VOL. 1, 1970-1973

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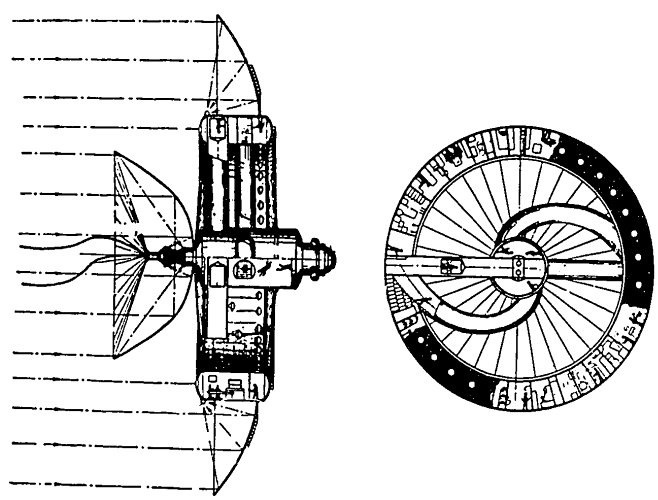
Translation

WORLD SPACE RESEARCH

Vol. 1, 1970-1973



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WORLD SPACE RESEARCH

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This special report contains translations of articles extracted from the YEZHEGODNIKI BOL'SHOY SOVETSKOY ENTSIKLOPEDII [Great Soviet Encyclopedia Yearbooks] since 1971 that deal with the space exploration programs of selected nations throughout the world. Entries for each year are divided into sections for both "Soviet" and "Non-Soviet" space research.

Volume I covers developments for the period 1970-1973; Volume II will cover 1974-1978. Supplements will be published annually as the yearbooks become available for translation.

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SOVIET SPACE RESEARCH IN 1970

Moscow YEZHEGODNIK BOL'SHOY SOVETSKOY ENTSIKLOPEDII in Russian No 15, 1971 pp 492- 503

[Article by L. Lebedev]

[Text] In 1970 the "Soyuz-9" manned transport ship and automatic stations to study the moon, Venus and near-earth and interplanetary space were launched. Launchings of artificial earth satellites for purely scientific and applied purposes continued.

The flight of "Soyuz-9" took place 1-19 June. In the 18-day scientific experiment the scientists set the goal of studying the effect of the prolonged exposure of a set of surrounding factors on the human organism, and primarily of verifying man's ability to actively work under conditions of weightlessness for a long time. It was important to also investigate the process of man's transition to the conditions of earth's gravity.

The flight program of "Soyuz-9" included a vast complex of scientific and technical, medical and biological studies, and experiments that were begun in the previous space flights.

The "Soyuz-9" spacecraft was launched at the Baykonur Cosmodrome on 1 June at 2200 hours.* The craft was piloted by the commander A. G. Nikolayev and the flight engineer, Candidate of Technical Sciences V. I. Sevast'yanov. During the flight of "Soyuz-9" a large number of dynamic operations were performed which were associated with its orientation. As a rule, they were performed using manual control. The cosmonauts conducted tests of the star sensor and the opticoelectronic instrument created for purposes of orienting the craft to earth during its flight over the earth's shaded side. In going through the methods and means of autonomous navigation Nikolayev and Sevast'yanov made various measurements, determined the orbital parameters and calculated the necessary trajectory corrections. On-board computer resources were used for a rapid solution to the navigational tasks.

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* Here and further--Moscow Time.

A number of experiments were associated with an investigation of the design characteristics of the craft. The cosmonauts measured the design deformations produced by the conditions of vacuum and solar heating, studied the work of the precision mechanisms and optic assemblies, tested the high-precision illuminators that guarantee the reliable operation of the optic instruments, and evaluated the effect of aerodynamic and gravity disturbances on the dynamic characteristics and controllability of the craft; they also tested different systems of long-term life-support.

To study the potentialities for man's living and working normally under conditions of a prolonged space flight the cosmonauts performed experiments to study the functions of the vestibular apparatus, the dynamics of arterial pressure, external respiration, the nature of pain sensitivity of the skin, the contrast sensitivity of the eyes, and the preservation of the characteristics of the visual apparatus. Studies were also made on the muscular strength of the arms and musculo-articular sensitivity. With the help of a special cybernetic device a study was made of the dynamic functions of man as an element in the control system. In order to construct the optimal life-support systems and develop scientifically substantiated rations for food and water consumption the energy expenditures of the cosmonauts during the flight were calculated.

Experiments of national economic importance occupied a large place. On the 188th orbit, when "Soyuz-9" was over the Indian Ocean, a complex equipment was conducted in which, besides the crew of "Soyuz-9," the "Meteor" satellite and the scientific research ship "Akademik Shirshov" participated. Radiosondes were launched from the ship to measure the temperature and wind velocity in different layers of the atmosphere. The "Meteor" AES [artificial earth satellite], having flown at the same time over this territory, transmitted a series of television photographs from an altitude about 630 km, while the cosmonauts observed this region from a lower orbit. (A similar experiment was conducted by the crew of "Soyuz-7" in October 1969).

Joint photography of the earth from meteorological satellites was also conducted over Africa, the Atlantic Ocean, and over the southern part of the Indian Ocean. During the flight the cosmonauts observed cyclones, recorded dust storms, and reported to earth observations on the state of the weather in individual regions of the globe. They photographed geographical and geological objects of the earth's surface. In the comprehensive experiment, photographs of regions of the North Caucasus, the Caspian and Aral seas, Kazakhstan and West Siberia were taken simultaneously from on board Soyuz-9 and from airplanes. Scientific experiments to study near-earth space included photographing of the earth's horizon, as well as the moon on the background of the earth's horizon. During the flight studies were made of the brightness of different objects in the visual region of the spectrum. The given experiment was set up in order to investigate the possibility of creating new systems of astronavigation. It is also needed by meteorologists to determine the upper border of clouds in order to develop a technique for automatically processing the information received from meteorological satellites. A total of over 50 different experiments were made during the flight, whereby each was performed several times.

"Soyuz-9" landed on 19 June at 14.59 75 km to the west of Karaganda. As the scientists expected, after a prolonged stay in a state of zero gravity specific difficulties developed in the cosmonauts that were associated with the adaptation of the organism to life on earth. In the first 2-3 days Nikolayev and Sevast'yanov noted that their sensations were analogous to the sensations of a man who had been on a centrifuge under the influence of a G-force of 2-2.5 units. The condition of the organism had practically been normalized by the 10th day after their return to earth.

The flight of the (AS) "Luna-16" automatic station in an earth-moon-earth orbit took place 12-24 September (it was launched 12 September at "1626 hours). The flight made it possible to solve the most complicated scientific and technical problem of astronautics--intake of samples of lunar rock by automatic means, and delivery of these samples to earth. The Luna-16 AS was designed as a landing stage (LS) with a soil intake device (SID) on which a "Luna-Zemlya" rocket with a recoverable apparatus (RA) was mounted. The station when it lands on the moon weights 1880 kg. This LS is a unified aggregate capable of transporting to the moon automatic systems with scientific apparatus of various designations. It is a multipurpose rocket block that has a liquid-propellant rocket engine, a system of tanks with propellant components, instrument compartments, and cushioning supports for landing on the moon. The propulsion system of the LS consists of the main engine of multiple engagement with controllable thrust for deceleration, and two low-thrust engines that operate in the final stage of the landing. In the instrument compartments of the LS there are computing and gyroscopic instruments of the control and stabilization systems, electronic instruments of the orientation system, radio transmitters and receivers of the on-board radio measuring complex that operate in several wavelength ranges, a program-time device to control the operation of all systems and aggregates, chemical sources of electricity and current transduvers, components of the thermoregulation system, autonomous radio facilities to measure altitude, and the horizontal and vertical velocity components during the landing on the lunar surface, as well as scientific apparatus to make temperature and radiation measurement both on the segment of the flight to the moon, and on its surface. On the outer LS surface there are antennas of the on-board radio complex, jet-propelled micro-engines of the orientation and stabilization systems, tanks with a supply of working fluid for the microengines, and optic gauges of the orientation system. In the take-off of the rocket "Luna-Zemlya" from the lunar surface the LS serves as a starting device.

The "Luna-Zemlya" rocket is a rocket block with liquid-propellant rocket engine (LPRE), and a system of spherical tanks with propellant components. On the central tank is fastened a cylindrical instrument compartment, in which there are the electronic computing and gyroscope instruments of the rocket's control system, the transmitting, receiving, decoding, and program-time instruments of the on-board radio complex of the rocket, storage batteries and current transducers, and instruments of the on-board automatics. On the outer surface of the IC of the rocket four collapsible-whip receiving-transmitting antennas are installed. The spherical recoverable apparatus (RA), which is separated from the rockets by radio command during its flight back to earth, is attached by metal tension bands to the upper part of the IC.

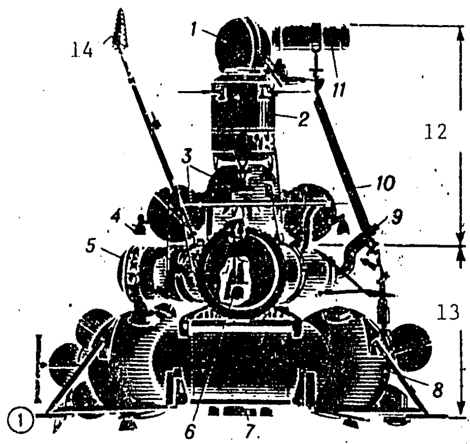
The RA (Figure 2) is a metal ball on whose outer surface a heat-protective coating has been applied to protect the apparatus with the equipment installed inside it from the effect of high temperatures during entry into the earth's atmosphere. Inside the RA is divided into three insulated compartments. In the largest volume compartment there are: radio direction finding transmitters that make it possible to find the RA during parachute re-entry and after landing on the earth, storage batteries, components of automatics, and an on-board programmer that controls putting the parachute system into operation. In the second compartment are located the folded parachute, four flexible antennas of the direction finding transmitters, two elastic tanks filled with gas that guarantee the necessary position of the RA on the earth's surface after landing. The third compartment is a cylindrical container for lunar soil taken from the lunar surface. The container has a reception opening, hermetically sealed by a special cover after the lunar rocks are placed in it.

The SID (Figure 3) is installed on the landing stage, and consists of three main parts: a drill with a system of electrical drives and drill apparatus; a probe on which the drill is attached; and drives moving the probe in vertical and horizontal planes. In the development of the SID special attention was focused on solving the task of creating a drill capable of drilling and collecting samples of lunar soil of varying density--from loose (dust-like) to hard, like the earth's basalt and granites.

A marker was installed on the LS of "Luna-16," and on the RA--a state sign (Figure 8).

The "Luna-16" AS was put into orbit as an artificial earth satellite by a more powerful satellite-launcher as compared to the satellite-launcher of the "Luna-9" AS and "Luna-13" AS (for a scheme of the flight of the "Luna-16"AS see Figure 4). The apogee of the intermediate earth orbit was 212.2 km; the orbital inclination was 51°36'. The trajectory correction made on 12 September guaranteed the insertion of the "Luna-16" station at the calculated point in circumlunar space, from which, due to the applied deceleration impulse it transferred to a circular selenocentric orbit with altitude 110 km, inclination relative to the plane of the lunar equation--70°, and orbital period--1 h 59 min.

On 18 and 19 September a maneuver in circumlunar space was executed, as a result of which the station switched to an elliptical orbit with parameters; aposelene--106 km, periselena--15 km, inclination--71°, and orbital period--1 h 54 min. After making trajectory measurements and the necessary orientation of the station at the calculated point in the orbit, the propulsion system was engaged, and "Luna-16," descending from orbit, began a ~ 250-kilometer path above the lunar surface to the point of landing. Then the engine was disengaged--vertical descent began (Figure 5). At altitude 600 m from the surface the main engine of the station again began to operate. The thrust pattern here was altered according to the selected control program and the incoming information from the Doppler velocity gauge and radio altimeter. At altitude 20 m the velocity of the station was reduced roughly to 2 m/s. Here the main LPRE was disengaged, and further deceleration occurred with the help of low-thrust engines. At altitude ~ 2 m they were



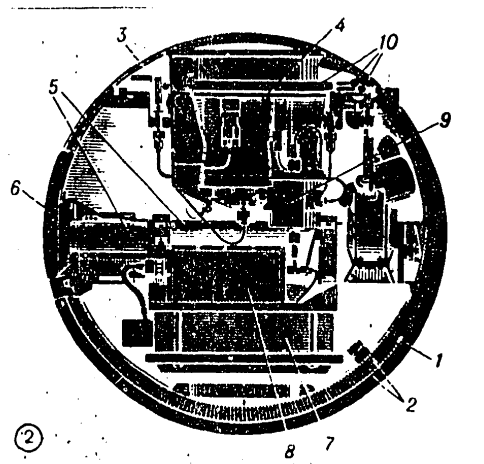


Figure 1. "Luna-16" Automatic Station

Key:

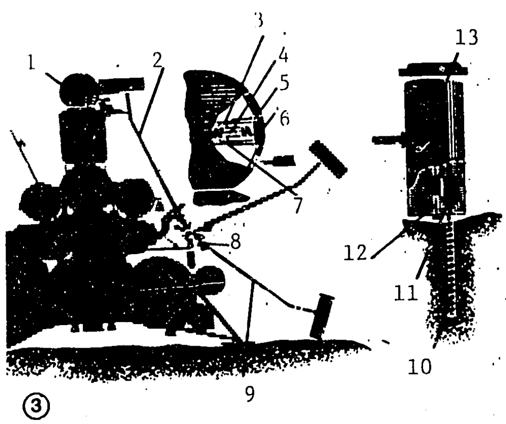
1. Recoverable apparatus
2. Instrument compartment of rocket
3. Propellant tanks of rocket
4. Controlling jets
5. Instrument compartment of landing stage
6. Engine of "Luna-Zemlya" rocket
7. Engine of landing stage
8. Propellant tank
9. Telephotometer
10. Probe of drilling mechanism
11. Drilling mechanism
12. "Luna-Zemlya" rocket
13. Landing stage
14. Antenna

Figure 2. Layout of Recoverable Apparatus of "Luna-16" Station

Key:

1. Housing of recoverable apparatus
2. Heat protection
3. Cover of parachute compartment
4. Parachute compartment
5. Container for lunar soil
6. Cover of container
7. Storage battery
8. Transmitters
9. Antenna switch
10. Antenna

disengaged by command from the gamma altimeter, and on 20 September at 0818 hours the "Luna-16" AS completed a soft landing on the surface of the moon in the region of the Sea of Fertility. The selenographic coordinates of the moon landing site: lat 0°41'S and long 56°18'E. The deviation from the calculated landing point was 1.5 km.



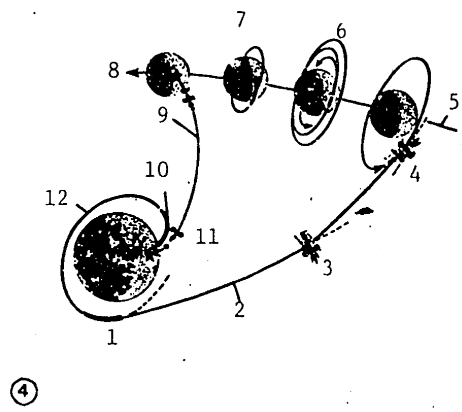


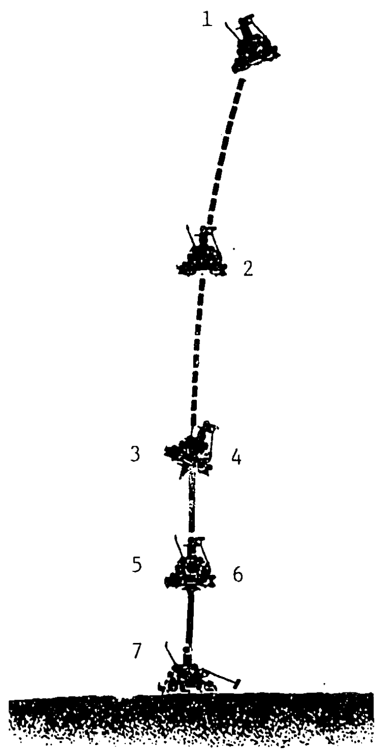
Figure 3. Scheme of Soil-Intake Device of "Luna-16" AS

Key:
1. Recoverable apparatus
2. Starting position of probe and drill
3. Ampule
4. Soil
5. Cover lock
6. Hermetic cover to ampule
7. Ampule positioning spring
8. Probe buffer
9. Operating position of drill and probe
10. Drilling charge
11. Rotor
12. Screw feed
13. Drill casing

Figure 4. "Luna-16" AS Flight Pattern

Key:
1. Acceleration
2. Earth-to-moon trajectory
3. Correction
4. Deceleration and transfer to artificial lunar satellite orbit
5. Moon's orbit
6. Maneuvering in a circumlunar orbit
7. Deceleration and soft landing
8. Takeoff from moon's surface
9. Moon-to-earth trajectory
10. Insertion into artificial earth satellite orbit
11. Separation of recoverable apparatus from rocket
12. Flight in artificial earth satellite orbit

After the station had landed on the moon, a set of operations was implemented that included measurement of the station orientation in relation to the local vertical, and verfication of the functioning of different aggregates and on-board systems. Further, at the command from earth the SID by complex manipulations provided contact of the electrical probe with the surface layer, drilling of the soil to a depth of 35 cm, intake of the soil, and its delivery to the container of the recoverable apparatus.



Key:

1. Propulsion system turned off
2. Rotation of station ceases Radioaltimeter and velocity gauge turned on
3. Controlled descent phase
4. Main engines turned on
5. Low-velocity descent phase
6. Main engines turned off, low-thrust engines turned on
7. Low-thrust engines turned off

Figure 5. "Luna-16" AS Lunar Landing Pattern

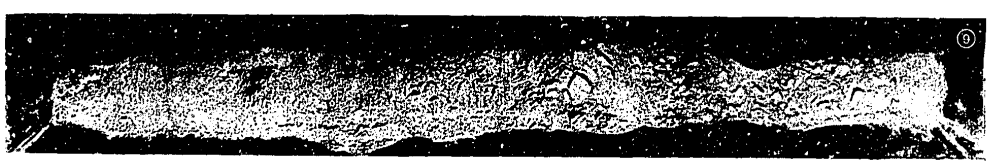


Figure 6. Overall View of Lunar Soil Transported by the "Luna-16" Station

On 21 September at 1043 hours the "Luna-Zemlya" rocket was launched automatically from the moon, and switched to a trajectory for the flight to earth. On 24 September, having separated from the space rocket, the RA entered the dense atmospheric layers at 0810 hours. After aerodynamic deceleration in the ballistic trajectory at altitude 14.5 km the parachute system was put into operation, and at 0826 hours the RA of the "Luna-16" station made a soft landing in the calculated region, 80 km southeast of Dzhezkazgan.

The lunar soil was transferred to the Special Reception Laboratory of the USSR Academy of Sciences, where it was studied. The total weight of the column of soil supplied by "Luna-16" was 101 g.

The drill was filled with loose lunar soil (Figure 6)--regolith, which is a dark gray (blackish) powder with varying grain size which is easily formed and sticks together in individual loose clumps. This feature significantly distinguishes the soil (regolith) from the earth's structureless dust; in this property it is similar to wet sand or the lumpy structure of the earth's soils. The graininess of the regolith is increased with depth; grains with an average size of about 0.1 mm predominate.

A small part of the soil at the bottom of the borehold, at depth 35 cm, consisted of large-grain material--the drill had touched solid rock or a separate large fragment of rock. The thickness of the regolith in the Sea of Fertility, at the point of sampling of the lunar soil was not greater than $\sim$ 35 cm, and possibly reaches 0.5-1 m, or somewhat more than a meter. The specific weight of the regolith in the natural bed was defined as $\sim$ 1.17 (1.20) g/cm^3. By mechanical concentration its density can be brought to 2.3 g/cm^3. The specific heat capacity of regolith equals 0.177 cal/g·deg, while the coefficient of heat conductivity in a vacuum equals $4.8 \cdot 10^{-6}$ cal/s·cm·deg (with density $\rho = 2.25$ g/cm^3 and t = 20-40°C).

The optic properties of the regolith were also investigated. The normal albedo is altered from 0.86 in the ultraviolet region of the spectrum to 0.126 in the near infrared region, and for the visible light equals 0.107. Such a value corresponds to soil somewhat lighter than is typical for lunar seas on the average, but close to the ground determinations of albedo of the Sea of Fertility in the region of the landing: for the Sea of Fertility on the average the albedo equals 0.69, while in the region nearest to the landing site of "Luna-16"--0.105.

Microscopic study of the lunar substance made it possible to separate two main sets of particles (Figure 7): particles of primary magmatic surface rocks of the type basalts, and particles subject to noticeable transformations on the lunar surface. The first are characterized by a fresh habit observed on earth only on newly crushed samples of permanent rocks. They do not carry traces of toughness, and have angular shapes. The second carry clear traces of fusion--sinter of complex shape, vitrified from the surface, a noticeable number of spherical fused formations--solidified drops of glass and metal habit.

In chemical composition the substance of the lunar soil is crushed rock of the basalt type. Comparative data on the composition of the regolith and crystalline rocks from the three lunar seas are given in Table 1.

It is apparent from the data of Table 1 that the sharpest difference in the composition of rocks brought by "Luna-16" consists of the low Ti content. It is practically the same with rocks of the Ocean of Storms, and almost reduced by half as compared to the Sea of Tranquility.

Table 1

Component	Crystalline rocks			Regolith		
	Sea of Tranquility, "Apollo 11"	Ocean of Storms, "Apollo-12"	Sea of Fertility, "Luna-16"	Sea of Tranquility, "Apollo 11"	Ocean of Storms, "Apollo-12"	Sea of Fertility, "Luna-16"
SiO_2	41	40	43.8	43	42	41.7
Al_2O_3	12	11.2	13.65	13	14	15.33
TiO_2	10	3.7	4.9	7	3.1	3.39
F[illegible]	19	21.3	19.35	16	17	16.64
MgO	8	11.7	7.05	8	12	8.78
CaO	10	10.7	10.4	12	10	12.49
Na_2O	0.5	0.95	0.38	0.54	0.4	0.34
K_2O	0.12	0.065	0.15	0.12	0.18	0.10
MnO	0.4	0.26	0.20	0.23	0.25	0.21
Cr_2O_3	0.6	0.55	0.28	0.37	0.41	0.28
ZrO_2	0.1	0.023	0.04	0.05	0.09	0.013
NiO	(0.007)	--	0.04	0.03	0.025	--

Figure 7. Main Types of Particles of Lunar Regolith (Magnified)

Figure 8. State Sign and Penant Mounted on the "Luna-16" AS

Key:
a. Igneous rocks and individual minerals
b. Glass balls, breccia, and sinter
c. Vitrified and scorified particles

Of great importance are differences in the composition of regolith and the parent rock of the same sea. These differences are repeated for the three seas. Correspondences in the Ti contents in the crystalline rocks and the regolith indicate that the regolith was formed in place, and was not brought here from far away (as volcano ashes). The regolish contains a reduced quantity of mafic elements, and consequently, must be more easily fusible than the basalt rock.

The first definitions of the age of the moon were obtained by the Rb/Sr-method in the crystalline rock, and in the fine fraction of regolith which provided $4.85 \cdot 10^9 - 4.25 \cdot 10^9 \pm 0.75 \cdot 10^9$ years. The average for the isochrone is 4.45 and $4.65 \cdot 10^9 \pm 0.5 \cdot 10^9$ years. This indicates that the samples of the three seas are very close in absolute age. The age of the moon corresponds to the age of the earth. The same results are obtained by $^{206}Pb/^{207}Pb$-method.

From the three seas of the moon rocks of one type were obtained--basalts. Variations in their composition depend on the conditions of melting, while the variations in regolith depend on what happens after melting. The rocks of the Sea of Fertility are close in composition to the rocks of the Sea of Storms. Insofar as the content of neutral gases in the regolith they are close to the regolith in the Sea of Tranquility.

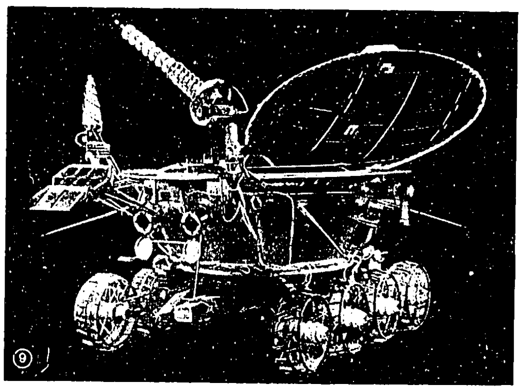
On 20 October the "Zond-8" AS began a mission to the moon and back to earth. The purpose of the experiment; to conduct physical studies of the flight path and in circumlunar space; to photograph the earth and moon; and to develop perfected on-board systems, aggregates, and designs of space apparatus. The station was put on the assigned flight trajectory to the moon from an intermediate orbit as an earth satellite. On 21 October there was a session to photograph the earth from a distance of 65,000 km. During the first 3 days of the flight during the communication sessions with the station television images of earth were transmitted. On 22 October at 0925 hours, when the station was a distance of ~ 250,000 km from earth a correction of the trajectory was made. As a result of the maneuver the "Zond-8" AS shifted to a new trajectory, and on 24 October circled the moon with the minimum distance from its surface equal to 1120 km. In the region of the moon the station measured the physical characteristics of circumlunar space, and photographed on color and black-and-white film the lunar surface. In order to work out one of the possible variants for returning space vehicles to earth, re-entry of the station into the atmosphere was from the Northern Hemisphere. After completing a ballistic re-entry into the atmosphere, the "Zond-8" AS splashed down on 27 October at 1655 hours in the assigned region of the Indian Ocean 730 km to the southeast of the archipelago Chagos.

On 17 November the "Luna-17" AS landed on the lunar surface in an assigned section of the Sea of Rains after transporting to it the "Lunokhod-1" self-propelled vehicle (Figure 9). For 10.5 months a unique space experiment was conducted using the lunar transport system to make an extensive set of scientific and technical studies.

The "Luna-17" AS consists of a unified landing stage (LS) and automatic mobile laboratory--the lunokhod. As in the flight of the "Luna-16" station the main tasks of the LS were: to make a correction of the flight trajectory on the segment of the flight from the earth to the moon, to guarantee the transition of the station to an orbit as an artificial moon satellite, to form a prelanding circumlunar orbit, and to land on the surface of the moon. The lunokhod and the folding ladders for its descent to the lunar surface were installed on the LS of the "Luna-17" station.

The "Lunokhod-1" automatic self-propelled vehicle consists of two main parts: a hermetically sealed instrument compartment and wheel chassis (Figure 10). The lunokhod weighs 756 kg.

The housing of the instrument compartment is made of magnesium alloys. Its upper part is used as a radiator-cooler in the thermoregulation system of the lunokhod, and is closed by a special cover that fulfills a double function. During the lunar night the cover closes the radiator and prevents emission of heat from the compartment. During the lunar day the cover is open, and the elements of the solar battery located on its inner side guarantee recharging of the storage batteries that power the on-board apparatus with electricity. The cover can be set at any angle within 0-180°, which makes it possible to make the maximum use of solar energy. In the anterior part of the instrument compartment illuminators are arranged for television cameras, electrical drive of the mobile high-directional antenna designed to transmit television images of the lunar surface to earth, a low-directional antenna that provides reception of radio commands and transmission of telemetric information, scientific instruments, and an optic angular reflector.



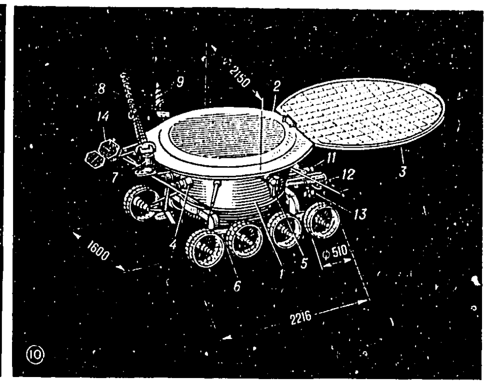


Figure 9. "Lunokhod-1" Automatic Self-Propelled Vehicle

Figure 10. "Lunokhod-1" Scheme of Automatic Self-Propelled Vehicle

Key: [To Figure 10 only]
1. Hermetically sealed instrument compartment
2. Radiator-cooler
3. Solar battery
4. Illuminators for television cameras
5. Telephotocamera
6. Block of chassis wheels
7. Drive of high-directional antenna
8. High-directional antenna
9. Low-directional antenna
10. Collapsible-whip antenna
11. Isotope source of thermal energy
12. Ninth wheel
13. Instrument to determine physico-mechanical properties of soil
14. Optic angular reflector

Figure 11. Fragment of Panoramic Photograph Taken on 19 January 1971

On the left and right side are installed two panoramic telephoto cameras each (whereby in each pair one of the cameras is connected by design to the detector of the local vertical), four collapsible-whip antennas for reception of radio commands from earth in another range of frequencies. The instrument compartment is installed on an eight-wheel chassis which guarantees movement of the automatic laboratory over the surface of the moon. The geometry of the undercarriage, the specific pressure on the ground, the traction characteristics of the chassis, the parameters of the flexible suspension, and the design of the bearing seat of the wheels make it possible to confidently move over the surface with loose, friable ground layer, to get over steep rises, and to cross craters and obstacles in the form of individual rocks or ridges of rocks comparable to the dimensions of the undercarriage.

The self-propelled chassis provides movement of the lunokhod with two velocities forwards and backwards and turns in place and in motion. The self-propelled chassis includes: the undercarriage, consisting of four blocks of wheels arranged in pairs, the block of automatics, the movement safety system and an instrument and set of gauges to determine the mechanical properties of the ground and evaluate the passability of the chassis. Each of the eight drive wheels has an individual actuator and independent torsion suspension. Within each nave of the wheel there are an electric motor, a reducer, a brake, a mechanism to disconnect the actuator, and gauges for the number of wheel revolutions and temperature. The lunokhod is turned by means of different velocities of the wheel rotation of the right and left sides and by a change in the direction of their rotation. The lunokhod is braked by switching the traction electric motors of the chassis to a pattern of electrodynamic braking. To maintain the lunokhod on slopes and to bring it to a full stop, the disk brakes are engaged with electromagnetic control.

The block of automatics provides control over the movement of the lunokhod by radio commands from earth, measurement and control of the main parameters of the self-propelled chassis, and automatic operation of the instruments to study the mechanical properties of the lunar ground. All movement is controlled with the help of five commands of movement and the command "stop." The movement control system included in the block of automatics of the chassis also has automatic devices for measuring out in time the rectilinear movement and executing turns at assigned angles. The movement safety system guarantees automatic stopping of the lunokhod with limit angles of list and trim and overloads of the electric motors of the wheels. If necessary one or several wheels can be disconnected from the actuator. Here the traction characteristics of the self-propelled chassis remain fairly high.

To warm the gas circulating within the apparatus there is an isotope source of thermal energy. Next to it there is an instrument to determine the physico-mechanical properties of the lunar ground and a mechanism for lifting and lowering the ninth wheel.

In the instrument compartment there are transmitting and receiving devices of the radio complex, instruments of the lunokhod remote control system, an electrical power system, blocks of commutation and automatics, instruments of the system for guaranteeing the thermal pattern, and electronic transducing devices of the scientific apparatus.

The lunokhod has two television systems. The system of small-frame television, whose two cameras are located in the anterior part of the housing, is designed to transmit television images of the locality to earth that are necessary to the crew controlling the movement of the lunokhod from earth. The second television system is designed to obtain a panoramic image of the surrounding locality and to photograph sections of the celestial sky, sun and earth for the purpose of the celestial orientation of the lunokhod. The system consists of four panoramic telephoto cameras of single-type design. They are arranged such that two of them provide a survey of the locality from the right and from the left of the lunokhod within somewhat over 180° in a horizontal plane and 30° in a vertical. The two other cameras provide an image of the locality and space within 360° in the vertical and 30° in the horizontal planes.

Maintenance of the necessary thermal pattern of the lunokhod is guaranteed by passive and active methods of thermoregulation. A reduction in the heat exchange between individual structural elements and the surrounding space is implemented by using screen-vacuum thermal insulation and special outer coatings with special optic properties. By forced circulation of the gas-heat carrier between the radiator and the instrument equipment implemented by the system of ventilators the heat is eliminated through the radiator into outer space. During the lunar night to heat the equipment of the instrument container special gates cut off circulation of the gas-heat carrier on the cooling circuit and direct it to the heating circuit where it is warmed by the isotope source. An estimate of the passability of the chassis is made with the help of a set of gauges which continuously measure the list and trim of the lunokhod, currents of the traction electric motors, number of revolutions and temperature of the wheels. The length of the path traversed by the lunokhod is determined by the number of revolutions of the drive wheels. To meter their slipping a correction is made that can be determined with the help of the freely rolling ninth wheel, which by a special drive is lowered to the ground and raised to the starting position.

The self-propelled vehicle is controlled by the crew from the Center for Long-Range Space Communications. The crew includes a commander, driver, navigator, operator, and flight engineer. On the "Lunokhod-1" and landing stage of "Luna-17" flags and markers are installed with the image of the state emblem of the USSR and a bas-relief of V. I. Lenin.

The "Luna-17" automatic station with "Lunokhod-1" on board was launched on 10 November at 1744 hours. It was put into orbit as an AES, and then, by using the engines of the last stage of the rocket launcher it was directed towards the moon. The trajectory corrections made on 12 and 14 November and braking operations made it possible to put the station in selenocentric orbit on 15 November with the following parameters: altitude above the surface of the moon--85 km; lunar orbital inclination 141°; orbital period 1 h 56 min. Then by complicated maneuvering of the station in circumlunar space, a pre-landing elliptical orbit was formed with periselene 19 km. On 17 November at 0641 hours the decelerating engine was engaged, and the station, having completed maneuvers analogous to the maneuvers of the "Luna-16" AS, made a soft moon landing at 0647 hours in the coastal region of the western section of the Sea of Rains, at a point with selenographic coordinates; lat. 38°17'N., and long. 35° W. At 0928 hours "Lunokhod-1" descended on a ladder from the landing platform and started to fulfill the program of scientific and technical studies and experiments.

The program provided for: conducting tests and working out a lunar transport system; acquiring experience in remote control of the self-propelled vehicle by a crew located on earth; investigating the topographical and selenological-morphological peculiarities of the region where the vehicles landed; studying the chemical composition and physicomechanical properties of the lunar ground; studying the radiation situation on the segment of the earth-moon flight, in circumlunar space and on the lunar surface; investigating the intensity and angular distribution of the extragalactic x-ray radiation and x-ray radiation from the universe from individual sources; and lunar laser ranging.

The topographical investigation of the locality was made on the basis of television panoramas and photographs of the lunar landscape and data on the length of the path traversed, the course, list and trim of the lunokhod during movement. To conduct scientific studies on the lunar surface the "Lunokhod-1" was equipped with the following set of instruments: a spectrometric instrument for analyzing the chemical composition of the lunar soil, a penetrometer to study its mechanical properties, a radiometric apparatus, an x-ray telescope, and an angular light reflector that was developed and manufactured in France for lunar laser ranging.

For experiments in lunar laser ranging two sets of ground laser-ranging apparatus were used. One set was created by Soviet scientists and engineers and was installed on the 2.6 m optic telescope at the USSR Academy of Sciences Crimean Astrophysical Observatory. The other was developed and manufactured by French scientists and engineers and was installed on a 1.05 m telescope located in the observatory of Pic-du-Midi in the Pyrenees.

The western part of the Sea of Rains where the station "Luna-17" landed is a gently sloping-waving plain on which a system of gently sloping ridge-like elevations with relative heights up to 200-400 m can be distinguished. The gently sloping-waving nature of the locality in this region was confirmed by the data obtained by the altimeter of the station "Luna-17" at the descent stage. Analysis of the television images of the locality and the parameters of movement of the lunokhod in the region of the moon landing site indicated that "Luna-17" had landed on the inner slope of a crater-like trough with diameter on the order 150-200 m. The point of landing is located in the western part of the trough, roughly in the middle of the inner slope.

In the first session of maneuvers, the "Lunokhod-1" was lowered from the landing stage along the eastern ladder and moved in an easterly direction for 20 m. Movement occurred down a 5-6° slope. In the panorama shown in Figure 11 the track made by "Lunokhod-1" on the surface of the moon and the landing stage of the station are visible. At the sites where the lunokhod had executed turns, the wheels raked the ground, and in the panorama the clotted structure of the soil is visible. Small rocks that are visible in the panorama, have in all probability, a bulk origin.

In the second session of maneuvers the "Lunokhod-1" was moved in a southeasterly direction and traversed 96 m in all. The lunokhod went up to a crater over 20 m in diameter. Around the crater an abundant inrush of rocks of acute angular shape with dimensions up to 0.5 m were observed. To the south 4-5 m from the stopping site on the edge of a small crater (diameter about 4m) a stone of unusual shape was found--a prism of penta- and hexagonal section lying on the long lateral edge; the length of the prism was 30-35 cm, diameter of the section 5-10 cm, and edges--flat.

In the third session of maneuvers the lunokhod went in a southeasterly direction over 50 m. If in the second session it passed the lowest point of the linear route of the first lunar day (below the landing point of the station by 2-3 m), then in the third session of movement the lunokhod reached a level roughly 1-2 m higher than the landing point of the station. Having advanced then a small distance twice, the lunokhod stopped near the edge of the crater in which the "Luna-17" had landed. During the first stage of maneuvers on the lunar surface the lunokhod traversed 197 m. On 24 November in the Sea of Rains night fell, during which time the lunokhod was in a stationary position. On 5 and 6 December with the approach of the morning terminator to the region where the self-propelled vehicle was standing, experiments in laser ranging were conducted. The ground apparatus of the USSR Academy of

Science Crimean Astrophysical Observatory sent towards the moon and recorded distinct reflected signals from the laser reflector of "Lunokhod-1." An analogous experiment was conducted by the French scientists in the observatory at Pic-du-Midi.

With the onset of the lunar day on 10 December "Lunokhod-1" left its stopping place and began to move in a southerly direction. It remained to investigate the lunar surface on a route stretching about 1.5 kilometers. On the path of the lunokhod there were many craters and rocks; it got over some of these obstacles and went around others. During the lunar noon from 14 through 17 December the self-propelled vehicle conducted studies and experiments in a stationary position, and then it again began to move to the south. In the communication session of 20 December the lunokhod encountered a crater about 100 m in diameter and 8-10 m deep and studied it thoroughly. In the communication sessions of 22 and 23 December all the operations were executed to prepare the vehicle for the lunar night which occurred on 24 December 1970 and continued to 9 January 1971. In this period the lunokhod was in a stationary position. In the second lunar day "Lunokhod-1" traversed a distance of 1522 m. It was 1370 m from the landing platform.

During the 35 days that the lunokhod was in operation, including two periods of active work under conditions of lunar day and lunar night, a large volume of information was obtained on the operation of the systems and the aggregates of the self-propelled vehicles and its chassis and on the results of the studies of the moon and outer space. During the 14 sessions of radio communication in which the apparatus was moved and maneuvered on the lunar surface 1719 m were traversed. Movement over the very complex relief with obstacles such as of craters, rocks, elevations, and slopes showed the good passability and maneuverability of the lunokhod. During its operation several tens of images were obtained showing different sections of the lunar landscape. Along the route of movement studies were continuously made on the physicomechanical properties of the surface layer. With the help of a spectrometer the main chemical elements that form the lunar rock in several regions were determined. Studies were also made of cosmic rays, and regular measurements were made of x-ray radiation sources in the universe.

The unique space experiment in the region of the Sea of Rains continued until 4 October 1971. For the work of "Lunokhod-1" on the lunar surface in 1971 and for the results of its scientific and technical studies and experiments, see the "YEZHEGODNIK BSE 1972" [Yearbook of the Great Soviet Encyclopedia 1972].

The "Venera-7" automatic interplanetary station (AIS) that was launched on 17 August reached the planet Venus on 15 December, studied the lower layers of its atmosphere all the way to the surface, and for the first time transmitted to earth scientific information directly from the surface of another planet in the solar system. The "Venera-7" AIS (Figure 12) was developed with regard for the accumulated experience in creating interplanetary stations and the studies conducted of Venus. In design "Venera-7" is analogous to the "Venera-4," "Venera-5," and "Venera-6" st-tions; it consists of an orbital module and descent vehicle. Its total weight is 1180 kg.

The station's orbital module, which is designed to transport the descent vehicle to the Venusian atmosphere, is a cylindrical hermetically-sealed housing, within which are placed the radio complex, celestial orientation systems, guidance, thermoregulation, chemical current sources, and the electronic block for the radiation dosimeter. The descent vehicle is attached to the upper platform of the orbital module, while the correcting engine unit is installed on the lower platform. On the lateral surfaces are solar panels, the parabolic antenna, optic instruments, and actuating elements of the celestial orientation system. On the ends of the solar battery panels, low-directional corkscrew antennas are installed. Radio communication with earth and trajectory measurements were guaranteed by the on-board radio complex which included antenna devices, receivers, transmitters, decoders, a program-time device, and auxiliary electronic equipment. The orientation system consists of optic-electronic instruments for solar, solar-earth, and solar-celestial orientation, blocks of automatics, and actuating elements--rocket microengines operating on compressed gas.

During the entire flight the station was mainly in a pattern of continual solar orientation. Communication with earth in this case was implemented through the low-directional antenna. At considerable distances from the earth a large volume of information was transmitted through the high-directional parabolic antenna.

The "Venera-7" descent vehicle (Figure 13) in contrast to those of the previous stations was designed not only for sounding and studying the Venusian atmosphere, but also for guaranteeing the operation of the scientific apparatus directly on the surface of the planet. It was refined also with regard to measurements obtained by the "Venera-5," and "Venera-6" stations that made it possible to pinpoint the values of atmospheric parameters at the surface of the planet, rated for external pressure up to 180 atm and temperature up to 530°C. This resulted in a roughly 100 kg increase in its weight as compared to the descent vehicles of the "Venera-5" and "Venera-6" stations. The housing design and the special thermal insulation protected the equipment of the descent vehicle from high temperatures and pressures. In order to reduce the overloads affecting the vehicle when it came in contact with the surface of the planet, a shock absorber was installed. Within the hermetically sealed instrument compartment of the descent vehicle the radio engineering, telemetry and measuring apparatus was placed as well as the blocks of automatics, electrical power sources, and the ventilator for the thermoregulation system. The parachute system was located above the instrument compartment. The parachute canopy was made of heat-resistant fabric designed for operation at temperatures up to 530°C. Markers with the bas-relief of V. I. Lenin and the embled of the USSR were installed on the descent vehicle (Figure 14).

