S.P. Korolev RSC Energia
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THE PART PLAYED BY THE DEPARTMENT OF LUNAR AND PLANETARY STUDIES OF THE STERNBERG ASTRONOMICAL INSTITUTE OF THE MOSCOW STATE UNIVERSITY IN THE LUNAR EXPLORATION BY MEANS OF ROCKET AND SPACE TECHNOLOGY

Since 1958, Russia has been maintaining an active effort of studying the Moon with the use of space technology. This effort passed through a series of phases, from the pioneering acts of delivering to the Moon surface a Soviet state emblem, and photographing the Far Side of the Moon to the preparations for short-term manned missions to the Moon, and, even further, to the developmental work on the programs and equipment that would be needed for large-scale lunar missions and for the deployment of a long-term manned lunar base. The effort was conducted incrementally, with each step addressing an increasingly complex task, and each step being an unprecedented "first".

All the early lunar probes, including the spacecraft of the E-6 series designed to accomplish the first soft landings on the Moon, were designed at the S. P. Korolev design bureau. Each of them represents an important milestone - they demonstrated that the Moon is an attainable goal, that a research spacecraft controlled from a great distance can circle the Moon and come back to Earth, and, finally, make a soft landing on the Moon and successfully conduct there scientific research. A radical hypothesis that the lunar surface is covered with a very thick layer of dust in which a Moon lander would inevitable drown was finally disproved.

In 1965, in view of the fact that the country's leadership put S.P.Korolev in overall charge of the effort to land a man on the Moon and bring him safely back to Earth, Korolev decided to focus the work of his team on the manned space flight, while the work on the lunar robotic craft was turned over to Lavochkin Design Bureau headed at the time by G.N.Babakin.

The team of the S.P.Korolev design bureau did a tremendous amount of extremely hard work preparing manned missions within the framework of the N1-L3 project. This project included the development of a powerful launch vehicle N1, and a lunar lander, a lunar orbiter, and a restartable acceleration/deceleration rocket stage that, taken together, constituted the L3 system. One of the items on the manned lunar program was a flight that was to take a man around the Moon and bring him back to the territory of our country. This flight was considered as an initial phase of preparation for a manned lunar landing mission. A descent vehicle capable of atmospheric re-entry at the escape velocity on return from the Moon and of controlled descent and landing/splash-down was designed, manufactured, passed developmental tests and several actual flight tests in unmanned mode (spacecraft Zond 3 through 8). An unmanned version of the lunar lander was successfully tested in Earth orbit.

Robotic lunar spacecraft were paving the way for the manned vehicles. One of their tasks was to provide the necessary reliable data. These craft addressed the need for a mapping survey, a more detailed knowledge of the microrelief, morphology and bearing strength of the lunar soil, a developmental testing of trajectories, control algorithms, reliable soft landing systems, and a vehicle for moving around on the

lunar surface. It was with this objectives in mind that the artificial lunar satellites were launched, which provided a photographic survey of the lunar surface at different scales. This facilitated the selection of the landing sites for the subsequent heavy soft-landing craft that were to deliver to the representative lunar areas moon-rovers remotely controlled from Earth, or to drill the upper lunar crust, taking samples and returning them to Earth. And, of course, these robotic probes also carried out their own independent scientific assignments.

After the N1-L3 project was terminated in 1976, the work on the manned lunar program continued in the form of the feasibility studies of a lunar base and a transition to the practical use of the lunar resources. This work, closely monitored by academician V.P.Glushko, was focused on the engineering studies of elements of the lunar expedition system, the philosophy, architectural principles and components of lunar bases, the selection of promising sites for the bases, the lunar research and development program. Since 1981, the team working on the lunar program was supervised by the Chief Designer Yu.P.Semenov.

RSC Energia conducted design studies of a super-heavy launch vehicle, and the space vehicles included in the lunar expedition system. The work on the lunar habitation module and specialized production modules was conducted under direction of academician V.P.Barmin at the Design Bureau of the General Machine-Building (KBOM), the work on the medium- and heavy-class moon rovers was conducted at the All-union Research Institute for the Transportation Machine-building (VNIITransmash), and the work on the mapping survey and relay satellites was conducted at Lavochkin NPO. The Central Research Institute of Machine-building (TsNIIMash) was the prime theoretical center of the space industry. Under the aegis of the Institute for Space Research of the Russian Academy of Sciences (IKI RAN), with RSC Energia playing an active coordinating role in the broad network of the organizations and research institutes of the USSR Academy of Sciences, a Program of Lunar Research and Exploration was being developed, which covered research of the Moon proper, and of the circumlunar space, as well as conducting on the Moon and from the Moon surface a broad gamut of scientific and applied experiments in the fields that would include biology and medicine, astrophysics, prospecting for mineral resources, manufacturing various one-of-a-kind substances and materials, and, first of all, propellant components. Many of the organizations did studies on the future-technology research equipment.

Promising candidate sites for lunar missions and locations for a manned lunar base were being selected, which involved finding a combination of terrain and global geological features that are both representative and interesting for research into the general structure of the Moon, and promising from the standpoint of future mining activities. Of special importance was the problem of the possible existence of subsurface water ice in certain areas.

