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Chapter 18

The First Soviet Lunar Flights*

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Abstract

This chapter is devoted to an analysis of the first Soviet pioneer lunar spacecraft (SC). This is the SC *Luna 1* (January 1959, "Mechta"—"A Dream") with the first close flyby of the Moon and scientific investigation of the near-Moon space, the first artificial planet. This was followed by the SC *Luna 2* (September 1959) with the first impact of the lunar surface and investigating the near-Moon vicinity to its surface. And, finally, there was the automatic interplanetary station *Luna 3* (October 1959), which made the first photos of the far side of the Moon and successfully sent them to the Soviet control ground station. The first lunar gravity assist was performed in this flight in order to fulfill the aims which were put to the station. We provide here an analysis of the Soviet science-technology achievements that allowed these outstanding projects to be realized. We also provide an analysis of their influence on the development of world cosmonautics including the first manned flight of Yuri Gagarin and subsequent lunar and interplanetary projects.

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Introduction

The Moon is of great importance for humankind. People dreamed of a flight to the Moon since olden times. Beginning with K. E. Tsiolkovsky, pioneers of cosmonautics paid great attention to lunar spaceflights, in particular, to scientific investigations of the properties of lunar trajectories, their energy, time and navigation characteristics. When practical astronautics began, the leaders of Soviet cosmonautics S. P. Korolev and M. V. Keldysh quickly included the lunar investigations in the Soviet space program, and the scientific and technological prerequisites for their realization were developed. Soon the first lunar projects were realized.

This chapter is devoted to an analysis of the first Soviet pioneer lunar spacecraft. This is SC *Luna 1* (January 1959, "Mechta"—"A Dream") with the first near flyby of the Moon and the scientific investigation of the near-lunar space, the first artificial planet. Then, there is the SC *Luna 2* (September 1959) with the first impact of the lunar surface and the investigation of the area surrounding the surface of the Moon. And, finally, there is the automatic interplanetary station *Luna 3* (October 1959), which made the first photos of the far side of the Moon and successfully sent them to the Soviet control ground station. The first lunar gravity assist was performed in this flight to fulfill the aims which were put to the station.

There is given here an analysis of the Soviet science-technology achievements that allowed the realization of these outstanding projects. Their influence on the development of world cosmonautics, including the first manned flight of Yuri Gagarin and the following lunar and interplanetary projects, are also dealt with.

Creation of Rocket-Space Technology and Science in the USSR

The practical possibility of lunar flights appeared only after World War II. During this time, the Soviet Union was obliged not only to restore our destroyed country, but also to ensure military parity with the United States. One of the main lines of this activity was in rocket technology and science. Here was utilized the unique experience of our country in the rocket investigations by K. E. Tsiolkovsky, F. A. Tsander, Ju. V. Kondratyuk, GIRD, GDL, RNII, "Katyusha" etc. It was also incorporated the German experience in rocket construction. Leadership of the Soviet Union paid close attention to rocket technology and science. Some decisions by the USSR Council of Ministers were taken regarding this. So, J. V. Stalin signed the first decrees "Problems of Jet Armaments" on 13 May 1946, and "On a Plan of Scientific and Investigating Works in 1953–1955 for Long-Distance Rockets" on 13 February 1953 [1]. As a result, in the course of about ten years, 1946–1957, the Soviet Union created modern rocket technology and science [1–5]. In particular, by the middle of 1957 was developed the intercontinental ballistic two-stage rocket R-7, 8K71, by the OKB-1 with the Chief Designer S. P. Korolev (Figure 18–1, [6], V. 3), in cooperation with many other technology, science and testing companies. With some modification, that rocket operates to this day, perhaps, as the best rocket [5]. Necessary infrastructure was created and cosmodrome "Baikonur" was built (Figure 18–2 [4]).

Figure 18–1: S. P. Korolev, I. V. Kurchatov, M. V. Keldysh, and V. P. Mishin—July 1959, Moscow. Credit: [6], Book 3.

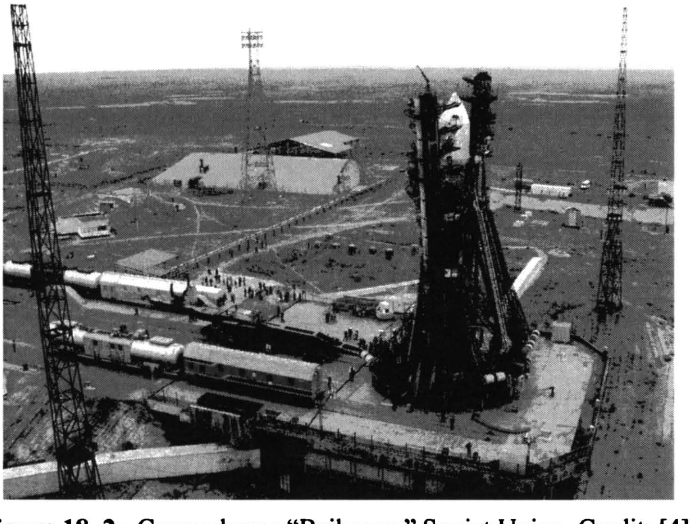


Figure 18–2: Cosmodrome "Baikonur," Soviet Union. Credit: [4].