The launching of the "Venera-7" AIS took place on 17 August at 0838 hours. Originally the station was put into an intermediate earth orbit. At 0959 hours at the command of the program-time device, the engine of the last stage of the rocket launcher was engaged for 244 s and reported to the station a velocity somewhat greater than the second escape velocity. On the flight to Venus on 2 October and 17 November 2 corrections of the trajectory were made that guaranteed arrival at the planet during radio visibility from ground measuring points. During the 4 months of the station's flight to Venus 124 radio communication sessions were held. The final stage of the flight of the "Venera-7" AIS occurred like the flight of "Venera-4," "Venera-5," and "Venera-6." When the station entered the atmosphere of Venus on 15 December at 0758.38 hours the descent vehicle was separated from the orbiter. Under the influence of aerodynamic forces the descent vehicle was turned with the nose section towards the approach stream and was maintained in this position by the damping device. During aerodynamic deceleration, the velocity of the vehicle relative to the planet was reduced from 11.5 km/s to 200 m/s. Here the maximum overloads reached 350 units, while the temperature between the impact wave and the housing of the vehicle equalled 11,000°C. At an altitude about 60 km from the surface of Venus, with external pressure on the order 0.7 atm, the system of automatics put the parachute into operation. On 15 December at 0834.10 hours the descent vehicle landed on the Venusian surface.

On the interplanetary segment of the flight of "Venera-7" the intensities of cosmic rays were measured with a radiation dosimeter. After the landing of "Luna-17" the study was made simultaneously on "Venera-7" and "Lunokhod-1." This made it possible to reveal important laws governing the dispersion solar particle streams in the interplanetary medium at various distances from earth. The instruments of "Venera-7," "Lunokhod-1," satellites and ground observations recorded solar flares and traced the dynamics of their development in space and time. An observation was made of the powerful chromospheric flare that began 10 December 1970.

On the "Venera-7" descent vehicle instruments were installed to measure temperature and pressure. Their gauges were resistance thermometers and aneroid type manometers that made it possible to measure temperature in the range from 25 to 540°C and pressure from 0.5 to 150 atm. The descent vehicle was equipped also with highly stable frequency generators. During the flight they were calibrated several times and compared with the frequency of the reference ground generators. All of this made it possible to determine, according to the amount of shift in the frequency of the signal received on earth (Doppler effect), the descent velocity of the vehicle in the Venusian atmosphere and the length of the path traversed during the descent with great accuracy.

In the final stages of descent, it was established by the change in the frequency of the radio signal that the descent velocity of the vehicle relative to the planet had become zero--the vehicle had landed. The change recorded after this moment in the frequency of the on-board transmitted corresponded precisely to the velocity relative to the earth of the section of Venusian surface where the vehicle had descended according to calculations.

Figure 12

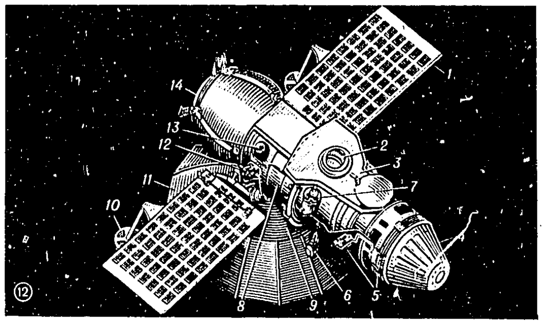


Figure 13

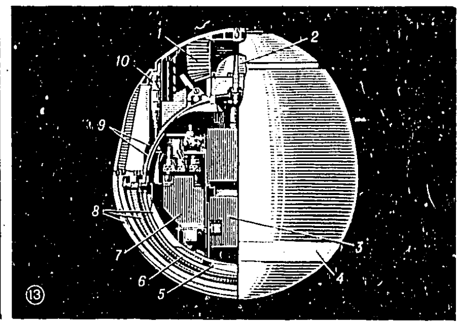


Figure 14

Figure 12. "Venera-7" Automatic Interplanetary Station

Key:
1. Solar panels
2. Celestial orientation sensor
3. Protective panel
4. Correcting engine unit
5. Collectors of pneumatic system with controlling jets
6. Counter of space particles
7. Constant solar orientation sensor
8. Orbital module
9. Radiator-cooler
10. Low-directional antenna
11. High-directional antenna
12. Block of automatics of pneumatic system
13. Cylinder of compressed nitrogen
14. Descent vehicle

Figure 13. "Venera-7" Descent Vehicle

Key:
1. Parachute
2. Transmitting antenna
3. Radio transmitter
4. Support ring
5. Damper
6. Heavy-duty housing
7. Commutation block
8. Thermal insulation
9. Heat exchanger
10. Cover of parachute compartment

Figure 14. Markers Installed on "Venera-7" Descent Vehicle

Signals from the descent vehicle were received after landing for another 23 min, whereby the level of the signal was roughly 100 times smaller than during the descent. This is explained most probably by the deviation in the axis of the vehicle's antenna away from the earth after landing on the surface. Analysis of the telemetry information received during the entire time the vehicle was descending and after landing indicated that the on-board commutator designed for alternate checking of different instruments remained in the same position. Therefore only information on the temperature of the environment was transmitted from the "Venera-7" lander. During the descent of the vehicle, a gradual rise in temperature took place. After landing, the temperature of the environment was not altered for the entire time that the radio transmitter was in operation on the surface of the planet. According to the nature of the change in the measured temperatures and velocity in time, the dependence of atmospheric temperature on altitude all the way to the surface was determined. It was found that the law of change in temperature is close to the adiabatic up to the actual surface. This fact is of fundamental scientific importance. According to the measurements made by "Venera-7" using the equations of hydrostatic equilibrium and gaseous state and the data of measurements by previous stations, the distribution of pressure and density in the atmosphere of Venus was computed for altitudes all the way to the surface. Regard for possible errors in measurement made it possible to estimate the tolerances for the temperature and pressure values obtained. The values of the atmospheric parameters on the surface of the planet at the landing site of the "Venera-7" descent vehicle are: temperature 475°±20°C, pressure 90±15 atm. The density of the atmosphere at the surface of Venus is roughly 60 times greater than the density of the atmosphere at the earth's surface. Measurements by "Venera-4," "Venera-5," "Venera-6," and "Venera-7" and the American spacecraft "Mariner-5" indicate that the Venusian atmosphere is stable and, at least to an altitude of 50-60 km, the variations apparently do not exceed several percents of the measured values of the atmospheric parameters.

In accordance with the program for joint studies of outer space by the socialist countries the satellites "Intercosmos-3" and "Intercosmos-4" were launched on 7 August and 14 October. The "Interkosmos-3" AES was designed to investigate radiation conditions in near-earth space, to study the relationship of the dynamic processes in the earth's radiation belt and solar activity, and to investigate the nature and spectrum of low-frequency electromagnetic oscillations in the outer ionosphere. On board were installed the following scientific instruments: a low frequency analyzer, equipment to study the composition and time variations in charged particles (protons, electrons, alpha-particles) and a magnetometer.

The ionized plasma mantle of the earth and the electrodynamic processes developing in it have long attracted the attention of scientists of many countries. The magnetic field of earth in which the plasma is located creates the conditions for comparatively easy emergence of a varying type of electrodynamic instability and electromagnetic oscillations. Depending on the place and the conditions of excitation in the ionosphere, waves of different spectral composition are formed. Before the launching of the "Intercosmos-3" AES low-frequency waves and howling atmospheric disturbances (brief signals in the kilohertz range) were recorded with ground apparatus; now scientists have the opportunity to study these phenomena directly in the ionospheric plasma. The low frequency analyzer designed to record radio waves in the 0.7-12 kHz range was developed and made by specialists of the USSR and CSSR. A comparison of the experimental data from the satellite and measurements from the earth's surface will help in a better understanding of the nature and conditions for excitation of electromagnetic waves in the ionospheric plasma, their structure, and the laws governing distribution. This information is important in order to guarantee radio communication between ground points and during reception of radio signals from space apparatus.

Studies of streams of charged particles have been made with an apparatus developed and made in the CSSR with the participation of specialists from the USSR. Charged particles that comprise the magnetospheric and ionospheric plasma have a broad spectrum of energy. Streams of particles with energy on the order of tens of kev are "spilled" out of the radiation belt into the lower ionosphere, lose energy, and increase the density of the ionosphere, thus governing the increase in absorption of radio waves. These "spilled" particles can have a great effect on the condition of the earth's ionosphere.

The three-component magnetometer installed on board the "Intercosmos-3" AES was designed to measure the intensity components of the earth's magnetic field and to determine the orientation of the satellite in space. The instrument was developed and manufactured in the USSR.

The scientific program of experiments on "Intercosmos-3" was successfully completed. The satellite's equipment operated especially intensively in the period from 7 through 13 August, from 19 through 26 August, and from 10 through 19 September 1970. This, in particular, was associated with active processes observed on the sun, including several large flares. On earth strong magnetic storms, disturbances in the ionosphere and other geophysical phenomena were noted. The instruments of the "Intercosmos-3" satellite recorded at this time a number of changes in the streams of radiation on the lower boundary of the radiation belt. High energy electron discharges into the dense atmospheric layers were also observed.

The launching of the "Intercosmos-4" AES continued the experiments that were started on the "Intercosmos-1" AES (see "YEZHEGODNIK BSE" 1970, pp 499-500). The scientific apparatus of the "Intercosmos-4" AES which was developed and manufactured in the GDR, USSR, and CSSR studied the ultraviolet and x-ray radiation of the sun; it investigated the effect of these emissions on the structure of the upper atmosphere of earth. Simultaneously with the satellite measurements, observatories in a number of socialist countries conducted radio astronomical, ionospheric, and optic observations in accordance with an agreed program.

The processing of the measurements made on the "Intercosmos-1" AES revealed important scientific results. On 20, 23 and 30 October 1969 the instruments of the satellite recorded three small x-ray flares. Here the x-ray polarimeter found polarization of the radiation with wavelength about 1Å. The discovery of polarization indicates that the radiation is governed by non-thermal processes, apparently, Bremsstrahlung of directed streams of electrons. Simultaneously using an x-ray spectroheliograph, a successful determination was made of the dimensions and shape of the region of the x-ray flare, and in certain cases individual elements of its structure were also recorded. It was found that the region of the flare has a fibrous structure with length about 1 angular minute and width less than 10-20 angular seconds. The fibers undergo rapid changes and, in addition, short-period variations are observed in the brightness of individual elements. The temperature in the region of the x-ray flare increases to 20 million degrees and over, while the mean electron density is increased to 10^{10} electron/cm^3. A detailed study of the polarization of the x-ray radiation will make it possible to obtain information that is necessary to explain the mechanism involved in the initial stage of development of the flare and the process of generation of the fixed part of their x-ray radiation.

While conducting the experiment, the Lyman-alpha photon flow recorded by the Lyman-alpha photometer was altered within 3.7-4.7 erg/cm^2·s. In several cases when the satellite entered the earth's shadow, the absorption by the upper atmosphere of solar radiation in the Lyman-alpha line was studied. This made it possible to determine the content and high-altitude distribution of the absorbing gas in the atmosphere at altitudes under 120 km as well as to study the latitudinal relationship of absorption in the range of latitudes 0-22°.

Measurements made by the optic photometer were processed. With this instrument an investigation was made of the properties of aerosol, which develops in the upper atmosphere of the earth apparently under the influence of meteor dust. The experiment was also based on the method of studying the effects of absorption. When the satellite entered the earth's shadow on 15 October 1969, an absorption curve was obtained which shows the monotonic incidence of the horizontal transparency of the atmosphere with a drop in the sun's altitude over the horizon; the experimental curve proved to be close to the calculated. On the curve obtained 23 October a brief anomalous drop in transparency of roughly 5 percent at an altitude of about 70 km was observed. It is probable that this is governed by the presence of a dust layer, which could have formed due to the meteor stream of Orion whose maximum density occurred on 22 October.

The x-ray photometer found important relationships between the x-ray flares and certain phenomena in the lower ionosphere. A comparison with the materials of ionospheric observations made it possible, in particular, to establish that between the x-ray radiation flares and their ionospheric effects there is a shift in time. It was also possible to determine the level of x-ray radiation in the 2-6 kev range with the appearance of small flares, flare fibers and protuberances.

A large volume of scientific information on the condition of the ionosphere at different times of the day and at different latitudes and longitudes was transmitted by the instruments of the "Intercosmos-2" AES (see "YEZHEGODNIK BSE 1970," p 500). A study of the ionosphere was made in a broad interval of altitudes from 200 to 1100 km. Data on the ion concentration and electron temperature in the ionosphere were obtained with the help of Langmuir probes for more than 100 complete turns of the satellite. Preliminary processing of the measurement results indicated that the concentration of charged particles in the ionosphere along the orbit was altered from $2 \cdot 10$ cm^{-3} to 10^6 cm^{-3}, and the temperature of the electrons from 800 to 3000°K.

In 1970 with the "Vertikal'-1" geophysical rocket, scientists of the socialist countries conducted a comprehensive scientific experiment to investigate the the ultraviolet, x-ray, and submillimeter radiation of the sun and the absorption of these emissions in the earth's atmosphere, high-altitude distributions of electron and positive ion concentrations as well as electron temperature, and meteor particles. The "Vertikal'-1" rocket was launched 28 November in the middle latitudes of the European sector of the USSR. The nose cone of the rocket consisted of a recoverable container and instrument compartment. The following scientific apparatus was placed in the recoverable container: a block of x-ray camera obscura and an x-ray spectroheliograph (Polish People's Republic); x-ray spectrometers (USSR); and an instrument to study meteor particles (Hungarian People's Republic and CSSR). In the instrument compartment were installed: Lyman-alpha photometer and radio-frequency capacitance probe (GDR); a device to measure submillimeter solar radiation and parameters of the earth's ionosphere, made in the USSR on the joint technical assignment of the scientists of the People's Republic of Bulgaria, GDR, USSR and CSSR. In the region of radio waves at frequencies 1.0, 1.5, and 2.0 MHz using the ground unit "AMA" (GDR).

The "Vertikal'-1" rocket reached an altitude of 487 km. The scientific equipment operated normally. On the descending segment of the flight trajectory, the recoverable container was separated at an altitude of 100 km and landed with the help of a parachute system.

The launching of a rocket astrophysical observatory which took place on 30 October was designed to make a comprehensive study of the sun. A set of scientific instruments that recorded the solar radiation in the region of ultraviolet and x-ray beams was installed on the oriented and stabilized platform located within the special container on the nose cone of the high-altitude rocket. The rocket observatory on the vertical trajectory reached an altitude of 500 km. After fulfilling the program of studies the container with the observatory was lowered to earth with a parachute system.

Launchings of the "Cosmos" series satellites continued; in 1970 72 satellites were launched (see the table). The results of the magnetic measurements of "Cosmos-321" were used to construct a model of the earth's magnetic field for 1970. "Cosmos-348" was a part of the second comprehensive experiment conducted jointly with the scientists and geophysicists of the People's Republic of Bulgaria, Hungarian People's Republic, GDR, Polish People's Republic, Socialist Republic of Romania, USSR and CSSR to study the earth's upper atmosphere, aurora borealis, and magnetic storms. The first comprehensive experiment in this domain was conducted in winter 1968 with "Cosmos-261" (see YEZHEGODNIK BSE 1969, p 496). The 1970 experiment, in contrast to the first, was conducted in summer. This made it possible to compare the data of the two experiments and to study the seasonal variations in the ionosphere. The scientific program of "Cosmos-368" provided for biological studies to be conducted. For this purpose the satellite was equipped with apparatus to test the experimental life-support systems for laboratory animals and to study the effect of space flight factors on living organisms. Instruments were also installed on the satellite to continue studies on the physical characteristics of outer space.

The main scientific experiment that was conducted on the "Cosmos-381" AES was the vertical impulse sounding of the ionosphere from top to bottom on 20 fixed frequencies in the 2-13.4 MHz. Radio signals were emitted for one second duration every minute to sound the ionosphere. The reflected signals were coded and recorded by the satellite's storage units. Over the territory of the USSR the signals were received without transformation by the ground stations. The reflected signals contained information on the distribution of electron concentration near the satellite. To study the electron concentration in the entire thickness of the ionosphere the three-frequency radio station "Mayak" was employed.

Great importance in the set of studies conducted with the "Cosmos-381" satellite was given to recording the intensity of solar radiation in certain ranges of wavelengths from 3 to 1500 Å. Simultaneous measurements of the electron concentration in the ionosphere and the intensity of ultraviolet radiation are very necessary in order to understand the interrelationship of the phenomena in the earth-sun system. Also installed on the satellite was an instrument which recorded the spectra of low-frequency electromagnetic waves that can be excited in ionsopheric plasma. The purpose of these experiments was to investigate the wave processes developing in the ionosphere. Certain measurements on the satellite were designed to determine the intensity of primary cosmic rays, radiation conditions and the earth's magnetic field.

The entire volume of scientific information was recorded by the telemetry-system storage unit and was transmitted by radio channels to earth when the satellite was in the zone of radio visibility of the ground measuring points. The satellite was equipped with an attenuation system. Its orbital position and angular position relative to the sun and the earth's magnetic field (this is necessary for processing and analyzing the scientific information) were determined using radio engineering devices, solar and magnetometric gauges. The power supply system consisted of a solar battery and chemical batteries that provide electricity to the on-board apparatus in the shadowed segment of the orbit and in the communication sessions with the measuring points. The system of thermoregulation maintained the assigned temperature and pressure in the instrument compartment. The successful flight of the orbital ionospheric laboratory "Cosmos-381" solved numerous, very complex, and at times contradictory problems that had faced its creators.

During the year four "Meteor" satellites were launched. The main task of the satellite launchings was to obtain meteorological information necessary for use in the operational weather service.

In 1970 geophysical studies continued by means of rocket sounding of the atmosphere.

Soviet spacecraft launched in 1970

Item No.	Launch date	Name of spacecraft	Apogee, (km)	Perigee, (km)	Orbital Inclina-tion	Orbital period (min)	Frequencies of radio trans-missions (megahertz) Remarks
1	2	3	4	5	6	7	8
1	9 Jan	Cosmos-318	295	204	65°	89.3	19.995
2	15 Jan	Cosmos-319	1537	209	82°	102	-
3	16 Jan	Cosmos-320	352	240	48.5°	90	-
4	20 Jan	Cosmos-321	507	280	71°	92	-
5	21 Jan	Cosmos-322	337	200	65.4°	89.7	19.995
6	10 Feb	Cosmos-323	333	206	65.3°	89.7	19.995
7	19 Feb	Molniya-1	39175	487	71°	11h,43m	-
8	27 Feb	Cosmos-324	492	283	65°	92	-
9	4 Mar	Cosmos-325	348	207	65.4°	89.8	19.995
10	13 Mar	Cosmos-326	393	512	81.4°	90.2	19.995
11	17 Mar	Meteor	543	555	81.2°	96.4	-
12	18 Mar	Cosmos-327	855	279	71°	95.6	-
13	27 Mar	Cosmos-328	340	213	72.9°	89.7	-
14	3 Apr	Cosmos-329	240	202	81.3°	88.8	19.995
15	7 Apr	Cosmos-330	548	514	74.1°	95.2	-
16	8 Apr	Cosmos-331	347	213	65°	89.9	19.995
17	11 Apr	Cosmos-332	786	755	64.5°	100	-
18	15 Apr	Cosmos-333	265	217	81.4°	89.1	-
19	23 Apr	Cosmos-334	508	281	71°	92.1	-
20	24 Apr	Cosmos-335	415	254	48.7°	91	-
21-28	25 Apr	Cosmos-336-343	1500	1400	74°	115	Eight AES put into orbit by one rocket launcher
29	28 Apr	Meteor	736	637	81.2°	98.1	-
30	12 May	Cosmos-344	347	206	72.9°	89.8	19.995
31	20 May	Cosmos-345	276	193	51.8°	89.1	19.995

Soviet spacecraft launched in 1970 (continued)

1	2	3	4	5	6	7	8
32	1 Jun	Soyuz-9	220	207	51.7°	88.59	15.008;18.06;20.008
33	10 Jun	Cosmos-346	289	201	51.8°	89.3	19.995
34	12 Jun	Cosmos-347	2073	223	48.4°	108	-
35	13 Jun	Cosmos-348	680	212	71°	93	-
36	17 Jun	Cosmos-349	350	203	65.4°	89.8	19.995
37	23 Jun	Meteor	906	863	81.2°	102	-
38	26 Jun	Molniya-1	39280	470	65°	11h,45m	-
39	26 Jun	Cosmos-350	267	204	51.8°	89.06	19.995
40	27 Jun	Cosmos-351	294	282	71°	92	-
41	7 Jul	Cosmos-352	309	205	51.8°	89.5	19.995
42	9 Jul	Cosmos-353	309	211	65.4°	89.4	19.995
43	2[illegible] Jul	Cosmos-354	208	144	50°	-	-
44	7 Aug	Intercosmos-3	1320	207	49°	99.8	-
45	7 Aug	Cosmos-355	342	202	65.4°	89.7	19.995
46	10 Aug	Cosmos-356	600	240	82°	92.6	20.005;30.0075;90.0225
47	17 Aug	Venera-7	-	-	-	-	928.429
48	19 Aug	Cosmos-357	500	282	71°	92	-
49	20 Aug	Cosmos-358	549	517	74°	95.2	-
50	22 Aug	Cosmos-359	910	210	51.5°	95.5	-
51	29 Aug	Cosmos-360	318	209	65°	89.5	-
52	8 Sep	Cosmos-361	326	207	72.9°	89.6	-
53	12 Sep	Luna-16	-	-	-	-	Soft landed on moon 20 Sep. Returned to earth 24 Sep
54	16 Sep	Cosmos-362	854	281	71°	95.7	-
55	17 Sep	Cosmos-363	324	210	65°	89.6	19.995
56	22 Sep	Cosmos-364	330	211	65.4°	89.6	-
57	25 Sep	Cosmos-365	210	144	49.5°	-	-
58	29 Sep	Molniya-1	39300	430	65.5°	11h,46m	-

Soviet spacecraft launched in 1970 (continued)

1	2	3	4	5	6	7	8
59	1 Oct	Cosmos-366	310	206	65°	89.5	19.995
60	3 Oct	Cosmos-367	1030	932	65.3°	104.5	19.542
61	8 Oct	Cosmos-368	421	212	65°	90.6	Satellite for biological studies
62	8 Oct	Cosmos-369	534	278	71°	92.3	-
63	9 Oct	Cosmos-370	307	208	65°	89.5	-
64	12 Oct	Cosmos-371	780	754	74°	99.9	-
65	14 Oct	Intercosmos-4	668	263	48.5°	93.6	-
66	15 Oct	Meteor	674	633	81.2°	97.5	-
67	16 Oct	Cosmos-372	828	786	74°	100.8	-
68	20 Oct	Cosmos-373	553	490	62.9°	94.9	-
69	20 Oct	Zond-8	-	-	-	-	Station flew around the moon and returned to earth 27 Oct
70	23 Oct	Cosmos-374	2153	536	63°	112.3	-
71	30 Oct	Cosmos-375	2164	538	63°	112.3	-
72	30 Oct	Cosmos-376	311	216	65.4°	89.5	-
73	10 Nov	Luna-17	-	-	-	-	Soft landed on moon 17 Nov. Transported "Lunokhod-1" to moon
74	11 Nov	Cosmos-377	305	208	65°	89.4	19.995
75	17 Nov	Cosmos-378	1763	241	74°	105	-
76	24 Nov	Cosmos-379	253	198	51.6°	88.7	-
77	24 Nov	Cosmos-380	1548	210	82°	102.2	-
78	27 Nov	Molniya-1	39430	435	65.3°	11h,47m	-
79	2 Dec	Cosmos-381	1023	985	74°	105.0	-
80	2 Dec	Cosmos-382	5040	320	51.35°	2h,23m	-
81	3 Dec	Cosmos-383	293	208	65.4°	89.3	-
82	10 Dec	Cosmos-384	314	212	72.9°	89.5	19.995
83	12 Dec	Cosmos-385	1005	982	74°	104.8	-
84	15 Dec	Cosmos-386	275	207	65°	89.2	-
85	16 Dec	Cosmos-387	560	528	74°	95.3	-
86	18 Dec	Cosmos-388	532	281	71°	92.3	-
87	18 Dec	Cosmos-389	699	655	81°	98.1	-
88	25 Dec	Molniya-1	39600	480	65	11h,52m	-

NON-SOVIET SPACE RESEARCH IN 1970

Moscow YEZHEGODNIK BOL'SHOY SOVETSKOY ENTSIKLOPEDII in Russian No 15, 1971 pp 503-510

[Article by V. Shitov: "Launchings of Foreign Spacecraft in 1970"]

Artificial Earth Satellites (AES)

In 1970 41 AES were put into orbit abroad, including 34 American (3 in the series INTELSAT-3, 1--ITOS, 1--SERT, 1--NATO, 1--"Nimbus," 1--TOPO, 2--NDS, 1--OFO, 1--RM, 1--NOAA, 1--CEP, 1--"Explorer," 19--secret military satellites, one West German (WIKA), two French (MIKA, "Peole"), one Japanese ("Osumi"), one Chinese ("China-1"), one Anglo-American ("Skynet 2") and one Australian ("Oscar 5"). The last two satellites were launched by American rocket launchers.

The main information about the orbits of the listed AES is given in the table. Below is a description of some of them.

INTELSAT-3F (Table, No 2). This was the sixth satellite in the INTELSAT-3 series, put into a near-stationary orbit over the Atlantic Ocean (long. 24,5° w). For the previous launchings see YEZHEGODNIK BSE 1970, p 500.

INTELSAT-3G (Table, No 18). This was the seventh satellite in this series, put into a near-stationary orbit over the Atlantic Ocean (long. 21°W).

INTELSAT-3H (Table, No 25). This was the last in the INTELSAT-3 series of satellites; it was to serve as a reserve in the communication system between North America and the Far East. The rocket launcher put the satellite into an intermediate orbit (see the Table). On the third orbit the on-board SPRE was engaged to transfer the satellite to a stationary orbit over the Indian Ocean, but within 14.5 s communication with it was lost and not successfully restored.

Before 1971 satellites of three models that belonged to the international consortium INTELSAT were put into orbit: INTELSAT-1 (240 channels of two-way radio telephone communication), INTELSAT-2 (240 channels), and INTELSAT-3 (1200 channels). By the middle of 1970 there were five satellites over the Atlantic Ocean; INTELSAT-1 ("Early Bird"), INTELSAT-2C ("Canary Bird"), INTELSAT-3B, INTELSAT-3F and INTELSAT-3G, three satellites over the Pacific Ocean; INTELSAT-2B ("Leni Bird 2"), INTELSAT-2D ("Leni Bird 3"), and INTELSAT 3D; and one satellite over the Indian Ocean INTELSAT-3C.

ITOS-1 (Table, No 3). This was the experimental variant of the ITOS meteorological satellite, which were to replace the ESSA satellites (see YEZHEGODNIK BSE 1970, p 501).

The housing of the satellite is in the shape of a parallelepiped (1.22 x 1.02 x 1.02 m) to which are attached solar panels that can be opened in orbit (Figure 1). The following instruments were installed on board; two television cameras of the APT system and two cameras of the AVCS system to obtain images of cloud cover during the day (each camera during one turn can take up to 11 pictures with resolution 3.2 km; the images obtained by the APT cameras were transmitted to earth in real time while those by the AVCS cameras--from recording); two infrared SR to obtain images at night--resolution 6.4 km, and during the day--resolution 3.2 km (images were transmitted in real time or from recording); an FPR to measure the albedo of earth; and an SPM to record the proton component of solar radiation.

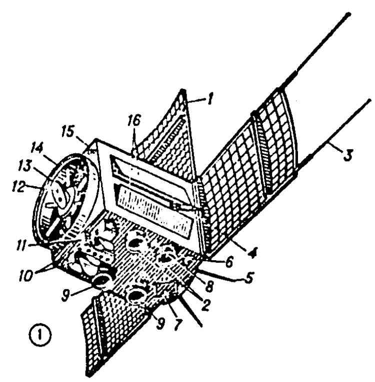


Figure 1. ITOS-I

Key:

1. Solar cell panels
2. Television cameras of APT system
3. Antennas (137.5 MHz)
4. Mechanism guaranteeing opening of solar panel
5. Antenna of command receiver (148.5 MHz) and radio range beacon
6. Gauge of direction to earth
7. Tourniquet antenna
8. Gauge of direction to the sun
9. Television cameras of AVCS system
10. SR
11. Radiometer to measure albedo of earth
12. Horizon monitor
13. Flywheel
14. Separation plane of satellite and last stage of rocket launcher
15. SPM to record proton component of solar radiation
16. Louvers of thermoregulation system

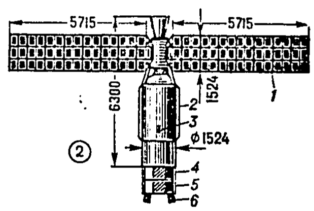


Figure 2. SERT-2 with "Agena-D" Rocket

Key:
1. Solar panels
2. "Agena-D" Rocket
3. Center of mass of object in orbit
4. Auxiliary module of SERT-2
5. Main module
6. Ion engine (2)

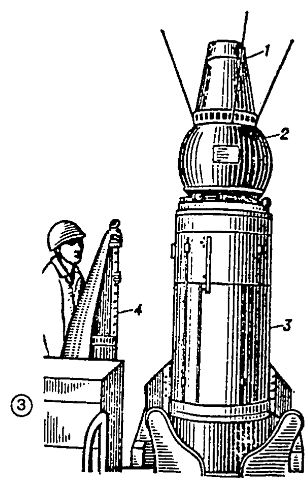


Figure 3. "Osumi"

Key:
1. Instrument container
2. Fourth stage of rocket launcher (SPRE with spherical housing)
3. Third stage of rocket launcher
4. Part of nose deflector

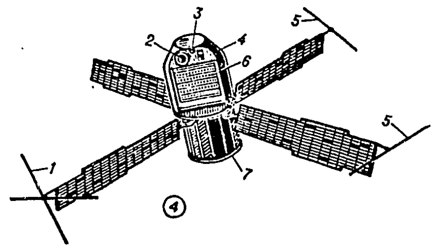


Figure 4. "Explorer 42"

Key:
1. Telemetry antenna
2. Star sensor
3. Device to engage star sensor
4. Sun sensor
5. Command antenna
6. Block of scientific equipment
7. Block of service equipment

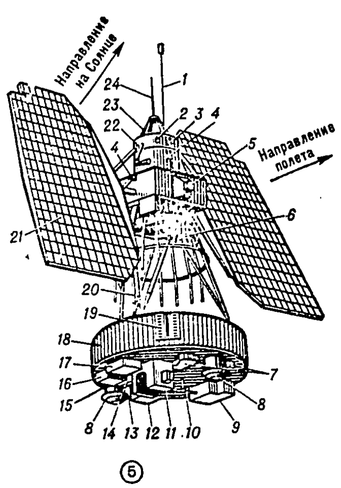


Figure 5. "Nimbus-4"
a. Direction to sun
b. Direction of flight

Key:
1. Extendable rod of gravitational or orientation and stabilization system
2. Pneumatic system fuel pipe connection
3. Jet nozzle for pitch orientation
4. Sun sensor
5. Horizon monitor
6. Panel with plug units
7. SCR radiometers
8. Antenna of range S
9. IRIS spectrometer
10. Antenna of IRIS system
11. THIR radiometer
12. SIRS spectrometer
13. BUVS spectrometer
14. IDC television camera
15. MUSE detector
16. Gauge of ultraviolet radiation used in SCR radiometers
17. FWS spectrometer
18. Container with scientific instruments and television cameras
19. Antennas (4) of radio range beacon
20. Design component
21. Solar panel
22. Jet nozzle for orientation in yaw
23. Jet nozzle for orientation in list
24. Command system antenna

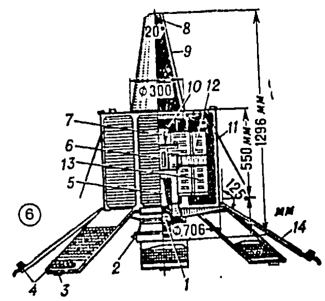


Figure 6. "Peole"

Key:

1. Device to form rod of gravitational orientation system
2. Triaxial gauge of oscillations
3. Sun sensors
4. Laser radiation reflectors
5. Electric motor providing rotation of rod of gravitational orientation and stabilization system
6. Magnetometer
7. Storage battery
8. Gauge used to determine albedo
9. Conical corkscrew antenna
10. Gauge of threshold overload (30 g)
11. Command-telemetry system antenna
12. Element of cushioning suspension of vehicle
13. Blocks of electronic equipment
14. Solar panel

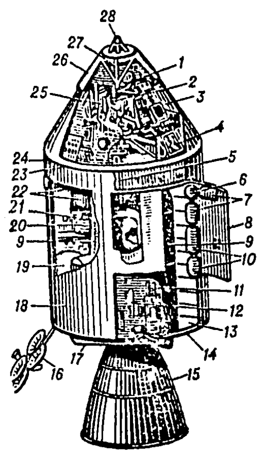


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Figure 7. Engine Module (EM) and Crew Module (CM) of the "Apollo" Spacecraft

Key:
1. Anterior section of module where equipment that guarantees landing on earth is placed
2. Control panel
3. Quick release entrance hatch
4. Rear section of CM where fuel tanks, orientation system engines, and others are located
5. Heavy-duty structural components that take the weight of the CM
6. Helium tank
7. Tanks with propellant for auxiliary engines
8. Block of auxiliary engines
9. Fuel tanks with sustainer
10. Tanks with oxidizer for auxiliary engines
11. Flowmeters in tank (9)
12. Sustainer
13. Radial element of rigidity
14. Rear platform
15. Jet of sustainer
16. High-directional antenna
17. Heat-protective screen of rear platform
18. Radiator of thermoregulation system (in wall of housing)
19. Tanks (2) with hydrogen for fuel components
20. One of two tanks with oxygen for fuel components and life-support system
21. Section where oxygen tanks (20) are
22. Batteries of fuel components
23. Thermoregulation system radiator
24. Passage between EM and CM
25. Lower section for equipment
26. Covering put on CM during launching, for heat protection in operation of SPRE of emergency rescue system
27. One of the main parachutes
28. Probe of docking assembly

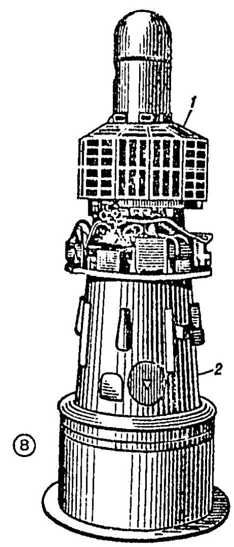

Figure 8. Satellite DIAL

Key: (1) Block of WIKA 2. Block of MIKA

The energy unit uses 10,000 solar cells and storage batteries. The thermoregulation system includes a radiator, heat screens on the front wall of the housing, louvers on the lateral walls, and multilayer coatings made of foil. The orientation and stabilization system includes two magnetic devices, and the "Stablelight" device. The QOMAO [Quarter-Orbit Magnetic Attitude Control System] magnetic device guarantees the orientation of the satellite's axis of rotation perpendicular to the plane of orbit; the MBC [Magnetic Bias Control System] magnetic device creates a dipole moment that guarantees the precession of the orbit by 1° per day so that it remains solar-synchronous. The "Stablelight" device, whose design employs a flywheel (the number of its revolutions is selected such that the satellite rotates 360° once per orbit, guarantees that the edge of the housing on which the television cameras and other instruments are mounted is always directed towards the earth. A scanning mirror is installed on the flywheel to guarantee that the earth's horizon is encompassed by the infrared gauges of pitch and list. For the initial orientation of the satellite's axis of rotation a sun sensor is used. The radio engineering system uses four antennas: a collapsible-whip for reception of commands and transmission of telemetry information, two dipoles (on the face of the panel) for transmission of images in real time and a tourniquet antenna for transmission of images from a recording. The satellite is tracked by 16 NASA stations that are included in the STADAN system.

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000100090025-4

It was launched together with the satellite "Oscar 5" (see below) by one booster. Both satellites went into a solar-synchronous orbit (located in the plane passing through the sun).

"Oscar 5" (Table, No 4). This is the Australian satellite translator designed for use by radio amateurs (it is also called Australis Oscar). Two transceivers are installed on board, one operates at frequency 29.45 MHz, the other--at 144.05 MHz (see YEZHEGODNIK BSE 1966, p 496).

SERT-2 (Table, No 5). It is designed to conduct tests of ion engines. It was put into orbit close to the calculated (circular with altitude 1000 km) together with the second stage ("Agena D") of the rocket launcher (Figure 2). The cylindrical housing of the satellite (length 1 m, diameter 1.52 m) consists of two compartments. In the main compartment there are two ion engines and equipment for conducting other experiments; in the auxiliary--two telemetry transmitters (136.23 MHz and 136.92 MHz), two command receivers, two magnetic sensors, a battery, an attenuation and initial orientation system gyroscope, and other service equipment. There are 33,300 solar cells (~1.5 kw) mounted on two panels to power the on-board equipment, in particular the ion engines, whereby the satellite is oriented such that the panels are in the plane of orbit which at first must be inclined 15° towards the sun. The satellite was put into an orbit such that during the next several months it would not enter the earth's shadow, and the solar cells could continuously provide a power supply to the ion engines. During the next 2-3 months the satellite will periodically enter the earth's shadow which will force the tests of the engines to stop, and then there will be another prolonged period during which time the satellite would remain out of the shadow. The stations in the STADAN and MSFN system track the satellite and receive telemetry information from it.

"Osumi" (Table, No 6). This is the first Japanese AES which was successfully put into orbit after four unsuccessful attempts. It is the fourth stage of the solid-propellant "Lambda-4" rocket launcher with an instrument container (Figure 3). The container weighs 23 kg and the equipment in it weighs 9.4 kg. The equipment includes a thermometer, an accelerometer, a transmitter (131.6 MHz), and a chemical battery rated for 30 h of operation. The transmitter ceased to operate within 11 h; the reason was apparently the overheating (over 100°C) of the equipment in the container as a consequence of the fact that the rate of combustion of the propellant charge of the fourth stage SPRE was lower than what had been calculated. The total expenditures for launching were 388 million dollars, including 333 million dollars to manufacture the rocket launcher.

DIAL. This is the joint French-West German experiment. With the French experimental rocket launcher "Diamant B" the DIAL satellite (this name refers both to the satellite as a whole and only the releasable unit WIKA) was put into orbit together with the last stage; the satellite consists of two units (Figure 8): WIKA (FRG) and MIKA (France. The main purpose of the launching was to test the rocket and the ground equipment. It is noted that this was the first launching from the Kuru testing site (French Guiana).

DIAL/WIKA (Table, No 10). The WIKA unit is designed to conduct certain scientific studies and is equipped with scientific instruments (10 kg). The housing is 1.15 m high, with maximum diameter 0.71 m. After going into orbit it was separated from the final stage. The telemetry system of the unit includes a transmitter (135.56 MHz), a program-time device and an omnidirectional antenna. The telemetry information is transmitted in real time. The scientific instruments include: three two-channel Lyman-alpha geocorona radiation detectors for ranges 1150-1350 Å and 1250-1350 Å; detector of the concentration of electrons with energy up to 1 Mev; a four-channel detector of protons and alpha-particles with energy 5-40 Mev, and a one-channel detector of protons, alpha-particles, and electrons with energy above 1.3 Mev; and a two-channel sensor of the magnetic field with intensity to 0.35 gauss (accuracy of measurement to $2.5 \cdot 10^{-5}$ gauss). The power supply for the on-board equipment is a silver-zinc battery (90 a·h) and 222 solar elements mounted on the lateral edges of the housing. The stations belonging to NASA in Quito (Ecuador) and those on Ascension Island belonging to CNES tracked the satellite (see YEZHEGODNIK 1969, footnote on p 507) as well as the French stations in Brazzaville, Wagadugu, Pretoria, Kuru, Fortaleza, and the Italian station in Kenya (apparently on the floating platform "Santa Rita").

MIKA (Table, No 11). This unit (a cylinder 0.6 m in diameter and 1.5 m in length) is designed to test the operation of the on-board systems of the rocket launcher and is not separated from the final stage. On the initial leg of the flight the unit's equipment malfunctioned and did not succeed in making the planned measurements. Despite this, the launching of the rocket with the satellite is considered successful.

NATO-1 (Table, No 12). This is a communication satellite designed for the military communications system of NATO and it should guarantee radio telephone and radio telegraph communication as well as transmission of data in a digital form. It can also be used in the military communications system "Skynet" and in the American IDCSP (see YEZHEGODNIK BSE 1969, p 505). It is a modified satellite of "Skynet" (see below), has the shape of a cylinder (diameter 1.37 m, height 0.81 m), total height together with the antenna block 1.6 m, and starting weight 243 kg. It is stabilized in orbit by rotation. The source of power supply is 7000 solar cells mounted on 8 panels on the lateral surface of the housing and two nickel-cadmium batteries.

The rocket launcher put the satellite into an orbit with perigee 274 km and apogee ~ 36,000 km; on its sixth revolution the on-board SPRE (thrust 2 m) placed it in a near-stationary orbit over the central part of the Pacific Ocean. In this orbit the satellite moved in an easterly direction, and by the end of April reached the calculated point of the stationary orbit (over the Atlantic Ocean in the region of Ascension Island), where its further shift was stopped with controlling je nozzles. The control center for the NATO communications system is located near of Brussels and the alternative center --in England.

"Nimbus-4" (Table, No 13). This is the fifth[6] in the series of "Nimbus" meteorological satellites. In design it is similar to the previous satellites (see YEZHEGODNIK BSE 1970, p 501) and is distinguished from them by the basic composition of the scientific instruments and by the presence of two orientation and stabilization systems: the main system (provides accuracy on all three axes to 1°) and the spare (uses an extendable rod 13.7 m in length), as well as a perfected radio command system that guarantees reception of up to 512 commands (in the previous satellites up to 128 could be received). The main tasks of the launching were to test the instruments for future meteorological satellites and the triaxial orientation and stabilization system. The following instruments were installed on the satellite (Figure 5); a backscattering ultraviolet spectrometer (BUVS) to study on a global scale the distribution of ozone in the atmosphere; an FWS (Filter Wedge Spectrometer) with filter and photometric wedge to determine on a global scale the content and vertical distribution of water vapor in the atmosphere; an SCR radiometer (Selective Chopper Radiometer) with a selective action limiter to determine the temperature profile of the atmosphere between the surface of the earth and altitude 64 km; a THIR infrared radiometer (Temperature Humidity Infrared Radiometer) to measure the infrared radiation of earth during the day and at night, for round-the-clock transmission of images of cloud cover, and to determine the temperature and relative humidity of clouds and the surface of dry land and the oceans; an IRIS[7] infrared spectrometer; a SIRS infrared spectrometer; a television system with IDC camera (resolution 1.6 km); a MUSE sensor to record ultraviolet solar radiation; and an IRLS system.

To track the satellite 16 stations of the STADAN system were used. The telemetry information is received in Fairbanks and Rosman while the television images can be received at over 500 stations, including over 80 in foreign countries.

"TOPO A" (Table, No 14). This is the first in the series of experimental satellites created by the topographical service of the United States Army Corps of Engineers. It is designed to work out a new technique that guarantees the geodetic linking of ground points in real time. It has the shape of a right-angle parallelepiped (0.35 x 0.30 x 0.23 m); solar cells are mounted on the surface; and on board there is a transponder and telemetry transmitters; and before the satellite goes into orbit flexible antennas are wound around its housing. The design uses assemblies and parts of the "Sekor" geodetic satellite (see YEZHEGODNIK BSE 1970, p 501).

