FTD-HT-23-744-70

AD 714428

FOREIGN TECHNOLOGY DIVISION

LUNA-16 - AN OUTSTANDING NEW ACHIEVEMENT OF SOVIET SPACE SCIENCE

by

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FTD-HT-23-744-70

EDITED TRANSLATION

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By: TASS Release of October 4, 1970

English pages: 19

Source: Izvestiya, October 4, 1970, pp. 1 and 2.

Translated under: Contract No. F33657-71-C-0142

UR/9003-70-000-000

LUNA-16 – AN OUTSTANDING NEW ACHIEVEMENT
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TASS Release

Outstanding achievements in the history of Soviet space science have marked this anniversary year dedicated to the commemoration of V. I. Lenin's 100th birthday. It is a year that has witnessed the flight of the Soyuz-9 spacecraft in a mission unprecedented both in terms of duration and in the scope and variety of its experimental assignments, a new Venus probe in the form of the Venera-7 automatic interplanetary station, and the successful launching of the Interkosmos-3 satellite. At the same time, ongoing regularly scheduled investigations of near-Earth space by satellites of the Kosmos series are contributing to the enrichment of science and technology with valuable information to ensure further progress in the conquest of space.

A radically new stage has been ushered in by the launching and successful completion of the sophisticated mission of the automatic Luna-16 probe. Returning on 24 September from its voyage to the Moon, the recovery module of this mission made a safe return to Earth, bringing with it samples of the lunar soil.

The Soviet space-exploration program is characterized by its purposefulness and planned systematic approach to the solution of new scientific and engineering problems. One of the primary directions of our program is the study of the Moon and the planets of the Solar System by means of automatic probes. The range of tasks to which these automatic vehicles provide solutions widens with every year. Not only is this form of space exploration far more economical than manned spacecraft, but it is reliable and ensures the transmission to Earth of invaluable scientific information precisely from those regions where human presence might be as yet impossible, impractical, or in any event extremely hazardous. Quite obviously, of course, this approach does not preclude direct human participation in scientific space exploration; on the other hand, manned missions are undertaken only when they are justified and necessary. Manned space flights, moreover, find a natural precursor in instrumented probes in their role as reliable ancillary tools in penetrating the unknown.

Priceless scientific data have been acquired, by scientists using automatic space vehicles, concerning the Moon and circumlunar space, Venus and Mars, and various regions of interplanetary space. The result of all this information has been to greatly expand our understanding of the Earth and the Universe, and occasionally to alter certain preconceived notions.

For more than ten years now the Moon has been an object of study by means of space probes. The first Soviet automatic probe – the Luna-1 – was launched toward the Moon during the early days of 1959. Approaching to within a few thousand kilometers of the lunar surface, the probe later entered a heliocentric orbit to become the first artificial solar satellite. The fall of that same year saw the Luna-2 station plant the Soviet banner on the Moon's surface in what was the first flight of a space vehicle from the Earth to another celestial body in the entire history of civilization. One month later, the third Soviet automatic probe, Luna-3, took the first photographs of the portion of the lunar surface invisible from Earth, transmitting these images back to our planet. In July of 1965 the Zond-3 instrumented vehicle again photographed the Moon's far side during a fly-by mission. It was on the basis of the photographs transmitted by these two probes that the first complete lunar map and globe were prepared.

New possibilities in the study of the Moon's surface were demonstrated by the flight of the Luna-9 automatic station, with its first soft landing on another heavenly body. This was mankind's first opportunity for a close-up view of the lunar surface layer. This success may simultaneously be regarded as a giant step forward on the endless path toward greater sophistication and perfection in automatic techniques for understanding the Universe.

At a later date, automatic artificial lunar satellites were developed to carry forward these investigations of the Moon and of near-Moon space. As a result of the Luna-10 and Luna-12 missions, it was possible to determine for the first time, from a circumlunar orbit, the nature of lunar rocks, which were found to be of similar composition to the basalts encountered on Earth. After executing a soft landing, Luna-13 performed a whole series of investigations on the lunar surface, specifically transmitting valuable information on the mechanical properties of the surface layer of the lunar soil.

These missions demonstrated the high efficiency of automatic devices in the exploration of celestial bodies.

The expedition of the US Apollo-11 spacecraft marked the beginning of manned flights to the Moon. The landing of Armstrong and Aldrin — and later of the Apollo-12 crew — on the surface of our natural satellite expanded still further the potentialities for lunar research. The first lunar rock samples, taken from two different locations on the Moon, were brought to Earth. Laboratory analysis of these samples has led to certain refinements in man's knowledge of the basic characteristics of this rock with respect to structure, chemical composition, and physical properties.

Nevertheless, the results thus far obtained do not yet provide a basis for definite conclusions on many fundamental problems of selenology involving the Moon's origin, age, and structure. Answers to these questions require an extensive program of new investigations, including rock studies on samples taken from a variety of locations on the lunar surface.