A highly accurate onboard system for the control of the rocket motion during launch was developed. There was also created a ground-based command-measuring complex ("KIK") with a network of ground-based stations for radio observation and a net of stations for optical observation [7]. This complex allowed the control and navigation of the rockets and spacecrafts motion.

Several groups of the specialists in the ballistics of rockets and spacecraft were also set up:

- a group in the Design Bureau OKB-1, now it is the S. P. Korolev Rocket Space Corporation (S. S. Lavrov, R. F. Appazov et al.);
- a group in the Branch of Applied Mathematics of the Mathematical Institute of the Soviet Academy of Sciences (OPM MIAN SSSR), now it is the M. V. Keldysh Institute of Applied Mathematics, Russian Academy of Sciences (D. E. Okhotsimsky (Figure 18–3 [8]), T. M. Eneev et al.);
- two groups in the Institute NII-4 of the Defense Ministry—a group of M. K. Tikhonravov, and a group of P. E. El'yasberg (Figure 18–3), etc.

Mathematical methods were developed for determining the rocket and SC orbits, and for the processing of trajectory measurements [9–13].

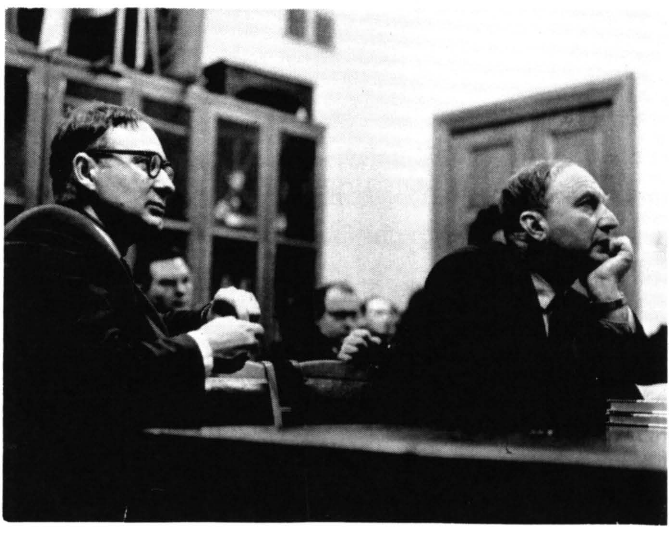


Figure 18–3: D. E. Okhotsimsky and P. E. El'yasberg, at a seminar in M. V. Lomonosov Moscow State University. Credit: [8].

Soviet electronic computers ("Strela" (Figure 18–4 [8]), "Ural," "BESM," etc. [14–16]) were created. These computers allowed, in particular, the quick processing of measuring information, determination of the rocket and spacecraft orbit, and prediction of their following motion. For these works, there were created two special Coordination and Calculation Centers—in the Institute NII-4, and in the Institute OPM MIAN USSR.

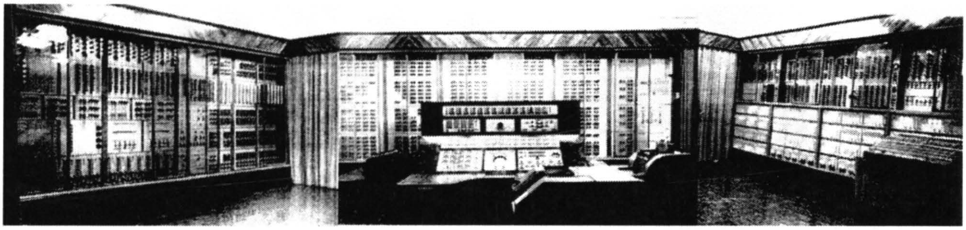


Figure 18–4: Computer "Strela," OPM MIAN SSSR—M. V. Keldysh Institute of Applied Mathematics, Moscow, 1959. Credit: [8].

As result, on 4 October 1957, the first artificial Earth satellite *Sputnik 1* was launched by the rocket R-7 [5]. The new space era in the history of our civilization had now begun.

Leaders of the Soviet space program S. P. Korolev and M. V. Keldysh have paid great attention to lunar space exploration. They undertook a major effort in organizing the science and technology needed to realize it [3]. Soon, using the rocket R-7, OKB-1 created the three-stage rocket-launcher (RL) 8K72 [5]—"Vostok-Lunnik," Figure 18–5 [17].

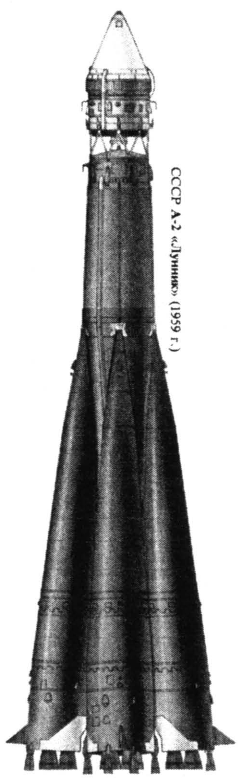


Figure 18–5: Three-stage rocket "Vostok-Lunnik" for flight to the Moon, 1958. Credit: [17].