NDS-11, NDS-12 (Table, No 15, 16). The purpose is the same as the previous satellites in this series (see YEZHEGODNIK BSE 1968, p 516 and YEZHEGODNIK BSE 1970, p 501).

"China 1" (Table, No 19). This is the first AES made in the People's Republic of China; it is apparently a ball 106.7 cm in diameter. According to the report of the Sin'khua agency, the on-board transmitter (20.009 MHz) operates in 1 minute cycles: transmission of the melody "Al yet Vostok" (The East Reddens)--40 s, interval--5 s, transmission of telemetry information--10 s, interval--5 s, and then a new cycle begins.

"Skynet 2" (Table, No 27). The second satellite for the British military "Skynet" communications system was to serve as a spare in case of the malfunction of the "Skynet 1" satellite (see YEZHEGODNIK BSE 1970, p 503). The rocket launcher put the satellite into an intermediate orbit with apogee ~ 36,000 km. On 21 August the satellite should have been switched to a stationary orbit over the Indian Ocean roughly 100 km from the "Skynet 1" satellite. However within 13 s after engagement of the SPRE, communication with the satellite ceased and all attempts to regain it proved unsuccessful.

OFO (Table, No 34). This is the research satellite designed to investigate the effect of alternating periods of weightlessness and accelerations (up to 0.5 g). The body consists of two sections. The total length is 1.19 m, and the maximum diameter is 0.76 m. In the lower section (a rectilineal eight-sided truncated pyramid) the radio electronic equipment is placed, and in the upper section (a truncated body with semispherical cone) is mounted the FOEP[8] block, within which there is a water-filled centrifuge with two frogs, in a special suspension system with equipment for their life-support, instruments to record signals from the sensors implanted in their otolithic organs and to record the electrocardiograms as well as equipment to regulate water temperature (15.6 ± 2.5°C), and pressure. All the equipment of the FOEP is mounted in a hermetically sealed container (length 0.46 m, diameter 0.46 m). Five antennas of the command-telemetry system, four stabilization system rods ~ 2 m that turn in orbit, and a device to slow down the rotation of the satellite (weights on cables) after its separation from the final stage of the rocket have been installed on the upper section. Experiments in orbit were conducted in cycles lasting roughly 8 min each with different intervals between cycles. It is believed that the flight program was fulfilled. Roughly within 3 days the frogs completely adapted to the conditions of zero gravity. It is assumed that when the data has been completely processed, it will be possible to prove that cosmonauts are able to remain for a long time in the orbital station without having to create an artificial gravity system (the otolithic organ of the frog is close to the human).

RM[9] (Table, No 35). The research satellite is made to test the instruments to record radiation and meteorological conditions along the flight path which were developed for use on manned spacecraft. The satellite consists of two toroidal sections each 0.76 m in diameter, which are connected to the final stage of the rocket (total length 1.68 m). The lower section is 0.38 m long, and sets of solar cells are mounted on its surface. In the upper section (length ~ 0.34 m) are located: equipment to monitor radiation, including an advanced dosimetry system (ADS) that records electrons with energy 0.6-4.0 Mev and protons with energy from 10 to hundreds of Mev and 3 standard ionization cameras to make standard measurements and compare them with the results obtained by the ADS system; and equipment consisting of two pairs of parallel planar detectors (7.6 cm apart) to study meteorological conditions.

The detector is a fine sheet (20 x 20 cm) on which are mounted 64 gauges (capacitors) consisting of four layers of polysulfide film. Meteor particles with weight 10^{-14}g are capable of penetrating one sheet (the density of the particle flow can be calculated), while those weighing over 10^{-12} g can penetrate a pair of parallel sheets, which makes it possible to calculate the velocity and direction of the meteor particles. It was launched together within OFO satellite (Table, No 34) by a single booster.

NOAA-1[10] (Table, No 38). This is the first operating variant of the ITOS meteorological satellite (see p 503). It has the shape of a parallelepiped (1.22 x 1. 02 x 1.02 m); three panels are attached to the body and on them 10,000 solar cells that guarantee a mean power of 250 w are mounted. The satellite was inserted into an orbit close to the calculated (circular with an altitude $\sim$ 1450 km) solar-synchronous orbit. The following instruments were on board: 1. Two television cameras of the APT system for continuous photographing of cloud cover with transmission of images in real time. The images are received by over 500 stations in 50 countries. 2. Two television cameras of the AVCS system for photographing cloud cover in remote regions, where there are no ground reception stations. The images are received by stations near Fairbanks (Alaska) and Wallops Island (Virginia). 3. Two infrared radiometers to obtain images of cloud cover at night (in the range 10.5-12.5 μ) and during the day (0.52-0.73 μ). 4. An FPR radiometer (see the description of the ITOS-1 satellite) to measure the earth's albedo. 5. An SPM instrument to record the proton component of solar radiation.

CEP[11] (Table, No 39). The research satellite is designed to study electron concentration and temperature as well as the flow of ions in the ionosphere, which, it is assumed, should facilitate the processing of data obtained from the NOAA-1 satellite. It was launched as a supplemental payload together with the NOAA-1 satellite (Table, No 38) by a single booster. Information from the satellite was transmitted for two revolutions as provided for by the program.

"Explorer 42" (Table, No 40). This is the research satellite designed to study the celestial sphere and sources of x-ray radiation. It was launched from the Italian marine launch complex "San Marco" located in the Indian Ocean at the shores of Kenya. It was inserted into an orbit close to what was calculated (circular with altitude 550 km). The satellite (Figure 4) is shaped like a cylinder (diameter 0.56 m, length 1.16 m) and consists of two blocks: one block of service apparatus (79.4 kg) and one of scientific apparatus (63.5 kg). Four panels that can be opened in orbit with solar cells that provide total power of $\sim$ 27 w are attached to the body of the first of these blocks. On the ends of each of the three panels there are two command and one telemetry antennae. The service apparatus includes a magnetic system for orienting the axis of rotation, a flywheel, a recording device, storage batteries and communications equipment. The block of scientific apparatus includes two independent identical sets of instruments which are installed symmetrically relative to the longitudinal axis of the satellite while their sensors are turned to opposite sides. Each set includes an argon-filled proportional counter to record x-ray radiation in the range

2-20 kev; two collimators, one of which provides a narrow (1 x 10°) and the other wide (10 x 10°) visual field for the proportional gauge; a star sensor, a sun sensor, and equipment to process the data obtained.

The proportional gauges scan a 10° band of the celestial sphere; to survey the entire sphere 1.5-2 months are required. To guarantee scanning the satellite is rotated (5 rpm); stabilization of the axis of rotation is guaranteed by a flywheel (2000 rpm). The orientation of the axis of rotation can be altered with a magnetic system, making it possible to survey different regions of the celestial sphere. From 5 to 24 hours are required to change the orientation.

When an x-ray source is found, its position on the celestial sphere, the intensity of its radiation and its change, and the energy spectrum are determined. The position of more intense sources is calculated with accuracy to 1', and of weak sources--to ~15'. Information from the satellite is transmitted both from recording and in real time.

"Peole"[12] (Table, No 41). The launching of the satellite is a preparatory stage for the "Eole" program that provides for a study of meteorological conditions in the Southern Hemisphere, where there are very few meteorological stations. Within the framework of this program in 1971 it is planned to launch the French satellite CAS-A which is designed to collect meteorological information from ~ 500 sounding balloons. The main tasks of the launching of the satellite "Peole" are: 1. Tests of radio systems that guarantee the collection of information from sounding balloons. 2. Tests of the gravitational orientation and stabilization system designed for the CAS-A satellite. This system uses a rod 10 m long formed by a special on-board device and made of tape (beryllium bronze) passed through draw-holes. There is a weight on the end of the rod to damp vibrations. The stabilization system should guarantee the on-board antenna are constantly directed towards the earth. 3. Study of the effect of space flight factors on the characteristics of experimental solar cells. Besides these tasks, there were also tests not associated with the "Eole" program: tests of the "Diamant B" rocket launcher, the nose deflector with a pneumatic separation system, the silver-cadmium battery and pyrotechnic devices, as well as geodetic measurements, for which there are 44 laser radiation reflectors like those which were installed on the "Diadem" satellites (see YEZHEGODNIK BSE 1968," p 520). The housing of the satellite (Figure 6) is shaped like an octahedral prism; on one of the platforms a conical corkscrew decimeter range antenna is installed to conduct experiments within the framework of the "Eole" program, and on the other platform--a device to form a rod for the gravitational orientation and stabilization system and eight opening panels with 2016 solar cells that provide power up to 20 w. On the edge of each panel five laser radiation reflectors are mounted, and another four reflectors--at the base of the conical antenna. On the lateral surface of the body there are antennas of the command-telemetry system. The on-board apparatus (a receiver, a transmitter, the magnetic orientation system with magnetometer, a storage battery and others) is placed within the cylindrical container which is attached to the body on a special shock absorbing suspension.

According to the program the satellite was to have been inserted into an orbit with perigee 730 km, apogee 800 km and inclination 15°. However the rocket launcher conveyed to the satellite a velocity lower than what was prescribed by 40 m/s, and it was inserted into a lower orbit (see the Table). In the opinion of the directors of the "Eole" program this should not affect the fulfillment of program.

Transport Ships

In 1970 the United States sent one manned spacecraft of the "Apollo" program to the moon.

"Apollo 13." The main tasks of the third manned flight to the moon were: to install on the moon the ALSEF[13] set No 2 that includes the radioisotope power unit SNAP-27, a telemetry system and scientific instruments (see below); to deliver to the earth $\sim$ 40 kg of lunar soil samples, including soil from a drilled hole 3 m deep; to conduct color television broadcasts from the lunar surface; to take movies (for the first time) of certain mechanical processes, in particular the process of drilling; to conduct experiments to study the mechanical properties of the ground, communication outside the limits of direct visibility, etc.; to photograph the lunar surface, the solar corona and zodiacal light; to study the luminescent particles around the craft; to insure that the last stage of the rocket launcher that has separated from the craft falls on the moon (seismic oscillations and waves of particles produced by the fall will be recorded by a seismometer and ion detector from the set of ALSEP No 1, which was installed by the astronauts of "Apollo 12"); to guarantee that the used launching stage (LS) of the lunar module (the LM) falls to the moon after the astronauts are transported from the moon to the main module of the ship (MM) which is in a selenocentric orbit (seismic oscillations will be recorded by seismometers from both sets of ALSEP); and to conduct color television broadcasts from the crew module (CM).

The crew of the craft included: James Lovell (commander of the craft), John Swigert (pilot of the MM), and Fred Haise (pilot of the LM). The astronauts were trained mainly on the same program as the first two lunar expeditions, but with regard for the specific nature of the program of the future flight. The astronauts' equipment was somewhat modified due to the experience accumulated in the flight of "Apollo 12." In particular, so that they could quench their thrust while working on the lunar surface, the astronauts wore new space suits designed with a special mouthpiece connected at the neck to a toroidal balloon containing up to 200 g water. The measures for microbiological protection and quarantine were analogous to the measures taken for the "Apollo 12" astronauts (see YEZHEGODNIK BSE 1970, p 508). A number of scientific instruments were to be installed on the moon; the ion detector, the ionization manometer, the spectrometer of particles in solar plasma, and the seismometer were the same as in the set of ALSEP No 1, while two other instruments were added; a detector of protons and electrons ($50 - 150\cdot10^3$ ev) at the lunar surface and an instrument to measure thermal flows passing from the depths of the moon to its surface through drilled holes. To drill holes

2.5 cm in diameter and up to 3 m deep on board there was an electric drill with an 0.4 hp electric motor and a silver-zinc battery to power it. It was proposed also that a trap for nuclei of inert gases contained in the solar wind be installed and returned to earth.

The ship was launched by "Saturn 5" (AS-508), which had basically the same characteristics as the (AS-507) rocket that launched "Apollo 12," with the exception that on all stages the fuel supply was somewhat increased and the last stage (rocket S-4B-508) had an additional device to insure its jettison to the moon. The ship (43.9 m) was almost completely like "Apollo 12." Certain changes were introduced into the power system of the MM. The astronauts had to emerge from the transport ship onto the lunar surface twice. The first exit was planned for 16 April at 1720 hours and the return at 1112 hours. The task was to install a color television camera, the American flag and instruments of the ALSEP set (150 km from the LM), drill three holes in the ground (two to measure the thermal flows and the third to take soil samples), and to collect samples from the lunar surface. The second exit was planned for 17 April at 0311 hours and the return at 0650 hours; the task was to collect samples of soil. According to the proposal schedule, at 0838 hours the preparation for blast-oil would begin; and at 1222 hours the blast-off from the lunar surface.

The launching took place at the calculated time of 1930 hours on 11 April. The final stage with the transportation was inserted into an orbit close to the prescribed one with perigee 190.14 km and apogee 197 km. The second firing (transition to a lunar flight trajectory and the start of rearrangement of the modules were conducted at the calculated time. A color television broadcast was held during the rearrangement. At 2315 hours the transport ship was separated from the stage, which, as a result of the spilling of propellant through its engine, went into a trajectory to the moon different from that of the craft. Later, at command from earth, this trajectory was corrected in order to guarantee that the stage would fall in the designated region of the moon. It fell on the moon approximately 140 km from the seismometer and ion detector, which recorded the phenomena produced by this fall. The first (nonmandatory) trajectory correction planned was dropped; the second was conducted at the calculated time, and the craft switched from a free path to a hybrid trajectory. The non-mandatory third correction was dropped. Lovell and Haise transferred to the LM to check the on-board systems and from there conducted a 30-minute television broadcast. On the morning of 14 April, soon after the return of the astronauts to the CM, an accident occurred which forced the lunar landing to be discontinued. In one of the two oxygen tanks (Figure 7.20), at first the pressure rose, then dropped to zero. As it was revealed subsequently, a short circuit occurred on board, the insulation of the conductors ignited, and the flame burned through an opening i the wall of the tank. The oxygen under high pressure burst out the tank, damaged the second tank and tore the panel covering the section in which the tanks were located (see Figure 7.21). The astronauts reported that they had heard a "bang" from the EM, and then a signal for malfunction in the power supply system to the CM appeared on the panel. After 3-4 minutes one of the three batteries of the fuel elements (FE) broke down, and in 20 minutes--the second. At 0511 hours when there remained 15 minutes of oxygen for the operation of the third battery of the FE, on the instructions of the flight supervisors, Lovell and Haise transferred to the LM and engaged its on-board systems in order to use the LM as a "lifeboat." The hatches of the transfer compartment were left open in order for the oxygen from the LM life-support system to penetrate the CM.[24] Swigert, who remained in the CM, disengaged all the on-board systems of this compartment. Calculations indicated that if consumed economically, the resources of the LM should last until approach to earth (3-4 days). NASA created a special committee which met every 8 hours, made a general analysis of the situation, and worked out recommendations for the NASA leadership.

To return the astronauts to earth it was necessary in the first place to shift the craft from the hybrid trajectory to a trajectory that guaranteed its return to earth after circling the moon (switching to the trajectory for return without circling the moon was not permitted by the power engineering characteristics of the ship). To correct the trajectory on 14 April at 0843 hours the engine of the landing stage (LS) was engaged, the ship switched to a trajectory that insured a landing in the Indian Ocean, but this was undesirable since there were no American participants of the search and recovery complex (SRC) there. It was decided to make yet another correction in order to insure the landing in the Pacific Ocean nearer to the calculated point; the second correction was made 15 April (after circling the moon) at 0241 hours with the LS engine. But then it became necessary to make an additional correction, since otherwise the ship would have passed 165 km from earth and would have gone on the second turn of an elliptical orbit with apogee of several hundred thousand kilometers, and when it again approached the earth the astronauts would have died. The third correction was planned for 16 April in the period from 0430 to 0730 hours. The astronauts were freezing and slept poorly. The correction was made at 0432 hours and provided an angle (6.05°) of entry into the earth's atmosphere, which, although it was within permissible limits (5.8°-7.3°), it was not optimal (6.25°-6.75°). To insure the optimal angle, on 17 April at 1253 hours, the fourth and last correction was made with the engines from the orientation system of the LM. The EM was separated on 17 April at 1315 hours, only 5 hours before the calculated landing time. The decision on the possibility of not separating the EM for a longer time was made in order to complicate the stabilization and thermoregulation of the craft, which, after the separation, remained in the unplanned arrangement "CM + LM." After the separation of the EM at a safe distance the astronauts photographed it in order to get an idea of the nature of the damages. The flight of the craft in the unplanned configuration continued more than 3 hours and no difficulties developed with stabilization. At 1627 hours all the astronauts transferred to the CM, and within 3 minutes the LM was separated from it and fell into the Pacific Ocean. Since a capsule with the radio-isotope for the SNAP-27 power unit was mounted on the outside of the LM, airplanes were sent to the splashdown area in order to take air samples for radioactivity. The NASA specialists claimed that destruction of the capsule and radioactive contamination were precluded. On 17 April at 1807 hours the

Non-Soviet spacecraft launched in 1970

Item No.	Satellite name	Booster rocket	Date of launch	Satellite wt, kg.	Parameters of initial orbit			Initial orbital period min
					Perigee, km	Apogee, km	Incli-nation	
1	Secret	"Titan 3B"	14 Jan	–	134	384	109.86°	89.69
2	INTELSAT-3F(F-6)	"Thorad Delta"	15 Jan	137[15]	35791	35807	0.90°	1436.20
3	"ITOS-1" ("Tiros-M")	"Thorad Delta"	23 Jan	310	1436	1482	102.00°	115.10
4	"Oscar 5"			17.7	1436	1480	101.96°	115.08
5	SERT-2	"Thorad Agena D"	4 Feb	1497[16]	996	1003	99.13°	105.15
6	"Osumi"	"Lambda 4S"	11 Feb	38[16]	340	5120	31.07°	144.20
7	Secret[17]	"Thor Burner 2"	11 Feb	150	772	874	98.71°	101.39
8	Secret	"Thorad Agena D"	4 Mar	–	167	257	88.02°	88.76
9	Secret[18]			59	441	513	88.14°	94.16
10	DIAL/WIKA	"Diaman B"	10 Mar	50	301	1630	5.44°	104.20
11	MIKA			65	312	1666	5.42°	104.67
12	"NATO 1" ("NATO A")	"Thorad Delta"	20 Mar	120[15]	34430	35786	2.80°	1401.60
13	"Nimbus 4"(Nimbus D")	"Thorad Agena D"	8 Apr	620	1094	1102	99.89°	107.29
14	"Topo A"			18	1065	1112	99.76°	107.09
15	NDS-11	"Titan 3C"	8 Apr	245	111217	112166	32.41°	6729.00
16	NDS-12			245	111506	112216	32.52°	6745.00
17	Secret	"Titan 3B"	15 Apr	–	130	388	110.97°	89.70
18	INTELSAT-3G (F-7)	"Thorad Delta"	23 Apr	137[15]	35780	35806	0.70°	1436.30
19	"China 1"	?	24 Apr	173(?)	441	2388	68.44°	114.09
20	Secret	"Thorad Agena D"	20 May	–	163	246	83.00°	88.62
21	Secret[19]			59	491	504	83.12°	94.59
22	Secret[20]	"Atlas Agena D"	19 Jun	–	31681	39862	9.90°	1436.00
23	Secret	"Titan 3B"	25 Jun	–	129	389	108.87°	89.70
24	Secret	"Thorad Agena D"	23 Jul	–	158	398	60.00°	90.04
25	INTELSAT-3H (F-8)	"Thorad Delta"	23 Jul	137[15]	19410	36052	13.30°	1043.00
26	Secret	"Titan 3B"	18 Aug	–	151	365	110.95°	89.67
27	"Skynet 2"("Skynet B")	"Thorad Delta"	19 Aug	129[15]	270	36068	28.04°	636.60
28	Secret	"Thorad Agena D"	26 Aug	–	484	504	74.99°	94.51
29	Secret[21]	"Scout" (?)	27 Aug		954	1222	90.02°	107.04
30	Secret[22]	"Atlas Agena D"	1 Sep	–	31684	39865	9.90°	1436.00
31	Secret	"Thor Burner 2"	3 Sep	–	735	874	98.75°	101.30

Non-Soviet spacecraft launched in 1970 (continued)

Item No.	Satellite name	Booster rocket	Date of launch	Satellite wt, kg.	Parameters of initial orbit			Initial orbital period min
					Perigee, km	Apogee, km	Incli-nation	
32	Secret[22]	"Titan 3B"	23 Oct	-	135	396	111.06°	·89.83
33	Secret[22]	"Titan 3 C"	6 Nov	-	299	35875	26.29°	635.10
34	OFO	"Scout"	9 Nov	133	304	518	37.41°	92.64
35	RM			45.4	303	526	37.41°	92.71
36	Secret	"Thorad Agena D"	18 Nov	-	185	232	83,00°	88.70
37	Secret				488	510	83.18°	94.63
38	NOAA-1 (ITOS-2)	"Thorad Delta"	11 Dec	309	1432	1472	101.94°	114.93
39	CEP[23]			2.3	1425	1475	101.90°	114.93
40	"Explorer 42" (SAS-A)	"Scout"	12 Dec	142.9	521	563	3.04°	95.30
41	"Peole"	"Diamant B"	12 Dec	70	636	749	14.98°	98.43

CM splashed down in the Pacific Ocean at a point with coordinates lat. 21°39' S and long. 165°23' W 700 m from the calculated point. The flight had lasted 142 h 54 min. The compartment splashed down normally, divers were dispatched to it, and the astronauts were lifted on board a helicopter which transported them to the aircraft carrier "Iwo Jima." A medical examination showed that Lovell and Swigert were in good health, but in Haise a certain health disorder was observed. All the astronauts were very fatigued and had lost weight (2.3-4.5 kg). Due to the safe return President Nixon gave to the astronauts and to the ground crew in Houston that saved the flight, the "Medal of Freedom"--the highest civil award in the United States (this medal was also awarded to the crews of "Apollo 11" and "Apollo 12").

A special commission investigated the causes of the accident and wrote a report with appropriate recommendations. In summarizing, it was noted that this was the first flight with a malfunction in the manned transport ships of the "Apollo" program; none of the tasks of the flight, with the exception of the lunar landing of the final stage of the rocket, had been fulfilled. The flight revealed the need for modifying the crafts in order to prevent fires in the oxygen medium, a certain moficiation in the second stage of the rocket launcher (to prevent longitudinal oscillations in the liquid oxygen lines), for a re-examination of the regulations governing the life-style of the astronauts in the last weeks before the flight (in order, as far as possible, to protect them from infection), and to make up the crews from experienced test pilots (until crafts are made that are sufficiently large to hold passengers). The safe return of the astronauts after such a serious accident was valued by the United States specialists as a demonstration of the extensive technical capabilities of the "Apollo" ships, the efficiency of the ground crew in an emergency situation, and the courage and high skill of the astronauts.

FOOTNOTES

1. Scanning Radiometer.

2. Flat Plate Radiometer.

3. Solar Proton Monitor.

4. Quarter-Orbit Magnetic Attitude Control System.

5. Magnetic Bias Control System

6. Of the four pre-vious launchings one was unsuccessful (18 May 1968)

7. For an expansion of the des gnations of this as well as the instruments listed below see YEZHEGODNIK BSE 1970, p 501.

8. Frog Otolith Experiment Package.

are a result of the engagement of the engines of the last stage of the rocket launcher which had to transport the satellite to the prescribed synchronous orbit with inclination 9.9°.

23. From materials of the report of President Nixon. In other sources this satellite is not mentioned.

24. It was noted in the press that if such an accident had taken place after the separation of the LC from the MM, then the astronauts would have inevitably died.

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SOVIET SPACE RESEARCH IN 1971

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[Article by L. Lebedev]

[Text] The "Salyut" orbital scientific station, the "Soyuz-10" and "Soyuz-11" manned transport ships, and automatic stations for studying the moon and Mars were launched in 1971. The launchings of artificial earth satellites for purely scientific and applied purposes have continued.

The "Salyut" permanent orbital scientific station is a complex new type of manned spacecraft designed to perform broad scientific and technical research and experiments in near-earth space. The "Salyut" station (see Figures 1 and 2) has three basic compartments: the transfer compartment (TC), the working compartment (WC) and the equipment bay.

The transfer compartment is one of the work facilities of the station. The hull of the TC is sealed. Elements of the life-support and heat regulating systems, the equipment of the "Orion" astrophysics observatory and the control panels are installed inside this compartment. Outside there are two solar cell panels, the search and guidance system antennas, light indicators which are switched on during final approach and docking, ion sensors, an outside scanning television camera, the heat regulating system units, round compressed gas tanks, and the telescope of the "Orion" observatory. The TC includes the assembly for docking the station with the "Soyuz" spacecraft in earth orbit. The TC is connected to the WC by a hatchway equipped with automatic and manual drives.

The working compartment is the basic working and living facility of the station. Structurally this part of the "Salyut" station is in the form of two cylinders 2.9 meters and 4.15 meters in diameter joined together by a conical cowling. The WC is also sealed. The equipment of the life support system, the radiotechnical and televisi n equipment, the control equipment for the onboard complex, the power supp.y, orientation and control of motion, telemetry, crew panels and work spaces, interior parts, devices to aid the crew in moving about and staying in place, scientific and experimental equipment and the food and water reserves are inside the WC. The radiator panels of the heat regulating system, the antennas of the communications systems and radiotelemetry, sun sensors and viewers are installed on the outer surface of the WC. A gas composition similar to the atmosphere on the surface of the earth and also the required temperature and humidity are maintained in the living quarters of the station. In order to work with the orientation and navigation devices, take photographs and make visual observations, the transfer and working compartments of the "Salyut" have 24 windows with replaceable or fixed equipment.

An unsealed equipment bay is located in the end section of the WC hull in which there is a concentration of equipment which provides for the control of the movements of the station--maneuvering to change the orbital parameters or orientation of the station in space. For this purpose, a multiple-use correction engine and fuel tanks are installed under the shielding in the equipment bay. The engines of the orientation stabilization system with fuel tanks and round compressed gas tanks (compressed gas is used as the working medium of the actuating elements) are placed on the hull of the equipment bay. The antennas of the radio communications and radio monitoring systems, lights, and heat regulating system units, ion sensors, outside scanning television camera, the solar cell panels and the search system antennas are placed on the hull of the equipment bay.

The power supply for the onboard equipment comes from a single power system which includes solar cells and chemical current sources. The panels with the solar elements are 42 m^2 in area.

The crew is delivered onboard the "Salyut" station by the "Soyuz" transport spacecraft. In connection with the performance of new functions, certain systems and devices of the spacecraft have been modified. In particular, a new structural design has been developed for the docking assembly. Its component elements--a docking pin and receiving cone--are installed on the hatch covers of the "Soyuz" spacecraft and the "Salyut" station, which open inward. After docking the spacecraft to the station, the units are rigidly joined mechanically, and their electric circuits and hydraulic lines are connected. A sealed tunnel is formed between the "Soyuz" and the "Salyut" which permits the cosmonauts to move from the "Soyuz" to board the "Salyut." After completion of the flight program, the crew returns to the "Soyuz," undocks the spacecraft and then returns to earth.

The "Salyut"-"Soyuz" space complex is 21.4 meters long. Its maximum diameter is 4.15 meters, and the sealed compartments are approximately 100 m^3 in size. The orbital complex weighs more than 25 tons. The "Salyut" station weighs 18,900 kg.

The "Salyut" scientific station was launched on 19 April. The orbit was corrected on the same day. Four days later, on 23 April at 0254 hours*,

* Moscow time is used here and hereafter.

the "Soyuz-10" spacecraft was launched, and at 0303 hours, it was inserted into the calculated orbit. The crew made up of the spacecraft commander V. A. Shatalov, flight engineer A. S. Yeliseyev and test engineer N. N. Rukavishnikov were onboard.

During the joint flight of the "Salyut" and "Soyuz-10" a number of studies were made to check out the fitness of the improved systems, providing for mutual search, long-range approach, final approach, docking and undocking of the spacecraft and the station. On 23 April, at 1315 hours, a correction was made to the "Soyuz-10" orbit. As a result of the correction, the distance between the vehicles decreased to several kilometers on the morning of the 24th of April. This made it possible to put the automatic rendezvous system into operation. In the given experiment the "Soyuz-10" was the "active" spacecraft and completed all of the maneuvers of rendezvous with the "Salyut" station. When the distance between the vehicles was reduced to 180 meters, the crew switched to manual control and docked the "Soyuz-10" with the "Salyut" station. The rendezvous, final approach and docking system and also the equipment used was developed earlier in the experiments with the "Cosmos" series of satellites and in the previous flights of the "Soyuz" transport ships. The basic difference of the operations on the given flight was that two space vehicles with significantly different masses were docked for the first time. The processes of maneuvering in direct proximity and docking, the control of the "station transport ship" space system are very different from the point of view of flight dynamics from experiments in which such operations are performed by like units as was the case earlier. Therefore the enormous practical experience obtained in docking the different type "Soyuz-10" and "Salyut" spacecraft, differing with respect to mass and geometric dimensions, was very useful to the future development of orbital stations.

The flight of the "Salyut"-"Soyuz-10" space system lasted 5 hours 30 minutes. During the flight the onboard systems were tested, and the dynamic characteristics were evaluated. After performance of the planned experiments, the crew undocked and separated the spacecraft from the station. Then the cosmonauts circled the "Salyut" during which time they examined and photographed the station from different sides. Then the vehicles drew apart and continued their joint flight, proceeding further with the program of scientific and technical experiments.

The flight of the "Soyuz-10" transport ship ended on 25 April: at 0159 hours it withdrew from its orbit and at 0240 hours it made a soft landing at 120 km northwest of Karaganda. The studies made during the flight of the "Soyuz-10" were the first phase of the joint program of operations with the "Salyut" orbital scientific station. Its flight continued. The variation of the orbital parameters of the "Salyut" during the period from 30 April to 15 May is presented in Table 1.

The second phase of the space experiment began with launching the "Soyuz-11" transport ship on 6 June at 0755 hours. The "Soyuz-11" transport ship was inserted in earth orbit at 0804 hours. It was piloted by the crew made up the ship commander G. T. Dobrovol'skiy, the flight engineer V. N. Volkov and test engineer V. I. Patsayev. At 1350 hours, a correction was made to the orbit using manual orientation. The "Soyuz-11" transport ship completed its flight at altitudes of 185 to 217 km with an orbital period around the earth of 88.3 minutes. On the morning of 7 June, the operation of rendezvous and docking in orbit of the "Soyuz-11" with the "Salyut" station was started.

Table

Orbital parameters	30 April 1971	7 May 1971	15 May 1971
Apogee (km)	277	269	260
Perigee (km)	251	249	242
Inclination (deg)	51.6	51.6	51.6
Orbital period (min)	89.6	89.6	89.0

The docking process was carried out in two steps. Initially the automatic control system brought the units to a distance of 100 meters from each other. The final approach was made by the crew of the "Soyuz-11". After the final approach of the "Soyuz-11" to the "Salyut", rigid mechanical docking of the spacecraft was carried out, and their electrical circuits and hydraulic communications were connected up. Then the astronauts checked the seal of the compartment and the operation of the onboard systems of the stations, the parameters of the microclimate. They opened the covers of the sealed hatch connecting the ship to the station. At 1045 hours, they entered the "Salyut" station and proceeded with the further flight program. The engineering-technical problem of delivering a crew by a transport ship onboard a scientific satellite station of the earth was solved for the first time. The first manned orbital scientific station in the world began functioning. Its orbital parameters at the beginning of the flight and after two corrections are presented in Table 2.

Table 2

Orbital parameters	7 June 1971 at beginning of flight	8 June 1971 after first correction	9 June 1971 after second correction
Apogee (km)	240	265	282
Perigee (km)	212	239	259
Inclination (deg)	51.6	51.6	51.6
Orbital period (minutes)	88.2	89	89.7

An important role in the experimental program onboard "Salyut" was played by the medical-biological research. It made up a significant part of the program on the 4th, 6th and 7th work days of the crew. They were also performed on other days. The purpose of the medical experiments was to monitor the state of health of the cosmonauts and to perform a basic study of the human organism for scientific forecasting of the reaction of various systems of the organism to the effect of the spaceflight factors. New specialized onboard clinical equipment was used for medical-physiological measurement. An especially deep study was made of the reaction of the cardiovascular system to weightlessness. The application of multichannel amplifying and conversion units and specialized medical equipment made it possible to obtain complex multilevel information about the activity of the vitally important systems of man, and primarily, the cardiovascular and respiratory systems. Significantly more parameters than before were monitored on the station crew: the volume and rate of inhalation and exhalation, arterial pressure, the propagation rate of the pulse wave through the arteries, and so on. The device made it possible to determine the phases of the cardiac cycle and measure the pulse of the femoral artery, to record 12 electrocardiograms and about 30 circulatory parameters. Blood was taken from all members of the crew for laboratory testing on the ground. In order to esimate the effect of the conditions of weightlessness on the changes in the human organisms during flight, measurements were made of the bone tissue density. Studies were performed of the visual characteristics of eyes, and the strength of the hands was measured.

The cosmonauts regularly performed physical exercises. They trained on a "treadmill" permitting the walking skills and muscle strength to be maintained in weightlessness. They used special suits which "loaded" the skeletal and muscular system. Thus, a number of measures were taken which were intended to some degree to compensate for the absence of the customary gravity.

Onboard the "Salyut", an experiment was performed with respect to studying the effect of the conditions of weightlessness on frog embryos and the development of certain types of higher plants.

An important contribution to the various branches of science and the national economy was made by the results of the experiments in studying earth and the atmosphere from space which the crew performed using the station equipment. One of the problems, the solution of which was worked on successfully by Soviet science and cosmonauts was the study of the optical characteristics of the day, night and twilight horizons of the earth. The crew of the "Salyut" also made spectrographic recordings of individual sections of the earth's surface in order to develop a procedure for distinguishing natural formations by the peculiarities of the reflection spectra characteristic of them. Serious attention was given to the problem of the effect of the layers of the atmosphere on the reflected radiation spectrum. The complex geophysical experiment was realized for these purposes. During the ninth working day the station crew made a spectral survey of the characteristic formations of the earth's surface and the coastal regions of the Caspian Sea. Simultaneously, an aerial photographic survey was made of the same regions from specially equipped aircraft of the Leningrad State University and USSR Academy of Sciences Expedition.

The cosmonauts constantly made observations and photographs of the various atmospheric formations and phenomena (typhoons, cyclines, and so on), the cloud cover and the characteristic sections of the earth's surface from the geological point of view. They also photographed the cloud cover above parts of Povolzh'ye. Simultaneously, the television survey was made of the same cloud formations by the "Meteor" satellite. The purpose of this experiment was to study the fine structure of the cloud systems and develop a procedure for decoding the television photographs received from the "Meteor" satellite.

The experiments with respect to studying the primary cosmic gamma radiation which were performed by the crew of the "Salyut" using a gamma telescope and also the astronomical observations using the orbital "Orion" observatory have important significance. During the flight of the "Salyut" station, spectrograms were made of the stars Beta Centauri and Alpha Lyra in the wavelength range of 2000 to 3800 angstroms. The work with the "Orion" system confirms the correctness of the basic principles of the creation of observatories beyong the atmosphere operating under the conditions of outer space and controlled by an astronaut inside an orbital station, used as the basis for its development. The crew of the "Salyut" also performed purely technical experiments connected with the testing and development of new instruments and space engineering units under actual conditions of orbital flight. The cosmonauts performed studies of the wide-angle viewer--a new device for exact orientation on the sun and planets. They performed multiple navigational measurements and used the onboard computer to determine the orbital parameters of the station. The new ion orientation equipment was checked out, the accuracy of the operation of the gyroscopic device was investigated, a study was made of the effect of the space environment on the optical surfaces of the ports and on the properties of special optical specimens investigated to develop astronomical instruments for use beyond the atmosphere. New elements of life support systems designed for long-range flights were tested.

By using the multifunctional "Era" equipment a study was made of the phenomenon of high-frequency resonance on the transmitting radio antennas. The parameters of the ionosphere were measured, and a study was made of the spatial distribution of the charged particles near the station. The potential of its hull was determined. Other processes and phenomena were investigated which accompanied the movement of the station in a rarefied low-temperature plasma. The cosmonauts performed experiments to measure the levels and tissue dosages of radiation which is important for an effective dosimetric monitoring system. Observations were made of the micrometeor situation in outer space.

The development of autonomous means and methods of orientation and navigation and also the control system for the "Salyut"-"Soyuz" complex during maneuvering demonstrated the good controllability of the new space system and effectiveness of the manual control and orientation.

The flight of the "Salyut" station with the crew onboard lasted 23 days. The cosmonauts completely carried out the program of scientific and technical experiments and on 29 June, after transferring the research material from the flight logs to the "Soyuz-11" ship, they took up their work places in its cabin. At 2128 hours, the "Soyuz-11" spacecraft and the "Salyut" stations undocked and continued further flight separately. In order to realize the reentry to earth, on 30 June at 0135 hours the braking engine of the "Soyuz-11" was switched on, and operated for the calculated time. In accordance with the program, after aerodynamic braking in the atmosphere, a parachute system operated and the soft landing engines were engaged directly before the earth.

The flight of the reentry vehicle ended in a smooth landing in the given area, but 30 minutes before landing rapid decompression of the cabin took place which killed the cosmonauts.

The spaceflight around the earth of G. T. Dobrovol'skiy, V. N. Volkov and V. I. Patsayev made an invaluable contribution to the development of cosmonauts. It offers the possibility of going ahead along the path of utilizing long-term manned orbital stations, opening up the road for new accomplishments. The unprecidented feat of the heroes will always remain in the history of the conquering of outer space.

From 29 June to 11 October the "Salyut" station functioned in earth orbit automatically. On 20 July the orbital parameters had the following values: apogee 262 km, perigee 223 km, orbital period 89.25 min, inclination 51.6°. On 11 October, the final operations were performed from the "Salyut" station to bring it out of artificial earth orbit. After orientation of the "Salyut" in space, the braking was switched on. As a result of its operation, the station went into the reentry trajectory; it entered the dense layers of the atmosphere above the given part of the Pacific Ocean and ceased to exist. Altogether, the "Salyut" station remained under the severe conditions of outer space for almost six months, and for all of this time the systems which provided for its functioning both in the manned and in the automatic modes operated continuously.

In 1971, the automatic self-propelled "Lunokhod-1" delivered to the surface of the moon on 17 November 1970, was still functioning (see YEZHEGODNIK BSE [Great Soviet Encyclopedia Yearbook], 1971). At night on 8 January, the communications sessions held with the "Lunokhod-1" and the program of the third lunar day was started. One of the basic problems of this period was getting the lunokhod to the location with given selenographic coordinates--the landing site of the "Luna-17" automatic station. It was necessary to estimate the accuracy and reliability of the navigation system and check the methods of navigation, remote control and guidance of the lunokhod. The self-propelled unit moved toward the landing stage over a new path (Figure 4). The general direction of motion was to the northwest. The current coordinates of the unit were determined using onboard navigational devices and they were periodically corrected with respect to the position of the sun and the earth. This provided for getting the unit to the calculated point

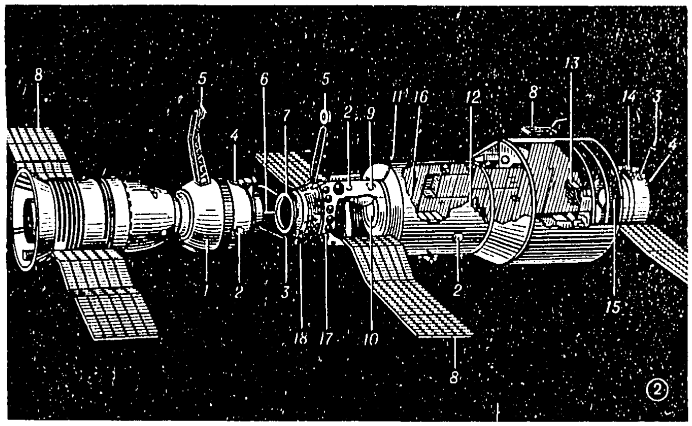

Figure 2. Diagram of the "Salyut" orbital station: 1--orbital compartment of the "Soyuz" transport ship; 2--lights; 3--scanning antenna of the search system; 4--television camera; 5--guidance system antenna; 6--docking pin; 7--receiving cone of the docking unit; 8--solar cell panels; 9--equipment of the "Orion" astrophysical observatory; 10--hatchway; 11--light indexes; 12--scientific equipment of the working compartment; 13--domestic equipment; 14--microengines of the orientation system; 15--unit compartment system; 16--cosmonaut's chair at the station control panel; 17--compressed gas bottles; 18--orientation sensor.

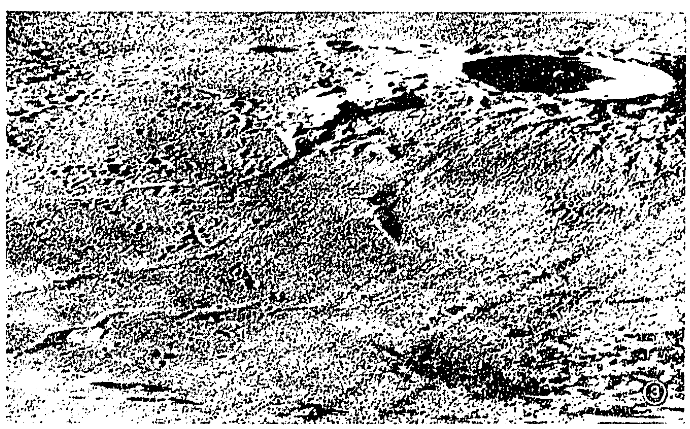

Figure 3. Fragment of the orbital panorama with image of the vicinity of Sinus Aestum of Oceanus Procelarum with the Eratosthenes crater

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at the given time. During the third lunar day it traveled a path 1936 meters long. On arrival of the lunar night on 21 January, the lunokhod was again in the stationary position, and on 7 February it began to move to the north, in the direction of Cape Heraclide (Figure 5). By 19 February, the planned three-month program of scientific and technical research and experiments was completed. In four lunar days the self-propelled laboratory had traveled 5228 meters. The analysis of the condition and the operation of the onboard systems demonstrated the possibility of continuing active functioning of the automatic unit on the lunar surface. For this purpose, an additional lunokhod work program was compiled. The successful functioning of the spacecraft continued 10.5 months and ceased on 4 October. The cessation of the active operation of the "Lunokhod-1" was caused by the burnup of its isotopic heat source, which led to a drop in temperature inside the unit during the eleventh lunar night from 15 to 30 September.

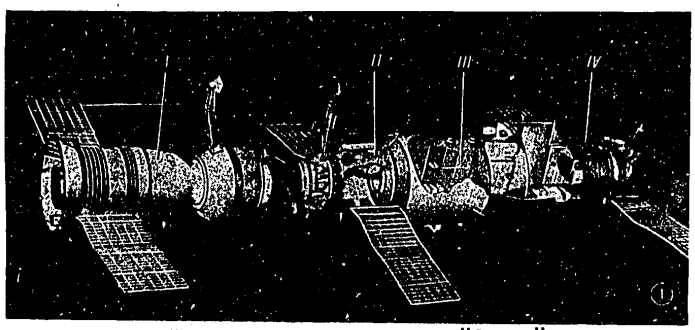

Figure 1. "Salyut" orbital station: I--"Soyuz" transport ship, II--transfer compartment; III--working compartment; IV--unit compartment.