The successful Luna-series missions, along with the demonstrated ability to return scientific instrumentation probes to Earth (Zond-5, Zond-6, and Zond-7 flights), confirmed the wisdom of the unmanned approach to the study of the Moon. Soviet scientists, designers, engineers, and specialists were faced with the task of further improving these automatic space vehicles and of developing new and sophisticated components and subsystems for the associated automatic systems. The achievements of our science in the area of automatic control and the availability of trained industrial teams made it possible to meet this challenge in splendid fashion. Proof of this assertion can be seen in the remarkable success of the Luna-16 station, whose mission provided a solution to one of the most vital scientific and engineering problems of space science — the sampling of soil on a celestial body of the Solar System and the return of that sample to Earth.

The Luna-16 automatic station consists of a landing (descent) stage with a core-sampling device and a "Moon-Earth" space rocket with recovery module. At the time of its landing on the Moon the station weighed 1880 kg.

The landing stage represents an independent multipurpose rocket unit equipped with a liquid rocket engine, a system of fuel-component tanks, instrument compartments, and shockproof lunar-surface landing supports. Also installed on the landing stage are the antennas for the on-board radio complex.

The landing stage power plant has a primary variable-thrust engine for deceleration (braking), as well as two independent low-thrust engines (low-power thrusters) which operate during the final landing phase. The primary engine of the landing stage is of the restartable variety.

Located in the instrument compartments of the landing stage are the computer and gyroscopic instruments of the control and stabilization system, the electronic instruments of the orientation system, the radio transmitters and receivers of the on-board radio-telemetry complex operating in several radiofrequency bands, the sequencer which controls automatically the operation of all systems and assemblies (subsystems), the chemical storage batteries and current converters, elements of the thermoregulatory system, autonomous radio facilities for measuring the altitude and horizontal and vertical velocity components during the lunar landing phase, telephotometers for the transmission of service information regarding the drilling area, as well as scientific instrumentation for the determination of temperature and radiation conditions both during the flight and while on the Moon's surface.

At the time of liftoff from the Moon the landing stage served as a launch platform for the Moon-Earth rocket.

Mounted outside the instrument compartments on the external surfaces of the landing module are the jet vernier thrusters for the orientation and stabilization systems, their fuel tanks, and the optical sensors of the orientation system. The upper portion of the landing stage contains the Moon-Earth rocket.

The Moon-Earth rocket is an independent rocket unit with a liquid jet engine and a system of spherical fuel-component tanks. Secured to the central tank is a cylindrical instrument compartment within which are located the electronic, computational, and gyroscopic instruments of the rocket control system; transmission, reception, decoding, and sequencing instruments of the rocket's on-board radio complex; chemical storage batteries, current converters, and electrical instrumentation for the vehicle's automatic systems.

Four transceiving whip antennas of the on-board radio complex are mounted on the outer surface of the instrument compartment.

Secured by means of metal tie bands to the upper portion of the instrument compartment is the spherically configured recovery module. The bands securing the recovery module are connected by means of a special explosive lock which is released on radio command from the Flight Control Center as the rocket approaches Earth.

The recovery module has the form of a metallic cylinder whose external surface has been treated with a special heat-protective coating to shield the module and the equipment within it from the effect of high temperatures during reentry into the Earth's atmosphere. The recovery module's internal area is divided into three separate compartments. In one of these, the largest in volume, are located: radio direction-finding transmitters to ensure the possibility of detecting the recovery module during its parachute descent and once on Earth, chemical storage batteries, automatic components, and the on-board programmer which controls the deployment of the parachute system.

The second compartment contains the parachute (folded), four elastic antennas for the direction-finding transmitters, and two gas-filled elastic balloons to ensure the required attitude on the part of the recovery module following its landing on the Earth's surface.

The third compartment is a cylindrical container for the soil samples taken from the lunar surface. On one side, this container has an intake opening which is hermetically sealed by a special cover after the Moon core samples have been accommodated within it.

The core-sampling device, which is installed on the landing stage, consists of the following three basic components:

- a drill instrument with an electric drive system and drilling implements;
- a boring rod to which the drill is attached; and
- drive gears to position the rod in the vertical and horizontal planes.

Special attention was given, during the design of the core-sampling mechanism, to the problem of creating a drilling tool capable of drilling and taking up a lunar soil sample of various density — from the most friable (in dust form) to the hardest, similar to the basalts and granites of Earth. Additional consideration was focused on designing a sampling mechanism of minimum weight and power consumption.

The core-sampling device of the Luna-16 probe proved to be entirely adequate to its assigned function of drilling, transporting the core sample taken from the lunar surface to the container of the recovery module, and accommodating it within the container.