This rocket was able to fly to the Moon with a total final mass of about 1,500 kg and a payload mass of 300–450 kg. The system of rocket motion control for launch, and the ground-based command-measuring complex (KIK), as well as the SC onboard navigation system were developed.

Young scientist V. A. Egorov (OPM MIAN SSSR, Figures 18–6, 18–7 [8]) developed the theoretical basis for the lunar trajectories [18]. He has first shown that it is possible to impact on the Moon without the correction using a hyperbolic orbit.

Some equipment for scientific space investigations was created [1].

Figure 18–6: V. A. Egorov (1930–2001). Credit: [8].

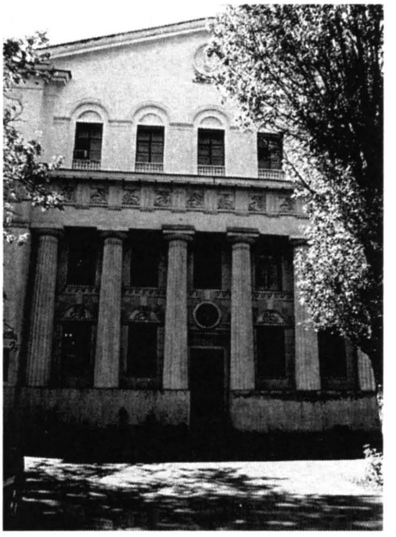


Figure 18–7: OPM MI AN SSSR—M. V. Keldysh Institute of Applied Mathematics. Credit: [8].

The First Flights to the Moon

The First Flight to the Moon

After three test starts, on 2 January 1959, at 19:41:21 Moscow time (MT), there was performed the world's first flight to the Moon [1, 19–22]. It was the Soviet spacecraft in the context of the Soviet Lunar Project E-1 of impact on the Moon. During the initial (powered) path of the trajectory, the Soviet rocket-launcher for the first time ever achieved escape velocity (the second space velocity), then exceeded it at about 175 m/s [1]. After that, the engine of the rocket was switched off, and the scientific "container," i.e. the spacecraft, separated from the rocket. The separate flights of rocket and spacecraft began.

The rocket and the spacecraft were launched on two close trajectories of passive hyperbolic flight to the Moon. The final rocket velocity (after ~730 seconds of powered flight) had to exceed the escape velocity by 134 m/s, and, according to the project, after 35 h, 28 m, 3 s (about 1.5 days) [1] of the flight, the SC had to meet the Moon. At the separation, the total mass of rocket was 1,472 kg, while the payload mass was 361.3 kg, including the SC mass of 187 kg.

Practically, in two hours of flight, according to measurements of flight parameters, the flight orbits of the rocket and probe were determined and it was found that the final real rocket velocity exceeded the nominal one by 41 m/s and was greater than the escape velocity by 175 m/s [1, 23–24]. This resulted in any shifting the SC from Moon. In ~1.5 days of the flight, the SC passed the Moon at the distance of ~5,995 km.

To observe the rocket flight by optical means from 14 Soviet stations and some foreign ones, a large cloud of sodium gas—an artificial Na-comet was created by the special device on the rocket, on 3 January, 3 h, 57 m, at the distance of $113 \cdot 10^3$ km from the Earth. During the flight, scientific measurements were taken, and the SC parameters (including parameters of its motion) were measured and sent to the Soviet stations.

A scheme of the geocentric flight is shown in Figure 18–8 [21]. The Soviet stations in Crimea and Kamchatka [1] as well as the US JPL station [24–25] confirmed the flight of *Luna 1* near the Moon and beyond it.

Then, the probe went out of the Earth sphere of influence and became the first artificial planet of the solar system [19–21]. Its distances to the Sun were $\sim 147 \cdot 10^6$ km in perihelion and $\sim 198 \cdot 10^6$ km in aphelion, see Figure 18–9 [21].

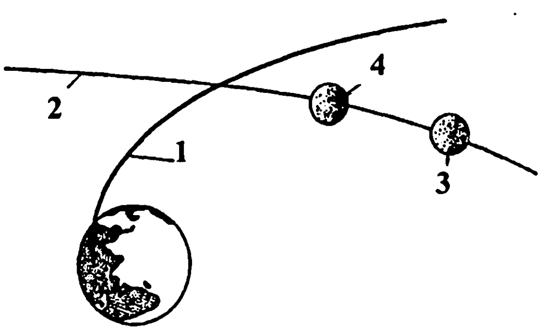


Figure 18–8: Geocentric flight of the spacecraft *Luna 1* (1: trajectory of SC; 2: Moon's orbit; 3: Moon at the SC start time; 4: Moon at the SC approach). Credit: [21].

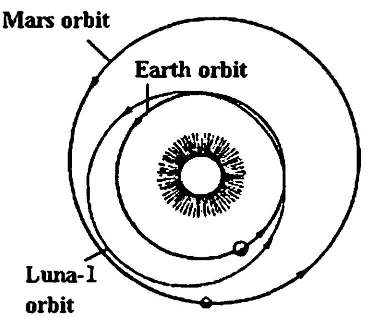


Figure 18–9: Heliocentric orbit of *Luna 1*. Credit: [21].