During the scientific research and the design engineering testing, the self-propelled automatic vehicle traveled a distance equal to 10,540 meters, which made it possible to examine the lunar surface in detail over an area of 80,000 m^2. For this purpose, using the vehicle's television system, more than 200 panoramas and more than 2,000 pictures of the lunar landscape were obtained. Moreover, at 500 points along the route a study was made of the physical-mechanizal properties of the surface layer of the ground, and at 25 points an analysis was made of its chemical composition.

While examining the landing area of the "Luna-17" automatic stations, the following were constructed: a topographic diagram of the route on a 1:1000 scale, a more precisely defined schematics of the individual sections on a 1:200 scale, topographic plans of the individual sections on a 1:100 scale obtained by the stereophotograi ietric method and altitude profiles of the route and characteristic craters.

The geological-morphological description of the area was made studying the panorama images using the topographic characteristics of the terrain, data on variations in the physico-mechanical and chemical properties of the soil and the positions of the vehicle along the path. The geological-morphological schematics of the areas where "Lunokhod-1" stopped were obtained, and a number of conclusions were drawn on peculiarities of the study area. The landing site of the "Luna-17" automatic station and the work area of the "Lunokhod-1" are a slightly undulating plain, on the surface of which there are cuplike craters, some more defined than others. This plain is made up of basaltoid rock and probably was formed by areal eruptions of lava. The rock was covered by a thin lower of regolith. With respect to general morphology, the nature of the regolith and the spread of the craters and rock, the investigated region is similar to the previously studied marine areas of the equatorial zone of the moon. This indicates the generality of the laws of formation and evolution of the lunar surface over the significant areas of the lunar seas. It was established that among the small craters (from 5-10 cm to 30-40 meters) the craters with smooth shapes predominate, and the number of fresh craters with even forms of relief amounts to no more than a few percentages of the total of all of the craters. This indicates that the process of formation of the craters on the surface of the moon extended over a long period of time, and the form of them varies with age--their outlines become smoother and softer.

a.
b.
c.
d.
e.
f.
g.
h.

Figure 4. Topographic schematic of the path of the "Lunokhod-1" from 17 November 1970 to 1 January 1971.

[Key on following page]

[Key to Figure 4 on previous page]

a. landing site of the "Luna-17" automatic station
b. path of movement of "Lunokhod-1"
c. studies of the chemical composition of the lunar soil
d. individual rocks
e. rock placers
f. craters and holes
g. central hil.s
h. direction of motion

On the panoramas, many rocks are visible with a cross section from 1-2 cm to 40-50 cm. The presence of the basic part of the rocks on the surface of the moon is connected with ejection of them from craters. Inasmuch as the number of rocks increases sharply near the large craters, it is possible to assume that these craters penetrate across the regolith to the rocky base.

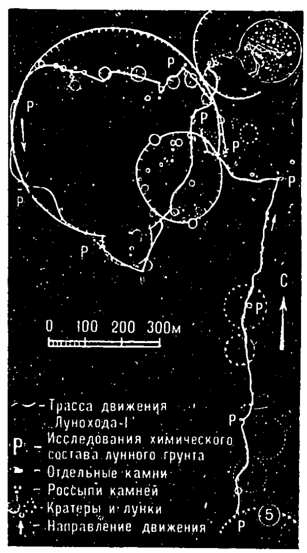

Figure 5. Topographic schematic of the path of "Lunokhod-1" from 7 February 1971 to 13 April 1971

Key: a. path of the "Lunokhod-1"
b. studies of the chemi^al composition of the lun. : soil
c. individual rocks
d. rock placers
e. craters and holes
f. direction of motion

The rocks in the material ejected from the fresh craters are quite varied with respect to shape. This obviously is connected with certain differences in the petrographic composition of the rock in the foundation. The rounded rock is basically encountered near the mature craters which can be interpreted as the result of the general direction of evolution of rock as a function of exposure time on the surface of the moon under the effect of exogenic factors.

The regolith which covers the surface of the rock is the weakly connected material of different grain size significantly less than 1 mm containing a noticeable amount of debris and different sized rock. This material is to a significant degree elastic, formed by crushing of the lower-lying rock. The rockiness of the regolith is different and most expressed in the structure of the crater swells. The thickness of the regolith varies sharply in the investigated area, and its fluctuations are within the limits from 1 to 5 meters. The surface evolution takes place under the predominant effect of two factors: 1) the formation of the impact-explosive and impact craters with sharp, even shapes accompanied by ejection of rock and 2) destruction of the craters occurring at different times accompanied by the surface erosion and destruction of the rock.

An express analysis of the chemical composition of the lunar soil along the path of the "Lunokhod-1" was made using the spectrometric equipment. During its functioning, the special isotopic source irradiated the investigated section of the lunar surface with x-rays, ionizing the atoms of different elements which enter into the composition of the lunar soil. Here reciprocal x-radiation occurred, the energy of which strictly corresponds to certain chemical elements. The recording of the reciprocal radiation and measurement of its energy made it possible to determine which elements were subjected to irradiation and what their content in the soil was. The chemical composition of the lunar soil was investigated at many locations with characteristic geological and morphological features. A study was made of the undisturbed surface, the craters of different ages (including the individual parts of the craters: bottom, slopes, swells), the rock lying at a depth of about 10 cm which was denuded during the special maneuvers of the lunokhod and also individual rocks. In addition, a complex study was made of a number of sections of the lunar surface: both the physical-mechanical and the chemical composition were determined in the same section. As a result of the studies of the chemical composition, variations in the aluminum, calcium, silicon, iron, titanium, and other element contents were determined. The data obtained confirm the general idea of the origin of the regolith as a result of crushing of the rock of basically basalt composition.

The physical-mechanical properties of the lunar soil were determined by several methods: the introduction of a conical-vane stamp into the soil with subsequent rotation, measurement of the interaction of the "Lunokhod-1" wheels with the soil and analysis of the images of its tracks. The use of several procedures simultaneously to obtain the information made it possible to determine the properties of the lunar soil in sufficient detail.

Along the entire path of the lunokhod, the soil is fine-grain material having noticeable forces of adhesion. With respect to granulometric composition and behavioral peculiarities, there are no significant differences from the soil at the landing sites of the other spacecraft, including the "Luna-16" automatic station (see YEZHEGODNIK BSE [Great Soviet Encyclopedia Yearbook], 1971). The fine-grained layer of soil basically has a depth of no less than 50-100 mm and is quite uniform with respect to depth. The uppermost layer of the soil is loose, powdery, easily deformed material. The bearing capacity of the soil determined by introducing a stamp is within the limits of 0.2 to 1.0 kg/cm^2, the resistance to rotational shear is from 0.02 to 0.09 kg/cm^2. The most widespread value of the bearing capacity was 0.34 kg/cm^2 and the most widespread resistance to rotational shear was 0.048 kg/cm^2. The indexes of the mechanical properties of the soil increase with depth. With repeated impressions by the die, good compacting of the upper layer took place with an increase in bearing capacity. The mechanical properties of the various lunar formations vary within broad limits. Along with the quite firm rock, lumps are encountered which are made up of conglomerate material and have low strength.

The scientific equipment for studying cosmic radiation of solar and galactic origin, monitoring of the radiation situation on the fly-by trajectory of the "Luna-17" station and recording the radioactivity on the lunar surface during the operations of the self-propelled unit was adjusted to record protons, electrons and alphaparticles of different energy primarily in the energy ranges inaccessible for study from the earth as a result of the shielding effect of its atmosphere. Part of the calendars were placed at different angles to the axis of the lunokhod which permitted not only measurement of the intensity of the particle flux but determination of their energy spectrum, and estimation of the composition of the cosmic rays, but also discovery of the nature of the angular distribution of the fluxes, that is, the direction of approach of the particles to the moon.

On the flight trajectory to the moon, radiometric equipment recorded the proton flux with an energy of 1 to 5 Mev from the very beginning of the flight of the "Luna-17" automatic station which exceeded by two orders the background particle flux in interplanetary space. During the four days of flight to the moon, the intensity dropped by approximately 5 times. At the same time, a slow restoration of intensity of the galactic cosmic radiation was recorded. The subsequent analysis calling on the solar data and data on the intensity of the protons of the same energy obtained by the analogous equipment on the "Venera-7" automatic station (see YEZHEGODNIK BSE [Great Soviet Encyclopedia Yearbook], 1971) demonstrated that the last phase of the drop in intensity of the large buildup of solar protons caused by the powerful proton solar flare occurring on 5 November 1970 was recorded. After the landing of the "Luna-17" automatic station on the surface of the moon, the intensity of the galactic cosmic radiation was approximately cut in half by comparison with the level recorded during the flight time. This indicates shielding of the radiometer from the isotopic flux of galactic cosmic radiation by the body of the moon and confirms the conclusions of low radioactivity of the surface layer of the moon previously drawn as a result of the flights of the "Luna" series of automatic stations. During the first lunar day on the surface of the moon from 17 to 20 November 1970, a buildup in intensity by three times from the level of significant (just as in the fly-by section) background was recorded, which was connected with the solar flares occurring during this period. On 12 December 1970, a significant buildup of intensity of the protons with an energy of 1-5 Mev began. On 13 December it reached a maximum, exceeding the background level by approximately 10^4 times. The intensity at the maximum was $1.3 \cdot 10^3$ $cm^{-2} \cdot sec^{-1} \cdot ster^{-1}$ for protons with an energy of 1-5 Mev. At the end of the day of 14 December, the intensity diminished sharply by approximately two orders, after which it decreased slowly for the next 8 days. The buildup in intensity of the solar cosmic radiation was caused by a series of flares occurring on the sun on 10 and 11 December. The previously obtained data and the results of the studies of the cosmic radiation using the "Venera-7" and "Lunokhod-1" automatic stations indicate that the proton activity of the sun had decreased slowly from its maximum in 1968-1969. A sharper decrease in proton activity was observed in the second half of December 1970.

The x-ray telescope installed on the "Lunokhod-1" made it possible to study the cosmic x-radiation background and the discrete x-ray sources. It included two proportional x-ray proton counters for the spectral range of 2 to 10 Å. Collimators were installed in front of the counters to limit the field of view of each counter to a cone with an aperture angle of about 3.5°. The axes of the counters were directed to the local zenith with the lunokhod in the horizontal position. A filter which was opaque for the investigated range of x-radiation was placed in front of the entrance opening of one of the counters. As a result, one of the counters recorded the cosmic x-radiation together with the background of cosmic particles, and the other counter, only the particle background, and it was the control. On rotation of the moon around its axis, the field of view of a telescope slid along the celestial sphere. In 18 to 20 hours the telescope rotated by 9 to 10°. Observations were made of the x-radiation with the lunokhod at the halt. One exposure time was 6 hours. As a result a strip on the celestial sphere intersecting the plane of the galasy in the vicinity of the constellation Cygnus was scanned. The results of the measurements of the x-ray background agree well with the preceeding data. The contribution of the galaxy to the x-ray background is very small. Discrete x-ray sources were observed.

The device for laser ranging of the moon manufactured in France and installed on the "Lunokhod-1" is a special light reflector made up of 14 three-sided prisms with the side of one face equal to 10 cm. The right angles between faces were maintained with a precision to tenths of angular seconds. The successful experiments performed in the Soviet Union and in French made it possible to obtain independent high-precision measurements of the parameters of the earth-moon system: in the first experiments the distance to the laser reflector was measured with an error not exceeding ± 3 meters.

The booster rocket with the "Luna-18" automatic station onboard was launched on 2 September. The station was launched toward the moon from earth orbit. During the course of the flight on 4 and 6 September, corrections were made to the trajectory. On 7 September on approaching the moon, the station was braked, as a result of which it went into a circular selenocentric orbit with the following parameters: altitude above the lunar surface 100 km, inclination of orbit to the plane of the lunar equator 35°, orbital period around the moon 1 hour 59 minutes. On flight along the selenocentric orbit the station maneuvered in order to work out the methods of automatic near-lunar navigation and land on the surface of the moon. The braking engine was started on 11 September, the station left its orbit and reached the surface of the moon in the vicinity of the continent surrounding the Mare Foecunditatis at the point with the coordinate 3°34' north latitude and 56°30' east longitude. The landing area was selected in a mountainous area which is of great scientific interest. However, as the measurements demonstrated, the approach of the station to the moon under these complex topographic conditions turned out to be unfavorable.

On 28 September, the "Luna-19" automatic station was launched. The basic purpose of the experiment was to perform scientific studies of the moon and lunar space from the orbit of an artificial lunar satellite. The station was sent to the moon from earth orbit. On 29 September and 1 October, corrections were made to the trajectory. On 3 October, as a result of a braking maneuver, the "Luna-19" automatic station went into circular selenocentric orbit with the following parameters: altitude above the surface of the moon 140 km, inclination of the orbit 40°35', orbital period 2 hours 01 minutes 45 seconds. As a result of a correction on 6 October, the orbital parameters became: aposelene 135 km, periselene 127 km, orbital period 2 hours 01 minute. On 26 and 28 November two more corrections were made to the station orbit. The orbital parameters began to have the following values: aposelene 385 km, periselene 77 km, inclination 40°41', orbital period 2 hours 11 minutes. The "Luna-19" automatic station conducted studies for many months in selenocentric orbit. By the results of the radiotechnical measurements of the orbital parameters, studies were made of the gravitational field of the moon by the method of systematic prolonged observations of the evolution of the orbit. Continuous measurements of the characteristics of the interplanetary magnetic field in the vicinity of the moon were made from onboard the station. It was recorded that the field from the illuminated side of the moon is several times stronger than the undisturbed interplanetary magnetic field. At the same time, on the night side the magnetic field is noticeably attenuated. Both of the indicated experiments were performed for more precise determination of the scientific concepts of the internal structure of the moon. By using the "Luna-19", the study of the characteristics of cosmic radiation in lunar space were continued. Simultaneously, analogous measurements were made by the equipment onboard the "Mars-2" and "Mars-3" stations. As a result, interesting, valuable scientific information was obtained on the dynamics of the variation in intensity of the corpuscular fluxes of cosmic radiation. Along with the studies indicated, the density of the meteor flux in lunar space was measured. The scientific research program of the "Luna-19" automatic station also included a survey of individual areas of the lunar surface. For this purpose, two optico-mechanical television cameras were installed on the station. Their characteristic feature was that the scanning of the image along the flight line was realized as the result of the orbital motion of the station itself.

Figure 3 shows a fragment of one of the orbital television panoramas. The large structural shapes of the lunar relief are clearly isolated on the panoramas: the seas, continents, craters and faults. Therefore they can be used to study the shapes of the basic geological structures, the degree of their destruction and the general nature of the relief and to gather the information required to reconstruct the history of the moon.

On 19 and 28 May, the "Mars-2" and the "Mars-3" automatic stations were launched toward the planet Mars (see Figure 9).

On 27 November, the "Mars-2" automatic station for the first time delivered to Mars a capsule inside which a USSR flag was included. On 2 December, for the first time in history the reentry vehicle of the "Mars-3" automatic station made a soft landing on the surface of Mars. The "Mars-2" and "Mars-3" stations became artificial satellites of the planet.

The "Mars-3" automatic station (see Figure 6) includes an orbital station and a reentry vehicle and is equipped with systems for autonomous control and orientation, radio control, trajectory measurements and data transmission, automation, power supply, heat regulation, onboard radio, a program and timing device, an engine and a set of scientific equipment. The "Mars-2" and the "Mars-3" automatic stations are similar with respect to structural design. The weight of each station was 4,650 kg. Structurally the orbital station is made up of the following basic parts: the instrument compartment (IC), the tank module (TM), the engine (EN) with the automation components, the solar cell, the antenna-feeder unit, and the heat regulating system regulators. The onboard systems of the station are located in the IC. The optoelectronic instruments of the system for astroorientation on the sun, the earth and a star and the autonomous navigation system and scientific equipment are located outside. The IC is connected to the TM which serves as the basic support element of the station. The EN is located in the lower part of the TM. Above, there is an adapter for attaching the reentry vehicle. The panels of the solar cell, parabolic and low directional antennas are mounted on the TM. The radiators of the heat control system are attached to one of the panel suspension beams. Part of the scientific equipment, two antennas for radio communications between the orbital station and the reentry vehicle, the antenna for the Soviet-French Stereo experiment and the microengines of the orientation stabilization system are installed on the solar cell panels.

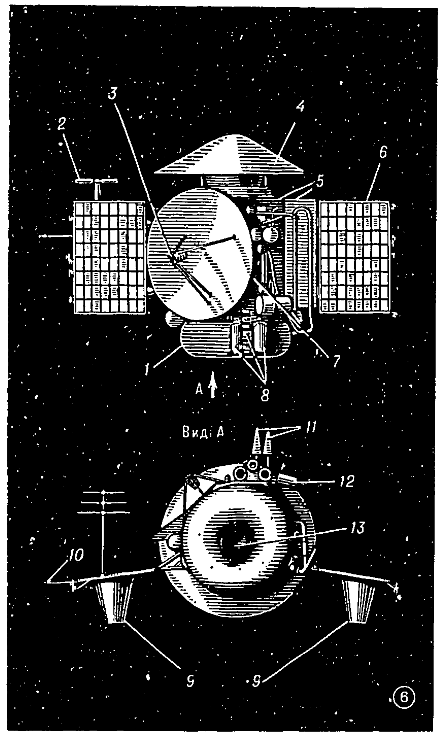

Figure 6. "Mars-3" automatic station: 1--instrument compartment; 2--antenna of the Stereo scientific equipment; 3--unidirectional parabolic antenna; 4--reentry vehicle; 5--radiations of the heat regulation system; 6--solar cell panel; 7--engine tank module; 8--optoelectronic devices of the astro-orientation system; 9--antennas for communications with the reentry vehicle; 10--magnetometer; 11--low-directional antennas; 12--optoelectronic device of the autonomous navigation system; 13--correcting and braking engine

Key: a. view A

The reentry vehicle (see Figure 7) consists of the automated martian station (AMS), the instrument-parachute container, the braking shield and connecting frame. On the frame there is a solid-fuel engine for conversion of the reentry vehicle from a flight trajectory to landing trajectory and the components of the autonomous control system for stabilizing the reentry vehicle after separation from the orbital station. The instrument-parachute container is made in the form of a torus. It is installed on the surface of the automatic martian station and is joined to it by means of straps. The pilot and main parachutes are placed inside the container. The container has a powder engine for releasing the pilot parachute, a soft landing braking engine and a parachute discharge engine, the antenna of the radio altimeter, the antenna for communications with the orbital station and scientific equipment. The cone-shaped braking shield is used for aerodynamic braking of the reentry vehicle in the martian atmosphere and shielding it from the high temperatures occurring in this case.

Inside the automated martian station there is a sealed instrument compartment. It has the equipment for the autonomous control system, the radio complex and telemetry, the scientific instrument modules, including the television panorama head. Outside are the scientific instruments with the mechanisms for remote use of them, the radio complex antennas, the antennas for putting the station into operation after landing. The required operating sequence of the systems is insured by the program-timing device. The heat control system for the reentry vehicle of the "Mars-3" station included vacuum-shielded heat insulation, radiation and electric heaters.

The control system included an orientation system, a gyroscopic unit providing for stabilization of the station in space, an onboard digital computer and autonomous space navigation system. The orientation system goes into operation on separation of the automatic station from the last stage of the booster rocket, and it functions for the entire flight time. The optical-electronic instruments define the location of the AMS with respect to the sun, and by using the gas jet microengines the automatic station is oriented in space in a position insuring normal functioning of the heat control systems, the power supply system and so on. With an increase in the distance between the earth and the automatic station, the orientation system, simultaneously following the sun and the star Canopus, positions the automatic station so that the highly directional antenna will be oriented toward the earth.

The autonomous control system permits stabilization and control of the station during operation of the last stage of the booster rocket, during correction of the trajectory and braking. When making the first two corrections data are transmitted to the onboard digital computer over the radio link to the ground on the magnitude and direction of the engine thrust required for making these maneuvers. The onboard digital computer also receives information from the gyrostabilized platform on the position of the automatic station in space. Processing the information, the onboard digital computer issues commands for turning the automatic station and for switching the engines on and off, and the autonomous control system performs these operations.

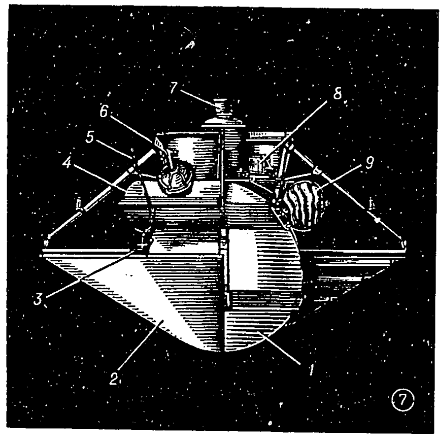

Figure 7. Reentry vehicle of the "Mars-3" station: 1--automatic martian station; 2--aerodynamic brake cone; 3--radioaltimeter antenna; 4--parachute container; 5--antennas for communications with the orbital stations; 6--engine for winding in the expended parachute; 7--engine for departure of the reentry vehicle; 8--instruments and equipment of the automatic control system; 9--basic parachute

In order to insert the station into the given artificial Mars satellite orbit and provide the required conditions for entry of the reentry vehicle into the atmosphere of the planet, an autonomous space navigation system is used. This system permits correction of the station trajectory as required on its approach to the planet. The optoelectronic instrument determines the actual position of the reentry vehicle with respect to Mars and transmits the data to the onboard digital computer which calculates the operating time of the engine and determines the orientation of the station space required for the trajectory correction.

The onboard radiotechnical complex together with ground units makes it possible to take trajectory measurements, receive commands from the earth, transmit telemetry and phototelevision information, receive and record the information coming from the reentry vehicle to the orbital station for subsequent transmission to the earth. For communications of the orbital station with the earth, two radio channels are used: a narrow-band and a wide-band channel. The narrow-band channel is used for trajectory measurements and transmission of telemetry data. It operates on decimeter radio waves. The wide-band channel using centimeter waves permits transmission of large volumes of information from the phototelevision units and scientific instruments. In the interplanetary flight segment and in the artificial Mars satellite orbit, radio communications with the station are maintained through the low-directional antenna system, and the station is oriented toward the earth through a parabolic antenna. The radio complex includes the receiving, transmitting and program-timed devices and the telemetry, television and antenna feeder systems.

In order to supply electric power for the onboard equipment, a solar cell and chemical current sources are used. During the entire flight the solar cell charged the buffer battery of the orbital station and supplied power to the equipment operating in the breaks between communications sessions. The electric power supply for the equipment during the communication sessions came from the buffer battery. The independent battery of the reentry vehicle was charged before separation of it. The heat regulating system of the orbital station is made up of vacuum shielding heat insulation, special heat control coatings and an active closed circulating system with the radiator heater constantly aimed toward the sun and the radiator cooler making contact with the cosmic environment. The heat exchange agent is the gas filling the IC. The gas is circulated by a fan. The engine provides for trajectory corrections of the station and braking on insertion into the artificial Mars satellite orbit. It is made up of a liquid-fuel jet engine with a fuel-feed pumping system, control units and a fuel tank module.

The "Mars-2" automatic station was launched on 19 May at 1923 hours. The station was first inserted into an intermediate orbit as an artificial earth satellite. The launch from the earth orbit to Mars was made at 2059 hours. The last stage of the booster rocket gave the automatic station a velocity close to the second escape velocity. The "Mars-3" automatic station was launched on 28 May at 1826 hours. The system for insertion of the "Mars-3" automatic station into the flight trajectory to Mars was the same as the insertion system for the "Mars-2" automatic station. During the flight to Mars, in order to insure the required accuracy of rendezvous with the destination planet, trajectory corrections were made for the stations. After the third correction on 27 November the "Mars-2" automatic station assumed a trajectory passing 1380 km from the surface of Mars. A capsule was separated from it which reached the planet. On the same day at 2319 hours, a braking maneuver was started. As a result, the speed of the station diminished, and it went into artificial Mars satellite orbit. On 2 December, after the third and final correction, at 1214 hours the reentry vehicle separated from the "Mars-3" automatic station. The orbital station continued its flight in the trajectory passing 1,500 km from the surface of the planet. The braking engine provided for insertion of the orbital station into Mars orbit.

The system for descent of the reentry vehicle to the surface of Mars is presented in Figure 8. The engine of the reentry vehicle providing for conversion of the vehicle to a trajectory for rendezvous with the planet was switched on 15 minutes after separation of the reentry vehicle and the orbital station. Then the reentry vehicle was turned to insure the required angle of attack when moving into the atmosphere. At 1644 hours, aerodynamic braking began, during which the stability of motion of the reentry vehicle was provided as

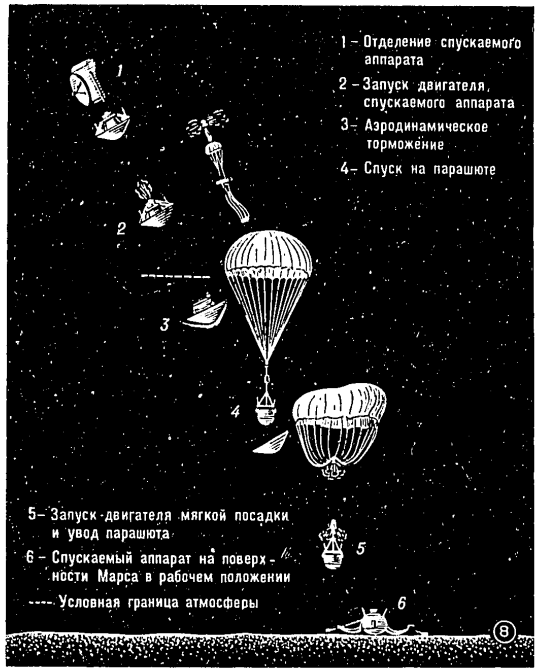

Figure 8. Landing pattern of the reentry vehicle of the "Mars-3" station.

Key:
1--separation of the reentry vehicle
2--starting of the reentry vehicle engine
3--aerodynamic braking
4--releasing the parachute
5--starting the soft landing engine and release of the parachute
6--reentry vehicle on the surface of Mars in the operating position
provisional boundary of the atmosphere

a result of the shape. Descent in the atmosphere above the martian surface lasted a little more than 3 minutes. At the end of the braking section, on command from the overload sensor, still with supersonic flight speed, the pilot parachute was released followed by the main parachute with reefed canopy. When the reentry vehicle braked to near sonic velocity, on signal from the program-time unit, the p-rachute canopy was completely opened. Simultaneously, the aerodynamic cone was released, and the radio-altimeter antennas for the soft landing system opened up. At an altitude of 20 to 30 meters, on command from the radio altimeters, the soft landing braking engine and the program-time unit giving the operating sequence for the automatic martian

a. b. d. c. e.

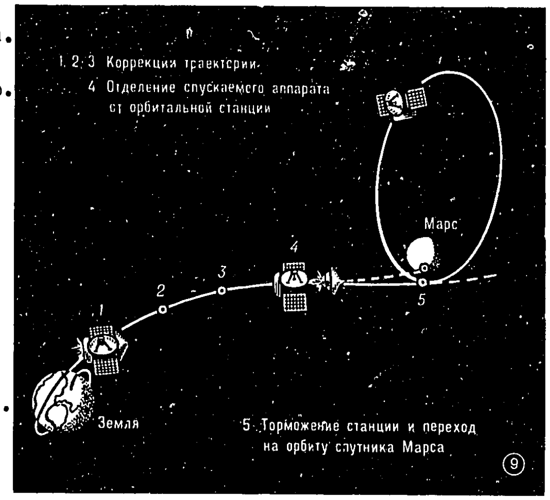

Figure 9. Schematic of the interplanetary flight of the "Mars-2" "Mars-3" stations

Key:
a. 1, 2, 3 --trajectory correction
b. 4--separation of the reentry vehicle from the orbital station
c. Mars
d. Earth
e. 5--braking of the station and insertion into Mars satellite orbit

station on the surface of the planet were switched on. At this time the parachute was jetissoned to the side by a jet engine to keep the canopy from covering the station. At the time of landing, a special shockabsorbing system protected the automatic martian station from possible damage.

The landing site of the automatic martian station was in the southern hemisphere of Mars between the Elektris and Phaetontis regions in the area with the coordinates of lat. 45°S and long. 158°W. A penant with the USSR hammer and sickle was on board. The station was put into operation 1.5 minutes after landing, and at 16 hours 50 minutes 35 seconds, the transmission of video signals from the surface of the planet began. They were received and recorded onboard the "Mars-3" artificial satellite, and then they were transmitted to the earth in the radio communic tions sessions. The video signals received from the surface of Mars were short-lived (about 20 seconds) and ceased suddenly.

By using the instruments onboard the "Mars-2" and the "Mars-3" stations, a very broad and varied scientific research program was carried out. During the flight on the path from the earth to Mars, the ion and electron spectrometers regularly measured the energies of solar wind particles, the composition of the particles and the temperature and speed of individual components of the solar plasma. The magnetometers performed measurements of the parameters of the interplanetary magnetic fields. The electron concentration in the interplanetary medium was determined for which data was used on the nature of the propagation of radio waves on two coherent frequencies. On the "Mars-3" automatic station, in addition, a joint Soviet-French "Stereo" experiment was performed to study the radio emission of the sun. Studies were made of the spatial structure, the direction and mechanism of the radiation process. The same equipment was used for scientific research performed from the artificial Mars satellite orbit. A study was made of the nature of the flow of the solar wind past the planet and its interaction with the ionosphere of Mars. The charged particle spectra and variations of the magnetic field were recorded.

Scientific equipment for measuring the temperature and pressure of the atmosphere, determining the chemical composition of the atmosphere, measuring the wind velocity, determining chemical composition and physical-mechanical properties of the surface layer and also obtaining a panoramic view using television cameras were installed on the reentry vehicle of "Mars-3" automatic station. The sudden cessation of signals from the automatic martian station prevented scientific information from being obtained.

In order to perform the studies of the characteristics of the atmosphere and the surface of the planet, the following scientific equipment was installed on the "Mars-2" and "Mars-3" orbital stations: an infrared radiometer for measuring the brightness temperature of the planet in the 8-40 micron band; an infrared photometer for studying the surface relief by the intensity of the CO_2 absorption bands; an infrared photometer for determining the water vapor content in the atmosphere of Mars; a scanning photometer for studying the brightness distribution of the planet in the 3600-7000 Å band; a radio telescope for measuring the radio emission of Mars on a wave of 3.4 cm permitting determination of the intensity and polarization of radio emission of the surface layer of the planet; the ultraviolet photometer for determining the density of the upper atmosphere of Mars and the atomic oxygen, hydrogen and argon content in it; two phototelevision cameras with different focal lengths. The atmosphere of Mars was also investigated by measuring the refraction of the radio waves emitted by the automatic station during its passes behind the disc of the planet.

The "Mars-2" and "Mars-3" automatic stations functioned for more than 8 months.

The "Vertikal'-II" geophysical rocket was launched on 20 August to an altitude of 463 km under the program for joint space research by the socialist countries.

The "Vertikal'-II" rocket was designed for continuation of the complex studies of the ultraviolet and x-radiation of the sun, the parameters of the ionosphere and meteoritic particles. The nosecone of the rocket was made up of a recoverable container and instrument compartment. The recoverable container of the rocket included equipment for heliophysical research (the Polish People's Republic, the USSR) and instruments for studying micrometeorites (the Hungarian People's Republic, the USSR, Czechoslovakia). Equipment was installed in the instrument compartment for heliophysical and ionospheric research (the German Democratic Republic and the USSR). The total weight of the nosecone of the rocket with the scientific equipment was 1300 kg. In the area where the "Vertikal'-II" was launched, measurements were made of the radio wave absorption on frequencies of 1.0, 1.5 and 2.0 megahertz using the "AMA" ground installation (the German Democratic Republic). On the descending section at an altitude of 90 km, the recoverable container was separated and landed using a parachute system.

The "Intercosmos-5" artificial earth satellite was launched on 2 December. It was designed for continuation of the studies of the radiationconditions in near-earth space, the study of the dynamics of corpuscular flows in the near outer space depending on the solar activity and to study the nature and the spectrum of the low-frequency electromagnetic oscillations in natural plasma. The space experiment was performed as a continuation of the research started on the "Intercosmos-3" artificial earth satellite. Scientific equipment was installed onboard the "Intercosmos-5" satellite for investigation of the composition and time variations of the charged particle fluxes (manufactured in Czechoslovakia), for recording and analysis of the spectrum of low-frequency electromagnetic waves and signals in the wave band from 70 hertz to 20 kilohertz (manufactured jointly by the specialists of the USSR and Czechoslovakia), a special telemetry system for transmission of information in a wide frequency spectrum to ground receivers (made in Czechoslovakia). Simultaneously with the operation of the scientific equipment on the satellite, the ground geophysics stations and observatories of a number of countries measured the low-frequency radiation of the upper atmosphere and ionosphere of the earth under a coordinated program.

The "Oreol" artificial earth satellite was launched on 27 December. The purpose of this experiment was to study the physical phenomena in the upper atmosphere of the earth in high latitudesand to study the nature of the aurora polaris. The scientific equipment and the experimental program were developed jointly by the Soviet and French specialists within the framework of the Soviet-French "Arkad" plan. The scientific equipment installed onboard the "Oreol" was designed for studying the proton and electron spectrum in a wide range of energies, measurements of the integral intensity of the protons and determination of the ion composition of the atmosphere. In addition to the scientific instruments, the following systems were placed onboard the satellite: the system for determining the orientation of the satellite in space using the sun sensor and a three-component magnetometer, a radio telemetry system for transmitting the measurement results to the stations for data reception and processing, the system for radio monitoring of the orbital parameters and the command radio link for controlling the satellite from the ground.

Soviet spacecraft launched in 1971

Item No	Launch date	Name of spacecraft	Apogee, (km)	Perigee, (km)	Orbital Inclination	Orbital period (min)	Frequencies of radio transmissions (megahertz) Remarks
1	2	3	4	5	6	7	8
1	12 January	Cosmos-390	296	208	65°	89.3	-
2	14 January	Cosmos-391	828	277	71°	95.4	-
3	20 January	Meteor	679	630	81.2°	97.6	-
4	21 January	Cosmos-392	300	207	65°	89.4	19,995
5	26 January	Cosmos-393	512	283	71"	92.2	-
6	9 February	Cosmos-394	619	574	65.9°	96.5	-
7	18 February	Cosmos-395	570	534	74°	95.4	-
8	18 February	Cosmos-396	310	212	65.4°	89.4	-
9	25 February	Cosmos-397	2317	593	65.8°	114.7	-
10	26 February	Cosmos-398	276	196	51.63°	88.9	-
11	3 March	Cosmos-399	310	209	65°	89.5	-
12	10 March	Cosmos-400	1016	995	65.8°	105	-
13	27 March	Cosmos-401	322	216	72.9°	89.6	-
14	1 April	Cosmos-402	279	261	65°	89.7	-
15	2 April	Cosmos-403	251	216	81.4°	89.0	19,995
16	4 April	Cosmos-404	1009	811	65.9°	103	-
17	7 April	Cosmos-405	706	676	81.3°	98.3	-
18	14 April	Cosmos-406	264	223	81.3°	89.2	-
19	17 April	Meteor	646	620	81.2°	97.2	-
20	19 April	Salyut	222	200	51.6°	88.5	-
21	23 April	Soyuz-10	246	208	51.6°	89	-
22	23 April	Cosmos-407	844	799	74°	101	-
23	24 April	Kosmos-408	1542	211	82°	102.1	-
24	28 April	Cosmos-409	1222	1185	74°	109.4	-
25	6 May	Cosmos-410	300	207	65°	89.4	19,995
26-33	7 May	Cosmos-411-418	1530	1408	74.5°	115	8 artificial earth satellites were inserted into orbit by 1 booster rocket

Soviet spacecraft launched in 1971 (continued)

1	2	3	4	5	6	7	8
34	10 May	Cosmos-419	174	158.5	51.4°	87.7	-
35	18 May	Cosmos-420	242	200	51.8°	88.8	-
36	19 May	Cosmos-421	492	283	71°	92	-
37	19 May	Mars-3	25000	1380	48.54°	18 hrs 00 min	On 27 Nov., inserted into artificial Mars satellite orbit
38	22 May	Kosmow-422	1020	994	74°	105.1	-
39	27 May	Cosmos-423	511	282	71°	92.2	-
40	28 May	Cosmos-424	309	214	65.4°	89.4	-
41	28 May	Mars-3	214500	1528	60°	12 days	Inserted into artificial Mars satellite, orbit on 2 December, and reentry vehicle completed soft landing on the planet
42	29 May	Cosmos-425	556	511	74°	95.2	-
43	4 June	Cosmos-426	2012	394	74°	109.3	-
44	6 June	Soyuz-11	217	185	51.6°	88.3	Orbital parameters after correction on 6 June
45	11 June	Cosmos-427	337	211	72.9°	89.7	-
46	24 June	Cosmos-428	271	208	51.8°	89.1	19,995
47	16 July	Meteor	650	618	81.2°	97.3	-
48	20 July	Cosmos-429	260	204	51.8°	89.0	-
49	23 July	Cosmos-430	322	206	65.4°	89.6	-
50	28 July	Molniya-1	39300	470	65.4°	11 hrs 45 min	-
51	30 July	Cosmos-431	262	202	51.8°	89.0	19,995
52	5 August	Cosmos-432	262	209	51.8°	89.0	-
53	9 August	Cosmos-432	259	159	49.5°	-	-
54	12 August	Cosmos-434	385	107	51.6°	89.0	-

Soviet spacecraft launched in 1971 (continued)

1	2	3	4	5	6	7	8
55	27 August	Cosmos-435	505	282	71°	92.1	-
56	2 September	Luna-18	-	-	-	-	Reached surface of moon on 11 September
57	7 September	Cosmos-436	550	514	74°	95.2	-
58	10 September	Cosmos-437	558	523	74°	95.3	-
59	14 September	Cosmos-438	321	212	65.4°	89.5	-
60	21 September	Cosmos-439	308	219	65.4°	89.4	19,995
61	24 September	Cosmos-440	814	282	71°	95.3	-
62	28 September	Cosmos-441	288	209	65°	89.2	-
63	28 September	Luna-19	140	140	40.35°	2 hrs 01 min 45 sec	Inserted into selenocentric orbit on 3 October
64	29 September	Cosmos-442	321	211	72.9°	89.5	-
65	7 October	Cosmos-443	325	211	65.4°	89.6	-
60-73	13 October	Cosmos-444	1550	1415	74°	115	8 artificial earth satellites inserted into orbit by 1 booster rocket
74	14 October	Cosmos-452	270	201	65°	89.1	-
75	19 October	Cosmos-453	522	281	71°	92.2	-
76	2 November	Cosmos-454	284	210	65.4°	89.2	-
77	17 November	Cosmos-455	516	282	71°	92.2	-
78	19 November	Cosmos-456	328	218	72.9°	89.7	-
79	20 November	Cosmos-457	1229	1192	74°	109.5	-
80	24 November	Molniya-2	39350	460	65.4°	11 hrs 46 min	-
81	29 November	Cosmos-458	523	281	71°	92.3	-
82	29 November	Cosmos-459	277	226	65.8°	89.4	-
83	30 November	Cosmos-460	533	520	74°	95.2	-

Soviet spacecraft launched in 1971 (continued)

1	2	3	4	5	6	7	8
84	2 December	Intercosmos-5	1200	206	48.4°	98.5	-
85	2 December	Cosmos-461	524	490	69.2°	94.6	-
86	3 December	Cosmos-462	1840	237	65.8°	105.7	-
87	6 December	Cosmos-463	307	215	65°	89.4	-
88	10 December	Cosmos-464	405	206	72.9°	90.3	-
89	15 December	Cosmos-465	1023	984	74°	105	-
90	16 December	Cosmos-466	302	207	64°	89.4	-
91	17 December	Cosmos-467	502	279	71°	92.0	-
92	17 December	Cosmos-468	830	788	74°	100.8	-
93	20 December	Molniya-1	39200	490	65.5°	11 hr 43 min	-
94	25 December	Cosmos-469	276	259	65°	89.7	-
95	27 December	Cosmos-470	272	195	65.4°	89.1	-
96	27 December	Oreol	2500	410	74°	114.6	-
97	29 December	Meteor	905	880	81.2°	102.7	-

Simultaneously with the measurements performed on the "Oreol," the ground geophysical observatories of a number of countries performed coordinated geophysical studies.

During 1971, four "Meteor" satellites were launched. They provided for obtaining meteorological information required for use in the operative weather service.

Two "Molniya-1" and one "Molniya-2" satellites were launched for operation of the long-distance "Orbita" space communications system.

Rocket sounding of the atmosphere was continued in 1971, and satellites of the "Cosmos" series were launched (81 satellites were inserted into orbit during that year).

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NON-SOVIET SPACE RESEARCH IN 1971

Moscow YEZHEGODNIK BOL'SHOY SOVETSKOY ENTSIKLOPEDII in Russian No 16, 1972 pp 519-527

[Article by D. Gol'dovskiy: "Launching of Foreign Spacecraft in 1971"]

Artificial Earth Satellites

In 1971, 46 artificial earth satellites were launched abroad, including 34 American satellites (three of the "Explorer" series; one OSO satellite; one TTS satellite, two DSCS; nine by the STP program: OV-1-20, "Cannon Ball II," "Musket Ball," five unnamed satellites and the "Astex"; 18 secret military satellites), two English ("Prospero" and "Ariel IV"), two French ("Turnesol" and "Eole"), two Japanese ("Tansie" and "Shinsei"), one Chinese ("China II"), one Italian ("San Marco III"), one American-Canadian (ISIS-II), one NATO ("NATO-II") and two of the INTELSAT international consortium satellites (INTELSAT-4A and INTELSAT-4B). The "Ariel IV," "Eole," "San Marco III," "ISIS-II," "NATO-II," "INTELSAT-4A" and INTELSAT-4B satellites were inserted into orbit by American booster rockets.

The basic information on the orbits of the enumerated artificial earth satellites has been included in a table. A description of some of these missions is presented below.

"Explorer XLIII" (Table, No 10). "Explorer-XLIII" was the next American research satellite of the IMP[1] series (see Figure 1) for studying high-energy particles, the interplanetary magnetic field and its interaction with the solar wind, solar activity, low-frequency emissions of the earth's magnetosphere, the solar corona and the Milky Way, the electric field of the earth and also when developing equip~ent to study outer space using comparatively inexpensively inserted satelli :s stabilized by rotation. The weight of the satellite was 288 kg, including 97.5 kg of scientific equipment. This was the heaviest satellite of the "Explorer" series. Its hull was in the shape of a regular octahedral prism (altitude 1.8 meters, maximum transverse dimension 1.4 meters). The solar cells mounted on the hull insure a total power of 110 watts. In the electric power supply system, silver-cadmium storage batteries are also used (total weight 5.4 kg). Four rods which unfold in orbit are attached to the hull: one of them 3.6 meters long has a magnetometer, and on the other there is a loop antenna. The two remaining rods 1.5 meters long each with weights on the ends are used for balancing. The hull also has 8 high frequency and 6 microwave rod antennas fastened to it. Four of the microwave antennas are 45.7 meters long each, and two are 6.1 meters long. These antennas unfold after insertion of the satellite into orbit and they are used to measure the electric fields and for radio astronomical investigations.

