4.5 Spacecraft Development and Testing

In February 1970, Babakin approved the preliminary design of Project M-71, which specified that the M-71C spacecraft should be launched in May 1971 (Figure 13). Its mission included the launch of the first Martian satellite and the launch of two spacecraft, Mars 2 and 3 (Figure 14), which were to be placed in a Martian orbit and deliver the first landers on the Martian surface. The M-71S spacecraft weighed 4,549 kilograms. This number included the weight of fuel and gas (2,385 kilograms). The Mars 3 spacecraft weighed 4,650 kilograms, including the weight of the lander (1,000 kilograms). To solve the specified scientific problems, the following instruments were to be installed on the spacecraft:

(a) Fluxgate magnetometer
(b) Infrared radiometer to study the distribution of the temperature on the Martian surface
(c) Infrared photometer
(d) Spectrometer to determine the concentration of water vapor in the Martian atmosphere,
(e) Photometer working in the visible part of the electromagnetic spectrum to study the reflectivity of the Martian surface and atmosphere

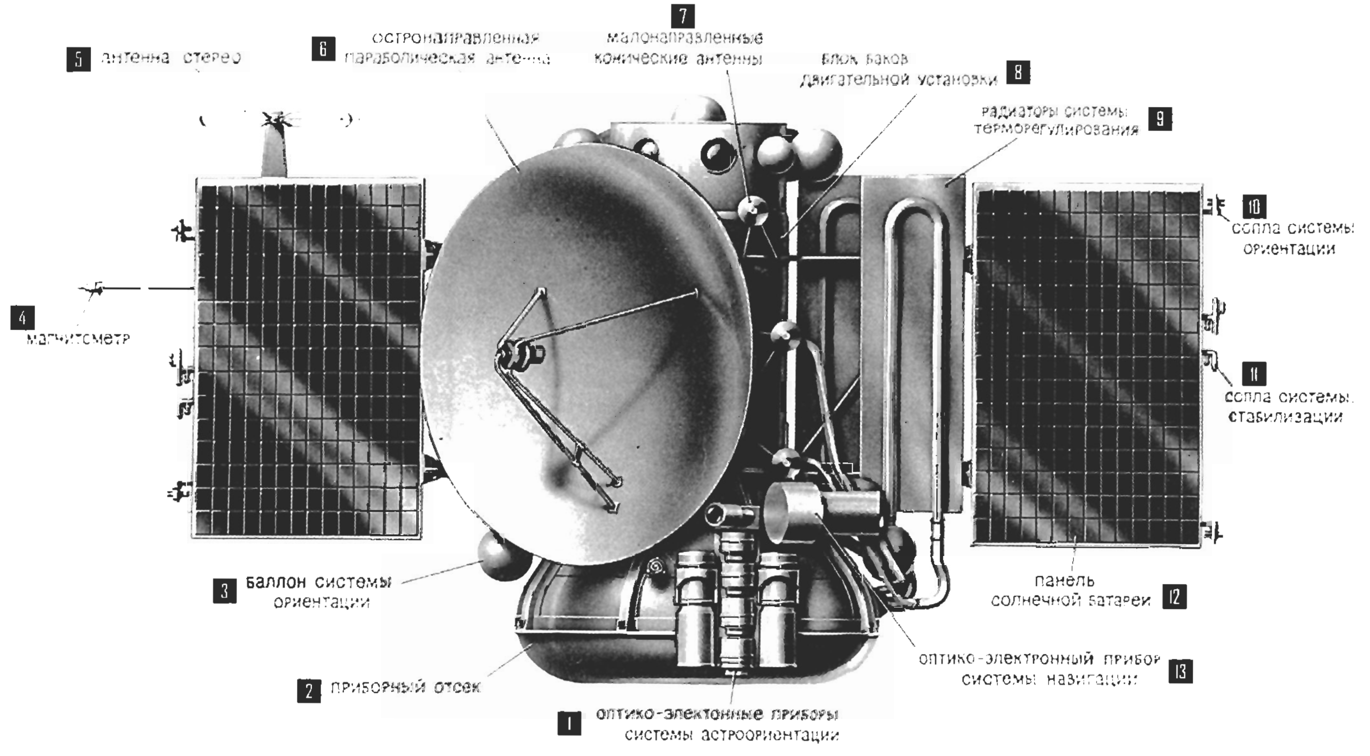


Рис. КОСМИЧЕСКИЙ АППАРАТ «М-71С»

Figure 13.
The M-71C Spacecraft—(1) optical-electronic devices of the astro navigation system, (2) instrument module, (3) container of the attitude system, (4) magetometer, (5) stereo antenna, (6) high-gain parabolic antenna, (7) low-gain cone antennas, (8) tanks of the propulsion system, (9) radiators of the temperature control system, (10) nozzles of the attitude system, (11) nozzles of the stabilization system, (12) solar panel, and (13) optical-electronic device of the positioning system

(f) Radiometer to study the dielectric permeability and the temperature on the Martian surface
(g) Ultraviolet photometer to study the Martian upper atmosphere
(h) Cosmic ray particles detector
(i) The detector to determine the kinetic energy of electrons and protons, the charged particles spectrometer
(j) Telephoto cameras with focal distances of 52 and 350 millimeters

In addition, the M-71S spacecraft and Mars 3 were equipped with stereo systems to support the joint Soviet-French experimental program to study solar radiation at the frequency of 169 MHz. The total weight of the scientific instruments installed in the Mars 3 spacecraft was 89.2 kilograms.

The landers of the spacecraft Mars 2 and Mars 3 carried the instruments to measure the Martian atmospheric pressure, the temperature, and the wind velocity, to define the chemical composition of the Martian soil, and to study the physical-mechanical properties of the soil's surface layer. In addition, two telecameras for making panoramic images of the landing sites were installed. Each lander contained 16 kilograms of scientific instruments.

The time remaining before the launch of the spacecraft was limited. To succeed, each stage of the project had to be completed in the shortest time. On the other hand, this approach should not degrade the quality and reliability of the spacecraft.

At that time, information about a new concept of space project management, developed in the United States, became available. The mass media indicated that the new management concept allowed for a reduction in the time for developing and building the ballistic rocket Polaris.

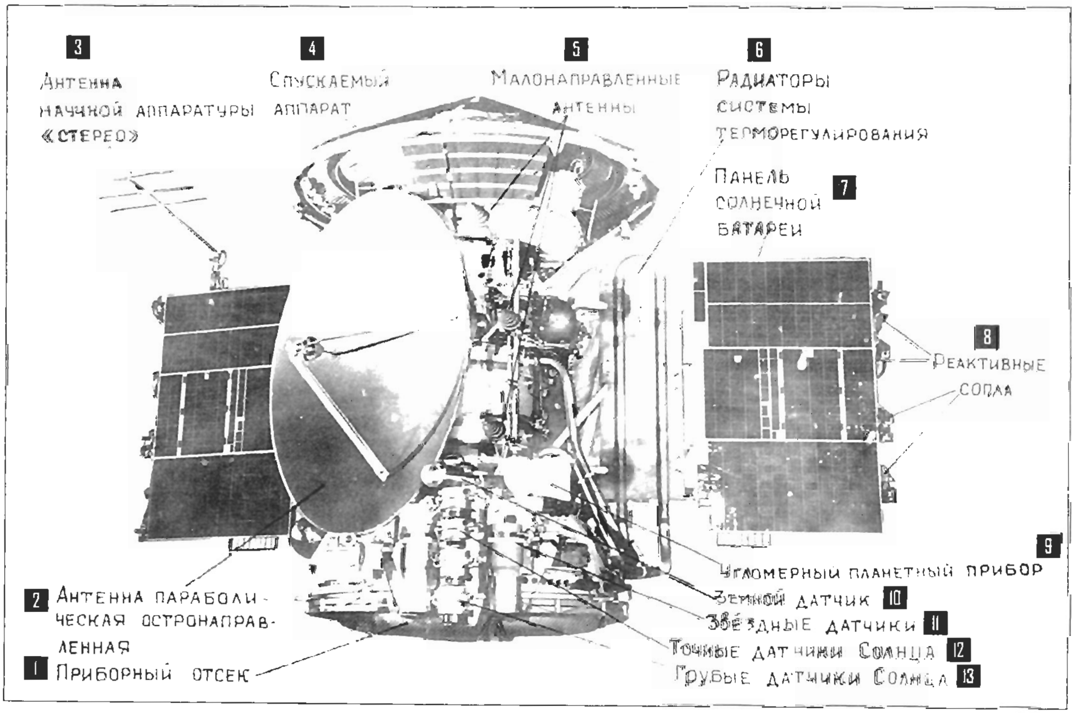


Figure 14.
The Mars 3 Spacecraft—(1) instrument module, (2) high-gain parabolic antenna, (3) stereo antenna of the scientific instruments, (4) lander, (5) low-gain antennas, (6) radiators of the temperature control system, (7) solar panel, (8) reactive nozzles, (9) device for planetary angle measurements, (10) Earth sensor, (11) star sensor, (12) precise solar sensor, and (13) rough solar sensor

In my view, the new concept was very attractive. At each stage of the project, the time limitations for each job were clearly outlined. At this time, Babakin appointed me his deputy for the development of spacecraft for the exploration of Mars and Venus. In addition to the technical problems, I was in charge of project assignments that should be finished on time and with a high quality. To reduce the time needed to develop and publish the design documentation, I decided to use the American system of planning and management. More than 15 days of exhausting work were required to outline the preliminary version of the management structure. The same time was needed for the administrative department to make some corrections, remove circular connections, to code events, and so on. As a result, a poster 3.5 meters in length, filled with events, connections and other information, was produced.

In November 1970, the management plan was approved by Babakin, and in June 1971, the technical documentation was issued. The skeptics who believed that the American management concept could not be used in Soviet Union were embarrassed. Minister Afanasiev instructed the Urals-Siberian plants to deliver the parts for the spacecraft and landers to our organization. As a result, we could soon initiate the complex program of testing operations.

The testing of the lander and its system consumed a lot of time. Fifteen launches of the meteorological rocket M-100B were performed to test the initiating and opening of the parachute system under different flight conditions. During testing operations, it was discovered that the main parachute had a tendency to collapse.

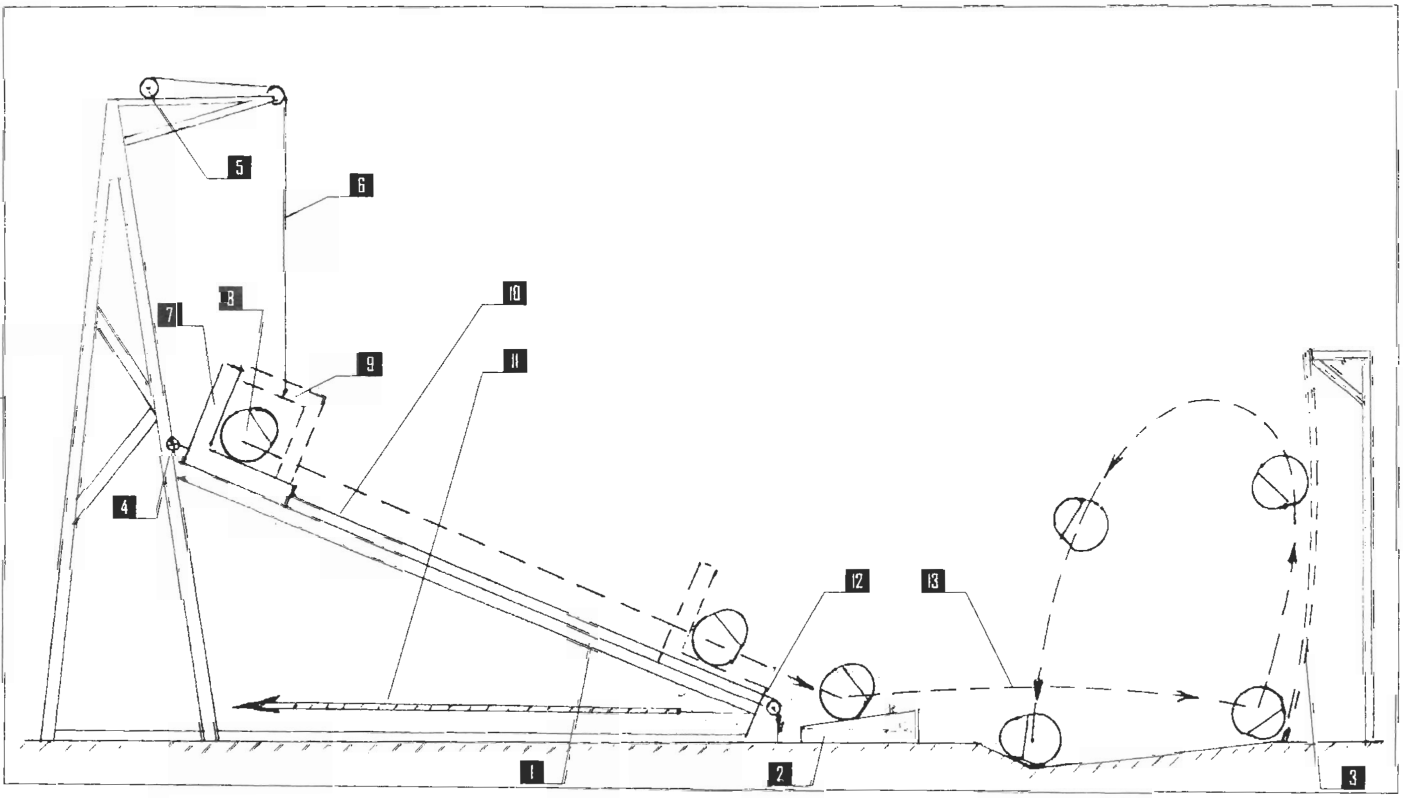


Figure 15.
The General Scheme of the Catapult—(1) catapult, (2) platform with the duplicate soil, (3) protective screen, (4) lock, (5) winch, (6) rope, (7) sledge-thermostat, (8) automatic Martian station, (9) top of the thermostat, (10), rope, (11) elastic shock absorber, (12) stopper, and (13) trajectory of the automatic Martian station after it hits the platform (α—angle of catapult slopes inclination, ß—angle of the platform inclination)

