Glushko in the early 1960's over rocket engine designs caused a schism in the Soviet space industry which delayed the manned lunar effort. Korolev's N-1 launch vehicle was selected for the manned lunar landing mission over competing designs from Chelomei and Yangel. Korolev died suddenly on 14 January 1966 during an operation, and the N-1/L-3 program was inherited by his deputy Mishin.

• **Semyen A. Kosberg**, Chief Designer of Rocket Engines. Kosberg was responsible for the development of the engines for the upper stage of the Luna, Vostok, and Voskhod launch vehicles, and for the second and third stages of the Proton launch vehicle. Kosberg died in January, 1965, and was succeeded by Alexander Konopatov.

• **Nikolai D. Kuznetsov**, General Designer of Aircraft and Rocket Engines. When Korolev could not convince Glushko to participate in the development of the N-1 booster, Kuznetsov was awarded the task of creating the main engines of all three stages of the N-1 as well as the first stage of the L-3 complex (i.e., the first four stages of the N-1/L-3). The Kuznetsov design bureau, which was located in Kuybyshev where Korolev's other boosters and spacecraft were manufactured, worked primarily for the aircraft industry and had little experience in rocket engines. In all, four engines (one type for each of the four stages) were developed. Following the cancellation of the N-1 program, the Kuznetsov design bureau was not involved in any further development of launch vehicle main engines, although his N-1 first-stage engines, NK-33, are now being considered for use in Western launch vehicles.

- **Alexei A. Leonov**, Cosmonaut and first man to exit a spacecraft. Following his famous 1965 space walk from Voskhod 2, Leonov was assigned in late 1966 as a senior member in the corps of 14 persons designated for the L-1 circumlunar program. In late 1967 he was chosen as one of 20 trainees for the L-3 lunar landing mission, which would require one of the two cosmonauts to perform three extravehicular activities (EVAs): two in lunar orbit and one on the lunar surface. In September, 1968, Leonov was selected to command one of three prime teams for the L-1 program. After the cancellation of the L-1 and the L-3 programs, Leonov went on to command the Soviet spacecraft involved in the Apollo-Soyuz Test Project in 1975.

- **Vasiliy P. Mishin**, Chief Designer of Spacecraft and Rockets and Principal Director of the N-1/L-3 program (1966-1974). Mishin assumed the leadership of the N-1/L-3 program upon Korolev's death in January, 1966. An able designer, Mishin had neither the influence nor the managerial skills of Korolev. Mishin could never overcome the ill-will and competition generated during the Korolev-Glushko feud. After losing the Moon race to the US and after four successive failures of the N-1, Mishin was replaced in 1974 by Glushko, who terminated the N-1 program in favor of his own heavy-lift booster, Energiya.

- **Nikolai A. Pilyugin**, Chief Designer of Autonomous Guidance Systems. Another member of Korolev's original Council of Chief Designers, Pilyugin established a reputation as an expert in guidance and control systems. He was called upon to develop the complex control system for the L-3 lunar lander.

- **Yuri P. Semenov**, Lead Designer of the L-1 lunar spacecraft, Chief Designer of the Mir space station and the Buran space shuttle, and later General Designer and General Director of the Energiya Scientific Production Association (descendent of the Korolev Special Design Bureau). After serving briefly at the Yangel Design Bureau, Semenov transferred to Korolev's OKB-1 where he was responsible for the design of the L-1 spacecraft. He succeeded Glushko as head of the Energiya Scientific Production Association in 1989.

- **Dmitri F. Ustinov**, Central Committee Secretary of the Communist Party and later Minister of Defense. Like Afanasyev, Ustinov was a highly influential person during the course of the Soviet manned lunar program era. He exerted overall control of the manned lunar programs through the Military-Industrial Commission of the Council of Ministers, and he was closely aligned with Glushko and Chelomei. Ustinov is credited with being the principal behind the dismissal of Mishin in 1974 and the termination of the manned lunar landing effort.

- **Mikhail K. Yangel**, General Designer of Spacecraft and Rockets (1954-1971). The Yangel Design Bureau (KB) in Dniepropetrovsk, Ukraine, was responsible for the development of several ballistic missiles and space boosters, in addition to small geophysical and Earth observation spacecraft. Yangel was assigned the task of creating the L-3's lunar landing system. He died in 1971 two months after the last of three Earth orbital tests of the L-3 prototype (T2K). Vladimir Utkin succeeded Yangel, but the L-3 effort ended a few years later. ●

Chronological Bibliography

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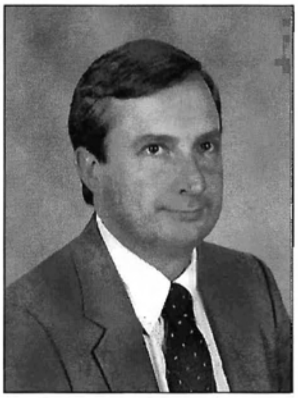
About the Author



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▶ ***Inside back cover: Transporting and erecting the huge N-1/L-3 launch vehicle complex presented numerous engineering challenges***

▶ ***Back cover: Although never successful, the launch of the N-1 was aweinspiring.***