The scientific equipment module includes 17 different charged particle detectors, a gamma spectrometer, electron and proton spectrometer, a device for determining the mass, speed, concentration and temperature of the hydrogen and helium ions of the solar wind, a device for studying the electric fields (it uses microwave antennas), a device for studying radio interference in the magnetosphere by a magnetometer and also two radiometers and an impedance sonde for studying the radio spectra of different celestial systems and bodies (including our galaxy, the sun and Jupiter) in the low frequency ranges not recorded by ground means.

The satellite is equippped with an all-purpose digital computer which insures the given sequence of performing the scientific experiments, adjustment of some of the scientific instruments, processing and storing the information. The computer weighs 5.7 kg, its intake is 5 watts, the capacity of the onboard memory is 4000 bits. The PCM temetetry transmitter operates on a frequency of 136.170 megahertz.

In orbit the satellite is stabilized by rotation. The axis of rotation must be perpendicular to the plane of the ecliptic. Optical sensors are used in the system for orientation of the axis of rotation, and micromotors operating on freon-14 are used as the actuating elements.

The "Explorer XLIV" (see Table, No 20) was the next American research satellite in the SR^2 series for recording x-radiation and ultraviolet radiation of the sun and also for developing a procedure for forecasting solar activity (see Figure 2). It weighed 118 kg. Its hull has the shape of a regular dodecahedral prism (altitude 0.58 meters, maximum transverse dimension 0.76 meters). Four panels with solar elements are fastened to the hull; each 0.18 x 0.53 meters in size. They also serve as elements of the turnstile antenna.

The scientific equipment module includes 18 different ionization chambers recording radiation in the 0.5-1700 Å range, a scintillation chamber (0.1-0.5 Å), a photometer (170-600 Å), a proportional counter (0.5-15 Å) and also a thermistor for measuring the skin temperature of the satellite on the shadow side. The satellite uses a transmitter which operates on a frequency of 137.710 megahertz for transmission of telemetry data in real time and for trajectory measurements, and it also has a transmitter (136.380 megahertz, 380 watts) for transmitting telemetry data from the recording. The capacity of the onboard memory is $5.4 \cdot 10^4$ bits.

In orbit the satellite is stabilized by rotation. The given orbital velocity (60 rpm) and the constant direction of the axis of rotation toward the sun with an accuracy of ±2° are insured by microengines which operate on the products of decomposition of hydrazine.

The "Explorer XLIV" differs from the previous SR satellites insofar as the higher sensitivity of its instruments.

The "Explorer XLV" (Table, no 43) was the first American research satellite in the SSS[3] series for electromagnetic studies, recording charged particles and testing certain onboard devices (Figure 4). An Italian launch crew from the Italian "San Marco" marine launch complex located in the Indian Ocean off the cost of Kenya launched the "Explorer XLV." It weighed 52 kg, the scientific instruments and tested onboard devices weighed 17.3 kg. The hull was in the shape of a regular octahedral prism (altitude 0.74 meters, maximum transverse dimensions 0.69 meters). The solar cells mounted on the hull provided a total power of 21 watts. An 18-element silver-cadmium battery was also used in the electric power supply system. A rod with the probe of the electric field analyzer and four antennas 0.61 meters long each for the telemetry command system were attached to the upper part of the hull, and two rods 0.61 meters long and one rod 0.76 meters long for the magnetometers and also two rods 2.7 meters long each for the probes of the second electric field analyzer were attached to the lateral surface.

The scientific equipment module included three charged particle detectors, three magnetometers and two electric field analyzers. A thermistor for measuring the aerodynamic heating in the remote lead section, the instruments for studying the effect of the ionizing radiation on integrated circuits and an experimental star sensor for indicating the orientation of the axis of rotation of the satellite with an accuracy to 0.1° were also installed on the satellite. The satellite uses a transmitter which operates on frequencies of 136.830 and 137.950 megahertz, and the command receiver (148.980 megahertz). The satellite is stabilized by rotation in orbit.

The OSO-VII (Table, no 35) was the next American OSO research satellite for studying the sun (see Figure 3). The calculated orbit of the OSO-VII satellite and the TTS-III satellite launched together with it was circular, 555 km high, but as a result of failure of the orientation system of the second stage of the booster rocket, the satellites were inserted into an unplanned elliptic orbit. This did not interefere with the performance of the planned research, although it complicated the processing of the information received from onboard the satellite. The satellite weighed 635 kg (about twice that of the preceding satellites in the OSO series), including scientific equipment weighing 225 kg. The satellite was made up of two hinged sections. One section having the shape of a regular octahedral prism rotated, providing for stabilization of the satellite in so doing. The second section which was called the "sail" retained constant orientation with respect to the sun, insuring that the instruments installed on it would be directed toward the sun. (For the dimensions and service systems of the OSO satellites see YEZHEGODNIK BSE [Great Soviet Encyclopedia Yearbook], 1968, page 516).

The scientific equipment module of the OSO-7 satellite includes an x-ray and ultraviolet spectroheliograph, coronographs operating in the visible and ultraviolet bands, three x-radiation detectors and also a detector of the gamma and neutron radiation of the sun. The spectroheliograph and the coronographs are located in the "sail" section, and the remaining devices, in the rotating section.

The TTS-III (Table, No 36) was the next American TTS (TETR) satellite for adjustment of equipment and training the personnel of the stations for tracking manned spacecraft. It was launched as an additional payload together with the OSO-VII satellite (Table, No 35) and was inserted into an orbit which was different somewhat from the calculated orbit, but this did not interfere with the performance of the planned mission. The weight is 20 kg, and the hull is in the shape of an octahedron. Transponders operating on frequencies of 136.620 and 259.700 megahertz were installed onboard. [For information on the preceding launches of the TTS (TETR) satellites see YEZHEGODNIK BSE [Great Soviet Encyclopedia Yearbook], 1969, page 505].

The DSCS[4]-I and DSCS-II (Tables, No 41 and 42) were the first pair of American satellites for use in the improved DSCS-2 military communications system. They were inserted into synchronous orbit above the Galapagos Islands. After the tests which were designed to last two months, one of them had to be transferred to an orbit above the central part of the Pacific Ocean, and the other, above the Atlantic Ocean. The DSCS-2 system is to provide global, continuous secret "strategic" and "tactical" communications (radiotelephone, transmission of digital and video information) with multistation access using ground stations of various types. The weight of each satellite (Figure 6) is 500 kg, including 80.7 kg of radio relay system. The satellite (total length 3.6 meters) is made up of two hinged sections. The outside cylindrical section (2.7 meters in diameter) carries solar elements providing a total power of 520 watts (directly after insertion of the satellite into orbit). There are also three nickel-cadmium storage batteries with a capacity of 12 amps of hours each used for the electric power supply for the satellite during the time spent in the earth's shadow. The outer section rotates (60 rpm) to stabilize the satellite. The axis of rotation is oriented perpendicular to the orbital plane. The inner section bearing the antenna modules and all of the radiotechnical equipment has a mechanical counter rotation system. Here the horn antennas rigidly connected to the inside section must be constantly directed toward the center of the earth.

The horn antennas providing strategic communications have a radiation pattern width of ~18°, and an amplification coefficient of 16.8 decibels, an effective emitted power of 28 decibels-watts and circular polarization. Their radiation pattern opens up the entire region of the earth visible from the satellite. The tactical communications are provided by two parabolic antennas (2.5°; 33 decibels; 43 decibel-watts). The antenna weighs 10 kg, the diameter of the reflector is 1.1 meter. It is aimed with an accuracy of 0.2° at defined parts of the earth and illuminates a spot 3200 km in diameter.

On the satellite there are 4 amplifiers based on a traveling wave tube with rated output power of 20 watts each. The informativeness of the radio relay system of the satellite is 10^8 bits/sec. It provides two-way radio telephone communications over 1300 channels with a total bank width of 410 megahertz in the frequency range of 7250 to 8400 megahertz. The command system of the satellite is designed for 192 different commands with a carrying capacity of 1000 baud, and the telemetry system, transmission of 182 different measurements with an informativeness of 250 bits/sec. The pulse-code or code modulation and pulse shift manipulation are used. For the trajectory measurements a radio beacon is used which sends coded signals.

Small solid-state rockets are used to unfold the outside sections; for counter-rotation of the inside section there are electric motors; for orientation of the axis of rotation and insertion of the satellite into a defined point of the synchronous orbit, micromotors which operate on the products of decomposition of hydrazine. In the counterrotation system for the inside section and in the system for orientation for the axis of rotation, infrared horizon sensors were used.

The satellites in the STP[5] program (Tables, No 22-29 and 38). In 1971 two launches were made within the framework of this program of the US Airforce providing for applied military research and testing of onboard equipment.

On the first launching (7 August) one "Atlas F" booster rocket was used to insert 8 satellites into orbit (some of them were equipped with onboard solid-fuel rocket engines for transfer to higher orbit).

1. The OV-1-20 research satellite weighs 70 kg. Its hull has a cylindrical shape (altitude 2 meters, diameter 0.71 meters).

2. The "Cannon Ball II" satellite for studying aerodynamic braking of orbital objects in the upper layers of the atmosphere weighs 400 kg. It is a cast brass sphere 0.66 meters in diameter on which are installed transmitters which operate on frequencies of 136.530 and 136.860 megahertz.

3. The "Musket Ball" satellite is a cast sphere 0.3 meters in diameter weighing 61 kg, and it carries no equipment.

4. A satellite (without name) for studying the aerodynamic braking of orbital objects in the upper layers of the atmosphere. It is an inflated spherical balloon 2 meters in diameter of mylar film weighing 0.9 kg.

5. A satellite (without name) for studying the aerodynamic braking of orbital objects in the upper layers of the atmosphere. It is an inflated spherical balloon 2 meters in diameter made up of film stretched over a wire grid. After filling the balloon with as the film evaporates and a spherical shell of wire screen remains 4.1 kg.

6. A satellite (without name) for studying the aerodynamic braking of orbital objects in the upper layers of the atmosphere. It is an inflated spherical balloon 2 meters in diameter made of evaporating film stretched over a wire screen. It weighs 6.3 kg.

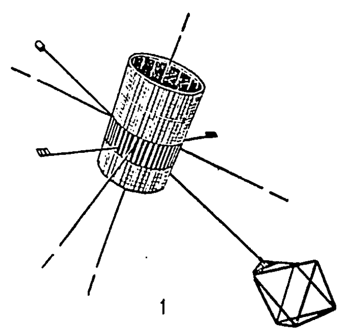

Figure 1. "Explorer XLIII satellite.

7. A satellite (without name) for adjusting radar. It is a hollow sphere 0.61 meters in diameter made of aluminum alloy. It weighs 1.8 kg.

8. A satellite (without name) for adjusting radar. It is a hollow sphere 1.12 meters in diameter made of magnesium alloy. It weighs 34 kg.

On the second launching under the STP program (17 October) the "Astex"[6] satellite was inserted into orbit. It is the last stage of a booster rocket with experimental equipment and scientific instruments mounted on it. In particular, this satellite is used to test a power plant with two roll type solar panels. The length of each panel in unrolled form is 4.9 meters, and the width is 1.7 meters. The diameter of the roll when coiled up is 0.25 meters. On the two panels there are a total of 17,250 solar elements. They provide a power of 1500 watts. In addition to the panels, equipment is installed on the satellite for communications experiments, in particular, to study the transmission of high frequency signals in the solar regions. There are instruments for recording protons, electrons and alpha particles, instruments for studying the effect of the solar flares on the atmosphere and for recording long-wave infrared radiation of the cold giant stars. The telemetry command system of the satellite uses 11 antennas, and the telemetry information is transmitted over 800 channels, over 248 channels in real time.

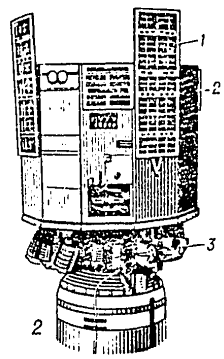

Figure 2. "Explorer XLIV" satellite: 1--panel with solar elements, 2--satellite hull; 3--micromotors.

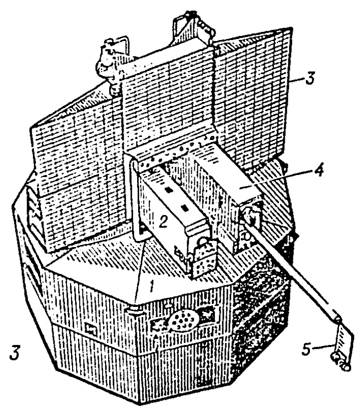

Figure 3. OSO-VII satellite: 1--rotating section; 2--spectroheliograph; 3--"sail" section; 4--coronograph module; 5--disc shaped sides of the coronographs on the rod.

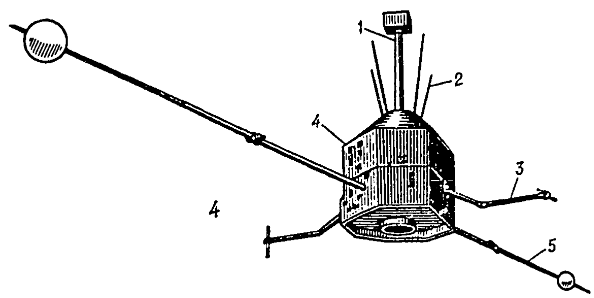

Figure 4. "Explorer XLV" satellite: 1--rod with electric field analyzer probe; 2--antenna of the telemetry command system; 3--rod with magnetometer; 4--solar panels on the satellite hull; 5--rod with probe of the second electric field analyzer.

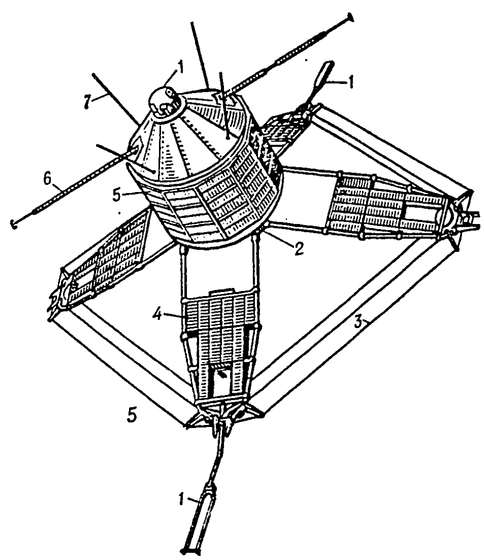

Figure 5. "Ariel IV" satellite; 1--scientific instruments; 2--hinge; 3--loop antenna of one of the instruments; 4--hinged solar panel; 5--solar panels on the hull of the satellite; 6--dipole antenna of one of the instruments; 7--antenna of the dielectric system.

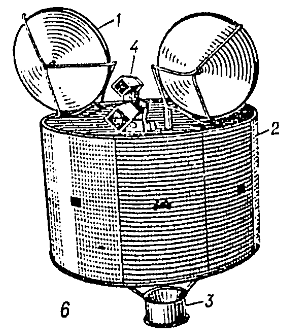

Figure 6. DSCS satellite; 1--parabolic antenna; 2--outside section of the satellite; 3--antenna of the telemetry command system; 4--horn antenna.

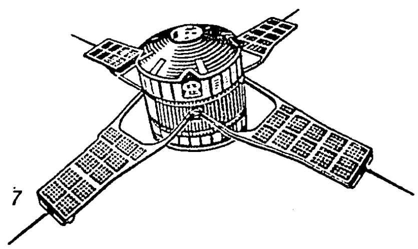

Figure 7. "Turnesol" satellite.

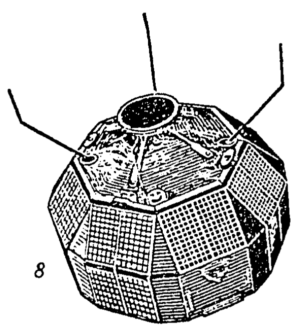

Figure 8. "Prospero" satellite.

The "Prospero" (Table, No 40) was the first English satellite (see Figure 8) launched by a domestic booster rocket. It was designed for testing the on-board equipment and for scientific research, in particular, for testing heat reflecting paint, electronic circuits and solar cells under space flight conditions as well as for studying meteors. It weighs 66 kg. Its hull is in the shape of a 24-sided prism (0.71 meters high, maximum transverse dimension 1.14 meters). In orbit the satellite is stabilized by rotation (200 rpm). The telemetry information is transmitted in real time and from recordings.

The "Ariel IV" (Table, No 44) is the next English "Ariel" research satellite (Figure 5) designed to study the interaction between plasma, charged particle fluxes and electromagnetic waves in the upper layers of the atmosphere. It weighs 100 kg. The hull is in the shape of a polyhedral prism (0.91 meters high, maximum transverse dimensions 0.76 meters). Four unfolding solar panels and antennas are fastened to the hull. Each panel is 1.2 meters long. Rods (0.9 meters long each) for removal of the instruments are mounted on the ends of the two panels. The scientific equipment module includes instruments for recording galactic noise (0.75 to 4 megahertz) and low-frequency radiation for measuring the plasma density and electronic temperature and also for recording the protons and electrons.

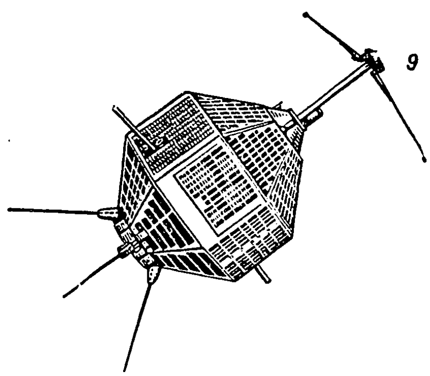

Figure 9. "Shinsei" satellite.

In orbit the satellite is stabilized by rotation. The orientation of the axis of rotation can vary within the limits of ±180° using a magnetic system. The telemetry transmitter operates on a frequency of 137.050 megahertz. (For more details on the service systems of the "Ariel" satellites see YEZHEGODNIK BSE [Great Soviet Encyclopedia Yearbook], 1968, page 520).

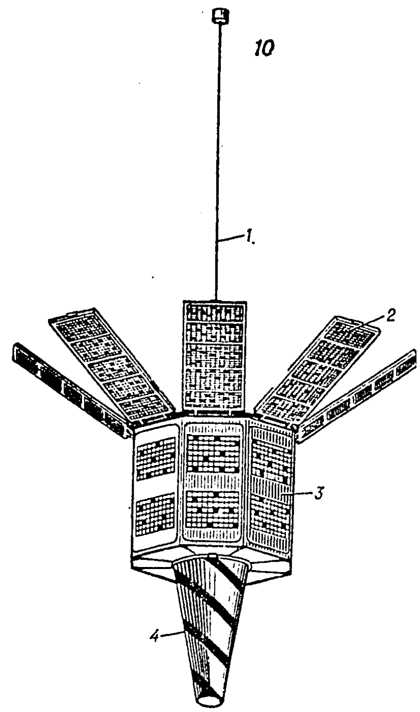

Figure 10. "Eole" satellite: 1--rod of the gravitational orientation and stabilization system; 2--solar panel; 3--satellite hull; 4--spiral antenna.

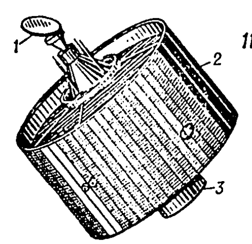

Figure 11. "NATO-II" satellite. 1--reflector of the radio relay system antenna; 2--solar panel on the satellite hull; 3--on-board solid-fuel rocket engine.

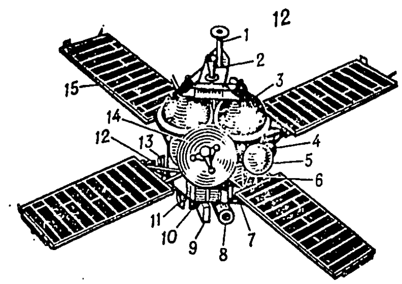

Figure 12. "Mariner IX" automatic interplanetary station: 1--omnidirectional antenna waveguide; 2--correction and braking engine (KTDU); 3--KTDU fuel tank; 4--Canopus sensor; 5--compressed nitrogen bottle; 6--louvers of the heat control system; 7--infrared interference spectrometers; 8--television camera with telephoto lens; 9--ultraviolet spectrometer; 10--television camera with wide-angle lens; 11--infrared radiometer; 12--solar sensor; 13--horn antenna; 14--highly directional antenna; 15--panel with solar elements.

The "Turnesol" (Table, No 14) satellite is the first French research satellite in the D-II series (see Figure 7) designed to study the hydrogen distribution in the solar system. The calculated orbit of the satellite is elliptical with a perigee of 470 km and an apogee of 610 km. It was inserted into an orbit somewhat different from calculated, but this was not reflected in the performance of the planned experiment. It weighs 96 kg, including 25 kg of scientific instruments. The hull is in the shape of a cylinder (0.8 meters high, 0.7 meters in diameter). Four panels with 1400 solar cells providing a total power of 56 watts are fastened to it. The scientific equipment module includes a spectrograph, a polarimeter, two photometers and a device for recording the Lyman-alpha solar radiation.

In orbit the satellite is stabilized by rotation (4 rpm), the axis of rotation must be directed toward the sun with an accuracy of ±30'. The given rotation rate and also the direction of the axis of rotation toward the sun are insured by sun sensors connected to the engines operating on compressed nitrogen.

The "Eoie" satellite (Table, No 31) was the first French satellite for radio relay at the center for gathering data from sounding balloons and for recording their movements in the atmosphere to study its circulation (Figure 10). The calculated orbit of the satellite was circular, 900 km high. It was inserted into an elliptic orbit, but this was almost not reflected at all in the performance of the planned experiments. It weighs 84 kg. The hull of

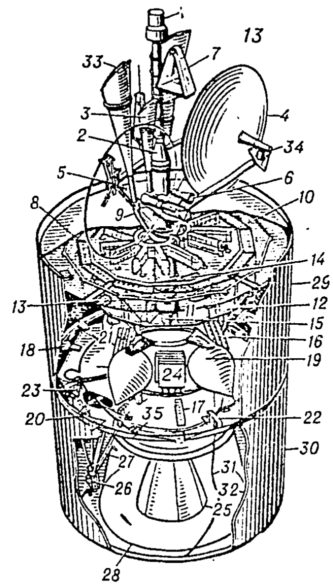

Figure 13. INTELSAT-4 satellite: 1--antenna of the telemetry command system; 2--central mass; 3--fixed receiving antenna; 4--rotating transmitting antenna; 5--mechanism regulating antenna; 6--telemetry horn antenna; 7--nutation damper; 8--quartz mirror coatings; 9--wave guide; 10--output multiplexes; 11--platform of the antenna unit with counterrotation system; 12--traveling wave tube (12 pairs); 13--converters of power fed to the traveling wave tubes; 14--electronic equipment of the telemetry command system; 15--bearing; 16--electronic equipment of the electric power supply system; 17--chemical battery module; 18--microengine (2) with thrust vector perpendicular to the longitudinal axis of the satellite; 19--tank (4) with hydrazine for the microengines; 20--sun sensor (3); 21--accelerometer; 22--horizon sensor (3); 23--connections of the onboard cable network; 24--electronic equipment of the system regulating the deceleration of the rotation of the satellite; 25--nozzle of the onboard solid-fuel rocket engine; 26--microengine (2) with thrust vector parallel to the longitudinal axis of the satellite; 27--heat protective shielding; 28--installation ring for joining to the last stage of the booster rocket; 29--front panel with solar cells; 30--rear panel with solar cells; 31--wall of the satellite hull; 32--solar cells; 33--fixed transmitting antenna; 34--antenna feeder 4; 35--microengine (2) for unfolding the satellite.

the satellite has the shape of an octahedral prism (0.58 meters high, maximum transverse dimensions 0.71 meters). Eight solar panels are fastened to one end of the hull, and a spiral antenna is fastened to the opposite end.

14.

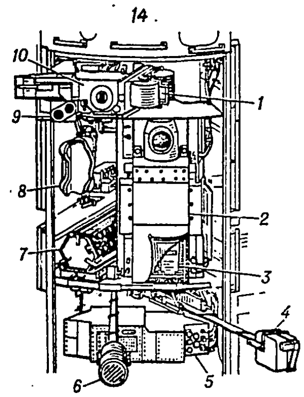

Figure 14. SIM No 1 complex and automatic satellite in command module (OBK): 1--holder with topographic camera film; 2--panoramic camera; 3--holder with panoramic camera film; 4--mass spectrometer; 5--alpha and x-ray spectrometer; 6--gamma spectrometer; 7--automatic satellite; 8--holder for the astronaut's food when extracting the holder with the film; 9--laser altimeter; 10--topographic camera (stellar camera behind it).

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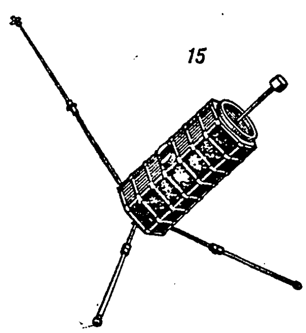

Figure 15. Automatic satellite inserted into selenocentric orbit.

A rod (10 meters long) of the gravity orientation and stabilization system providing for constant direction of the spiral antenna toward the earth advances from the hull in orbit. The solar elements are also mounted on the side surface of the hull. The total power provided by the elements is 20 watts. In the electric power supply system, the nickel-cadmium storage

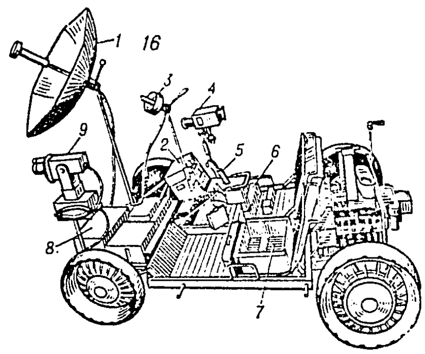

Figure 16. Lunokhod: 1--highly directional antenna; 2--control panel; 3--low-directional antenna; 4--movie camera; 5--control hangle; 6--holders with film; 7--seats; 8--transceiver for direct communications with the earth; 9--television camera.

battery is also used. The interrogations from the satellite are transmitted to the sounding balloons on the frequency of 464.486 megahertz. The information is received from the balloons on a frequency of 401.718 megahertz. The satellite recorder was calculated to record 893 parameters (six parameters comes from the sounding balloon on one interrogation). The possibility of simultaneous interrogation of up to 64 sounding balloons is provided for. The position of the sounding balloons is determined by the Doppler frequency shift with an accuracy of 2 to 5 km.

It was proposed that 500 balloons in all be launched (3.7 meters in diameter) which were to circulate at an altitude of 12 km in the southern hemisphere. Each balloon was equipped with ambient pressure and temperature gauges, a gauge for the helium pressure in the balloon, solar cells, a chemical battery, transceiver and antenna and also a self-destruction unit so that on completion of the experiment the balloons could be destroyed (otherwise they could present a danger to aircraft). A total of 479 balloons were launched from 21 August to 9 December 1971. Of them approximately half continued to be used as of December 1971. About 100 of the balloons were destroyed on 11 September 1971, as a result of an erroneously given command to switch on the self-destruction device.

The "Tansei" (Table, No 4) is a Japanese satellite for estimating the characteristics of the "Mi-4S" booster rocket. It weighs 63 kg. It is equipped with a transmitter for trajectory measurements. The battery source of electric power of the transmitter was designed for 7 days of operation. Special reflectors on the hull of the satellite permit it to be tracked by optical telescope.

The "Shinsei" (Table, No 34) is a Japanese research satellite (Figure 9) for studying the ionosphere, cosmic radiation and the high-frequency radiation of the sun. It weighs 65 kg. The hull is in the shape of a 26-sided prism (altitude 0.74 meters, maximum transverse dimension 0.72 meters). On the hull there are 5000 solar cells installed.

"China II" (Table, No 9). This is the second artificial earth satellite created by the Chinese People's Republic. It weighs 221 kg. The onboard transmitter operated on frequencies of 19.995 and 20.009 megahertz. The reception of signals from the satellite ceased on 23 March 1971.

The "San Marco III" satellite (see Table, No 16) was the next Italian research satellite in the "San Marco" series for determining the density of the upper atmosphere in the equatorial zone. The satellite was launched by an Italian launch crew from the Italian "San Marco" marine launching complex in the Indian Ocean off the coast of Kenya. It weighed 164 kg. The hull has a spherical shape (0.76 meters in diameter). (For information on the service systems and scientific equipment of the "San Marco" satellites see YEZHEGODNIK BSE [Great Soviet Encyclopedia Yearbook], 1968, pages 519, 520].

The ISIS-II (Table, No 13) is the next American-Canadian research satellite of the ISIS series for studying the ionosphere. It weighs 264 kg. The hull is in the shape of an octahedral spheroid (altitude 1.2 meters, maximum transverse dimension 1.3 meters). Eleven thousand solar cells are mounted on the hull. In the electric power supply system, three seventeen-element nickel-cadmium storage batteries are also used. Two crossed dipole antennas 73.2 and 18.7 meters long for sounding the ionosphere, the turnstile telemetric antennas (136 megahertz for transmission in real time and 400 megahertz for transmission from a recording) and the annular radio beacon antennas (136 megahertz) are attached to the hull. The scientific equipment module of the satellite includes an ionospheric probe, a very low frequency radiation receiver, devices for recording charged particles and measuring electron concentration and temperature, ultrashort wave radio beacons for studying the effect of ionospheric noise on the polarization and the amplitude of the signals, and a device for recording interference of galactic, solar and ionospheric origin and also two photometers.

In orbit the satellite is stabilized by rotation. The orientation of the axis of rotation is insured by a magnetic system connected to the sun sensor. (For more details on the service systems of the ISIS satellites see YEZHEGODNIK BSE, 1970, page 501).

The NATO-2 (see Table, No 3) is the next satellite for the NATO military communications system (see Figure 11). It was inserted into synchronous orbit above the Atlantic Ocean (above 18° west longitude). It weighs 243 kg. Its total length together with the antenna module is 1.57 meters. The hull is in the shape of the cylinder (altitude 0.81 meters, diameter 1.37

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meters). Seven thousand solar cells are mounted on the hull. In the electric power supply system 16 nickel-cadmium storage batteries with a total capacitance of 26 ampere hours are also used. Two radio relay systems operating in the X frequency band provide radio telephone, radio teletype and radio phototelegraphic communications. A traveling wave tube is used in each system with an output power of 3 watts, the effective emitted power is 44.4 decibel-milliwatts. The band width is 2 or 20 megahertz by choice. The command and telemetry systems operate in the 300-400 megahertz band.

In orbit the satellite is stabilized by rotation. The antenna module has a mechanical counterrotation system. The system for orientation of the axis of rotation includes sun sensors and infrared sensors of the earth's horizon, and as the servoelements, micromotors operating on the products of decomposition of hydrazine. (For information on the "NATO-1" satellite see YEZHEGODNIK BSE, 1971, page 506).

The INTELSAT-4A (Table, No 2) was the first satellite of the improved global commercial communications system INTELSAT-4 (see Figure 13). It was inserted into stationary orbit above the Atlantic Ocean above 24.5° west longitude. It weighed 1387 kg including 700 kg of fuel charge for the onboard solid-fuel rocket engine and 124 kg of hydrazine for the microengines. The total length of the satellite considering the antenna module and the nozzle of the onboard solid-fuel rocket engine protruding from the hull is 5.3 meters. The satellite hull has a cylindrical shape (height 2.8 meters, diameter 2.4 meters); 45,012 solar elements are mounted on the hull which provide a power of 569 watts at the beginning of operation of the satellite. The antenna module includes six directional antennas (four fixed and two rotating) located around the central mast and also two omnidirectional antennas (receiving and transmitting) of the telemetry system mounted on the central mast. The fixed antennas (two receiving and two transmitting) have a radiation pattern width of 17°, an effective emitted power of the transmitting antennas of 22 decibel-watts. The radiation pattern of the fixed antennas covers the entire region of the earth visible from the satellite. The two rotating antennas (4.5°; 33.7 decibel-watts) are transmitting antennas. The reflector 1.3 meters in diameter is directed toward a defined part of the earth and illuminates a spot 1500 km in diameter. The radio relay system can provide two-way radio telephone communications over 3000 to 9000 channels (depending on the antennas used) or transmission of television programs over 12 channels. Reception is realized in the range of 5,932 to 6,418 megahertz; transmission is realized in the range of 3,707 to 4,193 megahertz. The used band width in these ranges is 432 megahertz. In orbit, the satellite is stabilized by rotation (60 rpm). The axis of rotation is oriented with a precision of up to ±35° in the "north-south" and "east-west" direction.

/The antenna module is equipped with a mechanical counterrotation system insuring that the antennas of the radio relay system are constantly directed toward the ground. For unfolding the satellite, orientation of the axis of rotation, insertion at a defined point of a stationary orbit and correction of this orbit microengines are used which operate on the products of breakdown of hydrazine. The counterrotation of the antenna module is provided by electric motors. The axis of rotation is oriented by command from the sun sensors and the infrared sensors of the earth's horizon.

The INTELSAT-4B (Table, No 46) is the second satellite of the INTELSAT-4 series inserted into stationary orbit above the equator.

Automatic Interplanetary Stations

Two "Mariner" automatic interplanetary stations were launched in the United States in 1971. The "Mariner VIII" station was launched on 9 May by the "Atlas-Centaur" booster rocket. The second stage with the station lost control as a result of failure of the automatic pilot and fell into the ocean. The "Mariner IX" station was launched by the "Atlas-Centaur" booster rocket on 30 May and inserted in orbit around Mars (aerocentric orbit).

The "Mariner IX." The basic missions of this station were surveying and sounding of Mars from aerocentric orbit. Provision is made for mapping no less than 70% of the surface of the planet, in particular to select the potential section for landing of the "Viking" automatic stations which are to be launched towardMars in 1975. Initially such missions were given to the "Mariner VIII" station, and the "Mariner IX" station was to perform multiple (every 5 days) surveys and soundings of six defined regions of Mars to study the so-called "variable characteristics." As a result of an emergency on the "Mariner VIII" station its missions were given to the "Mariner IX" (see Figure 12) as the basic missions, and the study of the variable characteristics became secondary.

The station weighed 998 kg, including 450 kg of fuel for the correction-braking engine (KTDU). The altitude from the base of the scanning platform to the top of the omnidirectional antenna was 2.29 meters. The solar panels were 9.6 meters in size. The length of each of the four panels was 2.14 meters and the width was 0.9 meters. There were 4368 cells located on it. The total power provided by all of the elements is 800 watts on the earth and 500 watts on Mars. In the electric power supply system, a 600 watt-hour storage battery is also used. On the ends of the panels a sun sensor and the orientation system microengines are mounted. On the upper end of the hull a highly directional antenna is attached with parabolic reflector 1 meter in diameter. On the lower cover there is a scanning platform with television cameras and scientific instruments. The platform with the equipment weighs 82 kg. It can be rotated (electric motor drive) with respect to two axes by 218 and 69° respectively. The scientific equipment module includes a television camera with telephoto lens (resolution from an altitude of 1800 km is 0.1 km), a television camera with wide-angle lens (1.0 km), an infrared radiometer for measuring the surface temperature of Mars, an ultraviolet spectrometer for studying the composition and structure of martian atmosphere and an infrared interference spectrometer for studying the surface and also the composition and temperature of the atmosphere of

Mars. The regular radiotechnical system of the station is used for sounding the atmosphere of Mars during the radio set and rise. The trajectory measurements permit determination of the characteristics of the gravitational field of the planet for disturbances of the aerocentric orbit.

The transmitter operates on a frequency of 2295 megahertz (output power 10 or 20 watts), and the receiver on a frequency of 2210 megahertz. The maximum informativeness of the transmitter is 16,200 bits/sec. The capacity of the onboard memory is $1.8 \cdot 10^8$ bits, the recording speed is 132,300 bits/sec. The triaxial orientation system uses solar sensors, a Canopus sensor and inertial measuring module, and as the servoelements, 12 microengines operating on compressed nitrogen. The correction-braking engine (KDTU) (thrust 136 kg) operates on hydrozine and nitrogen tetroxide.

A booster rocket inserted the "Mariner IX" station into the flight trajectory towards Mars. On 5 June a flight correction was made. On the approach to Mars, 3 series of photographs of the planet were taken. On 14 November, the station transferred to the initial aerocentric orbit (the KTDU operated for braking 15 minutes and 20 seconds). The pericenter of the orbit was 1390 km, and the apocenter was 17,920 km, the inclination was 64.28°, the orbital period was 12 hours 34 minutes. On 16 November a correction was made to the orbit in order to decrease the orbital period to 12 hours, which creates the most favorable conditions for reception of data. The pericenter of the corrected orbit was 1,390 km, the apocenter was 17,140 km, and the orbital period was 11 hours 59 minutes.

Before the end of December 1971, a dust storn on Mars interfered with high quality photographing of the surface of the planet, but good photographs were obtained of Phobos and Deimos. By the end of December the storm had diminished, and a systematic survey of the surface of the planet began. On 30 December the station orbit was corrected a second time in order to increase the pericenter and increase the coverage of the terrain with each photograph without changing the 12-hour orbital period. The pericenter of the second corrected orbit was 1,653 km, the apocenter was 17,040 km, the orbital period was 11 hours 59 minutes. The "Mariner IX" station continued to operate in 1972.

Transport Ships

In 1971 the United States launched two manned spacecraft to the moon in the "Apollo" program.

"Apollo XIV." The basic goals of the fourth flight of the manned spacecraft to the moon were the following: landing in the continental area north of the Fra Mauro crater where as a result of an emergency onboard the "Apollo XIII" spacecraft the astronauts ad been unable to land on the preceding lunar expedition (see YEZHEGODNIK BSE, 1971, pp 508-510); the installation on the moon of the ALSEP No 3 complex including the SNAP-27 radio isotopic power plant, telemetry system and scientific instruments (see below); study of the local magnetic fields on the surface of the moon using a portable magnetometer; delivery of lunar soil samples to the earth; photographing and taking movies during walks on the surface of the moon; color television sessions from the lunar surface and from the crew compartment (CC); photographing the surface of the moon, counterglow and comets from selenocentric orbit; radiosounding of the moon from selenocentric orbit; study of the gravitational field anomalies of the moon by disturbances in the ship's selenocentric orbit; performance of technological experiments in weightlessness on the "moon-earth" path (electrophoresis, casting, the study of the thermal transmission and behavior of liquids); observations of phosphenes ("flares") on the "earth-moon" and "moon-earth" routes; insurance that the last stage of the booster rocket separated from the spacecraft and also the used takeoff stage of the lunar module (LM) after delivery of the astronauts from the moon to the main module of the spacecraft in selenocentric orbit hit the moon.

The crew of the spaceship: Alan Shepard (spaceship commander), Stuart Roosa (pilot of the command module), Edgar Mitchell (pilot of the lunar module). The astronauts were basically trained under the same program as the preceding lunar expeditions, but with consideration for specific nature of the program for the flight and experience from the emergency flight of the "Apollo XIII" spacecraft. The equipment of the astronauts was basically the same as on the preceding expeditions, but to facilitate the transport of equipment while walking on the moon, they had a two-wheeled dolly on inflated tires, and they were also equipped with a hose which, in case of an emergency on the moon in the portable life support system of one astronaut made it possible for him to connect his space suit to the other astronauts life support system from which cooling water was supplied. For breathing in this case, the astronaut will use his emergency oxygen reserve. The use of water from the life support system that was in good repair increased the emergency reserve of oxygen in the failed lifesupport system from 30 to 75 minutes, for it did not have to be expended on cooling the space suit. The microbiological shielding and quarantining measures were analogous to the measures for the astronauts of "Apollo XII" (see YEZHEGODNIK BSE, 1970, page 508).

The astronauts had to complete two walks on the surface of the moon lasting 4 hours 15 minutes and 4 hours 45 minutes. On the second walk they traveled more than 1 km and reached the edge of Cone Crater. It was proposed that a seismometer, an ion detector, an ionization manometer, an instrument for recording charged particles, a trap for the nuclei of the inert gas atoms in solar wind (the trap was returned to the earth) and a laser radiation spector as well as geophones ("active seismometer") and a grenade launcher. The geophones were to record the seismic vibrations which occurred when the astronauts set off small pyrotechnical charges using a special striker and also the vibrations from exploding the grenades. The grenades were to be launched on command from the ground several months after the astronauts left for the moon. The "Saturn V" (AS-509) booster rocket was used to launch the spacecraft. It had basically the same characteristics of the rocket for the "Apollo XIII" spaceship. The "Apollo XIV" spaceship (weight 44.5 tons) was analogous to the "Apollo XIII" spaceship, but the onboard equipment of the command module of the ship was modified to prevent emergencies of the type which occurred on the "Apollo XIII," and also to increase the oxygen reserve and electric power reserve if such an emergency occurred: in the oxygen tanks the combustible materials were replaced by incombustible materials, and possible sources of electric discharge were eliminated. An additional (third) oxygen tank and an additional silver-zinc battery with 400 ampere-hours reserve were installed.

The launch was on 31 January 1971 at 2103 hours* with a 40 minute delay caused by unfavorable meteorological conditions. The last stage with the spacecraft was inserted into geocentric orbit with a perigee of 186 km and an apogee of 192 km (the calculated orbit was circular at an altitude of 191 km). The second launch was made at the calculated time. The rearrangement of the compartments took 2 hours instead of the calculated 25 minutes, for the docking of the command module with the LM located on the last stage of the booster rocket was achieved only on the sixth attempt. The subsequent inspection of the docking module did not indicate any failures. Apparently a foreign body (dirt, ice) which had fallen out during the successful docking had caused the interference. Later it was discovered that one of the batteries of the LM provided a voltage 0.3 less than the rated value. However, no further drop in voltage occurred. On 4 February the spacecraft was inserted into the initial selenocentric orbit (107 x 313 km), and after 4 hours, transferred to the lower orbit (17 x 115 km) where the LM was to be separated. On 4 February the last stage of the booster rocket was dropped on the moon. The seismometer recorded the vibrations caused by the fall for 3 hours. On 5 February the LM with astronauts Shepard and Mitchell separated from the command module leaving Roosa behind. The command module shifted to a "rendezvous orbit" closer to circular (94 x 119 km), and at 0918 hours on 5 February the LM landed at the coordinates 3°40'27" south latitude and 17°27'58" west longitude (26 meters from the calculated point). The landing was complicated by the fact that after separation of the LM and the command module of the spacecraft it was discovered that the program for emergency return to the command module had been erroneously put into the onboard digital computer of the LM which would begin to automatically reprocess on switching on the braking engine of the LM. A "counterprogram" was successfully developed on the ground which was put into the LM computer.