* * *

The Luna-16 station carried a pennant and emblem depicting the Great Seal of the Soviet Union. The pennant, in the form of a thin rectangular metal plate, was mounted on the landing stage and bore on its front the inscription "Union of Soviet Socialist Republics" along with the Great Seal of the Soviet Union; on the back, along the right border, the inscription "Luna-16, September 1970," while the main field pictured the launch of the rocket from the surface of the Moon, the Moon-Earth flight path, a globe with the outlines of the Soviet Union, and an indication of the landing site of the recovery module.

The State Emblem, pentagonal in form, was mounted on the return vehicle. Its obverse bore the inscription "USSR" and the Great Seal of the Soviet Union, while the reverse depicted, in the center of the pentagon, the Luna-16 station engaged in sampling the lunar soil. Also on the reverse of the Emblem was the framing inscription "Luna-16, September 1970, Earth-Moon-Earth."

Execution of the Flight Program

The flight of the Luna-16 may be broken down into the following basic stages: launch and journey to the Moon, operation on the lunar surface, and return to Earth.

Launch and Journey to the Moon

Luna-16 was launched on 12 September 1970 and was injected into circumterrestrial orbit by means of a more powerful rocket booster than that used in the launching of Luna-9 and Luna-13.

According to data derived from the reduction of trajectory measurements, the parameters of the parking orbit from which Luna-16 was started on its way to the Moon were as follows: maximum altitude above the Earth's surface — 212.2 km; inclination to the equatorial plane — $51^{\circ}36'$.

Seventy minutes after launch, on a signal from the on-board sequencer, the booster's final-stage engine was started, imparting an additional velocity as a result of which the station entered a flight trajectory toward the Moon.

On the path to the Moon one of two scheduled midcourse trajectory corrections was carried out to ensure the probe's precise entry at the predetermined region of circumlunar space. The initial data for the correction — magnitude and direction of the correcting thrust, plus the time of engine ignition — were computed at the Coordination-Computer Center based on the results of trajectory telemetry processing. These data, in the form of special codograms, were radioed to the station during a scheduled communications sequence and "laid into" the memory unit of the sequencer.

At the outset of the communications sequence, using the control system as well as the optical sensors of the orientation system, the station was precisely positioned in space with respect to the Sun and Earth in order that the engine acquire its nominal alignment for correction. After completion of all preliminary operations, on 13 September 1970 a control command started the engine, which, burning for 6.4 s, imparted to the station the required corrective thrust. Subsequent trajectory measurements indicated that the probe would enter the prescribed point in circumlunar space with so high a degree of accuracy as to make unnecessary any second midcourse correction.

The correction actually carried out was designed to eliminate inconsequential deviations from the nominal in the flight path of the station.

Some idea of the extraordinarily stringent accuracy requirements levied on the performance of the on-board systems may be gained by reflecting that a deviation of one meter per second from nominal velocity at the moment of ignition of the final-stage engine (equivalent to only about 0.01% of this velocity) will result in an error of as much as 300 km on the Moon.

Following the station's arrival at the prescribed region of circumlunar space, preparatory operations were carried out and the descent-stage engine was fired for the second time in order to reduce the approach velocity to the Moon and shift the probe into the orbit of an artificial lunar satellite. The associated maneuvers required a high degree of precision both in the orientation of the station and in the magnitude of the deceleration thrust. The engine was ignited for this purpose on 17 September at 0200 hours 38 minutes, after which Luna-16 moved into a circular selenocentric orbit, 110 km distant from the lunar surface.

The next task to be successfully accomplished was the difficult one of shaping a predescent orbit with a low pericynthion. This orbit was essential to the creation of optimal conditions for the operation of the autonomous control systems during the phases of descent and touchdown on the Moon's surface. To this end, two maneuvers were executed while the station remained in selenocentric orbit for three days. By means of the first of these maneuvers, the form of the orbit was altered, becoming elliptical with an altitude at pericynthion (least distance from the Moon's surface) of 15 km, and at apocynthion (greatest distance from the surface) of 110 km. As a result of the second maneuver, the plane of the orbit in space was turned somewhat to the required position, with the altitude at apocynthion then standing at 106 km.

On 20 September at 0600 hours 06 minutes there was initiated one of the most vital stages in the entire mission — preparation for soft landing on the lunar surface. During the preparatory operations from 0600 hours 41 minutes through 0700 hours 31 minutes the probe was behind the lunar disk and all radio communication with it was naturally disrupted. After a number of operations involving the orientation of the station and the execution of programmed attitude control, at 0800 hours 12 minutes the descent-stage engine was fired, resulting in a reduction of the station's velocity to a value ensuring transition to a descent mode. At the same time the station was maintained in a strictly determined attitude by means of the stabilizing elements of the control system.

After achieving the prescribed values of altitude and vertical descent velocity, which were continually measured by the on-board Doppler velocity-meter and altimeter, the descent-stage engine was once again ignited. The probe's velocity dropped, at an altitude of 20 m, to approximately 2.5 m/s. At this height above the lunar surface the station's primary engine was shut down and the two low-power thrusters were engaged, ensuring a soft landing on the surface. These two engines were switched off in the immediate vicinity of the surface on command from the gamma-altimeter.