This spacecraft was named the *Luna 1*. It was the outstanding success and achievement of not only the Soviet Union but also of all the humankind. It was the first flight to the Moon. Firstly, the escape velocity was overcome. The first artificial satellite of the Sun was created. Some scientific measurements in the space between the Earth and the Moon, as well as in the vicinity of the Moon were taken. In particular, the absence of a magnetic field near the Moon was discovered. This flight became the realization of a very old dream of humankind to fly to the Moon. Because of this, journalists soon named this spacecraft "Mechta," or "Dream" (in English).

Then, two months later, on 3 March 1959, the first US probe to the Moon was launched, *Pioneer 4*. Its mass was ~6 kg. It passed the Moon at the distance of ~60,000 km and then became the second artificial satellite of the Sun.

The launch and flight of the first Soviet "Lunnik" showed the very high level of Soviet science and technology, the guidance and control systems [25], in particular. It resulted in hearings in the US Congress, which were held during the period 11–29 May 1959 [26].

First Impact on the Moon

Soon, on 12 September 1959, 9 h, 39 m, 26 s (MT) [3, 27] was launched in the USSR the second rocket and spacecraft to the Moon (*Luna 2*, Figure 18–10 [28]) with the goal to impact on the Moon.

Figure 18–10: The spacecraft *Luna 2*. Credit: [28].

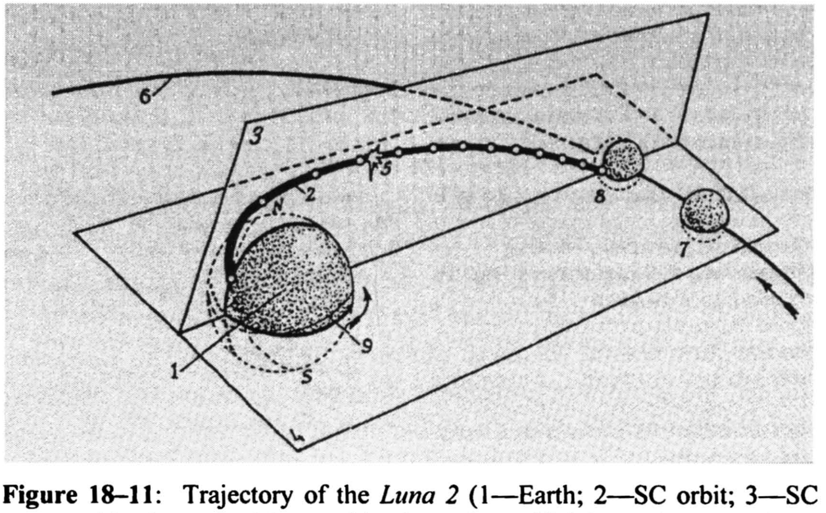


Figure 18–11: Trajectory of the *Luna 2* (1—Earth; 2—SC orbit; 3—SC orbit plane; 4—Moon orbit plane; 5—artificial Na-cloud; 6—lunar orbit; 7—Moon; 8—the point of the SC impact on the Moon surface; 9—Earth equator; N, S—North and South poles of Earth). Credit: [29].

On the way, an artificial sodium "comet" was made again to observe the flight. In ~1 d, 14 h, 23 m of flight, on 14 September, 00 h 02 m 24 s (MT), the SC *Luna 2* at the first time landed on the lunar surface. Figure 18–11 gives an orbit of *Luna 2* [29].

For the *Luna 2* orbit, velocity impact with the Moon was ~3.3 km/c. The impact on the Moon was confirmed by both Soviet and foreign observers using the experimental fixing of the loss of the radio signals from the spacecraft.

In particular, the information was sent in a timely fashion to Prof. A. C. B. Lovell, British Observatory Jodrell Bank [3]. NASA also used this data to determine the *Luna 2* orbit and to confirm the success of *Luna 2*.

Before the *Luna 1* flight, S. P. Korolev asked his RNII-colleague and friend, Arvid V. Pallo, to design a pennant ("Vympel") of the Soviet Union, to make it, put it on the space capsule and carry it to the Moon [23]. *Luna 1* was not able to bring it there.

Figure 18–12: *Luna 2* pennants. Credit: [28].

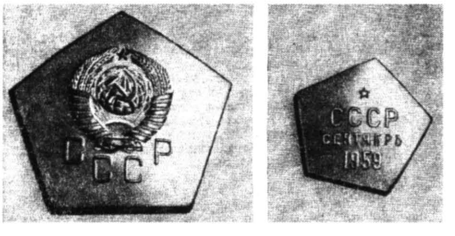


Figure 18–13: Elements of the pennants of the Soviet Union for the *Luna 2*. Credit: [20].