To eliminate this trend, it was necessary to reconsider the design of the parachute system. Different pyrotechnic systems, such as expanded cumulative cartridges, pyrolocks, pyropushers, pyrocylinders, and so on, were broadly used in the design of the spacecraft and lander. Pyrotechnic systems were tested extensively because, according to the standards established in the Lavochkin design bureau, the pyrosystem could be installed in the spacecraft only if it worked 12 times in different conditions without failures in an Earth-based facility.

To test the soft landing systems, five lander test models equipped with radio-altimeters, onboard automatic units, and gunpowder engines were dropped by parachute. The parachute system, with a reduced area of canopy, was used to provide the predetermined vertical descent speed for the lander test models. During all drop experiments, the soft landing system operated properly.

A special testing facility was used to check the protection efficiency and operation of the automatic Martian station after its impact with the rocky soil (Figure 15). The testing facility was made up of (1) a catapult, (2) a duplicate of the Martian soil, and (3) a wall designed for protection. Lander test models equipped with simulations of the onboard instruments, the standard pyrosystems, a program timer device, and a power system were dropped by parachute five times. While the parachute drops were performed, the temperature of the foam plastic cover varied from +50 degrees Celsius to -50 degrees Celsius. Simultaneously, the pitch angle varied from 0 to 180 degrees, and the angle of incidence to the duplicate soil changed from 0 to 10 degrees.

During testing, horizontal speeds of 28.5 meters per second and vertical speeds of 12 meters per second at the time of landing were simulated. The tests showed that foam plastic provides a proper shock absorption and protection of the capsule during landing and if the G-force does not exceed 180 units. The separation of aeroshell cover and the placement of the station in a vertical position under maximum speeds and with different directions of impact were accomplished properly.

In conclusion, the simulation of all flight conditions was made. The operational ability of the lander was checked in different stages of the simulated flight. Vibration and linear overloading tests simulated the launch of the spacecraft and its placement in an interplanetary trajectory. Centrifuge tests simulated the ballistic braking of the lander, and the drop of the automatic Martian station was simulated by the catapult with the load factor of 180 units. After the above simulations, the onboard program-timing device was initiated. By its command, the aeroshell cover was separated, the flaps were opened, and the station was placed in a vertical position.

Simultaneously, the transmitters and scientific instruments were turned on, and the x-ray spectrometer was placed on a duplicate of the Martian soil. The PROP-M instrument made its short trip, still analyzing Earth's soil. During the next 25 minutes, panoramic images and scientific data were transmitted and received by the radio system. In addition, for 25 hours, the station was tested in a vacuum chamber under a pressure of 6 mbar while being exposed to airflow with the speed of 25 m/sec. Daily variations of the temperatures of the Martian atmosphere were simulated as well.

Then the testing operations were completed, and a second communication session was started. A whole cycle of testing operations was made without any failures, and we became confident that the automatic station could accomplish the tasks planned for it.

The utilization of the lander in Project M-71 required that it be sterilized. The development of a sterilization procedure was assigned to Academician A.A. Imshenetskiy. The Institute of Sterilization and Disinfection of the Health Protection Ministry was responsible for sterilization procedures.

A few ways were proposed for the sterilization, namely, gaseous, utilizing methyl bromide, radioactive and thermal. None of these techniques could be used with the completely assembled lander. However the lander's parts could be independently sterilized by any of these techniques. To preserve the sterility of the lander during its assembly, a special sterile facility with a sluice chamber was built. This facility was equipped with filters through which air was transferred under low pressure. This facility was equipped with the bactericidal lamps.

4.6 The Spacecraft's Struggle to Mars

May 1971 had arrived. Recalling our trouble with the M-69 spacecraft, we nervously awaited for three upcoming launches. Spacecraft M-71 was launched on May 5, 1971. At first, the ignition of all three stages of the Proton rocket and booster block D worked properly. The spacecraft with booster block D was placed in the predetermined Earth orbit.

In approximately 1 hour, after orbiting Earth and approaching Guinea Bay, block D should have started a second time and transferred the spacecraft to

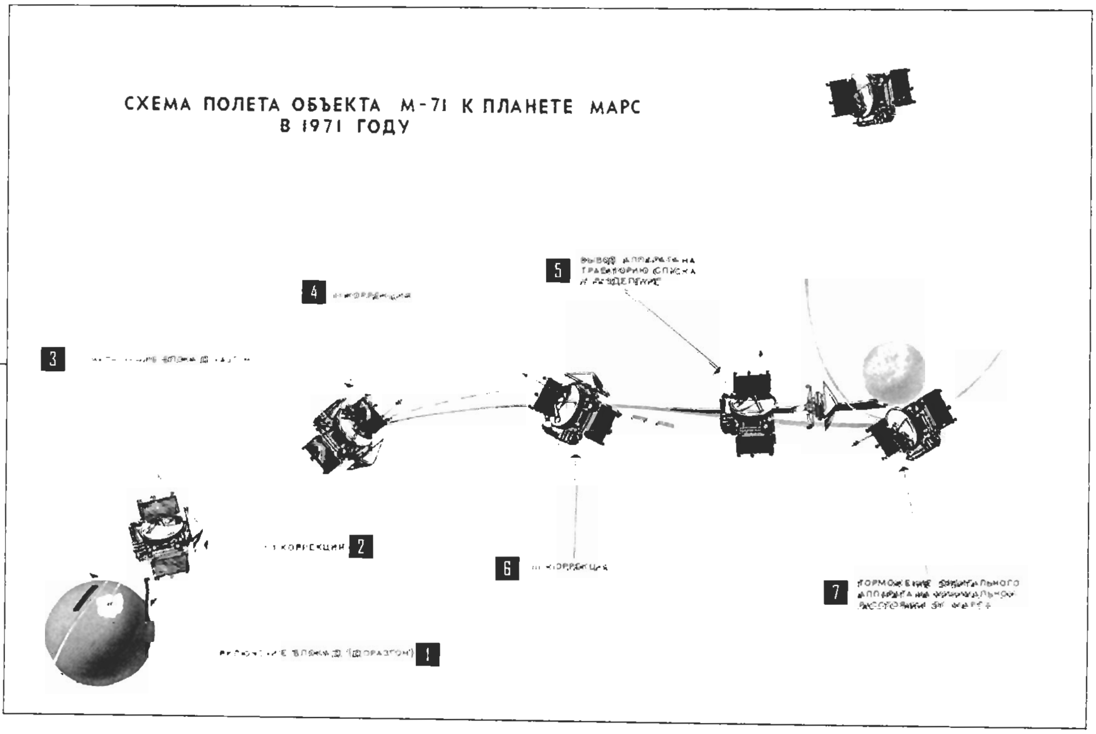
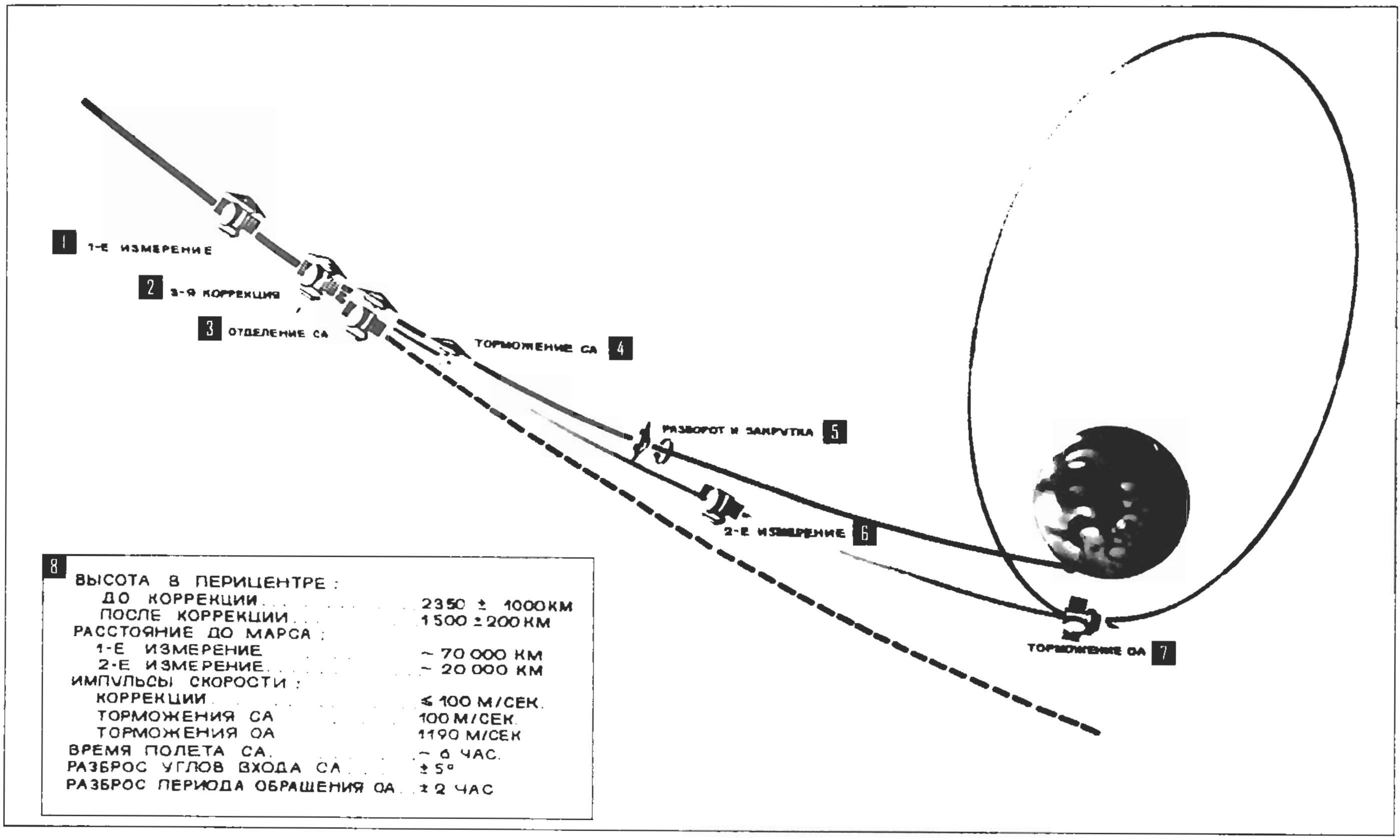


Figure 16.
The Flight Profile of the Mars 2 and 3 Spacecraft to Mars in 1971– (1) activation of block D (before boosting), (2) first correction, (3) activation of block D (boosting), (4) second correction, (5) injection of the spacecraft in the descent trajectory and separation, (6) third correction, and (7) braking of the orbiter at the minimal distance from Mars

an interplanetary trajectory. A ship in Guinea Bay did not show that the engines of block D had ignited. In a few minutes, block D flew over the Yevpatorijan (Crimea) control facility. The telemetered data showed that no command was issued to start the engine. An analysis showed that the operator had made a mistake. He issued an eight-digit code command to the spacecraft control system to activate block D for the second time in a reverse order. It was a human factor, not technology, that was responsible for the error.