The soft landing was executed at 0800 hours 18 minutes on 20 September in the region of the Sea of Fertility at a point having the coordinates 0°41'S and 56°18'E. Actual deviation from the center of the predesignated landing site was negligible.

Of great importance to the successful accomplishment of the Luna-16 flight mission was the work of the ground command-measurement complex. The data derived from the trajectory determinations systematically carried out by the facilities of the Deep Space Communications Center [Tsentr Dal'ney Kosmicheskoy Svyazi] were subjected to continuous computer processing. In this way it was possible to reliably determine the trajectory parameters of the Luna-16 station during all phases of the flight, to calculate and monitor circumlunar orbital maneuvers, and to predict and refine the coordinates of the landing sites on both the Moon and Earth. The reliable performance of the automatic systems on board Luna-16, the precision operation of the measuring facilities, together with clockwork flight control procedures, ensured that the probe would in fact land within the limits of the prescribed lunar target area and guaranteed the vehicle's later return, with its cargo of lunar core samples, to the predesignated region of the Soviet Union.

Operation on the Lunar Surface

After the landing on the Moon's surface, the on-board radio complex was engaged on command from Earth. Analysis of the information received indicated a normal status both for the station as a whole and for its individual systems. Also determined was the position of the station on the lunar surface. Following this, a command was transmitted to the station to activate the core-sampling device. The locking mechanism which had secured the sampler during flight was released and the boring rod was vertically positioned by one of the drive systems. A command from Earth switched on the telephotometer cameras which transmitted to Earth information on the drill site. Then, by means of a second drive mechanism, the rod was rotated 180° around the vertical axis to ensure that when the rod was subsequently withdrawn to the horizontal position the drilling-tool housing would have its working part facing the lunar surface. At the same time — also on command from Earth — a mechanism opening the cover of the drilling tool was activated. The bore rod was then lowered until the drill came into contact with the lunar surface. The drilling mechanism drive systems were engaged on a signal from the operator.

A special auger in the form of a hollow tube notched at the end was employed for the drilling and extraction of the core. Simultaneously with the drilling, the density of the soil under study was measured. The rate of auger penetration into the lunar surface was monitored from Earth. Upon completion of the drilling procedure, the auger with the lunar core was retracted into the drilling tool housing. The sampler rod drive was reactivated, with the rod raised to the vertical position and rotated 180° about its axis. The auger was brought up to the intake opening of the sealed container of the recovery module. The next command from Earth moved the auger with the core inside the container, after which the auger was separated from the drilling rig. Following this, the intake opening in the recovery module container was automatically sealed.

In addition to the accomplishment of the primary task — the acquisition of a lunar core sample — measurements were also made of the temperature of the structural components of the station and of the radiation level on the lunar surface. The results of these measurements were transmitted to Earth.

The next stage of the mission called for launch preparation and launch of the Moon-Earth rocket. This involved "laying in" the required velocity the rocket must achieve when lifting off the Moon into the memory unit of the rocket's control system. The Moon-Earth rocket was launched on command from Earth at 1000 hours 43 minutes on 21 September 1970.

Return to Earth

Following launch and after achieving the required velocity of 2708 m/s, the engine was shut down and the rocket with the recovery module continued on its way toward Earth. The flight path followed a ballistic trajectory. No provision was made for any midcourse correction of the return trajectory. The Deep Space Communications Center conducted regular trajectory measurements, the findings of which were used to update the landing area of the recovery module within the territory of Kazakhstan.

Approaching our planet, on 24 September at 0400 hours 50 minutes the recovery module was separated from the space rocket instrumentation compartment on command from Earth, entering the dense layers of the terrestrial atmosphere at 0800 hours 10 minutes. The vehicle's reentry velocity was somewhat greater than 11 km/s. The damping mechanism reliably held the vehicle in a position with its forward section facing the onrushing flow of air, thus ensuring the module the most favorable deceleration regime in the atmosphere. Maximum g-forces acting on the vehicle during aerodynamic braking reached 350, with the surface layer temperature at this point in excess of 10,000°C.

With the buildup in g-forces the sequencer was activated, along with the g-force and pressure command sensors. On a signal from the g-force sensor the parachute compartment cover was blown following the period of maximum temperature and g-forces. The drogue chute was deployed at a descent rate of 300 m/s at an altitude of 14.5 km. Later, on a signal from a barometric sensor, the drogue chute was jettisoned at a height of about 11 km and the main chute was deployed. This was accomplished by the activation of the directing-finding transmitters.

At 0800 hours 14 minutes the fixed-wing recovery aircraft and helicopters which had been concentrated in the prime recovery area began receiving radio signals, with the parachute-assisted descent soon visually observed from a helicopter which accompanied the module until touchdown. The module landed at 0800 hours 26 minutes at a point 18 km to the southeast of the city of Dzhezkazgan. Preliminary investigation revealed that the module had successfully withstood the conditions of the flight. The recovery module with the lunar core samples was taken to Moscow and the container with the soil was delivered to the Soviet Academy of Sciences.