On the directions from the administration and in response to a personal request from academician S.P.Korolev, the Moscow State University Sternberg Astronomical Institute Lunar and Planetary Lab headed by Dr. Phys.-Math. Sci. Yu.N.Lipsky took an active part in the lunar studies. In accordance with a number of governmental decrees it was, for a long time, the prime organization for scientific lunar research. The lab team, which consisted of his closest pupils who at that time were still very young graduates and postgraduates of the Moscow University, took part in activities ranging from providing methodological support for photographing the far side of the Moon to providing a procedure for selecting landing sites and mapping support for the

planned lunar missions. Ingenious proposals were put forward regarding the conduct of the planned space experiments and the subsequent interpretation of the obtained results.

At first, he and his closest associates were set a task of providing, on an extremely short notice, the theoretical support and specific proposals for the methods to be used for photographing the far side of the Moon from Luna 3 space probe and the interpretation of the obtained data.

During preparations for the soft lunar landings of the E-6 series space probes (Luna 9 and 13), this team was given the task of providing methodological support for the selection of the landing sites and implementation of panoramic photography with the subsequent processing of the obtained materials.

During the phase when the lunar surface was surveyed from lunar satellites, Yu.N.Lipsky's team was involved in the selection of the promising areas for the survey (paying special attention to the far side and areas close to the Moon limb), the scale of the survey, the referencing of the obtained materials to the existing data and selenodetic network and the extension of that network to the far side. A great deal of attention was paid to the photogrammetric processing of the pictures obtained from Luna 12 lunar satellite and unmanned lunar spacecraft Zond 6,7,8 which circumnavigated the Moon and came back to Earth.

Several years later, the results of this work, as well as open US publications on the results of the surveys conducted by Lunar Orbiter space probes and manned Apollo spacecraft, made it possible for this team to successfully complete a great and very important work of creating a series of lunar maps covering the entire surface of the Moon and lunar globes of different scales. Subsequently, the developed procedure was used by the team of the Lunar and Planetary Studies Department of the Moscow State University Sternberg Astronomical Institute to create similar globes for the planet of Mars based on the results from Soviet and US spacecraft.

One of the most critical issues that had to be addressed when working on the manned lunar mission program was assuring a safe landing on the Moon. The most important contribution to methodological materials concerning the actual landing conditions was made by Professor Yu.N.Lipsky's team. Having a good scientific background and a first-hand knowledge of the results obtained from the work of S.A.Lavochkin Design Bureau, they developed recommendations that became the basis for engineering work, including strength analysis, selection of structural materials, and of the design configuration that provides the maximum stability of the lander at the moment of touch-down and lift-off for return to Earth.

The team was involved in the selection of the promising landing sites, and the flight paths to approach them, including hypsometric profiles, the terrain description, the development of math models of the lunar surface for the selected sites, including a study of statistical distribution of craters, stones and slopes of different sizes. This work provided inputs for the developers of the lunar lander and the semi-automatic control system with a manual control loop for the precision landing phase, the development of the navigation charts for the crew and a method of quick reading of the charts by the crew during descent to the Moon.

The results of the work done to describe the microrelief and the soil properties at the proposed landing sites for the first manned missions became the basis for the design and development of the actual support kinematics of the landing gear of the lunar lander, as well as for the selection of the amount of propellant supply needed to perform the landing maneuver. These data were used to conduct analyses, to model

the actual environments, to make up analogs of the lunar soil, and to conduct developmental tests on the lunar lander mock-ups under conditions that are close to the actual environments.

Yu.N.Lipsky's team made a great contribution to the process of selecting promising sites for long-duration lunar missions in regard to the morphological description, the gypsometric support, proposals on the routs for manned moon rovers and their research program. This work further evolved into selection of candidate locations for a permanent lunar base, including its industrial area. This team was actively involved in the development of methodological recommendations on the optimal location and construction of the lunar base elements, on lunar production engineering, including mining and producing rocket propellants on a practical scale.

For more than two decades now, the team that was originally put together by Yu.N.Lipsky, has been headed by his pupil and closest associate, Doctor of Phys.-Math. Science, Head of the Lunar and Planetary Studies Department, V.V.Shevchenko. It was under his direction that were established and successfully developed new methods of remote investigation of the Moon, the planets and small bodies in the Solar system, and of the interpretation of obtained results. In particular, there was a significant development of the method for remotely determining the mineralogical composition of lunar rocks from spectral reflective properties.

This allowed to make a qualitative, and, to a large extent, a quantitative estimate of the chemical and mineralogical composition of the upper part of the regolith layer covering the near side of the Moon and to update its physical and chemical model. The tangible results obtained from these methodological studies are a series of practical works done to interpret the results of research conducted from both domestic and foreign ground instruments and spacecraft.

It should be noted that from those first buds that were so carefully and paternally nurtured by Professor Yu.N.Lipsky, there came into being a compact, close-knit, efficient and talented team, that is capable of carrying out the assigned tasks on short notice and at a highly professional level. This is the best memorial to their teacher whose 90^{th} anniversary was recently commemorated by the scientific community.