We lost the opportunity to launch the first Martian satellite. Besides that, we lost the radar beacon that provided information about the position of Mars in space. The flight profile of the preliminary design (Figure 16) could not be accomplished because precise data on the Mars position in space had not been acquired. These data were needed to calculate the angles at which the lander should enter the Martian atmosphere. Now the only hope left was that the space automatic positioning system would not fail. This alternative system was designed in case the M-71S spacecraft would fail.

A decision about its development was made in the summer of 1970 at the Council of Main Designers. The system used an optical angle measurement instrument, which was developed under the supervision of the main designer V.I. Kurushin. About 7 hours before reaching Mars, the instrument should perform the first measurement of the angular position of Mars with respect to the base coordinate system (Figure 17).



ВЫСОТА В ПЕРИЦЕНТРЕ :	
ДО КОРРЕКЦИИ	2350 ± 1000 КМ
ПОСЛЕ КОРРЕКЦИИ	1500 ± 200 КМ
РАССТОЯНИЕ ДО МАРСА :	
1-Е ИЗМЕРЕНИЕ	~ 70 000 КМ
2-Е ИЗМЕРЕНИЕ	~ 20 000 КМ
ИМПУЛЬСЫ СКОРОСТИ :	
КОРРЕКЦИИ	≤ 100 М/СЕК.
ТОРМОЖЕНИЯ СА	100 М/СЕК.
ТОРМОЖЕНИЯ ОА	1190 М/СЕК
ВРЕМЯ ПОЛЕТА СА.	~ 6 ЧАС.
РАЗБРОС УГЛОВ ВХОДА СА	± 5°
РАЗБРОС ПЕРИОДА ОБРАЩЕНИЯ ОА	± 2 ЧАС

Figure 17.
The Flight Profile of the Mars 2 and 3 Spacecraft Near Mars—(1) first measurement, (2) third correction, (3) lander separation, (4) lander braking, (5) pitch and yaw, (6) second measurement, and (7) orbiter braking

(8) Height of the pericenter:
Before correction—2,350 ± 1,000 km
After correction—1,500 ± 200 km
Distance to Mars:
First measurement—~70,000 km

Second measurement—~20,000 km

Speed Impulses:
Correction—≤100 m/sec
Lander braking—100 m/sec
Orbiter braking—1,190 m/sec
Time of lander descent—~6 hours

Scatter of entry angles for the lander: ±5 degrees

Scatter of rotation period of the orbiter: ±2 hours

The measured data should be transferred to the onboard computer of the control system, which calculated the vector for a third correction needed to relocate the spacecraft to a nominal trajectory. In accord with the results of calculations, the control system should issue the following commands:

1. Turn the spacecraft to a position required to perform the correction
2. Start the engine for the correction braking propulsion system, and stop the engine after the correction impulse is terminated
3. Turn the spacecraft to a position required for the lander to be separated and to separate a lander
4. Rotate the spacecraft about three axes using the Sun and star Canopus as reference
5. When the spacecraft approaches the planet, at the distance about 20,000 km, conduct the second measurement of the Mars angular position with respect to the base coordinate system

As a result of the second measurement, the onboard computer had to calculate the vector direction of braking impulse to relocate the spacecraft in the Martian satellite orbit. These operations should be performed automatically without commands from Earth. The test of the optical angle measurement instrument was performed at the control system testing facility and was completed successfully. Only 2 to 3 months were allocated to testing the computer programs. This limited amount of time caused concern.

On May 19 and 21, 1971, the spacecraft Mars 2 and Mars 3 were launched in an interplanetary trajectory. All stages of the Proton rocket and booster blocks D operated perfectly. In accord with the results of the outbound trajectory measurements, the first correction of the Mars 2 and Mars 3 spacecraft trajectory was made on June 5 and on June 8, 1971, respectively. The onboard equipment of both spacecraft performed without any problems. The group of flight managers started their routine work. Because of the particular flight trajectories to Mars, communication with the spacecraft was maintained at night.

After the communication sessions were completed, the management group analyzed the data acquired, then if it was necessary reconsidered the agenda for future communication sessions, and transferred the report of their work to Babakin. Then the group rested. Every morning, upon coming to work, we listened to the presentation of V.G. Timonin, who was the head manager. If it was necessary, we instructed the OKB departments to undertake the jobs required.

A bright sunny morning on June 25 did not forecast any troubles. The telephone on Babakin's dedicated line rang unexpectedly. "Come urgently," his troubled voice said. Gloomy Babakin was pacing his office. "I just spoke with Timonin," he said. "Communication with both Mars failed last night. Get the team together and fly out to Yevpatorija immediately."

I was amazed by Timonin's news. The defects of spacecraft Mars 2 and Mars 3 were exactly identical. The original transmitters, which work in the decimeter band, failed first. Then the duplicate transmitters were activated. In the beginning, they worked properly but later on failed as well. A command was given to start the transmitters working in the centimeter band. Telemetry data indicated that the centimeter band transmitters were activated and started to work, but the signals did not reach Earth. To avoid the development of an emergency situation, the transmitters were turned off, and we awaited directions from Moscow.

I telephoned Yu.F. Makarov, who was the assistant of Ryasanskiy and was in charge of the onboard radio system. He was already aware of the situation. We agreed that they will have a team of four people and we will have a team of three people.

In the middle of the vacation season, it was impossible to buy a ticket to Simferopol at the Aeroflot terminal. I attempted to buy tickets reserved for the staff of the Council of Ministers. Unfortunately, only tickets with a departure date of 1 week were available. From the Kremlin, I telephoned G.A. Tyulin, who was the deputy minister. I explained to him the situation with the Mars spacecraft and with the Aeroflot tickets.

Tyulin gave us permission to use the ministry's airplane. The airplanes of our ministry were parked at Vnukovo-3 airport. Like all passenger aircraft, they had Aeroflot written on their side.

In the morning of June 26, 1971, we flew out to Simferopol on airplane AN-24. During the flight, we discussed the information received and outlined the future plan of work. Finally, we arrived at Simferopol. The airplane landed and moved to the terminal. We proceeded down the stairwell and went to the exit.

Porters with their carts rushed toward us in a chaotic fashion. Upon exiting the airport, we turned around and observed a silent scene like in Gogol's play *Inspector*. Stunned porters are struggling to grasp the reality. In the middle of the vacation season, an empty airplane had arrived from Moscow.

Soon we reached the flight control facility and carefully analyzed the telemetry information. Strangely enough, there was no sign of the abnormal functioning of the telemetric system during the previous communication sessions. We discussed a suggested plan of actions with the management team and introduced some changes based on their comments.

At night, when the Mars spacecraft became visible, we began its implementation. The first night went by. A few straws of hope appeared for reestablishing communication in the decimeter band. A whole day was devoted to analyzing the telemetric data acquired at night and developing a new plan. The second night was productive. We identified the operating conditions in which the duplicate transmitters worked in the decimeter band without errors. Simultaneously, communication with

S.S. Kryukov, main designer of the Lavochkin design bureau

the original transmitters was reestablished, although the time of their operation was limited. However, the signal from the transmitters operating in the centimeter band did not reach Earth. The radiation sensor that was installed at the antenna's mirror permanently showed nothing. We could not find an explanation for this phenomenon.

The idea that the antennas absorbed solar energy, which heated and melted the radiator, was not justified by calculations. The antenna was directed to the Sun for no more than 10 seconds. The radiators were manufactured using silver solder whose melting temperature was 700 degrees Celsius. Nevertheless, in further projects, we installed a cloth tent above the antenna's mirror. The antennas' design did not change, but they operated perfectly with the tent.

The exhausting work was completed. For 2 days, we had not slept at all and now could get some rest. At that time, Minister Afanasiev was at the flight control facility. Probably, his visit was connected with the flight of the Soyuz 11 spacecraft.

The next day, Afanasiev asked me to present the results of our effort. Our actions were approved. Immediately after my presentation, the communication session with the Soyuz 11 spacecraft was initiated. By the loud speakers, the troubled voice of cosmonaut V. Volkov said, "It is impossible to eat the steaks," and in few minutes, his voice was heard again, "Fire in the spacecraft." I believed that his excitement could be explained by the fact that he predicted the danger. The head manager of flight asked, "Commander, what's happening on board?" G. Dobrovolskiy reported, "We had a short circuit but have already fixed it; Volkov is a little excited. Don't worry, everything will be all right." The next day, the team of cosmonauts of the Soyuz 11 spacecraft crashed during their flight back to Earth. Perhaps, some human beings can predict the danger. I recollect a similar example.

In March 1968, in the headquarters of the Council of Ministers, I met Yu.A. Gagarin. He was slightly overweight and wore a military greatcoat, which obviously did not fit him. Probably, he was waiting for somebody. At this time, the VPK Resolution, which determined the launch of the spacecraft Venus 5 and Venus 6, was almost completed. I told him jokingly, "Yuriy Alekseevich, we have the position of the main pilot vacant on the Venusian spacecraft." He did not respond to my joke and with gloomy smile said, "Maybe next time." In a few days, Yu.A. Gagarin died.

On July 1, we returned to Moscow and as usual began to work. We did not anticipate the future loss. Very soon, we were stunned with the news that Babakin died from a heart attack. The death of Babakin was an enormous loss for space technology and for our team as well. Nobody could replace him. Talented people are not born very often.

S.S. Kryukov, the former first deputy of Babakin, was appointed the main designer. Kryukov was a highly qualified specialist. He used to be the deputy of Korolev and was in charge of the development of the rocket that launched the first Earth satellite. In 1970, Kryukov got a position in the Lavochkin design bureau. The Babakin-Kryukov team was coordinated well and worked very productively.

The flight of spacecraft Mars 2 and 3 continued. In November 1971, a second correction of their trajectory was made successfully. A few days remained before the spacecraft would approach Mars. At that time, the Martian weather was not good for observations with the orbiter and especially with the lander. For the last few weeks, an unusually strong dust storm covered the whole surface of the planet. Astronomers indicated that such a large dust storm had never before been recorded on the Martian surface.

On November 21, 1971, the space automatic positioning system was used to make the third correction to the trajectory of the Mars 2 spacecraft trajectory. The Mars 2 spacecraft lander was directed to the planet. At the same time, the spacecraft was placed in a Martian orbit with a pericenter height of 1,350 kilometers and a period of rotation of 18 hours. This operation was not successful. Apparently, after the second correction, the Mars 2 spacecraft trajectory had been close to the predetermined trajectory.

Nevertheless, the onboard computer issued a wrong command to decrease the height of the pericenter of the flyby hyperbola. As a result, the lander entered the Martian atmosphere at the big angle and hit the Martian surface before the parachute system was activated.

Because of time limitations, the testing of the computer programs for the space automatic positioning system was not completed. We just did not have time to perform computer modeling of a situation in which the real and previously calculated trajectories would coincide.

Could we have avoided these results? Definitely yes, but only if the first space barter in the history of human civilization would have happened 1 year earlier, in 1971. The barter included the exchange of the American precise data for the Martian ephemeris for the Soviet data on Venus. If that had taken place and being aware that the spacecraft was close to its predetermined trajectory for a Mars flyby, we would have activated the Earth-based control system and the flight would have been controlled by commands from Earth.

A third correction to the Mars 3 spacecraft trajectory was made on December 2, 1971. The lander separated from the spacecraft and entered its predetermined trajectory for a Mars encounter. After 4 hours and 35 minutes, the lander entered the Martian atmosphere and landed at a location with coordinates 45° S and 158° W.

The spacecraft was placed in a Martian satellite orbit with a pericenter height of 1,500 kilometers and a period of rotation of 12 days and 19 hours. The predetermined period of rotation was 25 hours. The discrepancy between the real and the predetermined periods of rotation could again be explained by the time limitations, which did not allow for proper testing of the computer programs developed for the space automatic positioning system.

If the speed of the spacecraft changed rapidly, the control system miscalculated the impulses transferred by the gyro-integrator and issued a command to stop the engine of the correction braking propulsion system. That happened irregularly, usually before or after the predetermined impulse of the fast moving spacecraft had been exceeded.

Everybody impatiently waited for the information transmitted from the lander to the radio system onboard the spacecraft. Using the high-gain antenna, the information recorded on magnetic tape was transmitted to Earth when the spacecraft was in the state of three-axis stabilization.