Mission support for the flight of Luna-16 was effected by means of a far-flung network of ground trajectory-measurement points located within the territory of the Soviet Union and on the instrumentation vessels of the Academy of Sciences of the USSR. Flight control was the responsibility of the Deep Space Communications Center. All launch, ground command-and-measurement, and recovery teams turned in a precision performance and exhibited excellent coordination during the entire mission.

Lunar Core Sample on the Earth

Following its extraction from the recovery module, the sealed container with its content of lunar material was delivered to a special laboratory of the Soviet Academy of Sciences where it was placed in a receiving chamber. However, before installation in this chamber, dosimetric measurements were conducted, following which the container was carefully sterilized. The receiving chamber was equipped with a device for opening the container with the material, as well as for preliminarily studying and packaging it. All these operations were conducted in a monitored gaseous medium observing the necessary conditions of sterility.

After the ampoule was secured, a deep vacuum was created in the chamber by means of oilless pump facilities. Following this, the chamber was filled with a high-purity inert gas (helium) to atmospheric pressure. This excluded any interaction between the lunar matter and the components of the terrestrial atmosphere – oxygen, water, and sterilization products preliminarily removed during the vacuum process – which might have irreversibly altered the properties of the lunar matter. The container was opened and the auger removed from it by an operator located outside the receiving chamber employing a sterile instrument previously introduced into the chamber. Once extracted from the container, the auger was discovered to be covered with a thin layer of lunar dust. The matter taken from the auger was placed on a viewing tray, taking care to preserve the depth distribution of the matter in the sample. Following this, the matter was inspected and photographed through special chamber openings of optical glass. The photographic process was repeated at a variety of angles under different conditions of illumination and magnification.

In its basic mass the core sample taken consists of fine-grained mineral particles. The overall color of the matter is gray. The external appearance of the lunar matter taken by the Luna-16 automatic vehicle from the region of the Sea of Fertility attests to its friable structure and the presence of considerable cohesion between the particles. Dosimetric studies failed to reveal any significant excess in the gamma-radiation intensity of the lunar matter over that of Earth rocks with a low content of natural radioactive elements.

For further detailed study the lunar matter will be packaged in special containers and delivered to specialized institutes and laboratories. These containers will be extracted through a lock (sluice) arrangement to ensure preservation of the inert atmosphere surrounding the samples in the receiving chamber. Pending the outcome of toxicological and biological analysis, the lunar matter will remain for a period of quarantine in the receiving chamber. At a later date, studies will be made of the radiation, chemical, physicomechanical, thermophysical, and other properties of the matter. The findings of these investigations will be published in the scientific press.

* * *

With the completion of this extraordinarily important experiment in the Soviet space program radically new possibilities have been brought to bear on the study of the planets of the Solar System. For the first time in worldwide space engineering the fundamentally new problem of flying an automatic space vehicle to another celestial body, taking a sample of its soil, and returning it to Earth has been solved. Over and above the enormous scientific and technological significance of the event, the Luna-16 mission takes on marked importance because of the delivery to Earth of the lunar core sample. Vital to any understanding of the genesis and evolution of the Solar System is determination of the composition of the matter of which the various celestial bodies consist.

Scientists have already rather thoroughly studied the composition of the surface layer of the Earth and of those small bodies — meteorites — which somehow occasionally reach it. The next item on the agenda is a similar analysis of other objects in our Solar System. The successful completion of the Luna-16 mission provides the necessary preconditions for a more extensive application of automatic vehicles to the systematic study of specific regions on celestial bodies in a manner that is both reliable and economically feasible.

Valuable information was acquired during this flight regarding the space-worthiness of the new structural design and its high degree of reliability. This in turn will aid in the development of new space vehicle types in the near future.

This outstanding new achievement by our country has been dedicated by Soviet scientists, engineers, and workers — the men and women who created the Luna-16 space vehicle — to a signal event in the life of our people, the forthcoming Twenty-Fourth Congress of the Communist Party of the Soviet Union.