The first walk on the surface of the moon was made on 5 February and lasted 4 hours and 45 minutes. The astronauts set up the ALSEP No 3 instrument set and exploded the pyrotechnical devices (the resulting vibrations were recorded by the geophones), and the lunar soil samples were gathered. The instruments were delivered to the installation point on the dolly. The second walk was on 6 February and lasted 4 hours and 29 minutes. As a result of significant broken nature of the terrain and steepness of the slope of the Cone Crater (to 18°) as well as the complexity of estimating distance on the moon and maintaining direction in the absence of landmarks, the astronauts deviated from the correct path. Two and a half hours after the beginning of the walk, Shepard's pulse rate rached 150 beats per minute, and Mitchell's reached 128 beats per minute, and they were ordered to return although they had not

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* Here and hereafter, Greenwich time.

reached the edge of the crater. In the two walks the astronauts gathered 43 kg of specimens and took about 500 pictures of the lunar surface. On the whole they performed 206 out of the planned 215 operations on the moon. After staying on the moon for 33 hours and 30 minutes, on 6 February the astronauts took off from the moon and 2 hours later docked with the command module of the spaceship in selenocentric orbit. The scheme for rendezvous with the command module was different than on the preceding flights, and provision was made for docking in the first orbit of the LM and not on the second so that the astronauts, fatigued after their operations on the moon, were returned to the command module sooner. The used takeoff stage of the LM fell to the moon. The vibrations caused by the fall were recorded by the spectrometers for 1.5 hours. After being in selenocentric orbit for 66 hours and 38 minutes the command module transferred to the flight trajectory to the earth. On the "moon-earth" route technological experiments were successfully performed. The splash down of the reentry vehicle occurred on 9 February at 2105 hours at the point with the coordinates 27°2' south latitude and 122°40' west longitude 1.8 km from the calculated point. The flight continued for 216 hours 02 minutes. The instruments that the astronauts left on the moon operated normally, but the grenades could not be launched: the astronauts had installed the launcher unsuccessfully, and the remaining instruments could suffer in case of an explosion.

"Apollo XV." The missions of the fifth flight of a manned space ship to the moon were appreciably broader than during the preceding flights inasmuch as the improved model J spacecraft was used (the "Apollo XIV" was the last model H spacecraft). The basic missions of the fifth flight were as follows: landing in the continental area of "Hadley-Apennines" in direct proximity to the Hadley Rille (more than 100 km long, average depth 370 meters, average width 1200 mters) and to Mount Hadley Delta (altitude 3.6 km); installation of the ALSEP No 4 complex including the radio isotopic SNAP-27 power plant, telemetry system and scientific instruments (see below); delivery to the earth of approximately 80 kg of lunar soil samples, including cores 3 meters long from a hole drilled in the ground with a special electric drill; the route expeditions on the lunokhod; photographing and taking movies during walks on the surface of the moon; conducting color television broadcasts from the surface of the moon (after departure of the astronauts it was proposed that astronimical observations be made using TV cameras left on the moon) and from the crew compartment (CC); the surveying and sounding of the moon from selenocentric orbit using the set of SIM[7] No 1 instruments in the command module of the spacecraft; photographing the lunar surface from the crew compartment from selenocentric orbit, photographing the counterglow, the zodiacal light and solar corona; insertion of an automatic satellite into selenocentric orbit; observation of phosphenes; radiosounding of the moon from selenocentric orbits; study of the gravitational field anomalies of the moon by the disturbances in the spacecraft's selenocentric orbit insuring that the last stage of the booster rockets and the used takeoff stage of the LM fell on the moon.

The spacecraft crew: David Scott (spacecraft commander), Alfred Worden (command module pilot), James Irwin (LM pilot). The astronauts were trained with consideration for the specific nature of the program for the forthcoming flight, providing for trips on a lunar car and investigation of the moon using the SIM complex. The equipment of these astronauts differed somewhat from the equipment of previous expeditions: the reserves of the portable lifesupport system were increased to 8 hours, the space suits were improved so that they would allow greater freedom of movement and have greater flexibility because the astronauts had to be in the sitting position in the moon car for prolonged periods of time. For the "Apollo XV" mission post-flight quarantine was done away with for the first time, for on the flights of the preceding expeditions, no microorganisms had been detected either in the marine or continental regions of the moon.

The astronauts had to perform walks on the surface of the moon lasting 20 hours and during each walk take some trips in the lunar car (totalling 38 km), without, however, getting more than 5 km from the landing site so that in case of an emergency it would be possible to return to the LM on foot in 75 minutes (the emergency oxygen reserve in the life support system). Trips were planned to the Hadley Rille, to the foot of the Mount Hadley Delta and to the "north complex" group of craters, on the first, second and third walks respectively. The automatic satellite separated from the command module before its transfer to the flight trajectory to the earth. On the "moon-earth" route, the pilot of the command module took a walk in open space to transfer the film holders from two of the SIM No 1 cameras to the crew compartment. It was proposed that the following scientific instruments be installed on the moon: a seismometer, an ion detector, ionization manometer, magnetometer, solar plasma particle spectrometer, devices for studying thermal fluxes from the depths of the moon to its surface (the latter, in a three-meter hole drilled in the ground with an electric drill), a trap for nuclei of inert gas atoms in the solar wind (the trap was returned to the earth) and a laser radiation reflector. The SIM No 1 complex (Figure 14) for surveying and sounding the moon from selenocentric orbit included the following: a panoramic camera (resolution 2 meters when taking photographs from an altitude of 110 km), a topographic camera (resolution 20 meters), a stellar camera for gridding the photographs of the topographic camera by coordinates, a laser altimeter (resolution $\pm$ 2 meters) for gridding these photographs with respect to altitude, x-ray, alpha gamma ray spectrometers and also a mass spectrometer. The automatic satellite (Figure 15) delivered to selenocentric orbit weighed 36 kg. A magnetometer, charged particle detectors and a transmitter were installed on it. The latter was used both for telemetry transmissions and for trajectory measurements so that the characteristics of the gravitational field of the moon could be determined by the disturbances of the satellite orbit. The lunar car (Figure 16) weighed 211 kg, the load capacity was $\sim$ 400 kg, the length was 3.2 meters, the width was 2.1 meters, height 1.1 meter, distance between axles 2.3 meters, wheel gauge 1.83 meters, clearance 0.36 meters. The travel capacity was 65 km and maximum speed 13 km/hr. The turning radius was 6 meters. The lunar car was designed to take slopes up to 20° and surmount obstalces up to 0.3 meters high, cracks up to 0.7 meters wide. Each of the four wheels (0.8 meters in diameter) was a drive wheel and had an individual electric motor in the hub (0.25 horsepower) fed by chemical batteries. The front and rear wheels had independent steering.

The "Saturn V" (AS-510) booster rocket was used to launch the spacecraft. It was subjected to some modification (improvement of the jets of the liquid, fuel rocket engine of the first stage, and so on), which made it possible to decrease the launching weight by 40 tons in spite of the heavier payload. The "Apollo XV" spacecraft (weighing 46.26 tons) was the improved model J and had the following principal differences from the series H spacecraft: increased oxygen, hydrogen and electric power reserves in the command module which increased the overall reserves of the module from 10.7 to 14 days; the presence of the SIM No 1 set; increased oxygen, water and electric power reserves in the LM, which increased its total reserves from 49.5 hours to more than 70 hours; increased fuel capacity of the LM in connection with increasing its weight and to insure the possibility of longer horizontal maneuvers when landing to search for a suitable site; increased specific impulse of the engine of the landing stage of the LM as a result of enlarging the nozzle expansion stage (lengthening the nozzle tip); the presence of the lunar car.

The launch took place on 26 July 1971 at the calculated time of 1334 hours. The last stage with the transport ship was inserted into a geocentric orbit with a perigee of 168.0 km and an apogee of 169.9 km (the calculated orbit was circular 167 km high). The second launch and rearrangement of the compartment took place normally. On the "earth-moon" route, suspicion of failure of the sustainer valves arose, but a check showed that they were in working order, and a failure had occurred in the indicator. On 29 July the ship was inserted into the initial selenocentric orbit (108 x 314 km), and after 4 hours it transferred to lower orbit (14.5 x 109 km) where the LM was separated. On 29 July, the last stage of the booster rocket was dropped on the moon 80 km from the calculated point; on 30 July the LM with astronauts Scott and Irwin separated from the command module 26 minutes late, for the plug in the docking module was poorly connected, and Worden had to go into the transfer tunnel and manually fasten the plug. After separation Worden transferred the command module to the "rendezvous orbit" (100 x 121 km). The LM landed on 30 July at 2216.30 hours approximately 450 meters from the calculated point (26°04'54" north latitude and 3°39'30" east longitude).

Two hours after landing Scott opened the upper hatch of the LM and, emerging from it, examined and photographed the surrounding terrain from a height of 7 meters. The first walk on the lunar surface was on 31 July and lasted 6 hours 32 minutes. The astronauts completed the trip to the edge of Hadley Rille and on the return, installed all of the ALSEP No 4 instruments except the instruments for measuring thermal fluxes. The front wheel steering of the lunar car turned out not to be working, but the astronauts made all the turns using the rear wheel steering. The second walk was made on 1 August and lasted 7 hours 14 minutes. Before the beginning of the trip on the lunar car, the front wheel steering was fixed by instructions from the earth.

The path followed on the trip to the Mount Hadley Delta was shortened so that the astronauts had time to drill two holes for instruments and a third hole to take a core sample. The first two holes could only be drilled to 1.5 meters (instead of 3 meters), and the column with the core became stuck. Extraction of it was put off to the third walk. This walk took place on 2 August and lasted 4 hours 50 minutes. It was to be shortened in order to leave more time to prepare for the launch from the moon. Extraction of the column with the core from the ground took so much time that the trip to the "northern complex" had to be given up, and the astronauts were again dispatched by moon car to Hadley Rille. The total time for the three walks was 18 hours 36 minutes; the total distance traveled on the moon car was 27.2 km (9 km on the first walk, 12.5 km on the second and 5.7 on the third); in all the astronauts gathered 77 kg of lunar soil samples. Almost all of the missions were accomplished except the examination of the "northern complex" area. The moon car demonstrated high operating characteristics. The modified space suits were convenient for the astronauts, but brief periods of cardiac arrhythmia were observed in Irwin. After being on the moon for 66 hours 55 minutes on 2 August the astronauts took off from the moon, and after 2 hours docked with the command module. The used takeoff stage of the LM was dropped on the moon. The vibrat ions caused by the drop were recorded for almost an hour by the seismometers. The separation of the stage from the command module was delayed by one orbit, for a signal came that the hatches were not sealed. The hatches were opened and closed again. A test demonstrated a complete seal. Apparently, a foreign body had gotten into one of the hatches earlier. The command module stayed in selenocentric orbit for two more days, and the astronauts surveyed and sounded the moon using the SIM No 1 instruments. The cameras covered 12% of the surface area altogether, and the instruments sounded 20% of the area. Up to 20% of the photographs of the topographic camera were unsatisfactory as a result of failures in the image shift compensation device. Soon after beginning the survey, the laser altimeter failed. On 4 August the TV camera left on the moon was switched on. After 14 minutes of normal operation it failed. The astronomical observations by this camera had to be given up. On the 74th selenocentric orbit of the command module, an automatic satellite was separated from it which was inserted into orbit with a periselenium of 100 km and an aposelenium of 141 km. On 4 August, on the 75th orbit after being in selenocentric orbit for 145 hours 16 minutes, the command module was transferred to the flight trajectory to the earth. On 5 August, when the command module was 315,000 km from the earth, Worden took a walk in open space and transferred the film holders from the two SIM No 1 cameras to the crew compartment. All of the operations took 18 minutes (60 minutes according to the program). The crew compartment landed in the water on 7 August at 2046 hours at a point with the coordinates of 26°04' north latitude and 158°04'30" west longitude 8.8 km from the calculated point. During the landing one of the three parachutes collapsed, and the crew compartment landed in the water on two parachutes. The landing speed was 9.7 m/sec; there was a 16 g load (when landing on three parachutes these figures would be 3.5 m/sec and 8 to 10 g load respectively). The flight lasted 295 hours 12 minutes. The instruments left by the astronauts on the moon operated normally. The readaptation took 5 days for Worden, 9 days for Scott and 13 days for Irwin whereas no more than 50 hours were required for the astronauts of the preceding spacecraft. This is obviously explained by the highly saturated work schedule of the "Apollo XV" crew and the potassium loss.

Non-Soviet spacecraft launched in 1971

Item No.	Satellite name	Booster rocket	Date of launch	Satellite wt, kg.	Parameters of initial orbit			Initial orbital period, min
					Perigee, km	Apogee, km	Incli- nation	
1	Secret	"Titan IIIB"	21.01	--	138	418	110.86°	90.09
2	INTELSAT-4A[1]	"Atlas-Centaur"	26.01	1387	35791	36338	0.55°	1450.8
3	NATO-III	"Torad-Delta"	2.02	243	34429	35834	2.8°	1403.4
4	"Tansei"	"Mi-4S	16.02	63	985	1102	29.66°	105.95
5	Secret			-	763	832	98.83°	100.86
6	Secret			-	768	832	98.83°	100.90
7	Secret	"Thor-Doerner-2"	17.02	-	768	832	98.83°	100.90
8	Secret			-	768	832	98.83°	100.90
9	"China II"	?	3.03	221	269	1831	69.90°	106.18
10	"Explorer XLIII" (IMP)	"Torad-Delta"	13.03	288	352	205000	28.8°	99 hrs. 16.1 min
11	Secret[2]	"Titan-IIIB"	21.03	-	386	33800	63.19°	596.7
12	Secret	"Torad-Agena D"	24.03	-	156	246	81.52°	88.56
13	ISIS-II	"Thor-Delta	1.04	264	1360	1482	88.15°	113.67
14	"Turnesol" (D-IIA)	"Diaman-B"	15.04	96	457	697	46.37°	96.16
15	Secret	"Titan IIIB"	22.04	-	132	401	110.93°	89.85
16	"San Marco III"	"Scout"	24.04	164	222	718	3.23°	93.82
17	Secret	"Titan IIIC"	5.05	-	148(295)	332(35790)	28.7° (26.36°)	89.15 (630.95)
18	Secret[4]	"Torad-Agena D"	8.06	-	545	581	90.22°	95.90
19	Secret	"Titan IIID	15.06	-	183	299	96.41	89.38
20	"Explorer XLIV"(SR)	"Scout"	8.07	118	433	633	51.06°	95.23
21	Secret	"Torad-Agena D"	16.07	-	488	509	75.0°	94.59
22	OV-I-20			70	134	1960	92.00°	106.16
23	"Cannon Ball II"			400	134	1973	92.01°	106.29
24	"Musket Ball"			61	137	884	87.61°	94.87
25	Without name (inflated balloon of mylar film)	"Atlas F"		0.9	779	916	87.63°	101.90
26	Without name (inflated balloon of evaporating film on wire grid	(launch according to STP program)	7.08	4.1	779	916	87.63°	101.90

Non-Soviet spacecraft launched in 1971 (continued)

Item No.	Satellite name	Booster rocket	Date of launch	Satellite wt., kg.	Parameters of initial orbit			Initial orbital period, min
					Perigee, km	Apogee, km	Incli- nation	
27	Without name (inflated balloon of evaporating film of wire grid	"Atlas F" (launch according to STP program)		6.3	779	916	87.63°	101.90
28	Without name (hollow aluminum ball)		7.08	1.8	790	914	87.62°	102.00
29	Without name (hollow magnesium ball)			34	790	914	87.62°	102.00
30	Secret	"Titan IIIB"	12.08	-	137	423	111.00°	90.13
31	Eole	"Scout"	16.08	84	678	904	50.16°	100.62
32	Secret	"Torad-Agena D"	10.09	-	156	245	74.95°	88.48
33	Secret			-	492	507	75.07°	94.60
34	"Shinsei"	"Mi-4S"	28.09	65	869	1765	32.06°	112.92
35	OSO-VII	"Torad-Delta"		635	323	571	33.13°	93.40
36	TTS-III		29.09	20	398	571	33.09°	94.17
37	Secret	"Tor-Berner 2"	14.10	-	797	877	98.96°	101.68
38	"Astex" (by STP program)	"Torad-Agena D"	17.10	-	772	803	92.72°	100.65
39	Secret	"Titan IIIB"	23.10	-	134	415	110.94°	90.02
40	"Prospero"	"Black Arrow"	28.10	66	547	1582	82.06°	106.53
41	DSCS-I[1]		3.11	500	35067	36467	2.70°	1435.2
42	DSCS-II[1]	"Titan IIIC"		500	35341	36467	2.28°	1438.0
43	"Explorer XLV" (SSS)	"Scout"	15.11	52	233	26908	3.58°	466.85
44	"Ariel IV"	"Scout"	11.12	100	476	594	82.99°	95.35
45	Secret	"Torad-Agena D"	14.12	-	985	999	70.0°	104.93
46	INTELSAT-4B[1]	"Atlas-Centaur"	20.12	1387	35775	35790	0.30°	1436.1

[See notes on following page]

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[Notes to table on preceding pages]

1) The parameters of the final orbit close to stationary are indicated.
2) According to unofficial reports, this is a satellite for radiotechnical reconnaissance.
3) According to unofficial reports this is an IMEWS satellite (according to other data, two IMEWS satellites) weighing 0.7-0.9 tons for early detection of rocket launches, recording of nuclear blasts and the performance of other missions of a military nature. The values and the parentheses indicate parameters of the transfer orbits in which the target was left. It was not successfully inserted in the calculated orbit close to stationary. (For information on the preceding launch of the IMEWS satellite see YEZHEGODNIK BSE, 1971, page 509, Table No 33).
4) According to unofficial reports, this is the first LASP (Low Altitude Surveillance Platform) photographic reconnaissance satellite weighing approximately 10 tons.

FOOTNOTES

1. Interplanetary Monitoring Platform--platform for studying interplanetary space.

2. Solar Radiation.

3. Small Scientific Spacecraft.

4. Defense Satellite Communication System.

5. Space Technology Program.

6. Astex (Advanced Satellite Technology Experiment).

7. Scientific Instrument Module.

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SOVIET SPACE RESEARCH IN 1972

Moscow YEZHEGODNIK BOL'SHOY SOVETSKOY ENTSIKLOPEDII in Russian No 17, 1973 pp 522-529

[Article by L. Lebedev]

[Text] In 1972 automatic stations were launched to study the moon and Venus. Launchings of artificial earth satellites for scientific and applied purposes continued, and a comprehensive program for studying the planet Mars with the "Mars-2" and "Mars-3" automatic stations (which were put into circumplanetary orbits in 1971) was completed.

On 14-25 February the earth-moon-earth flight of the "Luna-20" automatic station (AS) took place. Samples of lunar soil were transported to earth; they had been taken from the remote bedrock region of the moon for the first time.

Structurally the "Luna-20" AS (Fig 1) is the same as the "Luna-16" AS (see YEZHEGODNIK BSE 1971, pp 493-494) and consists of a landing stage (LS) with a soil-intake device (SID), on which the "Luna-Zemlya" rocket with a recoverable apparatus (RA) is installed. The "Luna-20" flight configuration was similar to that of "Luna-16." A multistage rocket with the "Luna-20" automatic station was launched on 14 February at 0620 hours.

The station was launched towards the moon from an intermediate orbit as an artificial earth satellite. So that the AS would reach circumlunar space in the assigned region, the flight trajectory was corrected on 15 February. On 18 February, as a result of deceleration, the station was inserted into a circular selenocentric orbit with altitude 100 km, inclination 65°, and orbital period 1 hour 58 minutes. On 19 February the station was transferred to an elliptical orbit with aposelene 100 km and periselene 21 km.

To land the "Luna-20" automatic station in the calculated region of the moon on 21 February, the main retrorocket engine was engaged at 2213 hours.

Within 267 s the engine was disengaged, and the station executed a free fall to an altitude of 760 m. From then on, the station descended in a controlled descent mode, during which the thrust of the main engine was altered with the automatic control system. From an altitude of 20 m from the lunar surface, the low-thrust engines effected deceleration. At 2219 hours on 21 February "Luna-20" soft landed on the lunar surface at a point with selenographic coordinates lat. 3°32' N and long. 56°33' E. The station's landing site was located on a region of lunar bedrock that adjoins the northeast end of the Sea of Fertility. After the station had landed, the on-board systems were checked, and the position of the station on the lunar surface was determined. A telephotometric device took images of the lunar surface which were then used in the selection of the site for taking samples of lunar rock. Then, at the command from earth, operations to collect soil were started. The SID drilled the lunar ground and collected rock samples. Due to the increased resistance of the surface, drilling was done in several stages, with intermittent stops of the drilling device. The samples that were taken with the operator were placed in a container on the rocket and hermetically sealed.

The "Luna-Zemlya" rocket was launched at the command of the onboard program-time device on 23 February at 0158 hours. On 25 February on the final segment of the flight back to earth, the RA was separated from the rocket. After aerodynamic deceleration had occurred in the dense layers of the earth's atmosphere, the parachute system was put into operation and at 2212 hours the "Luna-20" RA (Figure 2) soft landed in the calculated area 40 km northwest of Dzhezkazgan. The lunar soil delivered to earth was taken to the USSR Academy of Sciences for analysis.

On the whole the soil or regolith collected by "Luna-20" (Figure 3) is a loose material of different grain size, light gray in color, considerably lighter than the regolity from the Sea of Fertility. As compared to the soil collected by "Luna-16" it consists of noticeably fewer fused particles. As in the case of the soil from the Sea of Fertility, that from the bedrock region of the moon has a high capability for electrification. The bulk weight of the soil is 1.1-1.2 g/cm^3. It is easily compressed to 1.7-1.8 g/cm^3. According to the data of granulometric analysis, the mean particle size is ~ 70-80 μm. There are more large particles over 1 mm in size in it than in the soil collected by "Luna-16." The lighter shade of the "Luna-20" regolith is confirmed by a study of the albedo. The value of the albedo is higher than in the samples brought by "Luna-16," "Apollo 11," and "Apollo 12." For the fines the albedo equals 0.083, for the ultraviolet region--0.145, for the visible region--0.200, and for the near infrared--0.260. The maximum reflection occurs at λ=4 μm and equals 0.370.

A microscopic study of the regolith from "Luna-20" revealed a sharp difference between it and the marine regolith from "Luna-16," "Apollo 11," and "Apollo 12." In the regolith there is a dominance of fragments of crystalline rocks and minerals with well preserved edges and chip surfaces.

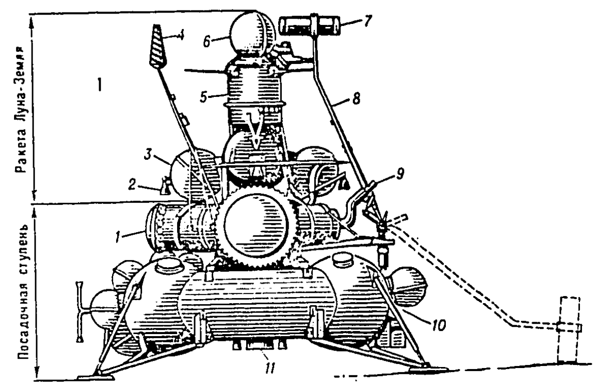


Figure 1. "Luna-20" Automatic Station

Key:
1. Instrument compartment of landing stage
2. Controlling jets
3. Rocket propellant tanks
4. Antenna
5. Instrument compartment of rocket
6. Recoverable apparatus
7. Drilling mechanism
8. Drill rod of drilling mechanism
9. Telephotometer
10. Propellant tank
11. Engine unit of landing stage
a. "Luna-Zemlya" Rocket
b. Landing stage

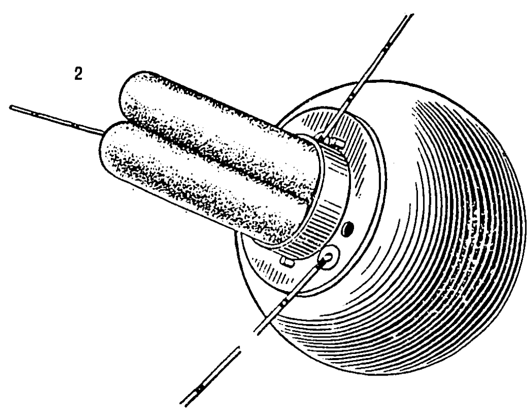


Figure 2. Recoverable Apparatus of "Luna-20" Station

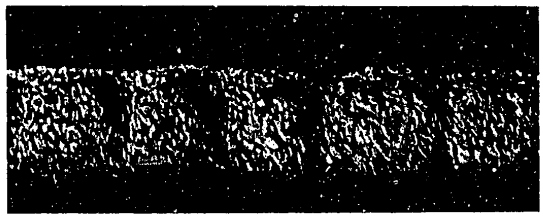


Figure 3. Overall View of Lunar Soil Delivered by the "Luna-20" Station

Few scorified breccia and spheroids, which are characteristic for the regolith of lunar seas, are observed. The main mass of the particles is composed of rocks of the anorthosite type, consisting to a considerable measure of feldspar (plagioclase). In them inclusions of metallic iron of varying shape and are constantly size encountered. Rocks of the basalt type are represented by a few particles of basalt that are completely analogous to the basalts of the lunar seas. In the fines of regolith (<80μ) from "Luna-20" the main component is anorthosite--50-60 percent. In the marine regolith usually about 1-2 percent of anorthosite is found.

Data on the content of the main components of the substances (in percent) brought by "Luna-20" are given in the table (for comparison, information from "Luna-16" is given).

	Crystalline rock		Regolith	
Component	Basalt "Luna-16"	Anorthosite "Luna-20"	"Luna-16"	"Luna-20"
SiO_2	42.95	42.4	41.9	44.4
Al_2O_3	13.88	20.2	15.33	22.9
FeO	20.17	6.4	16.66	7.03
MgO	6.05	12.0	8.78	9.7
CaO	10.8	18.6	12.53	15.2
TiO_2	5.5	0.38	3.36	0.56
Na_2O	0.23	0.4	0.34	0.55
K_2O	0.16	0.52	0.1	0.1

On 27 March at 0715 hours the "Venera-8" automatic interplanetary station (AIS) (Figure 4) was launched to the planet Venus. Like all the previous stations in the "Venera" series, "Venera-8" consisted of an orbital compartment and a descent vehicle. Its overall weight equalled 1184 kg; the weight of the descent vehicle was 495 kg. The "Venera-8" descent vehicle (Figures 5, 6) included significant structural changes due to the fact that the "Venera-7" station had refined the parameter of the Venusian atmosphere at the surface of the planet.

Simplification of the housing design of the descent vehicle made it possible to expand the composition of the scientific instrumentation and to implement measures that would increase the operating time of the apparatus on the Venusian surface. In the instrument compartment, where the scientific instruments, the radio engineering and telemetry systems, power sources, the automatics and thermoregulation units were placed, the necessary thermal pattern was insured by the increased efficiency of the thermal insulating shell and the installation of heat absorbers within the compartment. For transmitting scientific data to earth, a new antenna system consisting of two antennas was used: a corkscrew rigidly fastened in the upper part of the descent vehicle and an extension that could be pushed out of the parachute compartment after the vehicle had landed. The use of these two antennas guarantees reliable radio communication of the descent vehicle with earth, since due to the irregularity of the relief at the landing site, one of the antennas can prove to be disoriented with respect to earth. Markers with a bas-relief of V. I. Lenin and the state emblem of the USSR were installed on the "Venera-8" descent vehicle.

The "Venera-18" automatic station was at first inserted into an intermediate orbit as an artificial earth satellite. At 0842 hours it was launched from the earth orbit to a trajectory towards Venus. The engines of the final stage operated for 243 s and provided the station with a velocity of 11.5 km/s. The station's trajectory was corrected on 6 April in order to insure that the descent vehicle would land at the calculated time and site on the Venusian surface. During the interplanetary flight, 86 communications sessions were held with the "Venera-8" station; and the station was controlled, the condition of the onboard systems was checked, the trajectory parameters were measured and scientific studies on the physical processes occurring in outer space were conducted during those sessions. As the station flew in space around the planet and in its upper atmosphere, radiation levels and the density of hydrogen and deuterium were measured.

On 22 July, having travelled a distance of over 300 million km during the 117-day flight, "Venera-8" reached the vicinity of the planet Venus. At 1040 hours, upon entering the planet's atmosphere, the descent vehicle was released from the station. The velocity of the vehicle was reduced by aerodynamic deceleration from 1 .6 km/s to 250 m/s, after which the parachute system was put into operation. When the parachute had opened, transmission of scientific and service data began. The descent of the lander lasted for about an hour, and at 1229 hours it made a soft landing on the surface of Venus. It was the first time that a space vehicle had been landed on the illuminated side of the planet.

The program of experiments implemented with the scientific equipment installed on board the descent vehicle provided for: measuring atmospheric temperature and pressure on the diurnal side of Venus, measuring the intensity of illumination in the atmosphere and at the planet's surface, determining the content of ammonia gas in the atmosphere, calculating wind velocity at various levels of the atmosphere, measuring G-forces during aerodynamic deceleration, and defining the physical characteristics of the surface layer and the nature of surface rocks at the landing site.

Direct measurements of temperature and pressure were made with a system of gauges as the vehicle descended to the surface from an altitude of about 55 km and after it had landed. During the descent, the altitude over the planet's surface was measured by an onboard altimeter. No noticeable differences were found in the high-altitude and pressure profiles on the day and night sides of Venus, thus confirming the theoretical estimates of these characteristics. At the landing site of the "Venera-8" descent vehicle, the atmospheric temperature was 470 ± 8°C, and pressure was 90 ± 1.5 kg/cm^2; both values are very close to those obtained during experiments by the "Venera-7" descent vehicle which had landed on the night side of the planet (see YEZHEGODNIK BSE 1971, p 500).

Data obtained during the entire descent of the lander on illumination intensity in the atmosphere indicate that only a small part of solar radiation reaches the surface of the planet. The intensity of illumination at the landing site with the sun at an angle of 5.5 was within 100-300 lux. If the sun is at its zenith, then the intensity of illumination is not less than 1000-3000 lux. The intensity of illumination alters rather significantly from day to night.

Scientists had advanced the hypothesis that the Venusian clouds could contain compounds containing ammonia gas. For this reason, a gas analyzer was installed in the "Venera-8" descent vehicle. The instruments operates on the principle that the color of a chemical reagent will change when it is affected by ammonia gas. As a result of measurements made at altitudes of about 46 and 33 km, it was established that the volumetric content of ammonia gas is within the limits of 0.01-0.1 percent.

Measurements of wind velocity in the atmosphere indicated that at an altitude of 50 km, it equals 50-60 m/s; below 10-12 km it is about 2 m/s. Measurements indicate the presence of a latitudinal wind blowing from the terminator to the diurnal side, i.e. in the direction of the natural rotation of the planet.

Analysis of the level of radio waves emitted from the descent vehicle and reflected from the surface as the vehicle descended made it possible to evaluate the dielectric permeability and density of the ground. The measurements make it possible to conclude that in the area around the landing site the surface layer of the planet is fairly loose, with a soil density of 1.4 g/cm^3. A gamma spectrometer was installed on the lander in order to define the nature of the rocks constituting the Venusian surface layer. Analysis of the gamma radiation spectra recorded while the lander operated on the planetary surface made it possible to determine amounts of potassium, uranium and thorium in the surface layer. The soil at the landing site contains 4 percent potassium, 0.0002 percent uranium and 0.00065 percent thorium and is similar to the earth's granite rocks with respect to the content of radioactive elements and their ratio.

Eleven scientific experiments were conducted on board the artificial Mars satellites--"Mars-2" and "Mars-3" (see YEZHEGODNIK BSE 1972, p 517, 518). Seven of them were related to an investigation of the planet itself, three--to measurements of the parameters of the interplanetary medium, and one, which was performed jointly with French scientists--to study solar radio emission. Almost all the instruments of the station were oriented such that when it passed the periares they "looked at" the planet. The Martian surface was scanned by the instruments for roughly 30 min. Here the axes of the instruments intersected the planet along approximately half of a large circle. The infrared radiometer that received radiation of the planet in the remote section of the infrared range in wavelengths of 8-40 μm measured the temperature of the surface along the flight path. The paths began in the Southern Hemisphere, where the end of the Martian summer was approaching during the studied period, then intersected the equator and ended in the Northern Hemisphere. The starting points of the paths occurred in the regions where it was still morning, and the ending points--in the afternoon, evening and sometimes even night hours. The temperature along the route was therefore altered in broad limits: from +13°C (for lat. 11° S at 1400 hours local solar time) to -93°C (lat. 19° N at 1900 hours local solar time). In the region of the northern polar cap the temperature dropped below -110°. The difference measured between the temperature of the seas and the continents is about 10° near the local noon and can be explained by the difference in albedo.

4

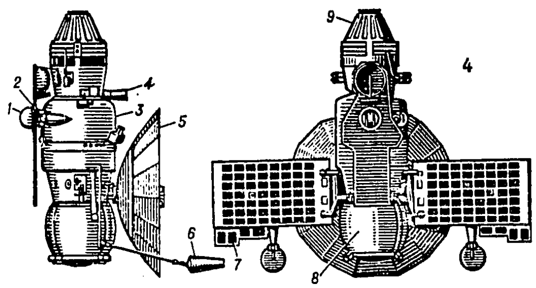
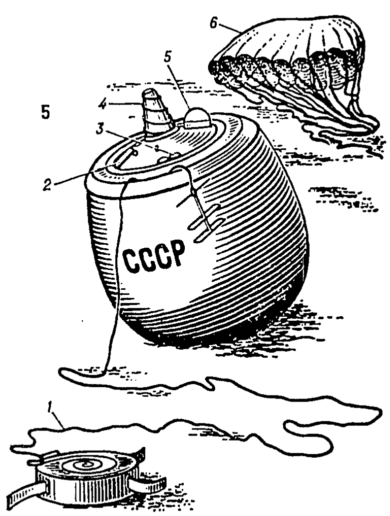


Figure 4. Automatic Interplanetary Station "Venera-8"

Key:
- 1,2,4. Celestial orientation system sensors
- 3. Instrument compartment
- 5. High-directional parabolic antenna
- 6. Low-directional antenna
- 7. Solar panels
- 8. Releasable apparatus
- 9. Correcting engine unit

5



Key:
1. Extension antenna (after firing)
2. Atmospheric pressure and temperature gauges
3. Gauges to measure illumination intensity
4. Main antenna
5. Extension antenna (before firing)
6. Parachute (after firing)

Figure 5. Releasable Apparatus of the Station "Venera-8" on the Surface of Venus

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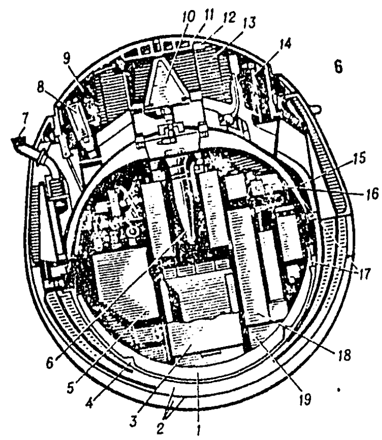


Figure 6. "Venera-8" Descent Vehicle

Key:
1. Damper
2. Outer thermal insulation
3. Radio transmitter
4. Housing of instrument compartment
5. Block of commutation
6. Ventilator
7. Pipeline of thermoregulation system
8. Transmitter antenna (extension)
9. Parachute compartment
10. Transmitter antenna (main)
11. Cover of parachute compartment
12. Pilot parachute
13. Main parachute
14. Antenna of radio altimeter
15. Heat exchanger
16. Heat accumulator
17. Internal thermal insulation
18. Program-time device
19. Heat accumulator

The on-board radio telescope measured the intensity and polarization of radio emission at wavelength 3.5 cm along the same path. It determined the temperature of the soil at depth 30-50 cm. As shown by the results of the measurements, the temperature under the surface at the indicated depth does not undergo diurnal oscillations. In addition to the temperature, the dielectric constant of the soil was measured. The measurements indicate that temperature changes in the soil and changes in the dielectric constant are associated: greater values of the dielectric constant correspond to greater values of temperature in individual areas. This means that the density of the soil changes along the path of measurements. Apparently, when the values of the dielectric constant are great, the soil is granular.

The infrared photometer measured the absorption in the carbon dioxide band with wavelength 2.06 μm. In processing the measurements the equivalent width of the CO^2 absorption band was computed; for this date from the laboratory calibration of the instrument and information on the composition of the Martian atmosphere and its scale of altitudes and temperature were used. The equivalent width makes it possible to compute the pressure at the surface. Differences in the pressure were recalculated into differences in altitudes, and thus the height of mountains and the depth of valleys were estimated. At the average level the pressure on Mars was taken as equal to 6 mbar.

The path outlined by the station "Mars-3" on 16 February 1972 passed through the southern end of Hellospontus, the northeast edge of Hellas, the dark regions of Lapigia and Syrtis Major, through Meroe, and in the region of Umbra encompassed the edge of the northern polar cap. The highest region was Syrtis Major (about 3.5 km), the lowest--outskirts of Hellas (-1 km) and the region to the north of Syrtis Major (from 0 to +1 km).

When the "Mars-2 and "Mars-3" stations went into orbit around Mars, a dust storm raged over the planet. During December the surface of Mars was covered with a dust storm; in January the dust settled; and the measurements made in the beginning of February indicated the complete disappearance of all phenomena associated with it. The measurements made by infrared photometer in December indicated that the altitude of the dust clouds was about 10 km over the mean level of the surface. Over higher regions the layer of clouds was thinner, and over the lower--thicker. Analysis of data of the scientific measurements of the "Mars" stations indicates that the mean radius of the dust particles is about 1 μm. Such particles must settle very slowly, which agrees with the total duration of the dust storm. On the other hand, photographs from the American apparatus "Mariner-9" made at the end of December show a significant increase in the transparency of the Martian atmosphere for 10 days. This can be explained by the presence in the dust clouds of a certain fraction of rapidly settling particles of comparatively large size--about 10 μm. With a photometer for studying the brightness distributions over the planet in the range 0.36 to 0.7 μm, clouds that were visible in blue beams (λ=0.36 μm) and not noticeable in red beams (λ=0.7 μm) were observed many times. Such clouds must consist of particles much smaller than a micron in size. For the most part, during the dust storm, there were particles of different sizes, and the ratio of one to another changed with time. The atmosphere of Mars and its cloud layer during the storm were, on the whole, less transparent for solar rather than planetary radiation. A considerable part of the solar energy is captured by the atmosphere and its temperature increased while the temperature of the surface drops as compared to normal conditions. Apparently, dust also plays a significant role in the thermal pattern of the atmosphere when conditions of transparency are normal. The important role of dust in the thermal pattern of the Martian atmosphere had been noted previously, but only the observations made during an actual dust storm could confirm the assumed phenomenon.

The narrow-band infrared photometer on the 1.38 μm water vapor absorption band showed that the amount of water vapor for the entire research period did not exceed 5 μm of precipitated water--a thousand times less than in the earth's atmosphere. This amount is smaller by an order than that previously found from a number of ground observations. It is possible that the reduction in moisture content is related to the season. It coincided with the dust storm, but it is not clear whether this coincidence was accidental. It is important that, as yet, no strong local fluctuations in the H_2O content in the atmosphere, "oases" of increased water content, have been found. Only relatively gradual changes in water content along the path if one does not consider the jumps in the northern polar cap area.

The ultraviolet photometer recorded the solar radiation dispersed by hydrogen and oxygen atoms in the upper atmosphere of Mars at altitudes from a hundred to tens of thousands of kilometers. As the station passed the periares, the instrument was pointed to the "horizon" of the planet, i.e. tangential to the surface of Mars. It recorded the radiation of atomic oxygen in three closely-arranged lines with wavelength 1300 Å, and radiation of atomic hydrogen with wavelength 1216 Å. According to observations of intensity in these lines, the density and temperature of the scattering atoms were computed. Near the surface, the Martian atmosphere consists mainly of carbon dioxide; however, at an altitude of around 100 km, it is broken down under the influence of solar ultraviolet radiation into a carbon monoxide molecule and an oxygen atom. The same breakdown process in water vapor results in the appearance of hydrogen atoms, which are 16 times lighter than oxygen atoms. Because of this, the Martian atmosphere above 300-400 km consists mainly of atomic hydrogen. Nevertheless, traces of oxygen are noted to an altitude of 700-800 km, where its concentration equals 100 atoms per 1 cm^3. The density of hydrogen drops very slowly, decreasing from 10,000 atoms per 1 cm^3 near the planet to 100 and even fewer atoms at an altitude of 10,000 km. At altitudes from 100 to 200 km, the temperature of the upper atmosphere rises, and at higher altitudes it becomes constant. The upper atmosphere of Mars is more like that of Venus than of earth. Apparently, this is associated with the fact that carbon dioxide predominates in the atmospheres of both Mars and Venus.

The study of the Martian inosophere was based on an analysis of signals from centimeter-range radio transmitters when the stations went behind the horizon of the planet or emerged from behind it. The ionosphere is "pressed" to the surface: the maximum electron density is located at an altitude of 140 km (in the earth's ionosphere, at 300 km). At an altitude of about 110 km, the second maximum is observed, and the electron concentration there is approximately three times lower. Also placed on board the stations was a complex made of three instruments designed to study the magnetic field and charged particles near the planet Mars. With a ferromagnetic probe the magnetic fie: near the planet was measured. Changes in the magnetic field that were eight times greater than the level of the interplanetary background were found. According to all three components of the magnetometer, the intensity of the field rose as it approached Mars.

It is possible that Mars has its own magnetic field of a dipole nature. According to measurements taken with electron traps on the "Mars-3" station, as the satellite approaches the planet, there is a rise in the stream of electrons and the electron temperature near the periares. At the same time, a section with hot electron gas far from the periares at a distance of 180,000-200,000 km from the planet was recorded. The charged particle spectrometer that records ions of the solar wind in the range of energies not greater than 10 kev indicated the presence of a zone of thermal ions near Mars. The shape of the outer boundary of this zone and the amount of the jump in velocity of the stream in the solar wind make it possible to propose the presence of a shock wave in the interaction of the solar wind with the upper atmosphere of Mars.

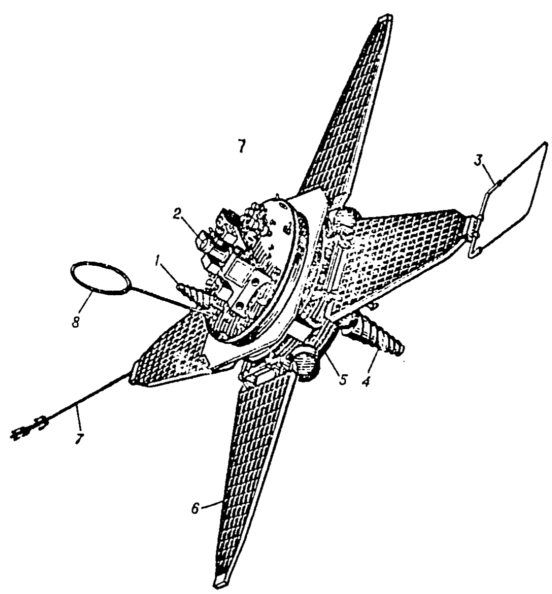
In the group of experiments conducted on the "Mars-2" and "Mars-3" satellites, an auxiliary role was given to photographing the planet. However, the photographs taken from "Mars-3" at great distances make it possible to pinpoint the compression of the planet, construct profiles of the relief of the planet and obtain color images of the Mars disk with different light filters. In the photographs were found important crepuscular phenomena, in particular, atmospheric luminescence approximately 200 km beyond the line of the terminator and a change in the color of the surface near the terminator. On some photographs the stratified structure of the Martian atmosphere can be traced.