To relocate the spacecraft to a position of three-axis stabilization, it was necessary to open the cover of the star sensor, which protected it from contamination by products of burning. According to calculations, the cloud of the burned products should disappear 30 minutes after the engine was turned off. The cover of the star sensor was opened. In a few minutes, the three-axis stabilization was lost. Dirt was deposited on the viewport of the Sun sensor.

After an hour, the cover of the second star sensor was opened, and the spacecraft was transferred to a position of three-axis stabilization. The transmission of panoramic images of the Martian surface recorded on the magnetic tape was initiated. The main engineer of NII KP, Yu.K. Khodarev, who was standing close to the rack where the signal was displayed, gave a command to reduce the signal because it was too strong. Then, the telephotometer data were transmitted. There was a gray background with no details.

In 14.5 seconds, the signal disappeared. The same thing happened with the second telephotometer. Why did two telephotometers working in independent bands simultaneously fail within a hundredth of a second? We could not find an answer to this question.

Later on, I discovered an interesting fact. During the second world war, British radio operators had their transmitters malfunction because of a coronal discharge while working in the desert of Lebanon during a dust storm. On Mars, the size of dust particles, the humidity, and the atmospheric pressure are much less, but the wind velocity is much higher than in the desert of Lebanon.

Perhaps, the coronal discharge was the reason why the signal from Mars suddenly disappeared. Even if the radio link worked properly, in a dust storm, we still would be unable to get the topography images. It was planned that after a 1-minute time interval, the transmission of the panoramic images would be followed by the transmission of data on the physical-chemical parameters of the Martian soil. It was especially valuable for science that data on the atmospheric pressure, temperature, and wind velocity at the Martian surface be acquired in conditions of an unusually strong dust storm.

The dust storm on Mars continued to rage. Both Mars orbiters continued to make images of the Martian surface, but the dust completely obscured the topography. Even the mountain Olympus, which had an elevation of 26 kilometers above the average Martian surface, was invisible. During one of the mapping sessions, the image of the full Martian disk with a distinct layer of clouds above the dust cover was obtained.

Transmitters that worked in the centimeter band failed. That was the reason why the scientific data and images from the Martian surface were transmitted in the decimeter band by the transponders that were "cured" in June. As usual, the main designer of the radio system, Ryasanskiy, had additional resources, but at this point, he did not speak of them.

For the radio systems of the Mars 2 and Mars 3 spacecraft, he generated a PN code, which allowed data to be transmitted in a special mode. That particular mode made it possible to increase the speed of transmission in the decimeter band. This allowed the transmission to Earth of all scientific data acquired by the Mars 2 and 3 spacecraft for the 8 months of their existence and completely accomplished the program of Mars exploration with the orbiters.

4.7 Main Results of Mars Exploration With the Mars 2 and 3 Spacecraft

The Mars 2 and 3 spacecraft were equipped with scientific instruments designed for the remote and planet-based study of the Martian surface and atmosphere.

As a result of this study, the temperature and atmospheric pressure on the Martian surface and the nature of the surface rocks along the tracks of the satellite orbits were defined. The data on the soil density, its heat conductivity, dielectric permeability, and reflectivity were acquired. The temperature in the lower atmosphere and its change with time and latitude were determined. The heat flow anomalies on the Martian surface were discovered.

Also, it was defined that the temperature of the northern polar cap was less than –110 degrees Celsius. Altimetry data along the satellite's tracks were obtained. It was defined that in the Martian atmosphere, the concentration of water vapor was 5,000 times less than in Earth's atmosphere. The data on extent, composition, and temperature of the upper atmosphere were obtained. The altitude of the dust clouds and the size of dust particles were determined.

The Martian magnetic field was measured. Colorful images of Mars were obtained. The optical compression of the planet has been refined. The layered structure of the Martian atmosphere, its luminosity at a distance of 200 kilometers beyond the Mars terminator, and the change in its color close to the terminator were discovered.

One of the most important accomplishments of Project M-71 was that the scientifically and technically intricate problem of a soft landing on the Martian surface was solved.

CHAPTER 5

THE LAST THRUST TO MARS

"The Russian Armada is moving towards the red planet." That was the headlines of many newspapers in August 1973. There certainly were reasons for newspapers to smell a sensation. In the Soviet Union and in the United States, two identical spacecraft, the main one and a duplicate, are usually launched. Because of the space race, this strategy was justified because the program should be carried on even if one of the spacecraft broke down. The world community was stunned by the fact that the Soviet Union launched four spacecraft. Scientists believed that the Soviet Union decided to make a powerful thrust in the exploration of Mars and solve many Martian problems. But the underlying reason for the launch of four spacecraft was more political in nature.

In 1975, the United States planned to deliver the Viking lander to the Martian surface. Scientifically, the Viking lander was much more advanced than the M-71 lander. Being aware of the potential failures of the M-71 spacecraft, the government made a decision to launch the spacecraft in 1973, before the results of the Project M-71 would be available.

However, in 1973, the ballistic conditions for flights to Mars were not good. The speed required to place a spacecraft in an interplanetary trajectory had to be increased. In addition, it turned out to be impossible, as required in Project M-71, to deliver the spacecraft with the lander to an orbit that would allow the descent to be slowed by one braking rocket.

The only solution that would be in accordance with the government resolution was to launch four spacecraft. Two of them would become Martian satellites and two other would deliver landers to the Martian surface. Their general design and the onboard systems were identical to the Mars 2 and 3 spacecraft.

However, a number of the scientific instruments had to be redesigned. Simultaneously, an additional radio system had to be installed on the lander so it could transmit to Earth the information acquired after the parachute started to be deployed. Apparently, this system increased the probability of receiving the data transmitted from the lander.

Yu.F Makarov, the deputy of the main designer of NPO KP, supported my idea to install a new radio system in the lander. When the system was completed and was placed in the lander, there was a "kind soul" who convinced the main designer that my solution was flawed. An unpleasant conversation took place with Kryukov. He accused me of the installation of a system that, in his opinion, had no value.

However, I was consoled later, when the telemetry data from the Mars 6 lander were transmitted exactly in this radio band. The technological documentation used in the new project, except the theoretical calculations connected with the specific date of the launch, was the same as for Project M-71. Beyond that, the joint effort to deliver parts and onboard systems was well coordinated. All of that gave hope that the spacecraft would be built on schedule.

There was concern about the concentration of four spacecraft simultaneously at the testing control facility (KIS). Four work places had to be organized. However, even with the extended 12-hour shift, at least eight teams should work. We realized that this would be a difficult stage, but it was not as difficult as we had thought.

Again, Mars challenged us. Suddenly, during testing of the power system, the onboard blocks started to fail. Analysis showed that in all cases the power system malfunctioned because of a failure of the 2T-312 transistor, which was fabricated at the Voronezhskiy plant. All blocks of the onboard equipment were literally filled with these transistors. An interministry commission carefully analyzed this problem and came to the conclusion that the reason of the transistor's failure was intercrystalline corrosion in the area of the transistor lead.

To save the gold resources, some "smart person" suggested that the gold leads be replaced by aluminum ones. The necessary tests were not made. And so 2 years later, this suggestion caused major trouble. The only way to remedy this situation was to replace the flawed transistors with transistors fabricated according to the old technology.

An experimental study showed that this task would require at least 6 months. This was exactly the time remaining until the spacecraft should be launched. To find a solution for this dead-end problem, A.N. Davydov, the head of the reliability department of the Lavochkin design bureau, was ordered to conduct a careful analysis of all known failures of the 2T-312 transistors, including failures in instruments of other organizations. Also, he was directed to consider the results of this analysis as it might affect the reliability of spacecraft already using this equipment.

The analysis showed that the transistor's failure rate begins to increase 1.5–2 years after its production date. For transistors installed in our instruments, that corresponded to the arrival date of the spacecraft to Mars. The probability of completing the flight program, while taking into account the possible failure of the 2T-312 transistors, was estimated at 0.5. Based on this information, the ministry officials made the decision to continue with the launch of the spacecraft as previously planned.

Testing of the spacecraft's power system proceeded at a full pace at KIS. Suddenly, another late night telephone call. The nervous shift supervisor informed us that they had an emergency and asked us to come over there urgently. There, I saw a very unusual scene. The control system was turned off, and gloomy operators were aimlessly wandering around the facility. We found that during the general testing operations, when the cover of the instrument module was opened and the onboard instruments could be easily accessed, a particular testing of the control system was required.

Technicians joined the connectors, and according to the technical procedure, the power system was turned on. Then the control system was tested for 20 minutes. However, soon it was discovered that the information obtained was not in accordance with the program commands. The program was stopped, and the circuit design was checked. It was found that the technician managed to join a hundred terminal connectors in a wrong way.

In spite of this obvious mistake, the connection had been approved by the department of technical control and by the military representative. That was clear by the records and signatures in the technical documentation. What happened; why had the triple control not worked? That was the rhetorical question.

I telephoned G.M. Priss, the deputy of Pilyugin. At NPO AP, he was in charge of the control system of the Martian spacecraft. I told him all the details of our emergency situation. For a while, Priss reflected and after that suggested that we drive over to NPO AP. We grabbed the test results and raced through the deserted Moscow night. During the trip, we developed a plan. We suggested that the control system be removed from the spacecraft and installed and tested in the testing facility of NPO AP. Only after the main designer and the military representative had approved the results of the test would the control system be installed in the spacecraft again. To reduce an inevitable delay in the testing of the power system, we suggested that the order in which spacecraft would be launched be changed. Specifically, we suggested launching the spacecraft where the emergency situation took place the last time.

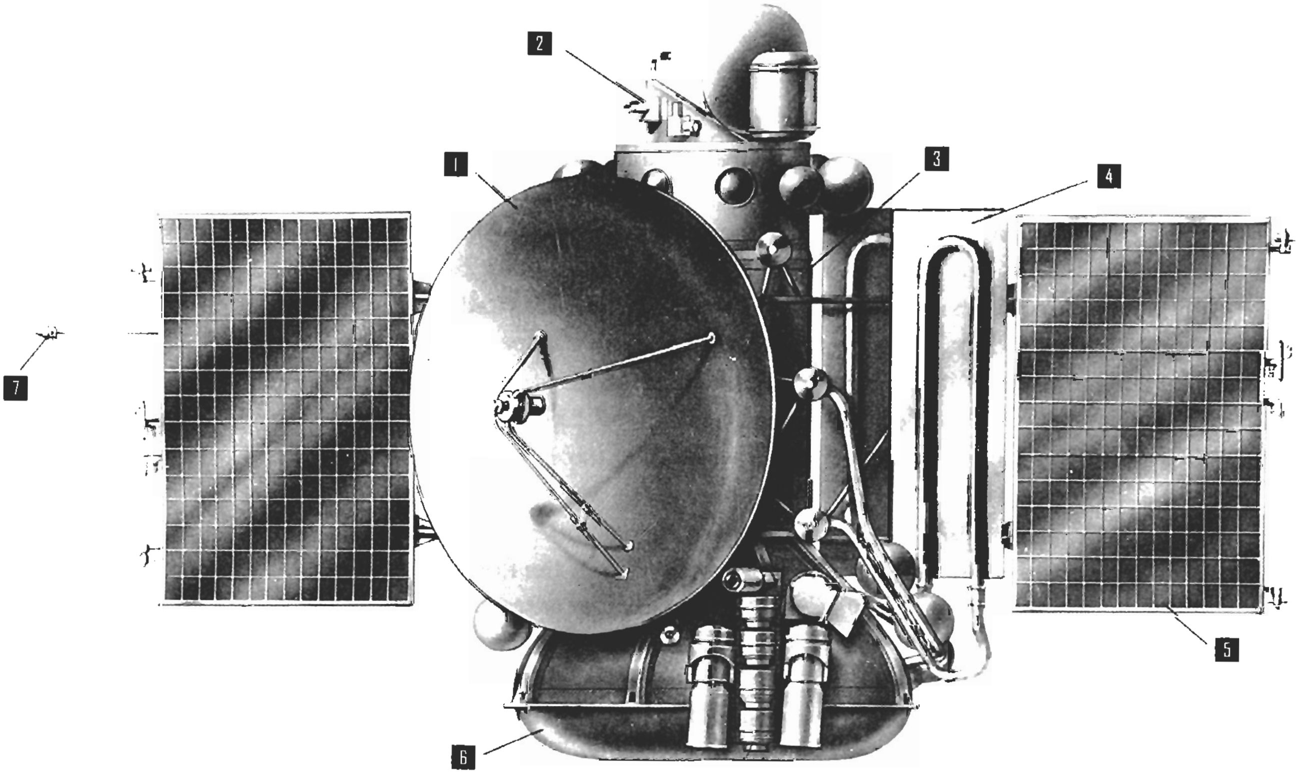
Eventually, we arrived at NPO AP. We passed the empty and resonant corridors and went upstairs into the office of Priss. We were awaited, and the flow charts of the control system were laid on the desk. Priss had already discussed the possible solution of the problem with specialists from NPO AP. During the last session, parameters of the control system were recorded. We put the notes with records on the desk. The specialists bent over the records and sometimes made short comments that I could hardly understand. That reminded one of a consultation near the patient's bed when doctors discuss the diagnosis and how to cure the disease.