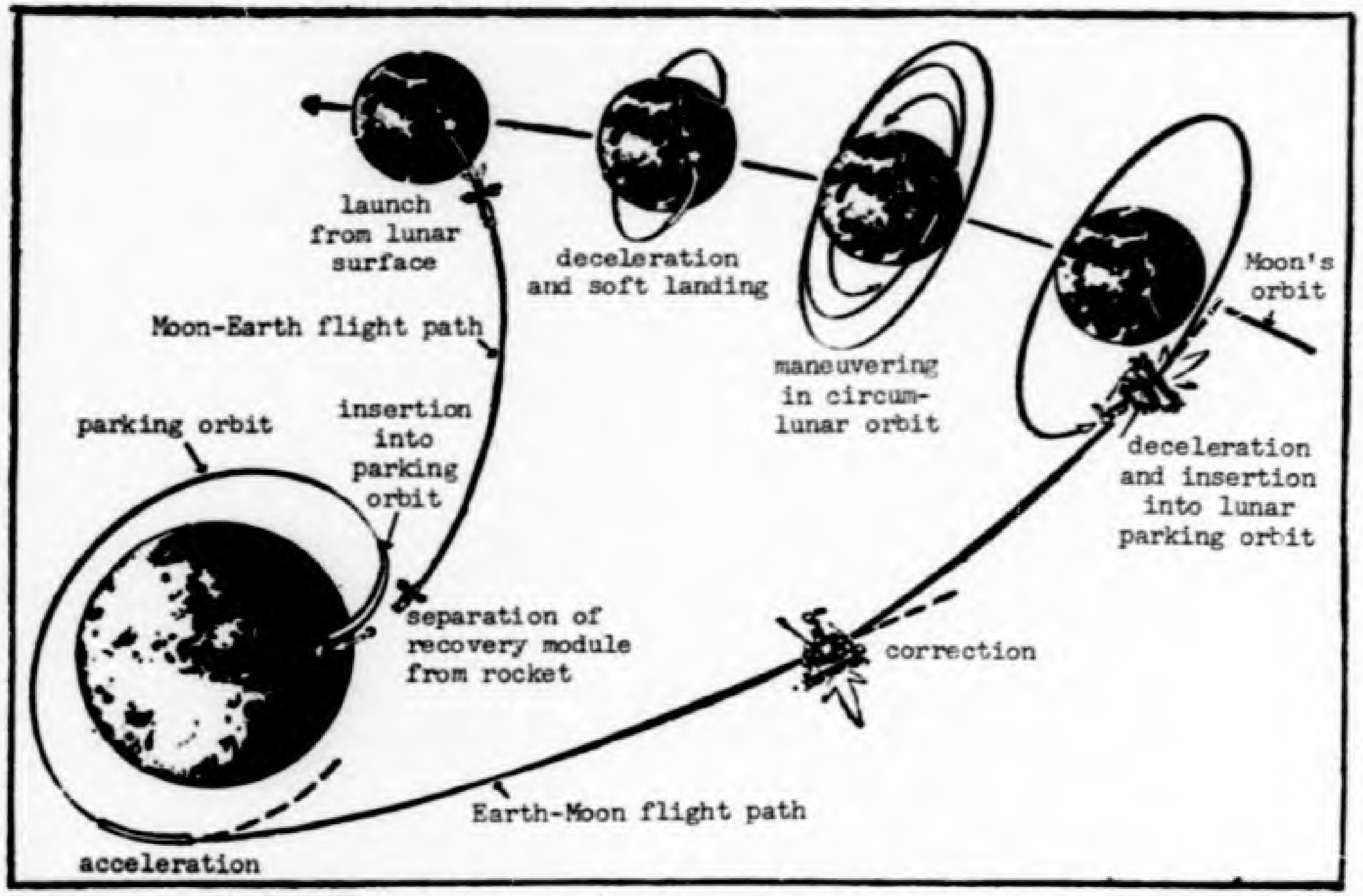
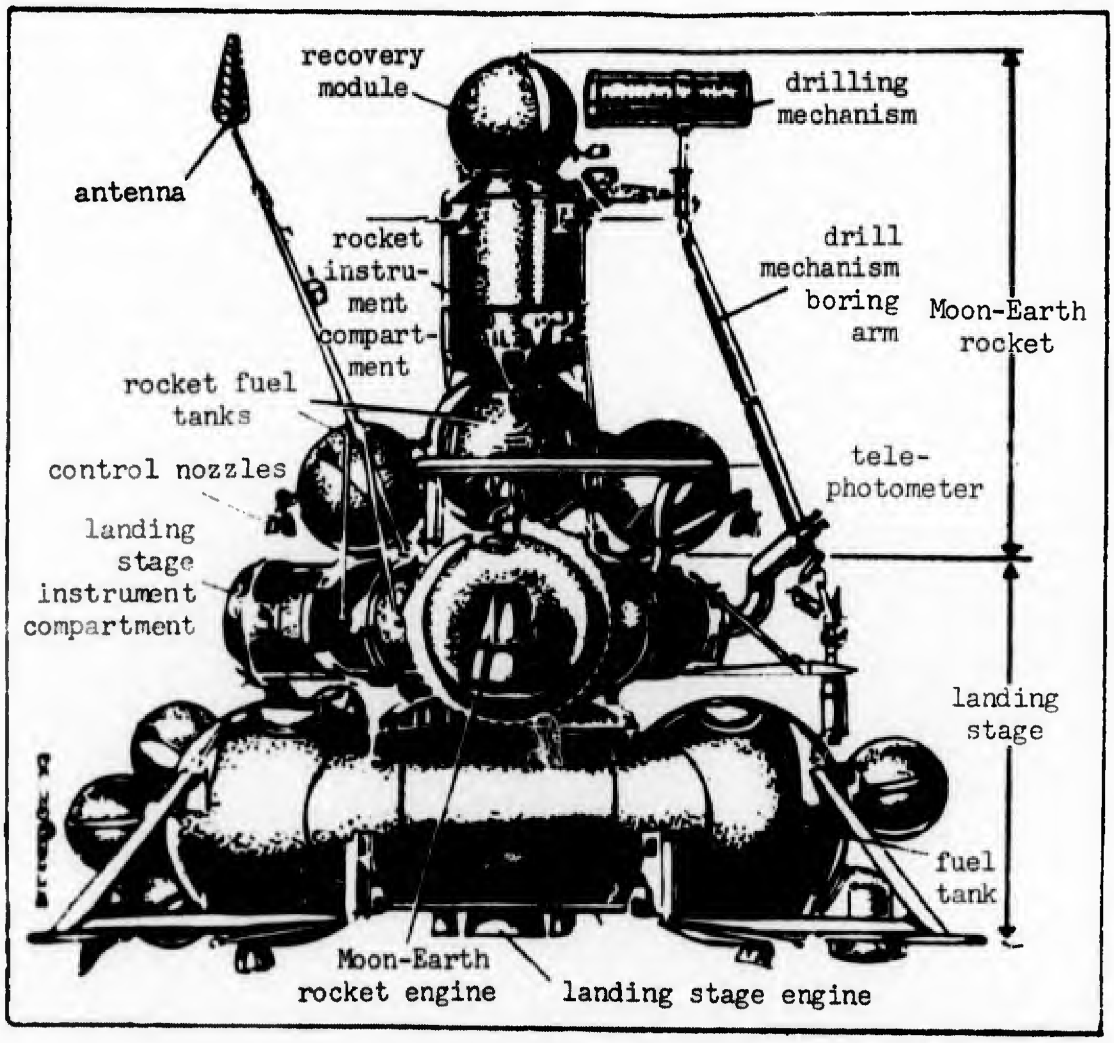