Now, *Luna 2* brought the pennants of the Soviet Union to the Moon. Two pennants (one in the container, another in the rocket) were metal "balls" (~7.5–9 cm and ~12–15 cm in diameter), with surfaces from pentangular elements where there were shown the USSR coat of arms with letters "CCCP" (USSR) and the words "CCCP Сентябрь 1959" ("USSR September 1959"), Figures 18–12 above and 18–13 [20, 30, 28]. And two pennants were metal ribbons (Figure 18–12 below) that were rolled and placed in two capsules filled with liquid. They were put in the container, too. The next day, 15 September 1959, Soviet Leader Nikita S. Khrushchev went to the United States and took a wooden box with a copy of the spherical pennant and two ribbons. There he presented them to President Dwight Eisenhower, Figure 18–14 [3].

According to the orbit determined by ballistic centers in NII-4 (P. E. El'yasberg group) and OPM MIAN SSSR (D. E. Okhotsimsky, T. M. Eneev, E. L. Akim group) after processing the trajectory measurements, the point of impact on the lunar surface was determined: longitude λ≈0°, altitude φ≈+29.1°, with a possible error of ~350 km.

Figure 18–14: N. S. Khrushchev presents to D. Eisenhower a copy of the *Luna 2* pennant, September 1959. Credit: [3].

To achieve such high accuracy it was necessary to use not only the navigation system of the rocket and the spacecraft, but also interferometer angular measurements made with two antennas of the Crimea Astrophysics Observatory of Physical Institute of Academy of Science, Soviet Union, Figure 18–15 [28, 31]. This point was also checked with scientists abroad. It is shown in Figure 18–16.

Figure 18–15: Antenna of the Crimea Astrophysics Observatory of Physical Institute, Academy of Science, Soviet Union. Credit: [28].

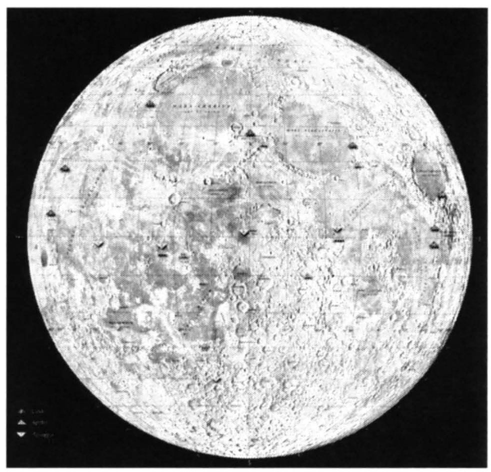


Figure 18–16 (right): Map of the Moon with places of hard and soft landing for Lunas, Surveyors, and Apollos: http://nssdc.gsfc.nasa.gov/planetary/lunar/moon_landing_map.jpg. Credit: NASA.

Some scientific investigations were made during this flight. The main discovery was the absence of the lunar magnetic field.

The US spacecraft *Ranger 4* first arrived on the Moon in 1962.

First Photos of Lunar Far Side

Shortly afterward, in about 20 days after the *Luna 2* flight, on 4 October, 03:43:40 (MT), 1959, the next lunar spacecraft, *Luna 3* was successfully launched, in Project E-2, a project to photograph the far side of the Moon [32].

Figure 18–17 gives an image of this spacecraft [3]. The spacecrafts *Luna 1*, *2* and *3* were being designed in OKB-1 by G. Ju. Maksimov (the chief designer, Figure 18–18), V. V. Molodtsov (E-1), V. K. Algunov (E-2), M. I. Gerasimova, N. I. Protasov, V. I. Petrov, O. G. Ivanovsky, M. S. Floriansky et al., at first, from ~June 1956 in K. D. Bushuev–S. S. Kryukov's Department 3, then, from ~March 1957 in M. K. Tikhonravov's Department 9.

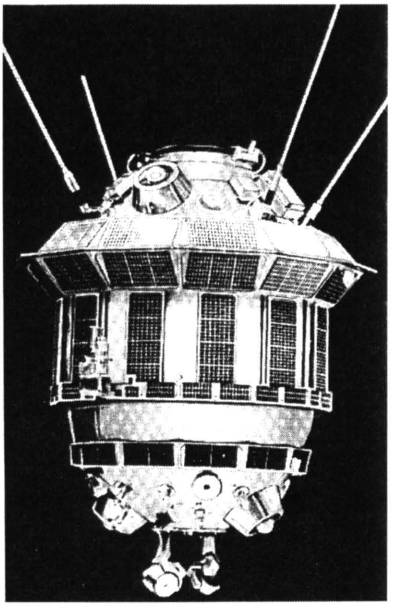


Figure 18–18: G.Ju. Maximov (1930–2001). Credit: [8].

Figure 18–17: Lunar station *Luna 3*. Credit: [3].

Some problems were quickly detected and very effectively resolved for this mission:

(a) Determination of space trajectory, Figure 18–19 (OPM MI AN, a group of D. E. Okhotsimsky under leadership of M. V. Keldysh [33], Figures 18–20, 18–21, and ballistic groups in OKB-1 [15] and NII-4);

(b) Creation of photo-TV device "Enisey" (NII-380, Leningrad Scientific-Research Institute of Television) [3];

(c) Development of radio system for sending commands from Earth to the spacecraft, and photographs from the spacecraft to Earth (NII-885, E. Ja. Boguslavsky, Figure 18–22 [3, 7]);

(d) SC orientation and stabilization system (NII-1 and OKB-1, a group of B. V. Raushenbakh, Figure 18–23 [3, 34]), etc.