Eventually, the meeting finished. I presented our suggestions to recheck the control system in the testing facility of NPO AP. However, the decision of Priss completely changed our plans. He indicated that analysis did not reveal any damage to the blocks of the control system. In addition, he suggested urgently, before the day shift would start to work and the military representatives of NPO AP show up, to place the control system in the spacecraft and test it again. He was concerned that being aware of the emergency situation, the conservative military department of NPO AP could veto the use of this control system and the launch of the spacecraft would not be feasible.

After our departure, the specialists from the Lavochkin design bureau dispersed and went home. Only one person, the director of this organization, A.P. Milovanov, could get them together. I telephoned him, excused myself for the night call, and briefly explained what happened and what decision had been made. He immediately understood the situation, asked me to calm down, and promised that all specialists would be at their workplaces when we come back to the Lavochkin design bureau.

We raced through the Moscow night again. Priss did not accompany us. He did not want to show up and provoke unnecessary questions. He was a very smart man. Only a person who was aware of all details of the design of the control system, who trusted the specialists and who was deeply concerned with the fate of the project,

Figure 18.
The Mars 4 and 5 Spacecraft – (1) high-gain antenna, (2) radiometer, (3) fuel tank, (4) radiators of the temperature control system, (5) solar panel, (6) instrument module, and (7) magnetometer



could make this crucial decision. About 5:00 a.m., we arrived at KIS of the Lavochkin design bureau.

All operators were already at their workplaces waiting for our instructions. As usual, the order of A.P. Milovanov was fulfilled. In cooperation with the specialists from NPO AP, we again checked the connections of the joints. They worked well. In an hour and a half, the test was completed. All parameters were in the proper range. Now we could rest. Soon the test of the power system was completed, and the spacecraft was delivered to the launch facility to be prepared for launch.

On June 21 and 25, 1973, the Mars 4 and 5 spacecraft (Figure 18) were launched. On August 5 and 9, 1973, the Mars 6 and 7 spacecraft (Figure 19) were launched. The Mars 4 and 5 spacecraft were launched earlier to have time to be stabilized in Martian satellite orbits and thereafter receive the information from the landers that would be delivered to the Martian surface by the Mars 6 and 7 spacecraft.

The exhausting work of the flight control group was begun. In the beginning, the flight proceeded properly, but after 2 months, the transmission of telemetry information from the Mars 6 spacecraft stopped.

It was the spacecraft whose control system we attempted to save at night. Probably, the 2T-312 transistor had failed. Only the channel for commands and for outbound trajectory measurements remained. Until the end of the flight mission, we did not receive any information about the spacecraft's systems. During the remaining 5 months of the flight, the Mars 6 spacecraft operated completely autonomously and completed intricate programs without commands from Earth.

Approaching Mars, the spacecraft measured its position with respect to Mars, calculated strength and direction of the correction impulse for its trajectory, performed the correction of the trajectory, calculated the direction of the lander descent, separated the lander from the spacecraft, and received and transmitted to Earth information from the lander at the point when the parachute system started to be deployed.

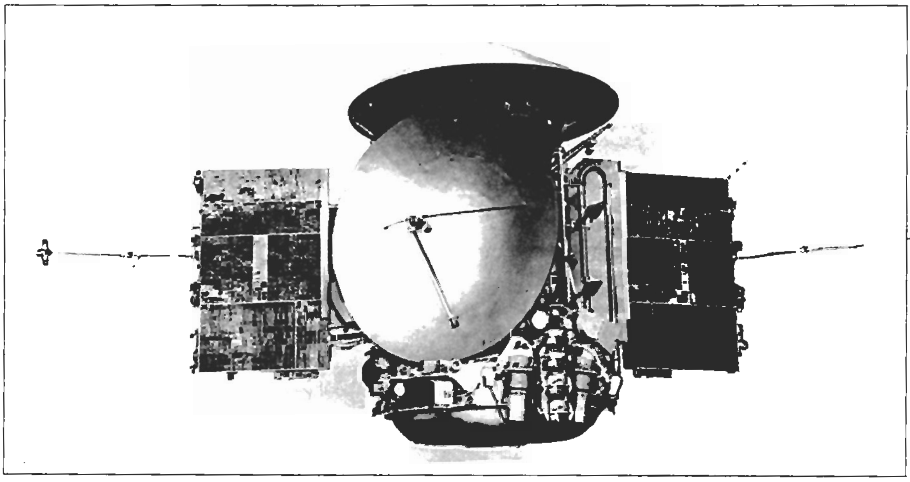


Figure 19.
The Mars 6 and 7 Spacecraft

The silent spacecraft accomplished the flight mission completely. The additional transmission channel was operative only during the descent of the lander. Information from the Martian surface had to be transmitted by the main radio channel to the Mars 5 spacecraft; however, the signal did not reach its destination.

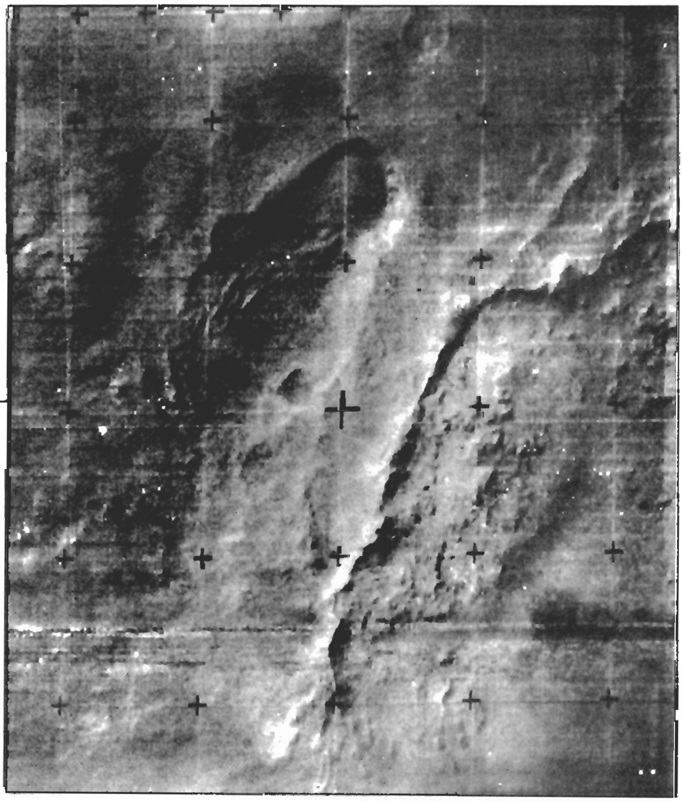
An analysis was performed after the flight and showed that the Mars 6 craft landed in the vicinity of the Valley Samara, which was characterized by a V-shaped cross-section profile. The coordinates of the landing site were 23° 54′ S and 19° 25′ W. Perhaps the landing occurred on a steep hill?

Because of the failure of the onboard systems, the Mars 4 and 7 spacecraft did not accomplish their flight program. In the Mars 4 spacecraft, the correction braking propulsion system failed, and as a result, the spacecraft did not enter a Martian satellite orbit. The Mars 4 spacecraft came within 2,200 kilometers of the Martian surface and made Mars images from its flyby trajectory. After separation from the spacecraft, because of the failure of the 2T-312 transistor, the Mars 7 lander was not put in an encounter trajectory and missed the planet by 1,300 kilometers.

Only the Mars 5 spacecraft went into satellite orbit with the following parameters: the height of apocenter 32,500 km, the height of pericenter 1,760 km, an inclination of 35 degrees to the Martian equator, and a 25-hour period of rotation. The spacecraft accomplished its flight mission completely. Mars 5 high-resolution images provided additional data about the planet (Figure 20).

Minister Afanasiev was deeply concerned by the numerous systems malfunctions that led to the failure of the Martian flight mission and to the loss of the Soviet Union as lead in this field. The results of Project M-71 were analyzed at a ministry meeting. Right after this meeting, S.A. Afanasiev and I met A.I. Shokhin, who was the Minister of the Electronic Industry. We asked him only one question: "How do we avoid numerous failures during the next flights?" We were not concerned with a single failure because the spacecraft systems continued to operate in that situation.

Figure 20.
Image of the Martian Surface Obtained From the Mars 5 Spacecraft



A.I. Shokhin offered two suggestions. The first one was to use the electronic components that were designed about 10 years ago and were fabricated in accord with well-developed technology. The second option was to choose advanced electronic components using a special program.

Without a second thought, we rejected the first suggestion. The second option was accepted. Programs were developed to choose the electronic components (they got the abbreviation MB). They increased the reliability of the onboard instruments. On the other hand, the cost of the MB electronic components was almost 10 times the previous cost. But, as they say, "The goal is worth the effort."

CHAPTER 6

HOW TO DELIVER MARTIAN SOIL?

6.1 Project 5NM

One of the main missions of the manned Apollo spacecraft was to deliver lunar soil to Earth. This problem could be solved by an automatic spacecraft as well. The idea of delivering lunar soil to Earth by automatic spacecraft was in the air and was awaiting a favorable situation to be realized.

In the summer of 1968, I visited Babakin. In my presence, Yu.D. Volokhov, who was the deputy director of the design bureau, and Babakin discussed the Soviet manned lunar program, which, in their view, was behind schedule. At this time, Babakin spoke about the possible use of the land rover developed at the Lavochkin design bureau for moving the Soviet cosmonauts about the lunar surface to collect samples of lunar rocks and deliver them back to Earth.

A sudden thought went through my mind, and I said, "What if on the lunar landing platform the land rover would be replaced by a rocket. The rocks could be collected and delivered to Earth." Babakin focused on this idea and thought for a while. His eyes moved to the right, then to the left, probably following his thoughts. Eventually, he returned to his usual mood and said, "But it is a very difficult problem." I responded, "I do not have expertise in designing lunar spacecraft and cannot make a decision." However, the idea attracted Babakin, and he issued instructions to work on it.

After careful consideration, it was concluded that the project could be realized only if the advanced technical decisions were used and strict weight limitations taken into account. Babakin gave much attention to this project. He was eager to see the project completed, and he always participated in the solution of intricate scientific and technical problems. Probably, the project was accomplished successfully because of the enormous efforts of Babakin.

At the beginning of 1970, the lunar project's problems had been solved. At this time, Babakin gave instructions for a technical proposal to consider how the

Martian soil would be delivered to Earth. In the summer of 1970, the technical assignments for Project 5NM had been completed. It was planned that in September 1975, the powerful N-1 rocket would launch the spacecraft and inject a payload of 98 tons in a predetermined Earth satellite orbit. This weight included the weight of the 5NM spacecraft (20 tons) (Figure 21). The orbiter, which weighed 3,600 kilograms, was designed to deliver the lander to Mars and to receive the telemetry data from the lander during its descent and landing on the Martian surface. The orbiter included the toroidal instrument module, which came from the M-71 project, and the propulsion system with the spherical fuel tank, which came from the M-69 project.

The lander, which weighed 16 tons, had an aeroshell screen with a central solid area with a diameter of 6.5 meters. At the perimeter of the solid cover, 30 petals were attached. After the spacecraft entered an interplanetary trajectory, the petals were opened, creating an aerodynamic cone with a diameter of 11 meters. The aeroshell screen covered the instrument module, which included the system that controlled the soft landing. Also, this system included the velocity meter, which worked on the Doppler principle, and the altimeter. In addition, the instrument module included the radio system, the program timing device, and the power system.