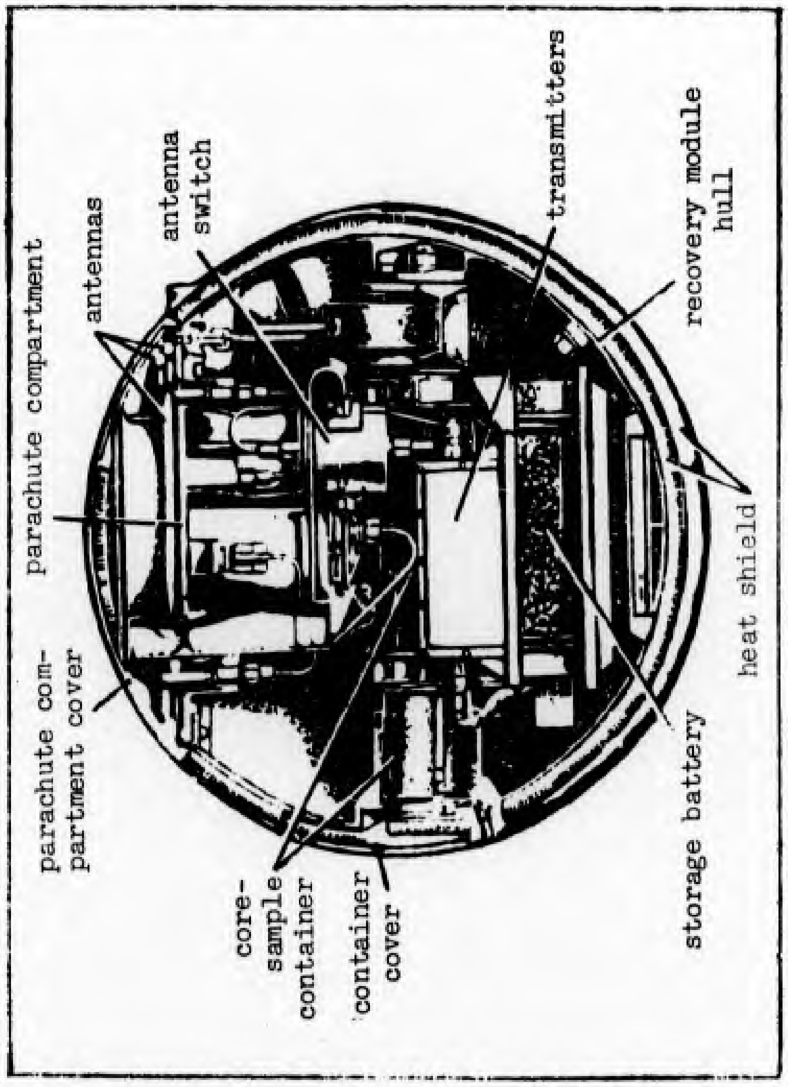