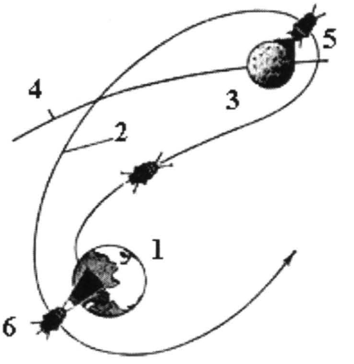
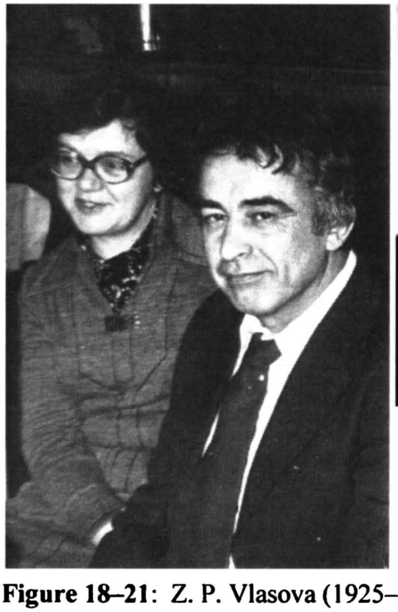


Figure 18–19 (left): Flight of the lunar station *Luna 3*. (1: Earth; 2: SC orbit; 3: the Moon; 4: Moon's orbit; 5: Photo of the lunar far side; 6: sending photos on Earth). Credit: [21].

Figure 18–20 (right): A. K. Platonov and D. E. Okhotsimsky (1921–2005). Credit: [8].



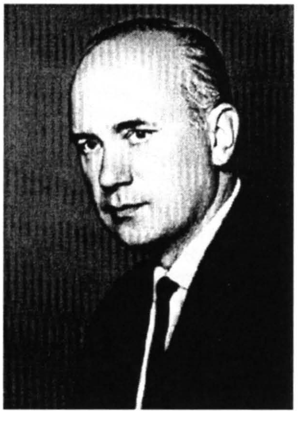


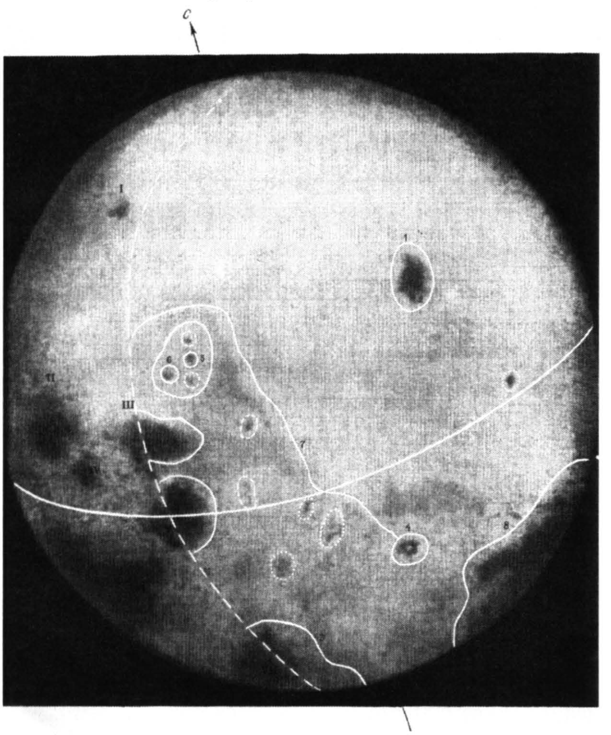
Figure 18–22 (left): E. Ja. Boguslavsky. Credit: [3].

Figure 18–23 (right): B. V. Raushenbakh. Credit: [3].

Figure 18–21: Z. P. Vlasova (1925–2005); M. L. Lidov (1926–1993). Credit: [8].

All these problems were very difficult. So, the trajectory had to correspond to the energy limitations of the rocket, to the capabilities of the spacecraft and its systems, to satisfy the conditions for photographing and sending the information to Soviet ground-based stations. It had to be stable enough in the initial data variations caused by the rocket control system errors in order to solve the problems without trajectory corrections after completion of launch and the beginning of passive flight. The basic study [33] allowed finding the trajectory. In particular, to realize the aims of this mission, the lunar gravity assist was suggested (probably, by D. E. Okhotsimsky), introduced to the trajectory and performed first during the *Luna 3* flight.

On 6 October, 17:16, 1959, in ~2.5 days of the flight, the spacecraft flew by the Moon, at ~6,200 km. On 7 October 1959, at a distance of ~65,000 km from the Moon, 70 percent of the Moon's far side was photographed. As the lunar station approached the vicinity of Earth the photos were relayed by TV-signals to the Soviet station during the radio connection time. Thus, for the first time, the far side of the Moon was photographed and shown to all humankind, Figure 18–24 [32]. In 1965, the Soviet spacecraft *Zond 3* made the photos for another part of the lunar far side [21].