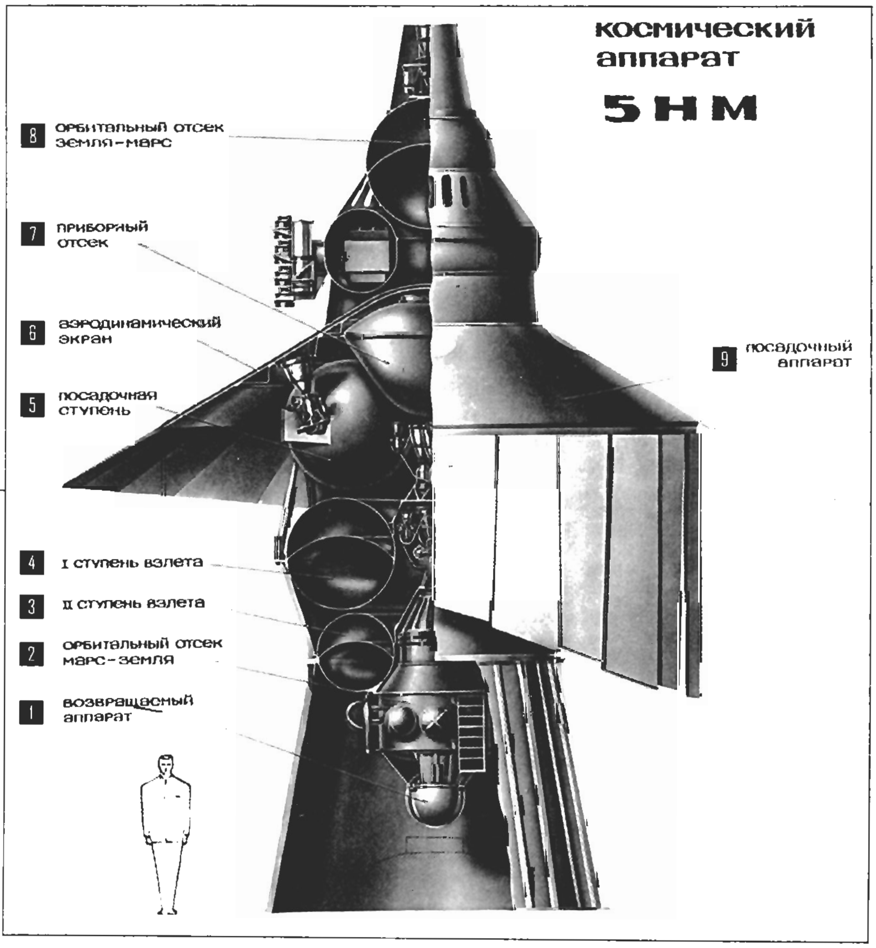


Figure 21.
The 5NM Spacecraft Designed to Deliver the Samples of the Martian Soil to Earth—
(1) returning capsule, (2) orbital Mars-Earth module, (3) second stage, (4) first stage, (5) landing stage, (6) aeroshield cover, (7) instrument module, (8) orbital Earth-Mars module, and (9) lander

The propulsion soft landing system was composed of four spherical fuel tanks and four propulsion engines, which controlled the thrust. On the top of the propulsion system, a two-staged booster rocket was installed. The rocket included the orbital Mars-Earth module, which weighed 750 kilograms, and a return craft, which weighed 15 kilograms and was designed to deliver 200 grams of Martian soil back to Earth. The design of the Venus 4/6 orbiter was used for fabricating the orbital Mars-Earth module.

To transfer the spacecraft from Earth's orbit to an interplanetary orbit, a two-staged boosting rocket was proposed. When the spacecraft would approach Mars, a trajectory correction had to be performed. Then the lander would be separated from the orbiter. To receive the telemetry data from the lander, the orbiter would be placed in a flyby trajectory.

At the same time, the lander would move along its trajectory and enter the Martian atmosphere. The asymmetrical aeroshield cover would cause the lander to perform a gliding descent. When the lander's speed would reach 200 m/sec, the aeroshield cover would be discarded, the propulsion system would be initiated, and the craft would land on the Martian surface.

When designing this project, I recalled the comments of Korolev at the meeting in the Lavochkin design bureau, who said that landing should be performed by engines without parachutes. Certainly, for this project, it would be beneficial to perform the landing without a parachute. It was planned that after landing communication between the lander and Earth would be maintained in the decimeter band.

Upon a command from Earth, samples of the Martian soil that had been chosen in the panoramic image areas would be collected and loaded in the capsule. In 3 days, after the lander autonomously defined its position by a command from Earth, a booster rocket with the orbital Mars-Earth module and with the returning capsule would be launched in a Martian satellite orbit.

The parameters of the orbit should be the following: a pericenter height of 500 km and a rotation period of 12 hours. After 10 months in a Martian satellite orbit waiting for a favorable date, the orbiter with the capsule would be transferred to an interplanetary trajectory and returned back to Earth (Figure 22). Approaching Earth,

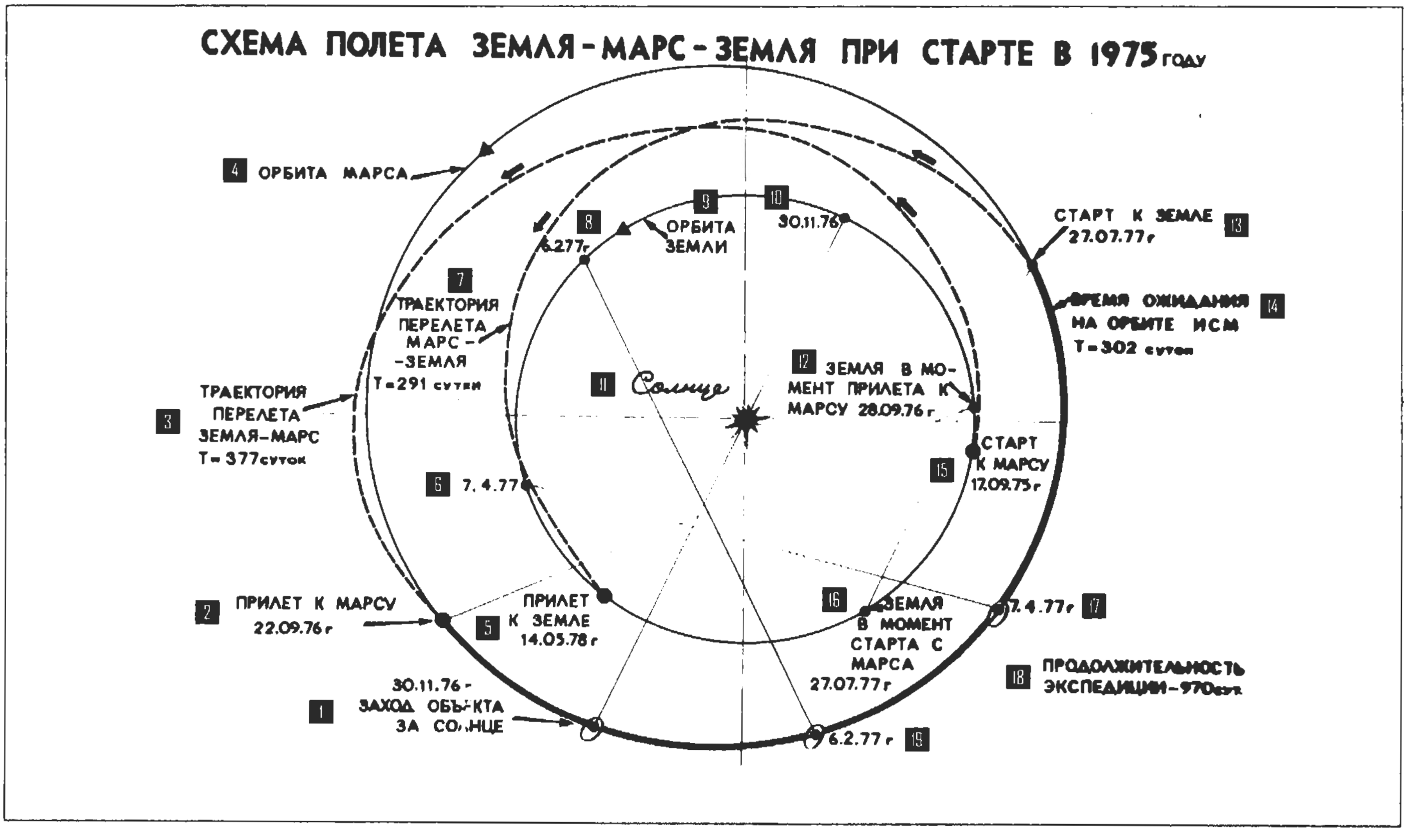


Figure 22.
The Profile of an Earth-Mars-Earth Flight If the Spacecraft Would Have Been Landed in 1975—(1) 30.11.76, spacecraft is positioned behind the Sun, (2) 22.09.76, arrival at Mars, (3) interplanetary Earth-Mars trajectory, T=377 days, (4) Martian orbit, (5) 14.05.78, arrival at Earth, (6) 7.4.77, (7) interplanetary Mars-Earth trajectory, T=291 days, (8) 6.2.77, (9) Earth's orbit, (10) 30.11.76, (11) Sun, (12) 28.09.76, Earth's position at the time of the spacecraft arrival at Mars, (13) 27.07.77, spacecraft is launched to Earth, (14) time that the Martian satellite spent in orbit, T=302 days, (15) 17.09.75, launch to Mars, (16) 27.07.77, position of Earth at the time when the spacecraft was launched from Mars, (17) 7.4.77, (18) duration of the expedition—970 days, and (19) 6.22.77

the return capsule would be separated from the orbiter. Because of aerodynamic braking, the speed of the capsule would decrease to 200 m/sec. At this time, the parachute system would be deployed and the radar beacon, which facilitates the capsule search, would be activated.

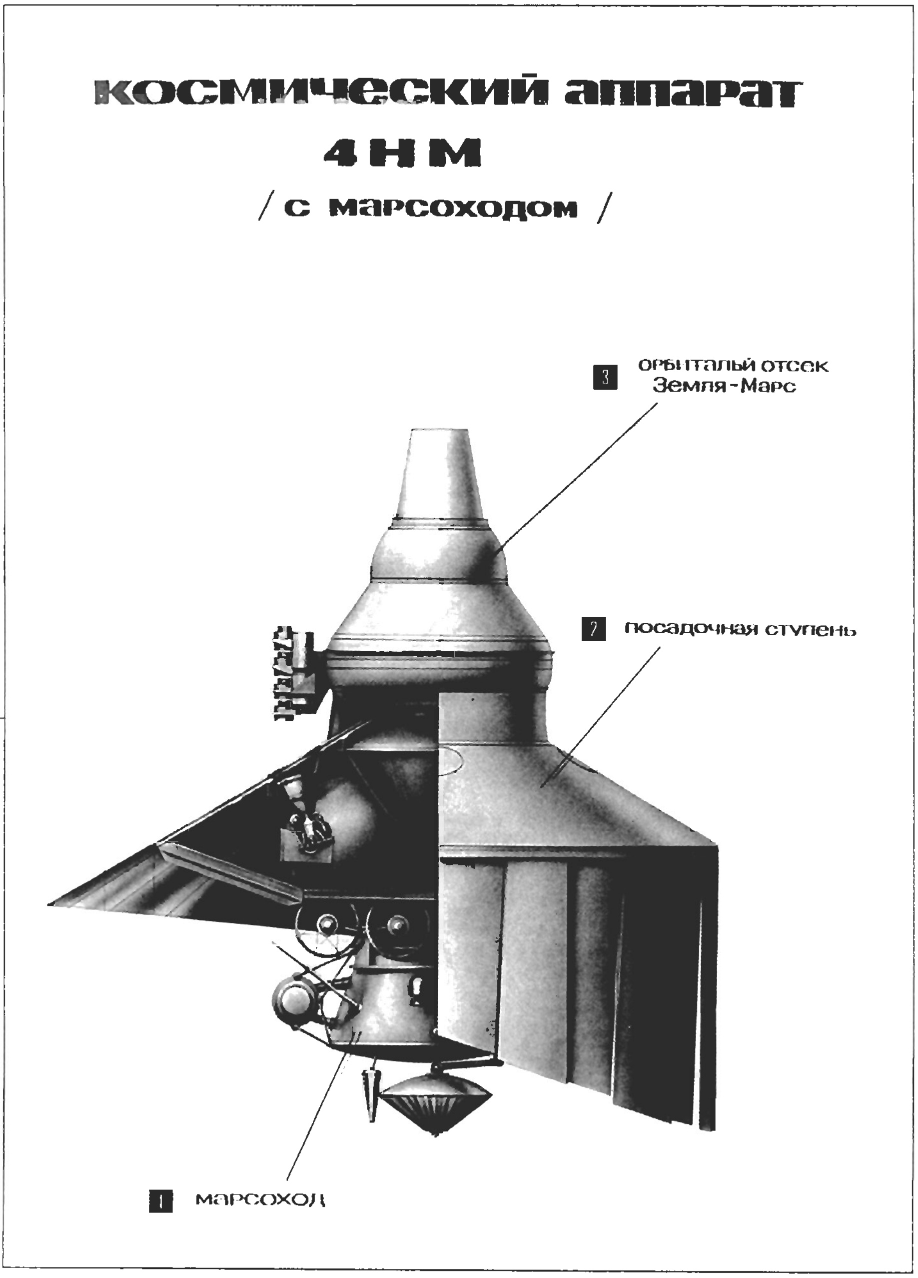
In 1973, to test the spacecraft and lander systems as well as to explore Mars with a rover, it was planned to launch the 4NM spacecraft (Figure 23). The project for the delivery of Martian soil was discussed at a scientific-technical meeting. Eventually, we came to the conclusion that it would not be feasible to accomplish it on schedule for the following reasons:

1. Biological contamination of Earth was possible. If the parachute system failed, the capsule would brake up. Biologists believed that Martian microbes might be present in Martian soil. On Earth, the Martian microbes could propagate with a very high speed. This experiment could be a major tragedy for Earth.