Diagram of the flight of station Luna-16



The station Luna-16



Layout of the Luna-16 recovery module

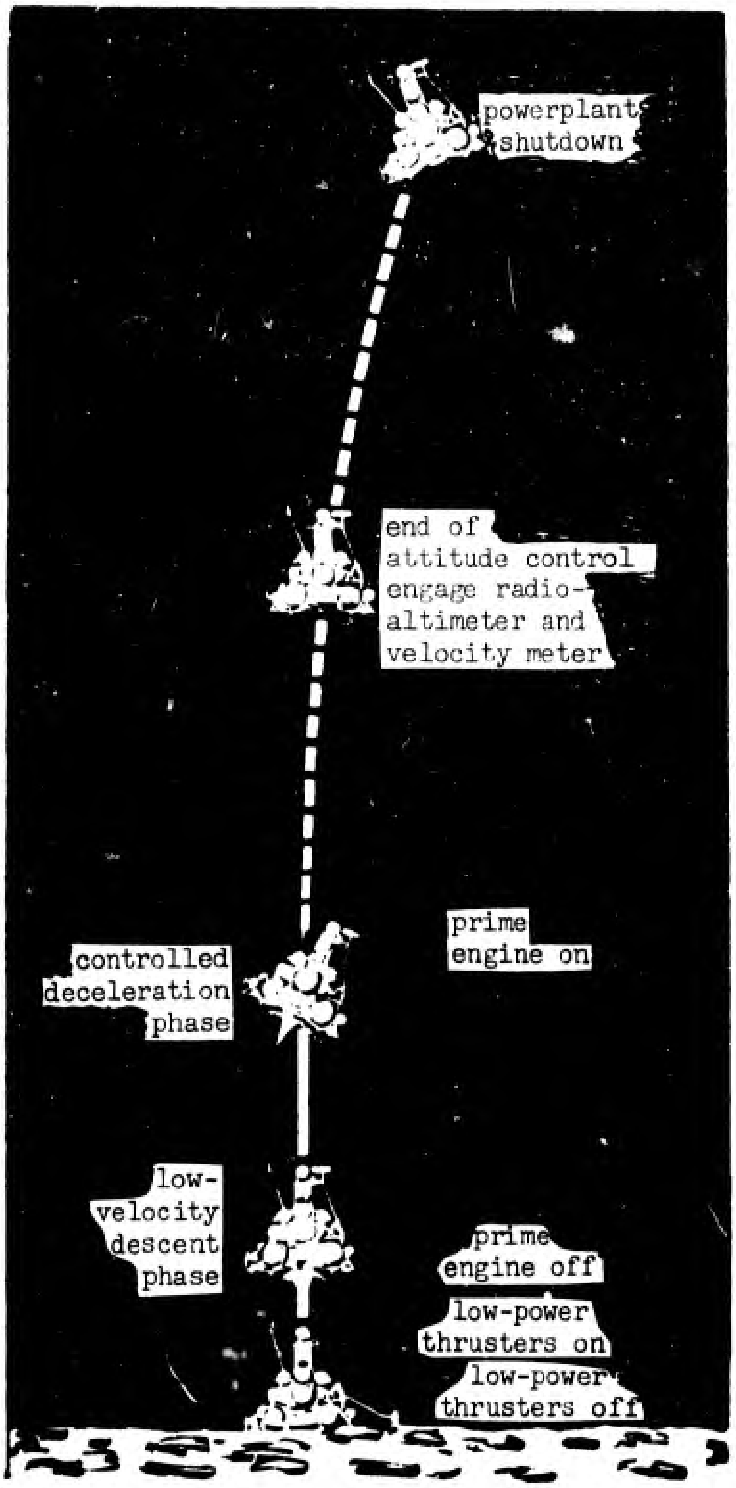


Diagram of the landing of Luna-16 on the Moon

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D		
(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)		
1. ORIGINATING ACTIVITY (Corporate author) Foreign Technology Division Air Force Systems Command U. S. Air Force		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED
		2b. GROUP
3. REPORT TITLE LUNA-16 - AN OUTSTANDING NEW ACHIEVEMENT OF SOVIET SPACE SCIENCE		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Translation		
5. AUTHOR(S) (First name, middle initial, last name) Unknown		
6. REPORT DATE 4 October 1970	7a. TOTAL NO. OF PAGES 19	7b. NO. OF REFS
8a. CONTRACT OR GRANT NO. F33657-71-C-0142 b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) FTD-HT-23-744-70	
	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
10. DISTRIBUTION STATEMENT Distribution of this document is unlimited. It may be released to the Clearinghouse, Department of Commerce, for sale to the general public.		
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Foreign Technology Division Wright-Patterson AFB, Ohio	

13. ABSTRACT

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DD FORM 1 NOV 65 1473

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Space Science Lunar-16 Lunar Probe Space Probe						

UNCLASSIFIED
Security Classification