On 14 April at 0354 hours the "Prognoz" automatic station was launched to study the activity of solar processes and the effect of these processes on the interplanetary medium and on the earth's magnetosphere. The station was put into the calculated orbit in two stages. First of all, the station together with a booster were inserted into an intermediate orbit as an artificial earth satellite. Additional velocity provided by the booster engine put the station into the prescribed orbit. In accordance with the scientific aspects of the flight program, the initial orbit was oriented with the apogee towards the sun.

Structurally the "Prognoz" automatic station (Figure 7) is a hermetically sealed container of cylindrical shape and covered on both sides with spherical endplates. Platforms to secure instrumentation are installed within the container. Scientific and telemetry equipment as well as the components of the solar orientation system that guarantees the temperature regimen and power supply are arranged on the platform. The hermetically-sealed container is filled with inert gas.

Arranged on the outer surface of the cylindrical part of the container are sensors and blocks of scientific apparatus, the actuating elements for the solar orientation system, cylinders with nitrogen and four solar panels. The magnetometer probe and the coil antenna for receiving radio radiation of magnetospheric and interplanetary plasma are installed on two of the solar panels. The gauges for the scientific apparatus and the solar orientation system and the antennas for the radio complex as well as the telemetry and scientific equipment are fastened to the endplates from the outside. The surface of the container where the instruments are installed is covered with screen-vacuum thermal insulation. The gauge sensors and the lateral surface of the container serving as the radiator of the thermoregulation system remain open. After separating from the booster, the "Prognoz" station weighs 845 kg.

The onboard radio telemetry complex works jointly with ground units to control the on-board systems, measure trajectory parameters and obtain scientific and telemetry information. During the flight the scientific data and information on the operation of the station's onboard systems are recorded in a special storage unit of the radio telemetry complex. Then the recorded information is transmitted to earth. For the normal functioning of the scientific equipment and the solar battery, it is necessary for the longitudinal axis of the station to be directed toward the sun. This is made possible by the solar orientation system and the gyroscopic stabilization system. The required temperature regimen in the instrument container is maintained by the thermoregulation system. Passive methods are also used to maintain the necessary temperature of individual components of the station. The necessary power supply for the station's instrumentation and systems is provided by a solar battery and a chemical current source.



Key:
1. Low-directional antenna of radio complex
2. Solar orientation sensor
3. Antenna of receiver of long-wave radio emitter
4. Low-directional antenna of radio complex
5. Instrument container
6. Solar panel
7. Probe of magnetometer
8. Antenna of receiver of low-frequency electromagnetic radiation

Figure 7. "Prognoz" Automatic Station

Four groups of instruments have been placed on board the satellite. The first group includes instruments to measure electromagnetic radiation of the sun emitted simultaneously with solar flares. The second group of instruments is designed to measure solar cosmic rays and high energy particles within and beyond the earth's magnetosphere. This group of instruments includes: a spectrometer to measure the streams of protons with energies of 1-35 mev and alpha particles and heavy nuclei of various energies; a Cerenkov counter to measure streams of electrons with energies of 40,000-140,000 ev; and a scintillation spectrometer to measure streams of protons with energies of 30,000-210,000 ev. The third group comprises instruments for recording solar wind plasma beyond the limits of the earth's magnetosphere, in the transitional zone between the front of the shock wave and the boundary of the magnetosphere, as well as within the magnetosphere. The fourth group of instruments includes receivers of radio emissions in the 1.6-8 kHz and 100-700 kHz region, a magnetometer, instruments to determine the spatial orientation of the station and equipment to measure the dose of penetrating radiation on the flight path.

The "Prognoz-2" automatic station was launched on 29 June. Like the "Prognoz" station, it was inserted into the prescribed trajectory from an intermediate orbit as an artificial earth satellite. The scientific equipment installed on board was designed to study the corpuscular, x-ray and gamma radiations of the sun, streams of solar plasma and their interactions with the earth's magnetosphere and magnetic fields in near-earth space. French apparatus for conducting experiments to study characteristics of the solar wind, the outer regions of the magnetosphere and solar gamma radiation and to search for neutrons of solar origin was also installed on the station.

On 7 April, in accordance with the program of cooperation of socialist countries in the field of space research and utilization for peaceful purposes, the "Intercosmos" satellite was launched. The satellite was designed to study the particles of primary cosmic radiation with energies of 10^{12}-10^{13} ev, the chemical composition and energy spectrum of high energy cosmic rays and meteor particles in near-earth space. Installed on board the satellite in order to conduct the scientific studies were a photoemulsion unit, a device to record meteoric substances and a multichannel telemetry system for instrument control. The photoemulsion unit with ionization calorimeter was made in the USSR on the technical assignment developed by specialists of the Hungarian People's Republic, the Polish People's Republic, the Mongolian People's Republic, the Socialist Republic of Romania, the CSSR and the USSR; the apparatus for recording meteor particles was developed and manufactured jointly by the USSR, the CSSR and the Hungarian People's Republic. The use of nuclear photoemulsion to record particles of cosmic radiation also determined various features of the flight--the satellite's orbit and its duration. The flight lasted four days. This period of time was sufficient for conducting the planned experiments whereas a longer flight could have led to a darkening of the photoemulsion and to a loss of part of the scientific data.

The "Intercosmos-7" satellite (Figure 9) was launched on 30 June to continue the studies of x-ray and ultraviolet radiation of the sun and their effects on the structure of the earth's upper atmosphere that were begun during the flights of "Intercosmos-1" and Intercosmos-4." The satellite's scientific equipment was developed and manufactured by specialists of the GDR, the USSR and the CSSR. During the flight of "Intercosmos-7," ground observatories of the socialist countries conducted radioastronomical, ionospheric and optical observations in accordance with the jointly-adopted program.

On 1 December the "Intercosmos-8" artificial earth satellite (Figure 10) was launched. The satellite was designed to continue studies of the earth's ionosphere, including the concentration of electrons and positively-charged ions near the satellite, the temperature of the electrons and their integral concentration between the satellite and the earth's surface. A recording was also made of the streams of electrons with energies over 40 kev as well as of protons with energies over 1 mev. The following scientific equipment was installed on board the satellite: an electronic unit for the ion traps and the Langmuir probe which was developed and manufactured by specialists of the People's Republic of Bulgaria; a "Mayak" radio transmitter and a corresponding device developed and manufactured in the GDR to record the readings of the Langmuir probe on the satellite's storage unit; an electronic unit for the high-frequency sounder developed and manufactured by specialists of the CSSR; and the sensors for instruments to measure the parameters of the ionosphere and semiconductor and gas-discharge counters of high energy electrons and protons--developed and manufactured in the USSR. Simultaneously with the "Intercosmos-8" missions a broad network of ground geophysical observatories and ionospheric stations conducted ionospheric studies and received signals from the satellite's radio transmitter.

On 4 April a Soviet rocket booster launched two satellites: the Soviet "Molniya-1" communications satellite and the French "MAS" small autonomous satellite. "Molniya-1" was designed to insure the operation of the system of long-distance telephone and telegraph communication as well as the transmission of programs of Central Television to points in the "Orbita" network located in the extreme North, the Far East, Siberia and Central Asia. The French "MAS" satellite belongs to a series created by the CNES for technological research. The first satellite in this series was also called "Solar Batteries" since its mission was to study the behavior of thin-layer solar battery components exposed to cosmic radiation and sharp temperature changes. The "MAS" satellite (Figure 8) is 56.2 cm high and weighs 15.4 kg. The body of the satellite is shaped like an octagon. Electronic equipment is placed inside of it. Two types of solar batteries were tested on the satellite: sulfur-cadmium and tellurium-cadmium. The "MAS" satellite was calculated to function for one year in orbit.

8

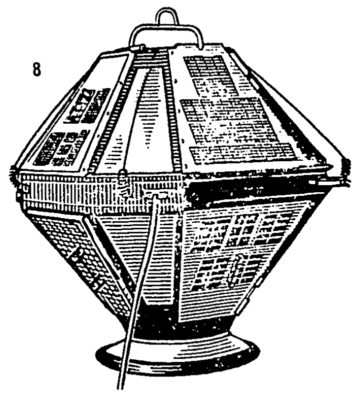


Figure 8. French Small Autonomous Satellite (MAS) before Launching

9

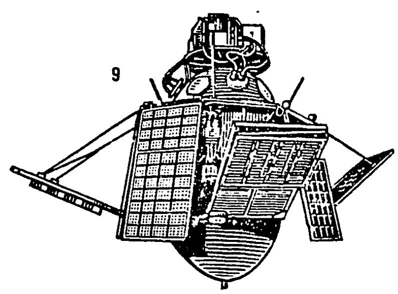


Figure 9. "Intercosmos-7" Artificial Earth Satellite

10

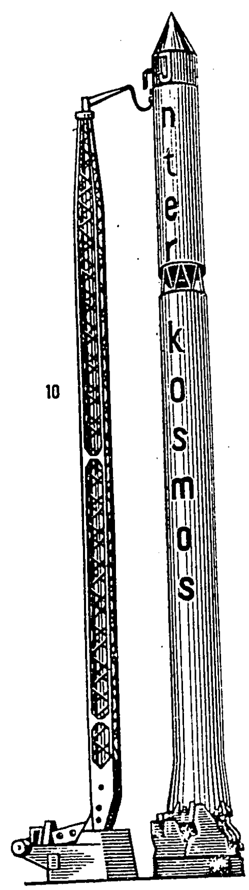


Figure 10. Rocket Launcher with the "Intercosmos-8" Artificial Earth Satellite

Soviet spacecraft launched in 1972

Item No.	Launch date	Name of spacecraft	Apogee, (km)	Perigee, (km)	Orbital Inclination	Orbital period (min)	Frequency of radio transmissions (megahertz) Remarks
1	2	3	4	5	6	7	8
1	12 Jan	Cosmos-471	323	202	65°	89.5	
2	25 Jan	Cosmos-472	1568	207	82°	102.4	
3	3 Feb	Cosmos-473	333	209	65°	89.7	19.995
4	14 Feb	Luna-20	-	-	-	-	Made soft landing on moon 21 Feb. Returned to earth 25 Feb
5	16 Feb	Cosmos-474	347	207	65°	89.8	
6	25 Feb	Cosmos-475	1013	977	74°	105	
7	1 Mar	Cosmos-476	651	618	81.2°	97.2	
8	4 Mar	Cosmos-477	328	212	72.9°	89.6	
9	15 Mar	Cosmos-478	319	213	65.4°	89.5	
10	22 Mar	Cosmos-479	549	517	74°	95.2	
11	25 Mar	Cosmos-480	1212	1183	83°	109.2	
12	25 Mar	Cosmos-481	540	279	71°	92.4	928.4
13	27 Mar	Venera-8	-	-	-	-	
14	30 Mar	Meteor	903	878	81.2°	102.6	
15	31 Mar	Cosmos-482	9813	210	52°	201.4	
16	3 Apr	Cosmos-483	345	212	72.9°	89.9	
17	4 Apr	Molniya-1	39260	480	65.6°	11h,45m	The satellites "Molniya-1" and "MAS" were launched by one rocket booster
18	4 Apr	French MAS	39260	480	65.6°	11h,45m	
19	6 Apr	Cosmos-484	236	203	81.3°	88.8	19.995
20	7 Apr	Intercosmos-6	256	203	51.8°	89.0	
21	11 Apr	Cosmos-485	506	280	71°	92.1	

Soviet spacecraft launched in 1972 (continued)

1	2	3	4	5	6	7	8
22	14 Apr	Prognoz	200000	950	65°	97 h	928.4
23	14 Apr	Cosmos-486	267	214	81.4°	89.1	
24	21 Apr	Cosmos-487	531	278	71°	92.3	
25	5 May	Cosmos-488	319	211	65.4°	89.5	
26	6 May	Cosmos-489	1010	980	74°	105	
27	17 May	Cosmos-490	310	212	65.4°	89.4	19.995
28	19 May	Molniya-2	39300	460	65.5°	11h,45m	
29	25 May	Cosmos-491	303	210	65°	89.5	
30	9 Jun	Cosmos-492	341	209	65°	89.8	
31	21 Jun	Cosmos-493	308	213	65°	100.8	
32	23 Jun	Cosmos-494	829	791	74°	89.3	
33	23 Jun	Cosmos-495	298	206	65.4°	89.6	20,008
34	26 Jun	Cosmos-496	342	195	51.6°	97 h	
35	29 Jun	Prognoz-2	200000	550	65°	92.6	
36	30 Jun	Intercosmos-7	568	267	48.4°	92.6	
37	30 Jun	Cosmos-497	812	282	71°	95.2	
38	30 Jun	Meteor	929	897	81.2°	103	
39	30 Jun	Cosmos-498	511	282	71°	92.1	
40	6 Jul	Cosmos-499	283	209	51.8°	89.2	
41	10 Jul	Cosmos-500	554	509	74°	95.2	
42	12 Jul	Cosmos-501	2149	222	48.5°	108.8	
43	13 Jul	Cosmos-502	284	206	65.4°	89.2	
44	19 Jul	Cosmos-503	304	208	65.4°	89.4	
45	20 Jul	Cosmos-504-511	1540	1425	74°	115.2	Eight AES were put into orbit by one rocket booster 19.995
46	28 Jul	Cosmos-512	294	207	65.4°	89.3	
47	2 Aug	Cosmos-513	340	209	65°	89.8	
48	16 Aug	Cosmos-514	999	959	83°	104.4	

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Soviet spacecraft launched in 1972 (continued)

1	2	3	4	5	6	7	8
49	18 Aug	Cosmos-515	300	205	72.9°	89.3	
50	21 Aug	Cosmos-516	277	256	65°	89.6	
51	30 Aug	Cosmos-517	305	207	65°	89.4	19.995
52	15 Sep	Cosmos-518	330	208	72.9°	89.6	19.995
53	16 Sep	Cosmos-519	343	210	71.3°	89.8	
54	19 Sep	Cosmos-520	39319	652	62.8°	710	
55	29 Sep	Cosmos-521	1030	973	65.8°	105	
56	30 Sep	Molniya-2	39200	480	65.3°	11h,45m	
57	4 Oct	Cosmos-522	342	214	72.9°	89.3	
58	5 Oct	Cosmos-523	507	283	71°	92	
59	[illegible] Oct	Cosmos-524	537	277	71°	92.3	
60	14 Oct	Molniya-1	39300	480	65.3°	11h,45m	19.995
61	18 Oct	Cosmos-525	292	208	65.4°	89.3	
62	25 Oct	Cosmos-526	511	282	71°	92	
63	27 Oct	Meteor	904	893	81.2°	102.6	
64	31 Oct	Cosmos-527	330	214	65.4°	89.7	
65	1 Nov	Cosmos-528-535	1495	1375	74°	114	Eight AES were put into orbit by one rocket booster
66	3 Nov	Cosmos-536	555	514	74°	95.2	
67	25 Nov	Cosmos-537	324	207	65°	89.6	19.995
68	1 Dec	Intercosmos-8	679	214	71°	93.2	
69	2 Dec	Molniya-1	39100	500	65°	11h,45m	
70	12 Dec	Molniya-2	39300	470	65.3°	11h,45m	
71	14 Dec	Cosmos-538	305	212	65.4°	89.4	
72	21 Dec	Cosmos-539	1392	1353	74°	113	
73	26 Dec	Cosmos-540	823	779	74°	100.8	
74	27 Dec	Cosmos-541	371	242	81.4°	90.3	
75	28 Dec	Cosmos-542	653	554	81.2°	96.4	

Three "Molniya-1" and three "Molniya-2" satellites were launched during 1972 to insure the operation of long-distance telephone and telegraph communication as well as the transmission of programs of Central Television to points in the "Orbita" network.

In 1972 three "Meteor" satellites were launched. The mission of these satellites was to obtain meteorological data necessary for use in the operational weather service.

Rocket sounding of the atmosphere was continued throughout the year and 71 "Cosmos" satellites were launched.

NON-SOVIET SPACE RESEARCH IN 1972

Moscow YEZHEGODNIK BOL'SHOY SOVETSKOY ENTSIKLOPEDII in Russian No 17, 1973 pp 529-541

[Article by D. Gol'dovskiy: "Launchings of Foreign Spacecraft in 1972"]

Artificial Earth Satellites (AES)

In 1972 33 AES were launched abroad, including 25 American (3--"Explorer" series, one--OAO, one--ERTS, one--"Nimbus," one--NOAA, one--"Triad," one--"R dcat," one "R dsat," one--"Oscar," and 14 secret military satellites), one Japanese ("Demna"), one Canadian ("Anik 1"), one FRG ("Aeros"), three of the West German organization ESRO ("Chaos 2," TD-1A, ESRO-4), and two of the international consortium INTELSAT (INTELSAT-4C and INTELSAT-4D). The satellites "Anik 1," "Aeros," "Chaos 2," TD-1A, ESRO-4, INTELSAT-4C and INTELSAT-4D were put into orbit by American rocket boosters.

Basic information about the orbits of the AES listed is in the Table. Below a description of some of them is given.

"Explorer 46" (Table, No 15). This is the first American satellite of the MTS[1] type to study the efficiency of meteor screens as well as to record meteor particles and measure their velocity. The satellite weighs 175 kg and is 3.2 m long. Twelve meteor screens 3.2 x 0.48 m in size have been mounted on four panels that open up in space. The span of the panels when opened is 7 m. The screens are in two-layers. Each consists of an outer sheet of stainless steel 25 μ thick and an inner sheet 50 μ thick. The gap between the sheets is 12.7 mm. Under each screen there are 8 detectors of meteor penetrations: when there is a penetration, the cell of the detector is depressurized. It is planned to use such screens on manned spacecraft. As a consequence of an error made during assembly, only two of the four panels with the meteor screens opened up in orbit, which did not permit the research program to be completely fulfilled.

"Explorer 47" (Table, No 20). This is the next American research satellite of the IMP[2] type (IMP-H, Figure 1) designed to study cosmic rays of solar and galactic origin, plasma and magnetic and electrical fields. The main task was to investigate the interaction of the solar wind with the tail of the earth's magnetosphere and to obtain data for forecasting solar activity. In addition, tests were conducted on the satellite on samples of various types of heat-protective coatings and experimental solar cells as well as a new fast-response telemetry system linked with the on-board data processing unit. The satellite weighs 390 kg (the heaviest satellite in the "Explorer" series). Its housing is in the shape of a rectilinear 16-sided prism (height 1.58 m, transverse dimension 1.36 m). Attached to the housing are eight collapsible-whip telemetry antennas, two 1.2 m rods with micro-engines operating on freon-14 and providing the assigned orientation of the axis of rotation (the satellite is stabilized in orbit by 45 rpm rotation), a 3 m rod with a magnetometer and a similar rod with an antenna for measuring the electrical field. The satellite is equipped with an on-board SPRE (solid-propellant rocket engine) to transfer the satellite from an intermediate elliptical orbit to an orbit that is close to circular with an altitude of over 200,000 km such that half of each revolution is located in the tail of the earth's magnetosphere while the second half lies beyond its limits. Thirteen scientific instruments were installed to study cosmic rays of solar and galactic origin, to determine the composition and energy spectrum of low energy particles emitted during solar flares, to study x-ray radiation during flares and the acceleration and modulation of particles under the influence of the sun, to analyze the ion content of the solar wind and its link to the temperature and composition of the solar corona, to investigate various characteristics of plasma in interplanetary space, transitional regions and the tail of the earth's magnetosphere, and to register protons, electrons, alpha-particles and positrons. The satellite was calculated to function for one year.

For the previous satellites of the IMP type see YEZHEGODNIK BSE 1968, p 518 and 1970, p 502.

"Explorer 48" (Table, No 28). This is the next in the series of American SAS[3] research satellites (SAS-B, Figure 2) designed to record 20-300 Mev gamma radiation and, in particular, to search for discrete sources of this kind of radiation, brief gamma bursts from supernovas and gamma pulses from pulsars that are analogous to their x-ray emissions. The satellite weighs 186 kg. The body is 1.3 m high, the maximum diameter is 0.55 m and the solar panels measure 4 m. The satellite includes a block of service equipment standard for SAS satellites (see YEZHEGODNIK BSE 1971, p 507, "Explorer-42" or SAS-A) as well as a block of scientific equipment where the gamma-telescope is placed on a 32-level base of spark chambers. This instrument insures localization of galactic and extragalactic gamma radiation sources accurate to 1.5°. The satellite was calculated to function for one year.

OAO-3 (Table, No 17). This is the next in the series of American OAO research satellites (OAO-C, Figure 3) designed for astronomical observations. After it was inserted into orbit, it was named "Copernicus." It weighs 2220 kg. The body is in the shape of a rectilinear octagonal prism (height 3 m, transverse dimension 1 m). The body and certain service systems are standard for the OAO satellites (see YEZHEGODNIK BSE 1967, p 505, 506 and 1969, p 505).

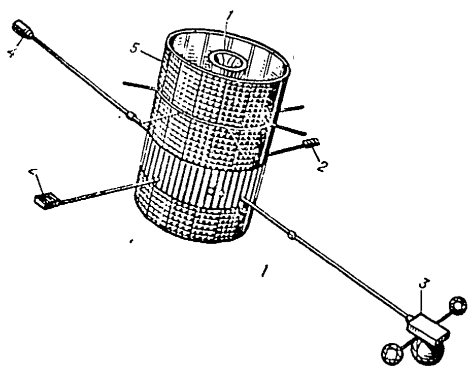

Figure 1. "Explorer 47" (IMP-H)

Key:
1. On-board SPRE
2. Block of microengines
3. Antenna of one of the scientific instruments
4. Magnetometer
5. Solar cells on body of satellite

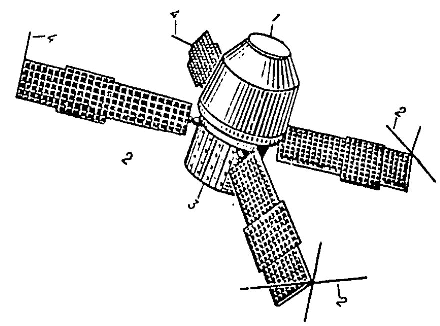

Figure 2. "Explorer 48" (SAS-B)

Key:
1. Block of scientific apparatus
2. Telemetry system antenna
3. Block of service apparatus
4. Command system antenna

Two panels with 52,000 solar cells are attached to the body. There are also nickel-cadmium storage batteries. The command radio line uses the meter range, while telemetry from on-board is transmitted on the narrow-band line of the meter range (136.260 MHz, 2 w) and the wide-band line of the decimeter range (400, 500 MHz, 10 w). The transmitter for the trajectory measurement system operates in the meter range (136.44 MHz, 0.16 w). The orientation and stabilization system (for tracking of the selected celestial object) makes use of an inertial measurement unit, velocity gyroscopes, a position gauge, sun sensors, four star sensors installed on the lateral surface of the body and an FES[5] star sensor.

The actuating elements of this system are microengines and flywheels (there is a magnetic system for discharging the flywheels). Homing on the selected astronomical target is rated accurate to 0.1 angular seconds. Those directing the program have claimed that an accuracy of 0.03 angular seconds has been reached. The deflection of the gyroscope is 2 angular seconds per hour--less than in all the previously made satellites. The thermoregulation system uses louvers, electrical heaters, circular heat pipes and thermal insulation.

The main instrument for the astronomical observations from the satellite is an ultraviolet telescope-reflector which is linked to a spectrometer. The diameter of the primary mirror, which is made of melted silicon dioxide, is 81.3 cm; it weighs 47.6 kg. The aperture is sufficient for recording ultraviolet radiation of stars of type O and B having the seventh stellar magnitude in the visible region of the spectrum. The effective focal distance of the optical system is 16 m. With the correct orientation of the telescope, one half of the light stream focused on the input slit of the spectrometer (dimensions for the slit are 24 x 3000 or 96 X 3000 μ) falls on it while the second half is deviated by the turned flaps of the slit to the FES sensor, which uses four photomultipliers.

The space between the body of the ultraviolet telescope and the body of the satellite is divided into eight compartments by partitions. The service equipment is located in five of them and x-ray telescopes developed in England are in the other three. They record radiation in the ranges 8-9 Å, 8-18 Å, and 20-60 Å, respectively, and make it possible to determine the sources of x-ray radiation accurate to 20-60 angular seconds. Observations with these instruments takes 10 times less time than those with the ultraviolet telescope. The satellite is calculated to function for one year.

ERTS-1 (Table, No 14). This is the first American ERTS[6] satellite (ERTS-A, Figure 4), which is designed to study the earth's natural resources. The main tasks of the satellite are: 1) to determine the nature and volume of information on natural resources and the environment that can be provided by automatic satellites; 2) to develop on-board and ground equipment for the collection, processing and analysis of satellite information on natural resources; 3) to obtain information for practical use in such areas as geology, ecology, agriculture and forestry, land use, oceanology, meteorology and hydrology, etc.; to relay information from "measuring platforms" (automatic meteorological stations, oceanographic buoys, sounding balloons, etc.)

The satellite weighs 891 kg, including the 235 kg payload; it is 3 m high, and the solar panels span 3.36 m. The satellite, which was created on the basis of the experimental "Nimbus" meteorological satellites (see YEZHEGODNIK BSE 1970, p 501), consists of a block of equipment for the orientation system and a block of scientific equipment which are connected by a framework. Solar cells provide 512 w of power.

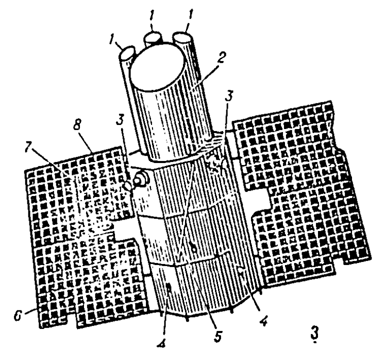

Figure 3. OAO-3 (OAO-C, "Copernicus")

Key:
1. Lens hoods of x-ray telescopes
2. Lens hood of ultraviolet telescope
3. Star sensor on body of satellite
4. Orientation system microengines
5. Balancing rod
6. Auxiliary solar panel
7. Meter range slit antenna
8. Main solar panel

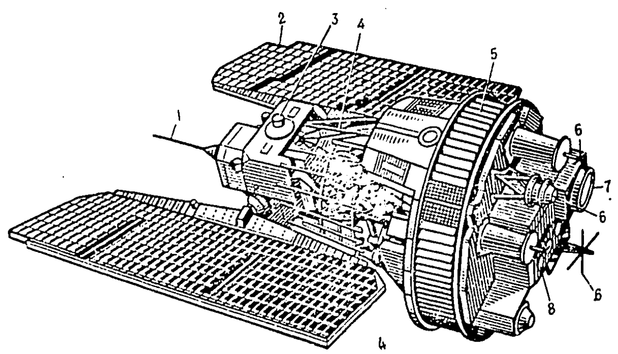

Figure 4. ERTS-1 (ERTS-A)

Key:
1. Command antenna
2. Solar panel
3. Block of equipment for orientation system
4. Truss structural part
5. Block of scientific equipment
6. Antennas
7. MSS camera
8. Set of RBV cameras

The triaxial orientation system (accurate to 0.7°) uses infrared sensors of the earth's horizon and gyroscopes and, as actuating elements, microengines that operate on freon and flywheels. The orbital correction system employs microengines with 0.5 kg thrust, each operating on the products of hydrazine breakdown. The thermoregulation system, which uses louvers, electrical heaters, radiators, multilayer thermal insulation, coatings, etc., guarantees a temperature of 20±10°C in the hermetically-sealed compartments. Commands to the satellite are transmitted on frequencies of 2106.4 and 154.2 MHz while telemetry from on board is transmitted on frequencies of 2287.5 and 137.86 MHz. Installed on the satellite are a set of three frame RBV[7] television cameras, an MSS[8] multichannel optico-mechanical scanning television camera and two video recorders. The RBV cameras photograph in the ranges 0.475-0.575, 0.580-0.680 and 0.690-0.830μ (the visible and near-infrared regions of the spectrum), and the visual angle of each camera is 15.9°. Photographing from a nominal altitude of 910 km, a frame covers an area of the earth's surface 185 X 185 km; resolution is 50 m; and the geodetic linking of the photographs after primary processing is accurate to approximately 1 km, and after the second processing--to better than 90 m. The MSS camera operates in the ranges 0.5-0.6, 0.6-0.7, 0.7-0.8 and 0.8-1.1μ (the visual and infrared regions of the spectrum); the visual angle is 11.5°. From a nominal altitude, a band 185 km wide is scanned and the resolution is 70 m. Geodetic linking of the photographs after primary processing is accurate to approximately 1 km, and after the second processing--to better than 230 m. Each video recorder can record images from the RBV camera (bandwidth of 3.2 MHz) and from the MSS camera (1.5 X 10^7 bits/s) continuously for 30 minutes. The satellite was calculated to function for one year.

Soon after the satellite had been launched, a malfunction in the electrical system made it necessary to disengage the RBV camera and one of the video recorders. However, American specialists have claimed that the information obtained from the MSS camera is of exceptional importance and demonstrates the highly-effective use of automatic satellites for the study of natural resources. In the beginning of 1973, the second video recorder also broke down and from then on, information from the MSS camera could only be received in real time.

For processing the information from the ERTS satellites, a special DPF[9] center that can process 1316 images per day has been set up. The center is equipped with a Xerox "Sigma-3" computer. All of the data is subject to primary processing, but only 5 percent of it undergoes secondary processing. In the first months that the ERTS satellite operated, the DPF center did not succeed in processing the data as scheduled, and there were, as a result, great delays in distributing the processed information to consumers.

The satellite is in a solar synchronous orbit, which makes it possible to repeatedly photograph the same areas of the earth with the sun at the same angle of elevation. The orbital period was selected such that the satellite passes over the same region of the earth every 18 days, i.e. during the one year the satellite is expected to function, the same region can be photographed 20 times (if there is no cloud cover).

"Nimbus-5" (Table, No 30). This is the next in the series of American experimental "Nimbus" meteorological satellites (Nimbus E, Figure 5). It weighs 717 kg. In its design and service equipment, it is like the previous "Nimbus" satellites (see YEZHEGODNIK BSE 1970, p 501). The scientific equipment includes a microwave (19.35 gHz) ESMR probe to record cloudiness, precipitation, ice and vegetation cover and water vapor content in the atmosphere; a five-channel NEMS microwave probe to record the vertical profile of atmospheric temperature and moisture; a three-channel SCMR radiometer for high-resolution mapping the earth's surface in the infra-red range in the interests of geology, hydrology, oceanology, meteorology and agriculture (the instrument insures, in particular, the differentiation of dry land and water as well as surfaces covered with or devoid of vegetation as indicated by the reflected radiation of chlorophyll); a TTPR radiometer to record the vertical temperature profile in sections covered only partially by clouds; a sixteen-channel SCR radiometer to record the vertical temperature profile of the atmosphere from the tops of the clouds to an altitude of 50 km; and a THIR radiometer to record the distribution of clouds and water vapor. The instruments listed, with the exception of the last two, are being used for the first time. The SCR and THIR radiometers were installed on the "Nimbus-4" satellite (see YEZHEGODNIK BSE 1970, p 501). The SCMR radiometer malfunctioned within 3.5 weeks after the satellite was launched.

NOAA-2 (Table, No 24). This is the next in the series of American NOAA (ITOS-D)[10] operational meteorological satellites. The Satellite (Figure 6) weighs 345 kg. The body is in the shape of a parallelepiped (1 x 1 x 1.2 m). The solar cells on three panels provide 500 w of power. In its design and service equipment, the satellite is like the previous ITOS satellites (see YEZHEGODNIK BSE 1971, pp 503, 504, 507). The satellite is equipped with an SR scanning radiometer to obtain images of cloud cover in the visible and infrared ranges of the spectrum (resolution 3.6 and 6.4 km, respectively), a two-channel VHRR radiometer for the same purpose (resolution 0.8-0.9 km), and eight-channel VTPR radiometer to obtain the vertical atmospheric temperature profile from the earth's surface to an altitude of 32 km, and an instrument for recording the proton content of solar radiation. The SR radiometer had been used on the NOAA-1 (ITOS-A) whereas the VHRR and VTPR radiometers are being used for the first time. NOAA-2 is the first operational meteorological satellite to be equipped solely with radiometers rather than with television cameras as well. The "Oscar-6" satellite was launched together with the NOAA-2 satellite by a single rocket booster.

"Oscar-6" (Table, No 25). This is the next "Oscar" relay satellite for use by radio amateurs. It weighs 18.6 kg. The on-board relay equipment operates on frequencies of 145.95 MHz (reception) and 29.5 MHz (transmission). The width of the band is 100 kHz. See YEZHEGODNIK BSE 1966, p 496 and 1971, p 505 for information on the previous "Oscar" satellites. The "Oscar-6" satellite was launched together with NOAA-2 by a single rocket booster.

"Triad-1" (Table, No 19). This is the first American experimental navigational satellite designed to test the autonomous system of compensating for orbital disturbances. It was made on the basis of the "Transit" operational navigational satellite (see YEZHEGODNIK BSE 1964, p 499, 500, 502). It weighs 94 kg. It consists of three units (one in the middle and one at each end) which are connected by rods that open up in orbit. The total length of the satellite when fully extended is 7.3 m. One of the end units contains the satellite's navigational equipment and the other contains the 37 w radio-isotope power unit; the middle unit houses the "Discus" gauge for the orbital compensation system. The gauge is a container in which a 2.5 cm platinum-gold ball moves freely. Disturbances in the satellite's orbit which are produced by the pressure of solar rays and aerodynamic deceleration, alter the relative position of the ball and the walls of the container; this is then recorded by electronic instruments that supply commands to the microengines compensating for the disturbances. Experiments using the "Triad-1" satellite were to be completed in 1973 after the freon used in the microengines had been exhausted. Transmitters on board "Triad-1" operated on frequencies of 150 and 400 MHz, which are standard for the "Transit" satellites. If the orbital compensation system proves effective, then the operation of the navigational system by military and civilian consumers will be significantly simplified and reduced in cost.

"Radcat"[11] (Table, No 21). This is the next satellite designed to adjust radars. It weighs 208 kg. The body is cylindrical (length 12 m, diameter 3 m). The satellite is calculated to function for 5 years. The "Radsat" satellite was launched together with this satellite by a single rocket booster.

"Radsat"[12] (Table, No 22). This is the next in the series of OV[13]-1 research satellites (see YEZHEGODNIK BSE 1969, p 504 and 1970 p 501) launched by the United States Air Force under the STP program (see YEZHEGODNIK BSE 1972, p 521, 524). The satellite weighs 725 kg. It is stabilized by rotation. Solar cells provide the power supply for the onboard equipment. Instruments have been installed on the satellite to study background gamma-radiation, ultraviolet radiation (170-800 Å) and the flow and spectral characteristics of charged particles, and samples of various types of thermal-protective coatings were mounted on the satellite for testing in the radiation belt. The satellite is calculated to function for one year.

Secret satellites of the United States Air Force. No official information about the names and tasks of the secret satellites is published. According to unofficial information secret satellites of the following types were put into orbit in 1972:

1. Two satellites for surveillance and photographic reconnaissance (Table, No 9 and 10). They weigh ~ 2 t. Solar cells mounted on large panels provide power supply. The orientation system is triaxial. The resolution of the photographic cameras is 0.6-2.4 m. On board there are means for developing the exposed film and transmitting the images to earth on a radio channel. The satellites can operate for 3-4 weeks.

2. Three satellites for detailed photographic reconnaissance (Table, No 7, 18 and 33). They weigh ~ 3 t. The orientation system is triaxial. The resolution of the photographic cameras is better than 0.6 m. The exposed film is returned to earth in special containers intercepted during parachute descent by airplanes equipped with trawl nets for this purpose. The satellite functions for 10-20 days.

3. Three "Big Bird"[14] satellites ("Big Bird-2, -3 and -4") for surveillance and detailed photographic reconnaissance (Table, No 1, 12 and 23) were launched under the 467 program. These satellites weigh 11.3 m and are ~ 15 m long. Solar cells and chemical batteries provide the power supply. The orientation system is triaxial. It is possible that they have a large antenna (diameter of reflector to 6 m) that can open up in space. Means for orbital correction to compensate for aerodynamic deceleration are provided for. The satellites are equipped with photographic cameras and possibly also means for photographing the earth in infrared and radars for lateral scanning. The resolution of some of photographic cameras is twice as good as the cameras on satellites for detailed photographic reconnaissance. For purposes of surveillance reconnaissance there are means on board for developing film and transmitting the images to earth on a radio channel. For the purpose of detailed reconnaissance there are several containers to return the exposed film to earth. The satellite's are calculated to function up to 3-4 months. "Big Bird 4" has operated the longest--for 91 days.

4. One IMEWS[15] satellite (IMEWS-3, Table, No 5) designed to detect launchings of strategic rockets from ground launching installations and from submarines, to record nuclear explosions and to fulfill other tasks of a military nature. These satellites (Figure 7) are being launched under the 647 program. They weigh over 0-8 t. The body is cylindrical (length ~ 7 m, diameter ~ 3 m) with solar panels that span ~ 7 m. The triaxial orientation system and the orbital correction system use sun and star sensors, and as actuating elements--microengines operating on the products of hydrazine breakdown and flywheels. The satellite is equipped with infrared (3-5 μ) detectors that use a telescope with aperture 0.9 m and a television camera as well as radiation detectors to detect nuclear explosions. The satellite is calculated to function for 18 months.

5. One BMEWS[16]-1 satellite (BMEWS-1/C, Table, No 32) designed to test equipment guaranteeing the detection of strategic rocket launchings. According to certain reports, these satellites are used in addition to the satellites IMEWS in the operational system to detect such launchings.

The BMEWS-1 satellites are being launched under the 949 program. They weigh 680 kg, including the 330 kg on-board engine to transfer the satellite for an intermediate to a synchronous orbit. The body is 1.5 m in diameter. The orientation system is triaxial. Supposedly, detectors of infrared and x-ray radiations as well as television cameras are being installed on the satellites.

6. Two meteorological prereconnaissance satellites (Table, No 8 and 26) designed to record the presence or absence of clouds in the regions subject to photographing by surveillance and detailed photographic reconnaissance satellites. The meteorological prereconnaissance satellites launched under the 417 program have been created on the basis of the "Tiros" civil meteorological satellites (see YEZHEGODNIK BSE 1966, p 494). They weigh ~ 150 kg.

There is no information on the purpose of two small secret satellites (Table, No 2 and 13) launched as additional payloads together with the "Big Bird-2 and -3" satellites. Supposedly they are shaped like an octagonal prism 0.3 m high with transverse dimension 0.9 m.

"Dempa"[17] (Table, No 16). This is the Japanese research satellite (Figure 8) to study plasma, electromagnetic waves and geomagnetism. It weighs 75 kg. The body is in the shape of a polyhedral prism (height and transverse dimension 0.7 m). Solar cells are installed on the body. In orbit the satellite is stabilized by rotation. As a consequence of the wind drift of the rocket booster the satellite went into an uncalculated orbit (perigee calculated orbit 700 km, apogee 2600 km). The satellite was expected to function for three months, but transmission of scientific data ceased after three days.