Near Side: I—Mare Humboldtianum; II—Mare Crisium; III—Mare Marginis; IV—Mare Undarum—not confirmed; V—Mare Smythii; VI—Mare Fecunditatis; VII—Mare Australe;
Far Side: 1—Mare Moscoviense; 2—Sinus Astronauts in Mare Moscoviense—not conf.; 3—Mare Australe (conf.); 4—Tsiolkovsky; 5—Lomonosov; 6—Joliot; 7—Montes Sovetsky—not conf.; 8—Mare Ingenii.

Figure 18–24: The first photo of the lunar far side, 7 October 1959. Credit: [32].

Review of Main Energy and Navigation Characteristics for the First Lunar Projects

Now, we give a brief summary review of main characteristics of the first Soviet lunar projects E-1, E-2, SC *Lunas 1*, *2*, and *3*, in energy and navigation [1–5, 16, 19–21, 24–25, 27–28, 32–33, 35–37].

Main Energy Characteristics

First, the main energy characteristics of the first lunar flights *Lunas 1*, *2*, and *3* are considered.

1. The spacecraft are launched to lunar orbit from the Soviet Cosmodrome Baikonur by a three-stage rocket 8K72 "Vostok-Lunnik" with a continuous active launch path. The rocket's initial mass is ~290 t [5].

2. The third stage initial mass is ~8,000 kg. Its thrust is ~50,000 N. The fuel is oxygen-kerosene, its mass is ~6,500 kg, the stage final mass is ~1,500 kg. The payload mass is ~350–450 kg. The gravity losses are large as the launch path is continuous and the flight-path angle is large at the final part of the launch. This indicated the necessity to change from a continuous launch path to a path with intermediate passive flight along a waiting orbit. This was made for the four-stage rocket 8K78 and next generation of lunar flights (*Luna 9*, etc.) and planetary flights [21].

3. To decrease the gravity losses and characteristic velocity during the launch from Baikonur, the optimal trajectory corresponds to the flight to the Moon in its extreme-south declination [19].

4. For the spacecraft *Luna 1*, *Luna 2*, hyperbolic geocentric trajectories were taken for the first flights to the Moon. Initial nominal velocity for passive flight exceeded the escape velocity by ~130 m/s. This gave a small enough influence of the rocket control system errors on the trajectory variations near the Moon (this was necessary because of absence of the trajectory correction during passive flight) and the flight duration of ~1.5 days. This duration of the flight gave the good possibility to observe the spacecraft approach to the Moon by the Soviet stations [19].

5. For the spacecraft *Luna 3*, to get the trajectory with a fly-by of the Moon for the photo and a return to the Earth, the elliptic geocentric trajectory with lunar gravity assist was used. Its initial nominal velocity for passive flight was lower than the escape velocity by ~60 m/s. This resulted in acceptable trajectory variations near the Moon for the flight without trajectory corrections [34]. The flight duration of ~2.5 days also provided a good possibility for observing the spacecraft near the Moon. Decreasing the initial velocity by ~190 m/s resulted in de-

creasing the launch time by ~6 sec and fuel mass consumption by ~100 kg. This allowed increasing the mass of the spacecraft from 187 kg to 278 kg.

6. This analysis shows the difficulties when there is no trajectory correction. The next generation of lunar flights (*Luna 9*, etc.) and interplanetary flights had orbital correction. This also allowed an increase in the flight duration which led to reducing fuel consumption at launch and decreasing the deceleration velocity near the Moon.

7. The *Luna 3* flight showed that the lunar gravity assist can help essentially to perform the space mission. Because of this, lunar and planetary assists were also used in some future projects.

Main Navigation Characteristics

The first Soviet lunar projects E-1 and E-2, the spacecraft *Luna 1*, *2*, and *3* have had no orbital correction.

1. The necessary accuracy of the flight was ensured by the launcher control system. This one was a combined system. First, it included an onboard inertial gyroscopic control system, developed by NII Avtomatiki i Priborostroeniya (NII AP), N. A. Pilyugin (Figure 18–25, [6], V. 2), V. I. Kuznetsov [38]. Additionally, for the second stage, until around 1970, the flight was controlled by a radio-control system (RUP, NII-885, M. S. Ryazansky [35, 38]). Figure 18–26 shows its scheme [35].

Figure 18–25: N. A. Pilyugin and S. P. Korolev, 1948, Kapustin Yar. Credit: [6].