2. The onboard systems and instruments had not been tested in real flight. Apparently, we were not aware how they would operate during almost 3 years.

However, Minister Afanasiev liked this project. He admitted that our arguments on biological insecurity were reasonable. Simultaneously, being confident that biological problems would be solved soon, he attempted to convince Babakin to begin the project . Nevertheless, Babakin did not agree. The minister suggested that I become the main designer of the project. He promised all kinds of help. The help of such a powerful and influential chief meant a lot, but I could not accept his offer. Afanasiev was disappointed, but he did not forget this project.

Figure 23.
The 4NM Spacecraft Designed for Mars Exploration With a Mars Rover—(1) Mars rover, (2) lander, and (3) Earth-Mars orbiter



6.2 Project 5M

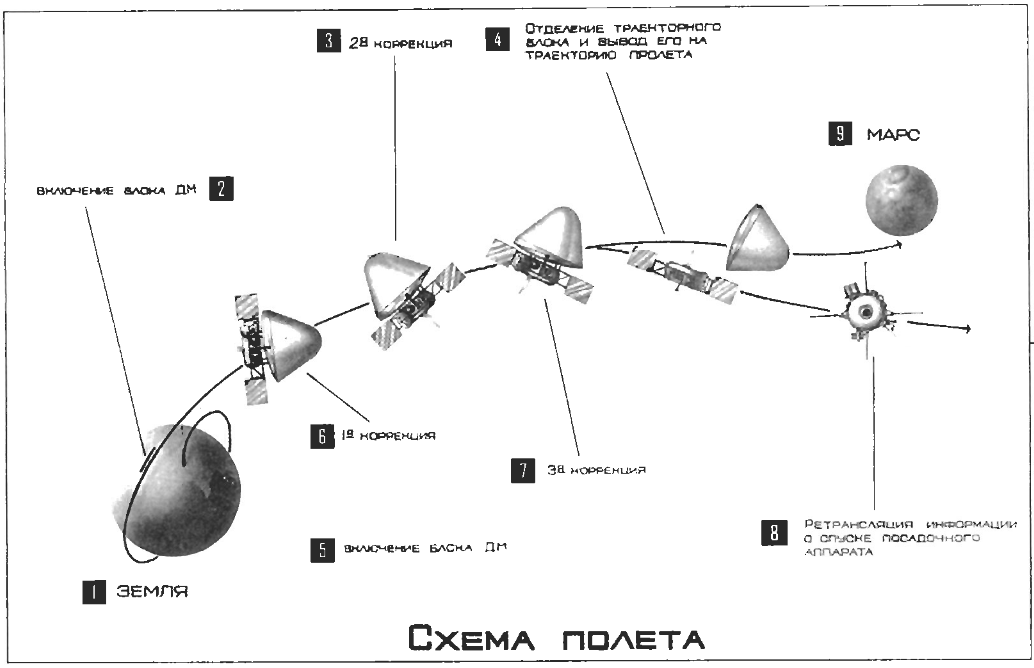


Figure 24.
The Flight Profile of the 5M Spacecraft— (1) Earth, (2) activation of block DM, (3) second correction, (4) separation of reactive block and its injection into flyby trajectory, (5) insertion of the DM block, (6) first correction, (7) third correction, (8) retransmission of the information on the lander descent, and (9) Mars

By 1974, we had acquired extensive experience in developing Martian spacecraft and testing their operation in the conditions of real flight. Again, Afanasiev ordered the development of a project for the delivery of Martian soil.

By this time, the situation had changed. The fabrication of the N-1 rocket had been stopped. Only the Proton rocket could be used for launching the spacecraft. The Proton rocket was able to place a payload of 22 tons in an Earth orbit. This weight included the booster block D.

This payload was insufficient to deliver Martian soil to Earth. To increase the spacecraft weight, we decided to perform the docking of two payloads launched by Proton rockets in an Earth orbit. Specifically, the first booster block D would be docked with the second booster block D, which in turn would be docked with the spacecraft. After docking and subsequent ignition of the D blocks, the spacecraft, which weighed 8,500 kilograms and consisted of the orbiter and lander, would be placed in an interplanetary trajectory.

The flight had to be performed with a trajectory that would eventually approach Mars. Upon approaching the planet and to receive data transmitted from the lander, the orbiter would be transferred to a flyby trajectory (Figure 24). The lander would perform a gliding descent and land on the Martian surface. Using the panoramic images, there would be a command from Earth and the Martian soil would be collected and loaded in the capsule, which was installed in the second stage of the booster rocket. The rocket, which weighed 2,000 kilograms, had to deliver the capsule with the soil to a Martian orbit.

To deliver the capsule back to Earth, the spacecraft with the return craft should be placed in a Martian orbit. In this orbit, the spacecraft had to be docked with the last stage of the rocket that contained the capsule. Then the capsule should be reloaded in the return craft.

When a favorable starting date arrives, the soil should start its trip to Earth. To place the spacecraft in a Martian orbit, it was necessary to launch a third Proton rocket. To avoid biological contamination, it was proposed to place the return craft in an Earth orbit, dock it with a manned spacecraft, reload the return craft into the manned spacecraft, and deliver the soil to Earth. Therefore, to deliver the Martian soil to Earth, it was necessary to launch three Proton rockets and to perform three automatic dockings in the space.

Apparently, this project was too intricate and unreliable. Because of the strict weight limitations, it was planned to use modern onboard instruments. Similar to Project 5NM, to check the onboard instruments in the conditions of real flight, it was planned at first to launch the 4M spacecraft to study Mars with a Mars rover. The designs for descent and landing for both crafts were identical (Figure 25).

Unfortunately, at this time, cooperation between the Soviet Union and the United States in the field of Mars exploration had not started. After the American Apollo program was completed, the Saturn V rockets, which were capable of placing a payload of 138 tons in an Earth's orbit, were destroyed. There was no doubt that if our countries combined their efforts and used a Saturn V rocket, the problem of delivering the Martian soil to Earth would be solved and complete biological security of Earth would be provided.

I presented the results of our work to main designer Kryukov and simultaneously emphasized the complexity of the project and the low probability of its success. Eventually, I suggested postponing the project until a better time. Kryukov did not agree with me, but I could not continue to work on the project, which, in my view, had no chance of complete success. As a result of this disagreement, the future development of the project was given to V.P. Panteleev, the deputy of the main

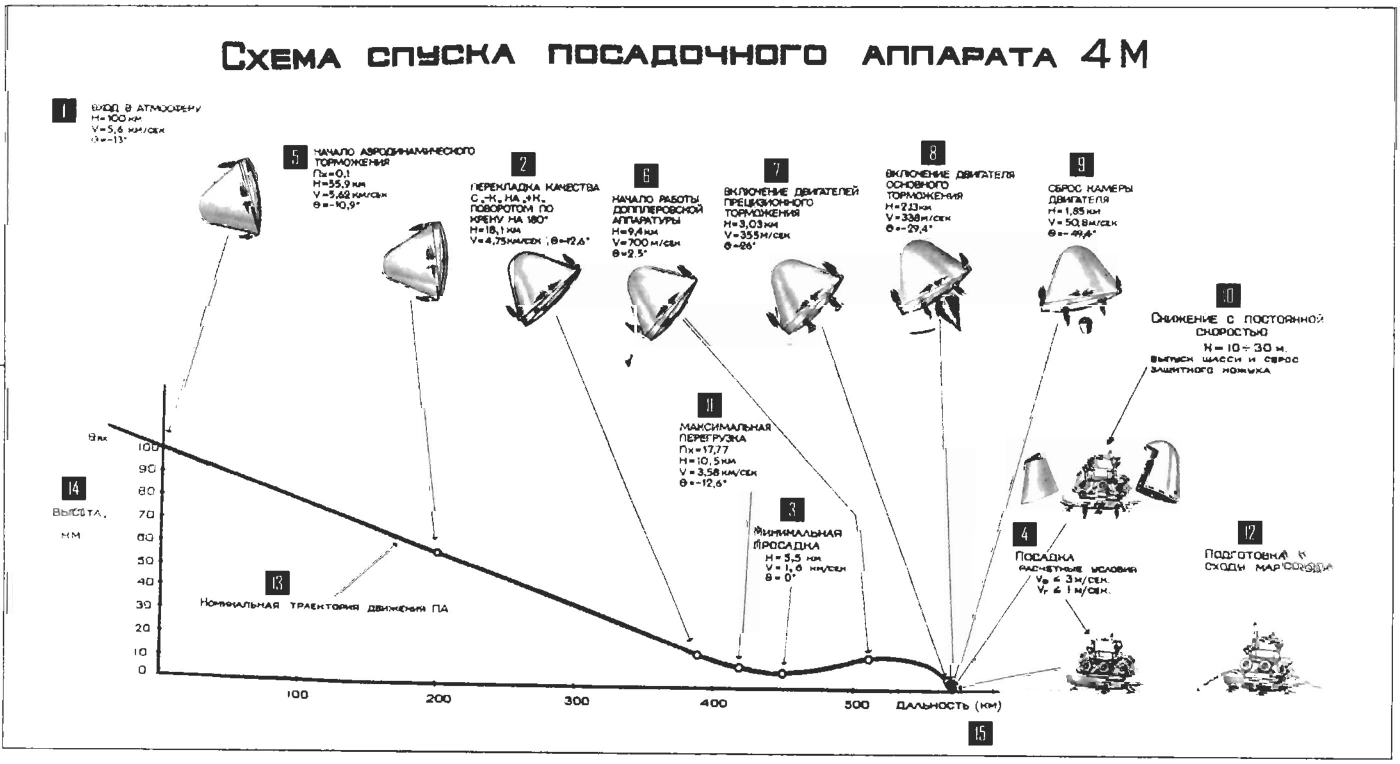


Figure 25.

The Design of the Descent and Landing of the 4M Lander Vehicle—(1) entrance in the atmosphere, altitude, H=100 km, speed of the entrance in the atmosphere, V=5.6 km/sec, angle of entrance in the atmosphere, θ=-13°, (2) rotation of the lander around its axis to change the direction of G-force, H=18.1 km, V=4.75 km/sec, θ=12.6°, (3) closest approach of the lander to the Martian surface, H=5.5 km, V=1.0 km/sec, (4) landing, predetermined conditions: V vertical ≤3 m/sec, V horizontal ≤1 m/sec, (5) beginning of the aerodynamic braking, H=55.9 km, V=5.62 km/sec, θ=-10.9°, (6) activation of the instruments that work on the Doppler principle, H=9.4 km, V=700 m/sec, θ=2.5°, (7) insertion of the engines of the precision braking H=3.03 km, V=355 m/sec, θ=26°, (8) insertion of the engine of the main braking, H=213 km, V=338 m/sec, θ=-29.4°, (9) dropping of the engine container, H=1.85 km, V=50.8 m/sec, θ=-49.4°, (10) descent with constant speed, H=10-30 m, removing of the undercarriage and dropping the aeroshell cover, (11) maximum overloading, H=10.5 km, V=3.58 km/sec, θ=-12.6°, (12) Mars rover activation, (13) nominal trajectory of the lander, (14) altitude (km), and (15) distance (km) designer. V.P. Panteleev was a highly qualified specialist and was persistent in achieving his goals.