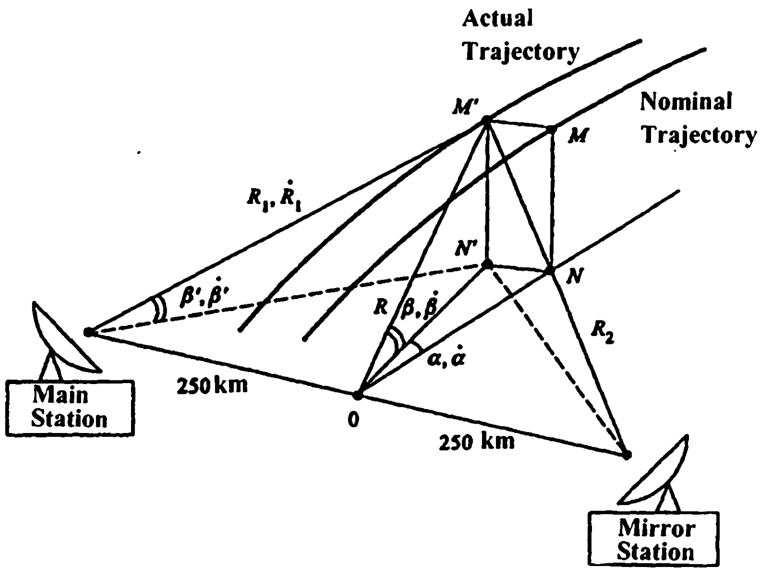


Figure 18–26: Scheme of the radio control system. Credit: [35].

2. The orbits of the launcher and the spacecraft were first estimated (for one to two hours) by the radar tracking—using the trajectory radio measurements on the launch path and the near-Earth path (to the range of $10–20 \cdot 10^3$ km) of the passive flight. The measurements of the range and angles in S-band (2.7–2.8 GHz) are used with errors of ~10–40 m and 5–10′. Ground-based stations Binokl-D (the range measurements), Kama-E (range and angles), Bambuk (time) were used for this purpose. An onboard last-stage launcher S-band impulse system "Fakel-S" was utilized.

3. Then, second, the spacecraft trajectory was updated using radio measurements by the system RTS-E1,2 of the long-range radio-communications (the system "velocity vector," RTS-12B). It was the world's first spacecraft radio system that used long-range radio measurements. The system was operated in meter-band (102–183.6 MHz). It was made especially for these projects by NII-885 and designed by E. Ja. Boguslavsky, Figure 18–22. The *Luna 1* flight showed that it operates up to ~$500–600 \cdot 10^3$ km. The temporary ground-based station in Crimea, near Simeiz, on the mountain Koshka (cat in English) was quickly constructed for that purpose. Here was used an antenna with area of ~100 m^2 for this system. The system was multifunctional and was used for tracking, telemetry and, in the case of *Luna 3*, for commands. There was an onboard two-way radio system RTS-12B—for receiving and transmitting radio signals in meter band on the spacecraft. The range, Doppler velocity, and angles were measured by this system with errors of ~20 km in range, and of ~15 cm/s in velocity. For the space-

craft *Luna 2*, two near 200 m^2 antennas of the Crimea Astrophysics Observatory were used to get the interferometer angular measurements and improve the orbit and impact point estimation.

4. For the *Luna 3* flight, OPM MI AN (V. A. Egorov, T. M. Eneev, M. L. Lidov et al.) developed and used at the control center in Simeiz an approximate graphic method for the determination of the *Luna 3* orbit from the range and range-rate measurements [39]. Another approximate method for analysis of the measurements was developed and used by the group from the NII-4 (O. V. Gurko et al.). The analysis showed that the real spacecraft practically moved along the nominal, exact trajectory.

5. As a result, the flights of the spacecraft *Luna 1*, *2*, and *3* showed that the launch control system and the spacecraft navigation system for these projects were accurate enough. *Luna 1* did not impact on the Moon, but it shifted at a small enough distance from the Moon, and most systems operated well. The following *Pioneer 4* flew at an essentially greater distance from the Moon. For *Luna 2* the impact point was close to the center of the lunar disc and was well estimated. *Luna 3* fulfilled its mission perfectly.

6. After these lunar projects, new, more complicated tasks were put in place. Using the experience received from the first missions, the Soviet space navigation system was developed—for the next lunar projects and for the interplanetary ones. So, soon, instead of the temporary station near Simeiz, permanent stations were created near Simferopol and Evpatoria, and other stations were developed. New, more exact radio systems were created. This allowed realization of the new projects, such as *Luna 9* (E-6), *Luna 10* (E-7), *Luna 16* (E-8-5), *Luna 17* (E-8), planetary flights.

Conclusions

The first Soviet lunar flights, together with the first Soviet satellites, Sputniks, made a very deep impression on the entire world. They became important steps in the evolution of humankind, showing the great potential for humankind in space.

In addition, they increased the authority of our country, manifesting the very high level of science, technology and education in the USSR, especially in the areas of rocketry and cosmonautics, radio engineering, control systems, calculation technology, mechanics, mathematics. They showed that the Soviet people are very talented. These flights showed the very large power of Soviet rockets, and, simultaneously, the high accuracy of their control systems. Together with our nuclear capabilities, this showed the high level of the Soviet war industry. This helped to ensure the balance in the world and following long peaceful life for our people.

These lunar flights also provided a powerful impetus for the subsequent space projects, in particular, for the manned flights beginning with Yu. A. Gagarin's flight, and for planetary and lunar investigations—both in the Soviet Union and in the United States. Lunar projects remain on the agenda to this day.

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