6.3 The Continuation and the End of the 5M Project

To simplify the flight design and to decrease the number of space dockings, V.P. Panteleev decided to increase the weight of the spacecraft after modifying the booster blocks D. This modification included the installation of additional fuel lines and their connectors to transfer fuel after the blocks were docked. The fuel had to be transferred from an active block D, which functioned as a first stage, to a passive block D, which functioned as the second stage.

Both blocks injected the spacecraft in an interplanetary orbit. Because of these modifications, the weight of the spacecraft was increased from 8,500 to 9,335 kilograms. The additional increase of the spacecraft weight required a change in the design of the lander's descent. To achieve this goal, the lander's gliding descent had to be replaced by a ballistic descent. In addition, the lander's shape and design had to be changed.

At the first stage of the project, the lander was designed in the shape of a headlight. In this stage, the headlight was replaced with a conical aeroshield cover, which was like an umbrella and had a diameter of 11.35 meters. The center was a solid part of the cover with a diameter of 3 meters, into which the thick, tube-like beryllium spokes were installed. The spokes were covered with fiberglass. Before the spacecraft was launched, the spokes were folded along the lander's axis. After the spacecraft would be injected into an interplanetary trajectory, the spokes would be opened to create the aeroshield cover.

All suggestions about a possible weight decrease of onboard instruments had been carefully analyzed. As a result, the design of the spacecraft, which weighed 9,135 kilograms and consisted of the orbiter (1,680 kilograms) and lander (7,455 kilograms), was developed. The lander included a two-stage booster rocket, which weighed 3,190 kilograms, and the Mars-Earth return craft.

In January 1976, Kryukov approved the preliminary design of the return craft, which had to deliver the Martian soil and whose weight should not exceed 2 percent of the spacecraft weight. With these weight limitations, there was hope that the project could be completed. However, the problem of biological contamination had not been solved. Simultaneously with the development of the technical assignment, we started the second stage of the project to find a solution to the weight limitations. To do that, a number of highly advanced technical solutions to decrease the weight of the spacecraft were implemented.

The idea of Academician A.P. Vinogradov was very helpful. He suggested conducting thermal sterilization of the soil samples while in the Martian orbit. This suggestion completely solved the problem of biological security of Earth. In addition, the implementation of this idea would lead to a significant decrease in the weight of the spacecraft. Apparently, when the weight of the sample return craft would be decreased by 1 kilogram, the weight of the spacecraft could be decreased by 10 kilograms. The following parts were removed from the return craft: parachute, radar, battery, and automatic unit. The return craft, with a weight of 7.8 kilograms and speed of 12 km/sec, would enter Earth's atmosphere like a meteorite. After aerodynamic braking, the speed of the craft would be decreased to a few tens of meters per second, and the craft would fall to Earth.

According to calculations, the scatter of the craft landing site was restricted to a circle with a radius of 40 kilometers. The search for the craft was to be performed with helicopters equipped with instruments designed to detect a radioactive source in the returning craft. The second stage of the project provided the opportunity to decrease the weight of the spacecraft up to 4 percent of the spacecraft weight.

Many organizations were involved in the development and fabrication of the spacecraft. In 1978, when the first models and parts of the spacecraft were designed, the Head Institute issued a statement in which the complexity of the project, its high cost, and low probability of success were indicated. Based on this statement, Minister Afanasiev decided to discontinue the project for Martian soil return.

This decision seriously damaged the prestige of the Lavochkin design bureau. Apparently, many organizations strongly believed in the ability of the Lavochkin design bureau to accomplish the most intricate of technical assignments. This was the reason their specialists concentrated on this project. But all of a sudden, they were out of business!

The main designer, Kryukov, who said he was guilty of mismanaging the project, resigned. At that time, V.M. Kovtunenko, the deputy to the main designer of Yushnoe NPO in Dnepropetrovsk, was appointed the main designer of the Lavochkin design bureau.

Kovtunenko had been working at Yushnoe NPO in Dnepropetrovsk for many years. In the beginning, he developed ballistic rockets. During the last 10 years, before he was appointed the main designer of the Lavochkin design bureau, Kovtunenko was in charge of the Intercosmos satellites, which were developed according to a cooperative program among socialist countries and were designed to study the space near Earth. The Intercosmos satellites were developed using the design of one of the Cosmos series satellites. They had small weight, a simple design, and were launched in an Earth's orbit with the two-stage Tsyklon rocket.

Naturally, the problems that had to be solved by the recently appointed main designer to develop the interplanetary automatic spacecraft were not similar to the problems with which he dealt while developing the Intercosmos satellites. Kovtunenko decided to find his own way in this new field. He was fascinated with the idea of creating the multipurpose spacecraft to study the Moon, Venus, and Mars. In 1979, the design of the UMVL spacecraft (Universal Mars, Venus, Luna) started to be developed.

At the same time, Kovtunenko decided to continue the development of the Venus automatic spacecraft initiated by main designer Kryukov. These spacecraft had to be launched in the next 3–4 years. During this period of time, Kovtunenko hoped to develop the UMVL spacecraft and use it to perform the broad planetary and lunar study.

However, the pace of the development of the new spacecraft was slow. That could be explained by an unlucky choice of the project manager, who was the former party functionary, a skillful politician whose only desire was to be recognized and nothing more. In addition, Kovtunenko had a difficult time in establishing effective contacts with such "heavyweights" of the space industry as V.P. Glushko, N.A. Pilyugin, M.S. Ryasanskiy, and others. Apparently, without their support, it was difficult to achieve a quick success in the development of new spacecraft. Therefore, the Phobos 1 and 2 spacecraft (Figure 26) were launched only in 1989, 10 years after their development had been initiated. The flight program outlined: (1) to place the Phobos 1 and 2 spacecraft in a Martian orbit, (2) to approach the Martian satellite Phobos, (3) to land two automatic stations on Phobos' surface, (4) to conduct a remote distance study of Phobos soil chemistry from a flyby trajectory, and (5) to conduct an extensive study of Mars from its satellite orbit.

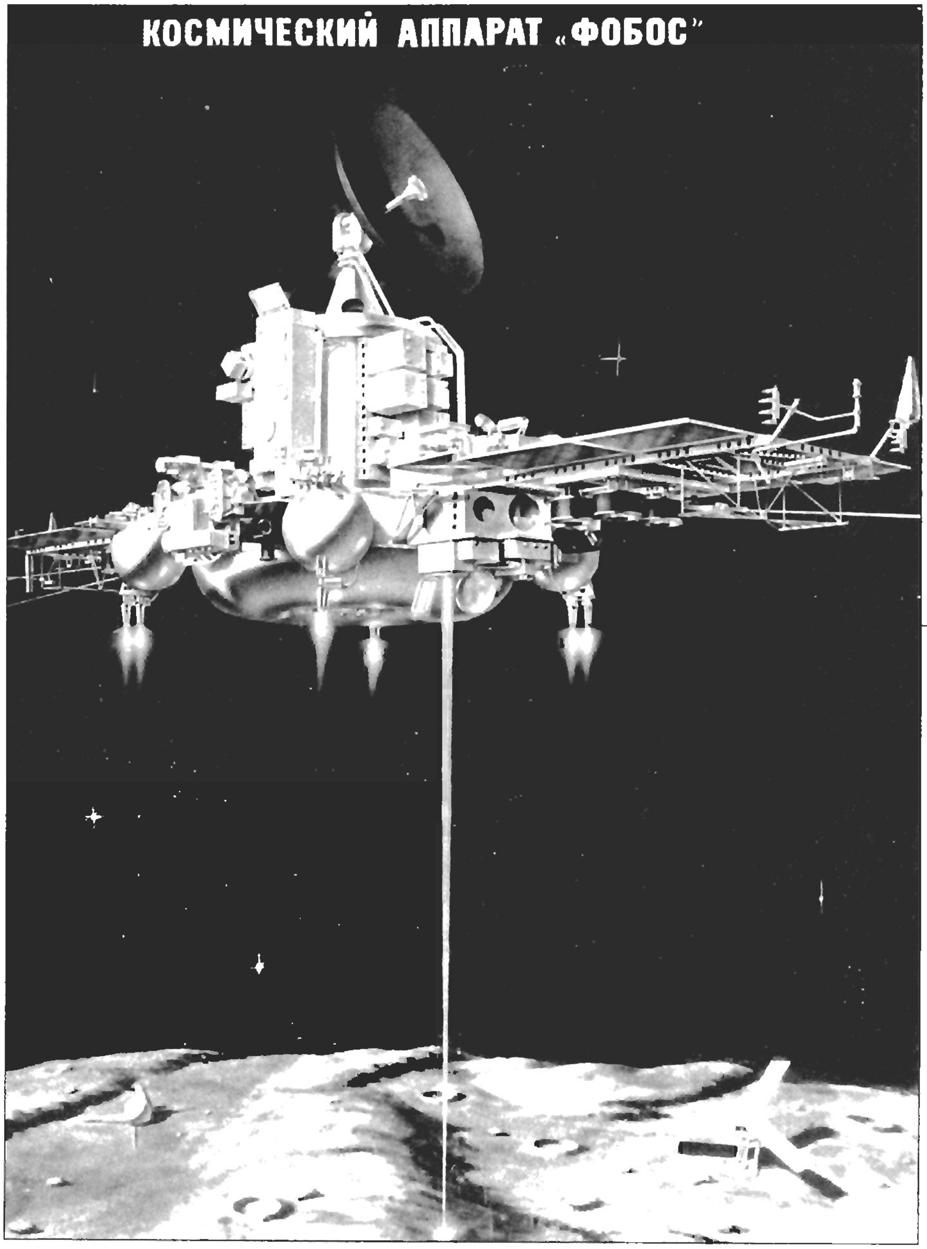


Figure 26.
The Phobos 2 Spacecraft

Figure 27.
The Mars 96 Spacecraft

Unfortunately, neither spacecraft accomplished the flight program because of the huge mistakes that were made during their construction and because of neglecting the rules established in Korolev OKB when designing the first interplanetary spacecraft.

The first spacecraft failed in the interplanetary trajectory as a result of two unfavorable circumstances: (1) the failure to issue onboard the correct command to transfer the propulsive mass to the micro-engines of the spacecraft's attitude system and (2) a logic error in the onboard prohibition systems that should have disconnected the fuel line while the spacecraft was in a position of three-axis stabilization.

The second spacecraft failed in a Martian satellite orbit. That happened because the computer program named "e minimal" was not included in the onboard software. If the power voltage decreased below a predetermined level, the program "e minimal" would have automatically issued a command to disconnect all onboard systems except the systems needed for the spacecraft to survive. All interplanetary automatic spacecraft developed at OKB-1 and the Lavochkin design bureau carried the program "e minimal" onboard, and the first attempt to exclude it from the computer software led to sad result.

The Mars 96 spacecraft (Figure 27) failed as well. This spacecraft was built to perform an extensive study of Mars from its orbit with penetrators dropped to the Martian surface. The Mars 96 spacecraft was not injected in an interplanetary trajectory.

Today, it seems that the Soviet and, thereafter the Russian, program of Mars exploration was ended on a sour note. However, there is the Russian proverb that says: "One beaten person is worth two unbeaten ones."

As soon as the Russian economy is stabilized, young creative minds who have already developed the original approach to Mars and Phobos exploration will overcome and succeed.

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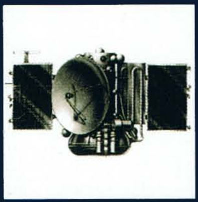

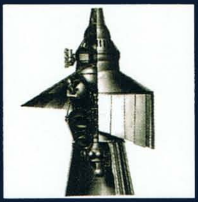

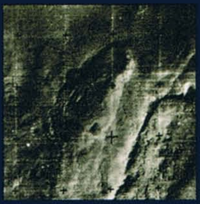

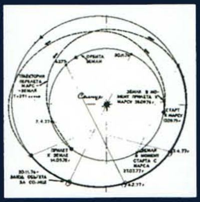

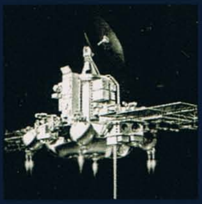

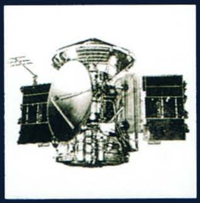

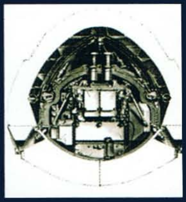

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