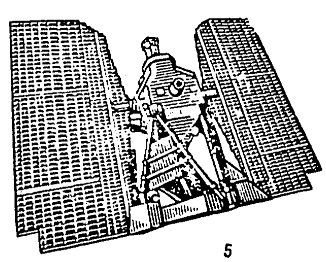

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Figure 5. "Nimbus 5" ("Nimbus-E")

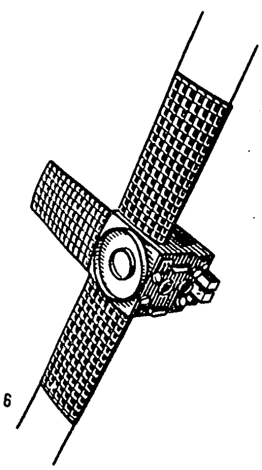

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Figure 6. NOAA-2 (ITOS-D)

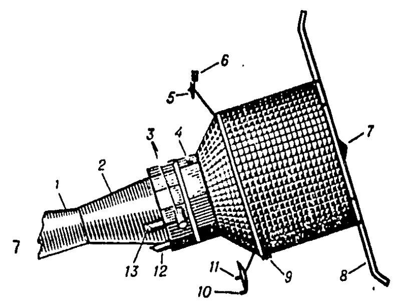


Figure 7. IMEWS

Key:
1. Sun visor of telescope 2
2. Telescope used by infrared sensors
3. Star sensors for orientation system
4. Electronics compartment
5. Antenna used to transmit to earth information from infrared detectors
6. Auxiliary detectors to find nuclear explosions
7. Main detectors to find nuclear explosions
8. Additional solar panels (main panels mounted on lateral surface of satellite body)
9. Block of orientation system engines
10. Command system antenna
11. Antenna to transmit to earth information from television camera
12. Television camera
13. Orientation system sun sensor

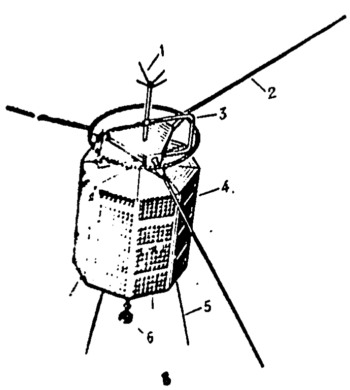
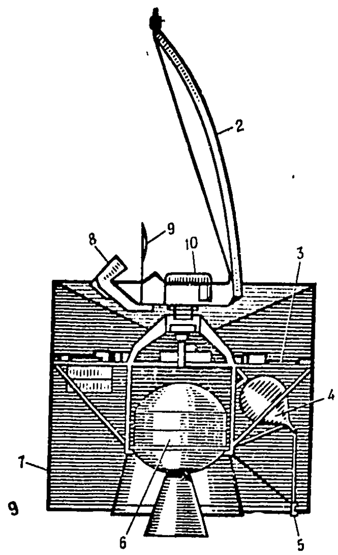


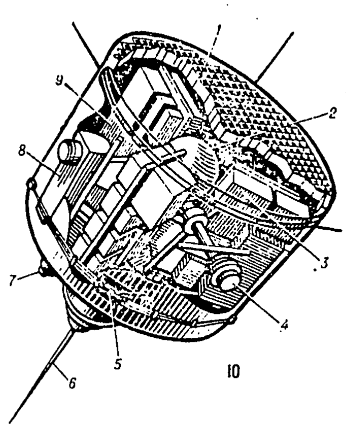
Figure 8. "Dempa" (SS No 2; REXS)

Key:
1. Decimeter-range telemetric antenna
2. Collapsible-whip antenna (2 m long)
3. Coil antenna
4. Solar panel
5. Meter-range command telemetry antenna
6. Instrument extended on rod



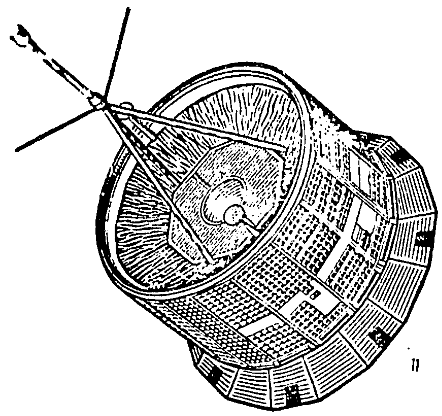
Key:
1. Command-measuring system antenna
2. Relay antenna
3. Shelf to mount electronic equipment
4. Tank with hydrazine for microengines
5. Microengine
6. On-board SPRE to transfer satellite from intermediate to stationary orbit
7. Solar cells on lateral surface of satellite body
8. Horn antenna
9. Auxiliary transmitting antenna
10. Electric motor of anti-rotation antenna block

Figure 9. "Anik 1"



Key:
1. Solar cells
2. Tank with hydrazine
3. Ultraviolet spectrometer
4. Mass spectrometer
5. Device to retard rotation of satellite (weights on cables)
6. Impedance probe
7. Microengine
8. Instrument to record temperature of neutral component of atmosphere
9. Analyzer employing the braking field principle

Figure 10. "Aeros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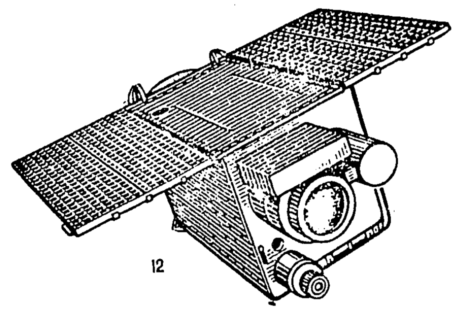
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Figure 11. "Chaos 2" ("Chaos A-2")

Figure 12. TD-1A

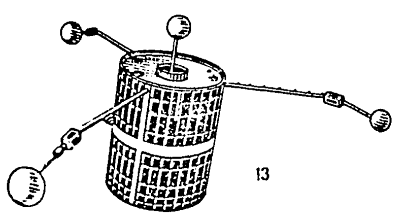
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Figure 13. ESRO-4

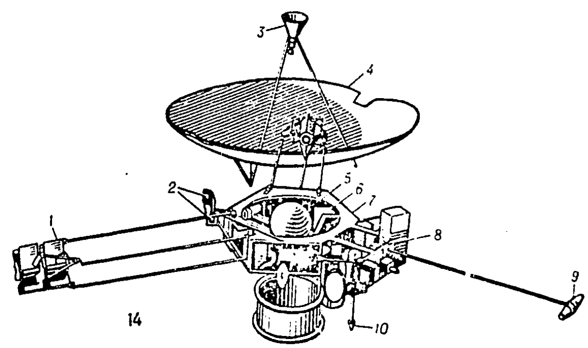

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Figure 14. "Pioneer 10" Automatic Interplanetary Station

Key:
1. Radio-isotope power engineering unit
2. Microengines
3. Horn antenna
4. High-directional antenna reflector
5. Command system equipment
6. Star sensor
7. Large container
8. Small container
9. Magnetometer
10. Conical antenna

"Anik 1"[18] (Table, No 27). This is the first "Anik" communications satellite (Figure 9) for the commercial communications system serving the territory of Canada. It was made in the United States with the participation of Canadian firms. The launch weight of the satellite is 530 kg, and the weight in stationary orbit after burn-off of the propellant of the on-board SPRE is 270 kg. The body is cylindrical (length 3.5 m, diameter 1.8 m). On the lateral surface of the body over 20,000 solar cells have been mounted providing a total of 300 w power. The relay antenna has a reflector 1.5 m in diameter, width of beam pattern 3 x 8°, and effective emitted power 33 db·w. Twelve relay units are installed on the satellite, each of which provides transmission of color television on one channel or radio telephone communication on 960 channels. The width of the band of each television channel is 56 MHz. Communication on the "earth-satellite" line is implemented in the range 5925-6425 MHz, on the line "satellite-earth"--in the range 3700-4200 MHz. In orbit the satellite is stabilized by rotation, and the antenna block is equipped with a mechanical device for counter-rotation. Two sun sensors and two earth horizon sensors are used in the satellite's systems of orientation, rotation and counter-rotation velocity regulation and orbital correction; the actuating elements are microengines operating on the products of hydrazine breakdown. The on-board SPRE which moves the satellite from an intermediate to a stationary orbit has a thrust of 2.5 t and operates for ~ 45 s.

One of the most important tasks of the satellite is to relay television programs and to guarantee communication to remote small populated areas in the northern section of Canada. The ground complex of the communication system should include two main transceiving stations for television, two transceiving stations for radio telephone communication, and 25 television reception stations.

"Aeros" (Table, No 31). This is the satellite of the FRG (Figure 10) for aerodynamic studies. It weighs 127 kg, and the body is cylindrical (length 0.74 m, diameter 0.91 m). On the upper platform solar cells are mounted. In orbit the satellite is stabilized by rotation (10 rpm). The magnetic system provides constant orientation of the axis of rotation to the sun. Two microengines with 1.4 kg thrust each, operating on the products of hydrazine breakdown, are designed to compensate for aerodynamic deceleration: after 4-5 months in orbit these microengines were to increase the satellite's velocity to ~ 80 m/s and return the satellite to the initial orbit in order to guarantee the calculated functioning time (not less than 6 months). The scientific apparatus includes a mass-spectrometer to study the chemical composition of the atmosphere; an analyzer using the braking field principle to measure energy and calculate the ions and electrons in the atmosphere; an impedance probe to measure the electron concentration in the ionosphere; an ultraviolet spectrometer to record solar radiation in the range 155-1062 Å, and an instrument for recording the temperature of the neutral component of the atmosphere. The last instrument was made in the United States, the others in the FRG.

"Chaos-2" (Table, No 4). This is the second in the series of "Chaos" research satellites ("Chaos A-2", Figure 11) designed and built by the West European organization ESRO to study the magnetosophere and the shock wave. It weighs 117 kg, including 30 kg of scientific equipment. The body is in the shape of a 16-sided prism (height 0.75 m, transverse dimension 1.33 m). In its design and service equipment, the satellite is like the "Chaos-1" satellite (see YEZHEGODNIK BSE 1969, p 507). The scientific equipment includes an induction magnetometer, an electrostatic analyzer to record electrons and protons, devices for recording radiation with frequency 20-250 Hz, various types of detectors to record charged particles and an instrument to record meteor particles.

TD^{19}-1A (Table, No 6). This is the research satellite (Figure 12) made by the West European organization ESRO to record galactic and extra-galactic emissions in different regions of the spectrum as well as gamma and x-ray radiation of the sun. It weighs 472 kg, including 145 kg of scientific apparatus. The body, which is 2.1 m high, consists of two rectilinear sections placed one on top of each other; the service equipment is placed in one of them, and scientific equipment is in the other. Solar cells mounted on two panels provide 320 w power. This is the first satellite made by ESRO to have a triaxial orientation system. One of the axes must be directed towards the sun accurate to 0.5 angular minutes. The satellite is rotated on this axis 360° per orbit in order to scan the celestial sphere. The orientation system uses sun sensors, an earth horizon sensor and gyroscopes, and as actuating elements, flywheels and microengines operating on compressed argon are used. The scientific equipment includes two ultraviolet telescopes (ranges 1000-3000 Å and 2000-3000 Å), a spectrometer of primary cosmic ray charged particles and various types of detectors to record x-ray radiation (2-30 kev and 20-700 kev) and gamma radiation (50-500 mev and 70-300 mev).

The satellite was expected to function not less than six months (until November 1972 when the conditions of its illumination intensity would become unfavorable). Within two months after it was launched, both on-board recording devices malfunctioned, and information began to be received in real time only. Although numerous additional stations were connected for reception (a total of almost 40), only half of the research program was fulfilled by November 1972. As a result, it was decided to continue the research until the end of the unfavorable illumination period (November 1972-February 1973) when the satellite enters the earth's shadow for a long time in each revolution and the solar batteries do not provide power supply to the on-board equipment. During this period the scientific instruments were disengaged, and the satellite itself was switched from a triaxial orientation mode to a rotational stabilization mode. Although the satellite was not designed for this, it succeeded. On 16 February 1973 the satellite was returned to a triaxial orientation mode by commands from earth. The scientific equipment was also engaged again. It has been proposed that it will operate for several months more.

ESRO-4 (Table, No 29). This is the research satellite (Figure 13) created by ESRO to study the concentrations of neutral particles and ions in the ionosphere in regions of aurora borealis and particles of solar origin in order to reveal how they penetrate and disperse in the magnetosphere. The satellite weighs 115 kg, including 32 kg of scientific equipment. The body is cylindrical (height 0.9 m, diameter 0.76 m). The solar cells mounted on the lateral surface of the body provide 60 w of power. The satellite is stabilized in orbit by rotation (65-70 rpm) while a magnetic system is used for orienting the axis of rotation. Balls of various diameters are extended on rods located on the axis of rotation and on three rods perpendicular to this axis. Two of them are probes to measure electric potential; the other two serve for balancing. Besides these probes, the scientific equipment includes a mass spectrometer to study the concentration and composition of neutral particles weighing 1-44 atomic units in the F-layer of the ionosphere, electrostatic analyzers to record electrons and protons with energies of 0.15-150 kev, and two telescopes to record protons (0.2-90 and 2-100 Mev) and alpha particles (4-240 and 2.5-360 Mev) of solar origin in the regions of aurora borealis.

For information on the previous ESRO satellites--ESRO-2B (IRIS-1), ESRO-1A ("Aurora") and ESRO-1B ("Boreas")--see YEZHEGODNIK BSE 1969, pp 506-507 and 1970 p 503.

INTELSAT-4C and INTELSAT-4D (Table, No 3 and 11). The third and fourth of the INTELSAT-4 satellites are used in the international global commercial communication system (see YEZHEGODNIK BSE 1972, p 525). They were put into orbit over the Pacific and Indian Oceans, respectively.

Automatic Interplanetary Stations (AIS)

In 1972 the "Mariner-9" AIS continued to function; it is in an orbit around Mars. On 3 March the "Pioneer-10" AIS was launched by the "Atlas-Centaur-Burner 2" rocket booster to study Jupiter from a fly-by trajectory.

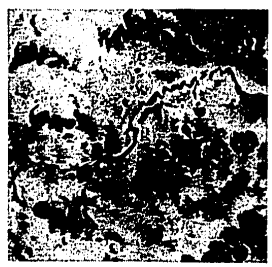
"Mariner-9". The station, which was designed to photograph and sound Mars, was inserted into orbit as an artificial Mars satellite on 14 November 1971 (see YEZHEGODNIK BSE 1972, p 525, 526). The AIS functioned until 27 October 1972 when, due to the consumption of the on-board supply of compressed nitrogen for the orientation system microengines, the on-board equipment was disengaged at a command from earth. The station had operated in an aerocentric orbit for 349 days, completing 697 revolutions in this time. At the moment that operation ceased, the periapsis was 1650 km and the apoapsis was 16,900 km. It is expected that the station will remain in aerocentric orbit for 50-100 years. The station was in full operation for 517 days, from its launching on 30 May 1971 until 27 October 1972. During that time, it fulfilled over 46,000 commands from earth.

The "Mariner 9" station completely fulfilled its assignments. It transmitted to earth 7329 photographs of Mars and its satellites--Deimos and Phobos. The photographs encompassed the entire surface of the planet. Five potential landing sites were selected for "Viking" landers, which are proposed for launching in 1975. As a result of the Martian studies

Photograph of Phobos, satellite of Mars, taken by the "Mariner-9" station

with the help of the AIS "Mariner 9" it was established that this planet is geologically active and has volcanoes and craters that exceed the dimensions of those on earth. Certain signs were found that in the geological history of Mars it is possible there was a period when water streams flowed over its surface. It was found that the changes in the external appearance of the planetary surface observed from earth are produced by dust storms and clouds. In the equatorial region a "fissure" was found several thousand kilometers long. Its depth is 3-4 times greater than the depth of the Grand Canyon in the United States. The minimum surface temperature recorded was -123°C, and the maximum +27°C. The minimum atmospheric pressure at the surface (2.8 mbar) was recorded in the region of the equator, and the maximum (13 mbar) at the poles. In relation to Deimos and Phobos it was established that they are always turned with one side towards Mars. On their surface there are many craters, apparently of impact origin.

"Pioneer 10." The main tasks of the station are to investigate the magnetic field of Jupiter and its radiation belts, to study the thermal balance and distribution of temperature in the external atmosphere of the planet, to obtain images of the planet and some of its satellites, to pinpoint the ephemeris and the mass of the planet, and to study the characteristics of the satellites of Jupiter, especially IO, which, it is assumed, has an atmosphere. On the segment of the flight to Jupiter and after the flight around the planet there are plans to study the solar wind, the interplanetary magnetic field and cosmic rays as well as the meteor substance, especially in the asteriod belt between the orbits of Marx and Jupiter. The "Pioneer-10" experiment proposes to determine the danger of the asteriod belt and radiation belts of Jupiter to space vehicles, as well as to work out certain technical aspects of flights to outer planets.



Section of Martian surface with trench resembling traces of water erosion on earth

The "Pioneer 10" station (Figure 14) weighs 260 kg, including 30 kg of scientific instruments and the weight of the on-board supply of propellant for trajectory correction and orientation and stabilization of the rotation axis 27 kg. The height of the station is 2.9 m; the maximum cross dimension (diameter of the high-directional antenna reflector) is 2.75 m. The heavy-duty component of the station is a "large container" in the shape of a hexagonal prism (1.4 x 0.7 x 0.36 m), in which the service equipment is placed. A "small container" is attached to one of the lateral edges of the large container, and it also is in the shape of a hexagonal prism. Part of the scientific apparatus is placed in it. Two cantilevers 2.7 m long each and a rod 6.6 m long are attached to the large container at an angular distance of 120° from each other. On each cantilever two blocks of the radio-isotope power engineering unit are extended, and on the rod is the magnetometer. The total electrical power of the radio-isotope unit (PU^{238}) at blast-off from earth is 160 w, at Jupiter it is not less than 134 w, and within 5 years after launching--120 w. The thermoregulation system uses louvers, thermal insulation, and coatings with a low radiation coefficient. The station is stabilized by rotation (4.8 rpm).

The systems for trajectory correction, orientation, and stabilization of the rotation axis use sun sensors and a star sensor, and as actuating elements, there are 12 microengines with thrust 180-635 g, each operating on products of hydrazine breakdown. The radio engineering system (frequency of reception 2292 MHz, power of transmitter 8 w) provides information content of 1024 bit/s in the flight around Jupiter. The capacity of the on-board recording device is 49,152 bits. The service systems of the AIS are rated for operation for not less than 900 days.

The scientific apparatus includes a magnetometer, plasma analyzer, detector of charged particles, a set of Geiger-Muller counters, a cosmic radiation detector, a radiation detector, a ultraviolet photometer, a photopolarimeter to obtain images of Jupiter and its satellites, an infrared radiometer, a set of telescopes to observe the meteor substance, and a set of meteor particle detectors. "Radio-eclipse" sounding of Jupiter and Io is provided for by the standard radio equipment of the station, and "celestial-mechanical" studies are made possible using the results of the station's trajectory measurements. For communication with "Pioneer 10," the "Mars" tracking station in Goldstone, United States (the diameter of its antenna reflector is 64 m) and the tracking station in Tidbinbilla, Australia (until July 1973 and its reflector was 26 m in diameter, then it was increased to 64 m in diameter) were used.

The "Pioneer 10" station was launched 3 March 1972; on 25 May it intersected the Mars orbit; on 16 July it entered the asteroid belt, and on 15 February 1973 it left this belt. The density of the fine meteor particles the most dangerous for the AIS (diameter 0.01-0.1 mm) in the asteriod belt was lower than expected: the station did not suffer any damages. It should pass the minimum distance from Jupiter (~ 130,000 km) on 4 December 1973. In 1972 three trajectory corrections were made, which should guarantee the assigned parameters of the flight path.

According to calculations, in the middle of 1976 the station will intersect the orbit of Saturn, in 1980--the orbit of Uranus, and in 1984--the orbit of Pluto. Going beyond the limits of the solar system the station will move in the general direction of the star Alderbaran. It is planned to maintain communication with the station until that moment when it is 2.4-2.9 billion km from earth, i.e., until 1979. Measures are being proposed which would permit communication to be maintained until 1986.

Manned Transport Ships

In 1972 the United States launched two manned spacecraft to the moon under the "Apollo" program. This marked the completion of the "Apollo" program.

"Apollo-16." The main tasks of the sixth lunar expedition were: landing in the region of the crater Descartes, where it was hypothesized that signs of volcanoes would be found; installing on the moon the ALSEP set No 5, which includes a radio-isotope power engineering unit, a telemetry system, and scientific instruments (see below); transporting to earth ~ 90 kg of lunar soil samples, including core samples ~ 3 m long from the hole drilled in the ground by a special electric drill; line expeditions on the moon rover, conducting studies using a portable magnetometer and penetrometer; photographing different astronomical objects with an ultraviolet spectrograph brought to the moon; photographing and taking movies during the moon walks; recording space radiation and solar wind particles with a detector mounted on the body of the lunar module (LM); conducting color television broadcasts from the lunar surface (with a TV camera left on the moon it was proposed to photograph the launching of the cosmonauts from the moon and certain astronomical observations) and from the crew module (CM); photographing and sounding the moon from a selenocentric orbit with the SIM No 2 set in the main block of the craft (MBC); photographing the lunar surface from the CM in a selenocentric orbit; putting the automatic satellite into a selenocentric orbit; radio sounding the moon from a selenocentric orbit; study of anomalies of the lunar gravity field from disturbances of the craft's selenocentric orbit; observations of phosphenes; conducting an experiment to separate substances by electrophoresis under conditions of zero gravity; studying the effect of space radiation on biological specimens and the effect of different space flight factors on microorganisms; guaranteeing that the last stage of the rocket launcher that has separated from the craft and the used launching stage of the LM fall to the moon so that seismic sounding can be conducted.

The crew of the craft: John Young (commander of the transport ship), Thomas Mattingly (pilot of the MBC), and Charles Duke (pilot of the LM). The training and equipment of the astronauts were basically the same as for the astronauts of "Apollo 15" (see YEZHEGODNIK BSE 1972, pp 527-529). The astronauts had to make three moon walks, each lasting 7 h, and each time they had to travel on the moon rover (total rated distance of routes 25.7 km) without going, however, more than 5 km from the landing site so that in case of emergency they could return to the LM on foot in 75 min (the life of the emergency oxygen supply in the portable life jackets). In the first walk it was planned to travel to the west of the landing site towards the craters Spook and Flag, in the second--to the south towards the South Ray crater and the Stone mountain, and in the third--to the north towards the North Ray crater and Smokey mountain. The astronauts were, in particular, to climb in the moon rover up a slope of the Smokey mountain to an altitude of 210 m (inclination ~ 10°) as well as up the outer slope of the North Ray crater to its edge and photograph the inner part of the crater.

On the flight back to earth the MBC pilot emerged into open space to transfer to the CM a film cassette from two cameras of the SIM No 2 set.

The SIM No 2 set placed in the MBC also included cameras and instruments that were included in the SIM No 1 set on "Apollo 15." The automatic satellite (weight 38.6 kg) is separated from the MBC before its transfer from a selenocentric orbit to the flight trajectory to earth. The ALSEP No 5 set, which the "Apollo 16" astronauts were to install on the moon included: a seismometer ("passive seismometer"), a stationary magnetometer, an instrument for studying the thermal flows coming from the depths of the moon to its surface (probes of the instrument are placed in holes ~ 3 m deep), geophones ("active seismometers"), and starting devices with grenades. The geophones record the seismic oscillations during the detonation by the astronauts of 21 small pyrotechnic charges using a special firing pin as well as oscillations produced by the explosion of the grenades which are planned to trigger at command from earth at a distance of 150, 300, 900 and 1500 m several weeks following the departure of the astronauts from the moon.

The moon rover is the same as on "Apollo 15."

The "Saturn-5" AS-511 rocket, which is similar to the "Saturn-5" AS-510 used to launch "Apollo-15," was used to launch "Apollo-16." Unlike the AS-510, however, the AS-511 had eight (rather than four) braking solid-propellant rockets on the first stage to insure its withdrawal even in the case where one rocket malfunctions.

Launching occurred at 1754 hours GMT on 16 April 1972. The last stage with the transport ship was inserted into an initial geocentric orbit with apogee 178 km and perigee 169 km (the prescribed orbit was circular with altitude 167 km). The second launching and the rearrangement of the modules occurred normally. Only one of the four possible trajectory corrections was required during the flight to the moon. Mattingly conducted an experiment to separate substances by electrophoresis, and observations of phosphenes were made.

On 19 April the ship went into an initial selenocentric orbit (107 x 304 km) and after four hours transferred to a lower orbit (19.8 x 109.3 km), where the LM was to separate. On 19 April the last stage of the rocket launcher landed on the moon.

On 20 April the LM with astronauts Young and Duke on board separated from the main module where astronaut Mattingly remained. The next operation--the transfer of the main module to a "rendezvous" orbit (98.4 x 125.6 km)--took place after an almost 6-hour delay since there was a malfunction in the back-up control circuit for the main module sustainer and time was needed to insure that the engine was safely engaged because it was not possible to use the back-up system in case of an emergency. The LM landed at 0224 hours GMT on 21 April, six hours later than the calculated time; it was 200 m west and 150 m north of the calculated point of landing (Lat 9°00'01" S and long 15°30'59" E). The delay in the landing forced an alteration to be made in the flight program; in particular, the length of the third excursion on the lunar surface was reduced. The first excursion was made on 21 April and lasted 7 hours 11 minutes. The astronauts installed an ultraviolet spectrograph and directed it as various astronomical targets (photography was automatic); they installed the particle detector and put the moon rover into operation, erected the American flag, and opened the ALSEP No 5 set about 200 m from the landing site, installing, in particular, probes to measure thermal streams in three-meter holes. Young accidently tripped and broke the cable connecting these probes to the telemetry equipment, and the studies of thermal streams had to be discontinued. During the first excursion, the astronauts travelled 4.2 km in the moon rover, reaching the Spook and Flag craters. The second excursion was made on 22 April and lasted 7 hours 23 minutes. The astronauts set out for Stone Mountain and South Ray crater in the moon rover and climbed the slope of the mountain to an altitude of approximately 230 m; from there they had a view of approximately 30 km. Descending the mountain, the moon rover reached a speed of 17 km/h. During the second excursion, they travelled 11.5 km. The third excursion was made on 23 April and lasted for 5 hours 40 minutes. In the moon rover the astronauts climbed the outer slope of North Ray crater to its edge. During the third excursion, they travelled 11.4 km. In the three excursions the astronauts collected a total of 97.5 kg of soil samples.

Having been on the moon for 71 hours 02 minutes, the astronauts were launched from the surface on 24 April in the launching stage of the LM; two hours later they docked with the launching stage of the main module. They did not succeed in insuring that the used LM launching stage would fall to the lunar surface because they left one of its switches in the wrong position and, as a result, the remote commands for stabilization of the separated launching stage were not processed. Due to the malfunction in the back-up control circuit for the sustainer, the main module remained in selenocentric orbit after the astronauts had returned to it for only one rather than two days; this did not allow them to photograph and sound the moon in accordance with the full flight program. For the same reason, the altitude of the main module's orbit was not increased before the automatic satellite was separated. Due to its low orbital altitude, this satellite remained in selenocentric orbit for only 35 days rather than an entire year.

On 25 April, in its 64th revolution around the moon and having been in selenocentric orbit for 125 hours 52 minutes, the main module was transferred to a trajectory for flight back to earth. On the same day, when the main module was about 300,000 km from earth, Mattingly performed a space walk to transfer to the CM film cassettes from the two cameras of the SIM set. The EVA lasted 1 hour 04 minutes.

Duke takes a soil sample

The CM splashed down on 27 April at 1945 GMT at a point with coordinates lat 0°24' S and long 156°20' W and 0.8 km from the calculated point of entry and 1.6 km from the aircraft carrier of the search and rescue fleet.

The flight of "Apollo-16" lasted 11 days 1 hour 51 minutes. The instruments the astronauts left on the moon, with the exception of the instrument to measure thermal streams, operated normally. The command to trigger the grenades was given on 23 May 1972. Three of the four grenades were triggered and they fell at distances of 150, 300 and 900 m from the firing site. The fourth grenade was not fired in order to prevent damage to other instrumentation. The TV camera left on the lunar surface was engaged several times and ceased to operate on 4 May 1972 with the onset of night in the landing area. Analysis of the samples did not reveal the expected rocks of volcanic origin. The astronauts completely readapted to earth conditions within two days after their return, i.e. considerably faster than the "Apollo-15" astronauts; this is considered to be a consequence of the more effective alternating work and rest schedule, the less strained work routine on the moon and the enrichment of the diet with potassium (in particular, potassium was added to the orange juice which the astronauts were required to drink in great quantities).

"Apollo-17". The main tasks of the seventh (and last) lunar expedition under the "Apollo" program included: to land in the "Taurus-Littrow" region (to the south of the Taurus Mountains and the Littrow Crater), where it was assumed that signs of volcanism would be found; to install the ALSEP No 6 set, which includes a radioisotope energy unit, a telemetry system and scientific instruments (see below); deliver to earth about 95 kg of lunar soil samples, including a core sample 3 meters long from a bore-hole drilled into the surface by a special electric drill; conduct expeditions in the moon rover to make studies using a portable gravimeter, a short-wave probe and a penetrometer with self-recorder; photograph the lunar surface during the expeditions; place explosive charges at various distances from the recording instruments so that after the departure of the astronauts from the moon, lunar seismic sounding could be conducted; record solar wind and cosmic radiation particles with a detector mounted on the lunar module (LM); conduct color television broadcasts from the lunar surface (it was proposed that the launching of the astronauts from the lunar surface could be photographed with the TV camera) and from the crew module; photograph and sound the moon using the SIM No 3 set located in the main module from a selenocentric orbit; photograph the lunar surface from the CM in a selenocentric orbit; sound the moon from a selenocentric orbit using the craft's standard radio engineering equipment; investigate the anomalies of the lunar gravity field according to disturbances of the selenocentric orbit; observe phosphenes; study the effect of cosmic radiation on biological specimens (bacteria, seeds, ciliate Protoza, etc.) and on the nerve cells from the brains of dwarf mice; conduct experiments to study heat transfer in liquids and gases under the condition of 0-gravity; and insure that the last stage of the separated rocket launcher and the used LM launching stage would fall to the lunar surface so that seismic sounding could be conducted.

The crew of the craft included: Eugene Cernan (commander), Ronald Evans (pilot of the main module) and Harrison Schmitt (LM pilot). Schmitt is the only professional scientist (a geologist) to participate in the "Apollo" program lunar expeditions. The astronauts had to make three expeditions on the lunar surface, each of which lasted seven hours; during each excursion, they travelled in the moon rover (the total calculated distance to be travelled was 32.3 km). In the first excursion there were plans to travel south from the landing site to the Steno and Emory craters, in the second--west to the Southern Massif mountains, and in the third--north to the Sculpture Mountains and the Northern Massif. On the flight back to earth from the moon, the main module pilot was to walk in open space and transfer exposed film cassettes to the CM.

The ALSEP No 6 set included: an instrument to study thermal streams from the depth of the moon to its surface; a stationary gravimeter to record tidal phenomena on the moon and to find gravity waves in outer space; a mass spectrometer to study the composition of the lunar atmosphere at the surface; an instrument to determine the characteristics of meteor particles that reach the surface of the moon as well as particles of soil discharged when large meteorites fall on the moon; geophones ("active seismometers") to record the seismic oscillations produced by the explosion of charges and the impact of the used LM launching stage when it falls to the surface; and a neutron detector. All of the instruments listed above, except for the instrument used to study thermal streams, were delivered to the moon for the first time. The probes to study the thermal streams were placed in boreholes drilled about 3 meters deep in the ground; after the core sample had been taken, the neutron detector was placed in the borehole, and the exposed detector targets were returned to earth.

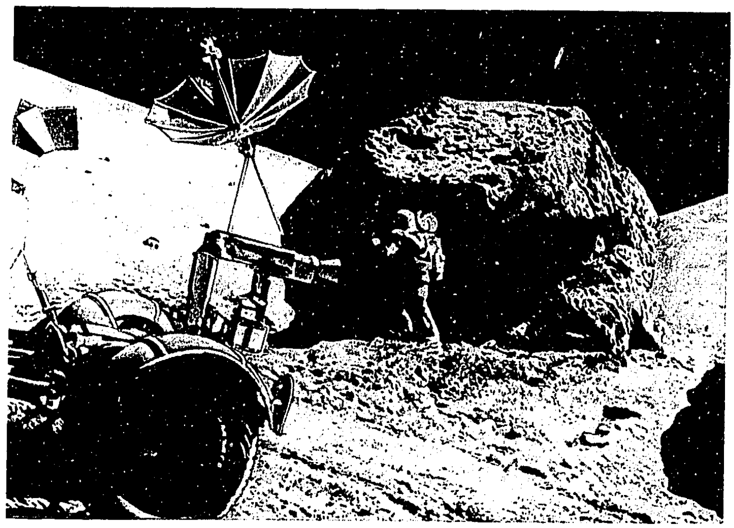
The SIM No 3 set included: a panoramic camera, a topographical camera, a stellar camera to link photographs taken by the topographical camera by coordinates, and a laser altimeter to link photographs taken by the topographical camera by altitude (and to obtain a profile of the lunar surface); a radar to measure physical characteristics of the moon, an ultraviolet spectrometer, and a scanning infrared radiometer to obtain a high resolution thermal map of the moon (the last three instruments were used for the first time).

The total weight of the equipment used in studies on the lunar surface was 545 kg and in studies from selenocentric orbit--475 kg. The moon rover was somewhat modified so that it could carry more weight (27 kg more).

The "Saturn 5" AS-512 booster, which is like the "Saturn 5" AS-511 used to launch "Apollo-16," launched the "Apollo-17" craft (which weighed approximately 47 tons).

"Apollo-17" was launched on 7 December at 0533 hours GMT. The last booster stage together with the transport ship was inserted into an initial geocentric orbit with an altitude of approximately 170 km (the calculated orbit was circular with altitude 167 km). The second launching, the rearrangement of the modules and the flight to the moon occurred normally. This earth-moon flight required only one trajectory correction. The astronauts conducted experiments to observe phosphenes and to investigate heat transfer under the conditions of weightlessness.

On 10 December the transport ship was inserted into an initial selenocentric orbit (94 x 316 km), and four hours later, it transferred to a lower orbit, where the LM was to be separated. On 10 December the final stage of the rocket booster fell to the moon (150 km from the projected point). Seismic oscillations produced by the impact were recorded by seismometers installed on the moon. On 11 December the LM with astronauts Cernan and Schmitt on board separated from the main module, in which astronaut Evans remained. The main module was transferred to a "rendezvous" orbit (100 x 130 km). The LM orbit was corrected in order to reduce the periselene to 13 km. The LM landing stage engine was engaged to decelerate somewhat earlier than in the periselene a plan different from that followed in previous flights. Such a flight plan was dictated by the fact that the projected landing site was much closer to the eastern edge of the lunar disk and with the formerly-used plan, it would not have been possible to calculate the trajectory after the LM emerged from behind the moon. The LM landed on 11 December at 1955 hours GMT 200 m east and 80 m south of the calculated point. The coordinates of the landing site were lat 20°9'41" N and long 30°45'26.9" E.



Schmitt at large moon rock near the Northern Massif

The first excursion on the lunar surface took place on 11 December, the day that the astronauts landed, and lasted 7 hours 13 minutes. The astronauts put the particle detector and the moon rover into operation, erected the American flag, and opened the ALSEP No 6 set roughly 100 m from the landing site, installing probes into the 3-meter boreholes to measure thermal streams. A core sample 3 meters long was obtained, and the neutron detector was placed in the hole. In the first excursion, the moon rover travelled 2.6 km, and the astronauts reached Steno crater but abandoned the trip to Emory crater because the oxygen in Cernan's life-support system was overconsumed. The second excursion occured on 12 December and lasted 7 hours 37 minutes, a record time for all "Apollo" lunar expeditions. In the moon rover, the astronauts reached the foot of the Southern Massif. At the small Shorty crater, soil of an orange color was found; Schmitt and various other scientists first assumed that this might indicate volcanism (the emergence of water vapors that have oxidized iron), but analysis of samples b ought to earth did not confirm this hypothesis. During the second e cursion, the moon rover travelled 19.6 km. The third excursion occurred on 13 December and lasted 7 hours 15 minutes. In the moon rover the astronauts reached the foot of the Sculpture Mountains

Non-Soviet spacecraft launched in 1972

Item No.	Satellite name	Booster rocket	Date of launch	Satellite wt, kg.	Parameters of initial orbit			Initial orbital period min
					Perigee, km	Apogee, km	Incli-nation	
1	Secret	"Titan 3 D"	20 Jan	11300	156	332	97.00°	89.41
2	Secret[2]			60	472	549	96.59°	94.86
3	INTELSAT-4C[2]	"Atlas Centaur"	23 Jan	1387	35598	35888	0.7°	1432
4	"Chaos-2" ("Chaos-A-2")	"Thorad Delta"	31 Jan	117	406	~240000	89.91°	7477.1
5	Secret[2]	"Titan 3 C"	1 Mar	> 800	35762	35856	0.87°	1434
6	TD-1A	"Thorad Delta"	12 Mar	472	525	552	97.55°	95.41
7	Secret	"Titan 3 B"	17 Mar	~3000	130	409	110.98°	89.91
8	Secret	"Thor Burner 2"	24 Mar	~150	803	885	98.80°	101.83
9	Secret	"Thorad Agena"	19 Apr	~2000	155	277	81.48°	88.85
10	Secret	"Thorad Agena"	25 May	~2000	158	306	96.34°	89.17
11	INTELSAT-4D[2]	"Atlas Centaur"	13 Jun	1387	35779	35891	0.5°	1436.1
12	Secret	"Titan 3 D"	7 Jul	11300	174	251	96.88°	88.77
13	Secret[2]			60	497	504	96.15°	94.66
14	ERTS-1(ERTS-A)	"Thorad Delta"	23 Jul	891	901	920	99.12°	103.27
15	"Explorer 46" (MTS)	"Scout"	13 Aug	175	493	811	37.70°	97.65
16	"Dempa" (SS No 2;REXS)	"Mi-4 S"	19 Aug	75	244	6289	31.03°	156.85
17	"Copernicus" (OAO 3, OAO-C)	"Atlas Centaur"	21 Aug	2220	735	743	35.01°	99.49
18	Secret	"Titan 3B"	1 Sep	~3000	143	380	110.5°	89.71
19	"Triad-1"	"Scout"	2 Sep	94	716	863	90.14°	100.68
20	"Explorer 47" (IMP-H)	"Thorad Delta"	23 Sep	390	201000	235600	28.63°	17670
21	"Radcat"	"Atlas Burner 2"	2 Oct	208	730	748	98.44°	99.64
22	"Radsat" (OV-1-22)			725	732	751	98.45°	99.69

Non-Soviet spacecraft launched in 1972 (continued)

Item No.	Satellite name	Booster rocket	Date of launch	Satellite wt, kg.	Parameters of initial orbit			Initial orbital period min
					Perigee, km	Apogee, km	Incli- nation	
23	Secret	"Titan 3 D"	10 Oct	11300	159	282	96.47°	88.93
24	NOAA-2	"Thorad Delta"	15 Oct	345	1450	1459	101.77°	115.01
25	"Oscar 6"			18.6	1448	1461	101.76°	115.01
26	Secret	"Thor Burner 2"	9 Nov	~150	813	872	98.65°	101.80
27	"Anik 1"[2]	"Thorad Delta"	10 Nov	530	35775	36483	0.4°	1455.5
28	"Explorer 48"(SAS-B)	"Scout"	15 Nov	186	442	632	1.90°	95.20
29	ESRO-4	"Scout"	22 Nov	115	251	1170	91.11°	99.00
30	"N‑mbus-5"(Nimbus E)	"Thorad Delta"	11 Dec	717	1091	1105	99.95	107.25
31	"Aeros"	"Scout"	16 Dec	127	224	866	96.94°	95.57
32	Secret[2]	"Atlas Agena"	20 Dec	680	31012	40728	9.7°	1440.4
33	Secret	"Titan 3 B"	21 Dec	~3000	138	378	110.45	89.68

1. Weight of secret satellites taken from unofficial sources.
2. Elements of final orbit indicated.

and the Northern Massif. Due to the lack of time, the route was cut somewhat shorter, and the rover travelled only 13.5 km.

The length of the excursions totaled 22 hours 05 minutes, and the distance covered by the moon rover equalled 35.7 km; in all three of the excursions together, a total of 113 kg of soil samples was collected (all of these statistics represent records for the "Apollo" lunar expeditions).

On 14 December, having been on the moon for 74 hours 59.5 minutes, the astronauts were launched from the lunar surface and, two hours later, docked with the main module (the third attempt was successful). The used LM launching stage fell 15 km from the landing site of the "Apollo-17" craft. After separating from the landing stage, the astronauts photographed and sounded the moon for two more days from a selenocentric orbit. On 16 December, in its 75th revolution around the moon and having been in selenocentric orbit for 147 hours 48 minutes, the main module was shifted to a trajectory for the return flight to earth. On 17 December when the main module was approximately 290,000 km from earth, Evans performed a space walk and transferred film cassettes to the CM. The EVA lasted 1 hour 7 minutes. The CM splashed down on 19 December at 1924 hours GMT at a point with coordinates lat 17°54' S and long 166°07' W, and four kilometers from the aircraft carrier of the search and rescue fleet.

The flight of "Apollo-17" lasted 12 days 9 hours 51 minutes, a record for the "Apollo" lunar expeditions. Except for the stationary gravimeter, all the instruments left by the astronauts on the moon operated normally.

The astronauts readapted to earth conditions within three days. In flight they complained of stomach pains; a change in their diet and pills relieved the pain. Cardiac arrhythmia was not observed as in the flight of "Apollo-15." Technically, the flight of "Apollo-17" was practically irreproachable: except for a small delay in the launching, there were no deviations from the flight program or any significant malfunctions.

FOOTNOTES

1. Meteoroid Technology Satellite

2. Interplanetary Monitoring Platform

3. Small Astronomical Satellite

4. Orbital Astronomical Observatory

5. Fine Error Sensor

6. Earth Resources Technology Satellite

7. Return Beam Vidicon

8. Multi-Spectral Scanner

9. Data Processing Facility

10. These satellites are being launched by NASA, and after insertion into orbit they are transferred to the National Oceanic and Atmospheric Administration (NOAA). In the NASA documents these satellites are called ITOS (Improved Tiros Operational Satellite).

11. Radar Calibration Target

12. Radiation Satellite

13. Orbital Vehicle. The satellite "Radsat" has also the designation OV-1-22.

14. "Big Bird." Previously these satellites were called LASP (see YEZHEGODNIK BSE 1972, p 529, Table, footnote 4).

15. Integrated Multi-Purpose Early Warning Satellite (see "YEZHEGODNIK BSE 1972, p 529, Table, footnote 3).

16. Ballistic Missile Early Warning Satellite. The English journal FLIGHT, in contrast to all other foreign sources, calls this space object the experimental navigational satellite "Time Machine 3."

17. "Radio wave." The satellite also has the name SS No 2 (SS--Scientific Satellite) and REXS (Radio Exploration Satellite).

18. "Anik"--"brother" in the Eskimo language.

19. Thorad-Delta (the satellite is named after the rocket launcher used).

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SOVIET SPACE RESEARCH IN 1973

Moscow YEZHEGODNIK BOL'SHOY SOVETSKOY ENTSIKLOPEDII in Russian No 18, 1974 pp 517-526

[Article by L. Lebedev]

[Text] The "Soyuz-12" and "Soyuz-13" transport ships and automatic stations for studying the Moon and Mars were launched in 1973. Launches of artificial earth satellites for scientific and applied purposes were continued.

Manned Transport Ships

"Soyuz-12." The "Soyuz-12" transport ship was launched from Baykonur on 27 September at 1518 hours with a crew made up of commander V. G. Lazarev and flight engineer O. G. Makarov. During the time since "Soyuz-11" was launched, a number of changes were introduced into the structural design of the "Soyuz" spacecraft. In order to prevent dangerous situations from arising during complex dynamic processes such as docking or undocking with another vehicle, separation of the spacecraft compartments, and so on, space suits for the crew were introduced. Part of the space in the reentry vehicle was given over to the system to support the operation of the space suit. Accordingly, the crew of the spacecraft was made up of two people. The "Soyuz-11" spacecraft had an improved control system and, in particular, an improved control system with respect to the ion sensors. The "Soyuz-12" was made in the transport version, and therefore it had no solar panels.

The orbital flight program was designed for two days and included the following: complex checking and testing of the improved onboard system; further development of manual and automated control procedures when performing maneuvers and during orientation and stabilization of the spacecraft; photographing various sections of the earth's surface in nine different bands of the electromagnetic radiation spectrum--from visible to infrared.

In executing the first day's flight program, cosmonauts Lazarev and Makarov performed operations to maneuver the "Soyuz-12" spacecraft into an earth orbit. After these maneuvers, the orbital parameters of "Soyuz-12" were: apogee 345 km; perigee 326 km; orbital period 91 minutes; orbital inclination 51.6 degrees.

On 29 September after completing the experiments, operations were performed to prepare the spacecraft for return to earth. Before reentry, the spacecraft was oriented, and the braking engine was switched on at the calculated time. On completion of the operation of the engine, the spacecraft compartments were separated, and the reentry vehicle transferred to the reentry trajectory. At an altitude of 7.5 km, the parachute system was put into operation; the soft landing engines responded directly at the ground, and at 1434 hours the reentry vehicle landed in the calculated area 400 km southwest of Karaganda.

"Soyuz-13." The "Soyuz-13" transport ship was launched at Baykonur on 18 December at 1455 hours with a crew made up of commander P. I. Klimuk and flight engineer V. V. Lebedev. The "Soyuz-13" spacecraft differs from its predecessors. This difference is determined by the main goal of the space experiment: the "Soyuz-13" is an orbital astrophysics observatory. In order to perform astrophysical research, the "Orion-2" equipment was installed on board "Soyuz-13". The mission of this equipment was to obtain spectrograms of the stars in the ultraviolet range. The "Orion-2" telescope with photo attachment was installed outside the orbital compartment at the docking unit. The "Orion-2" equipment has a protective cover which provides for normal temperature conditions, preventing the telescope from overheating on the solar side of the orbit and from overcooling on the shadow side. In the dome opposite the telescope lens there is a "window" with a two-flap cover which opens during the experiment. The telescope is aimed at a given section of the sky as follows: first the crew commander, using the manual control system and the system gyroscopes oriented the ship as precisely as possible so that the optical axis of the stationary telescope would be aimed in the direction of the quite bright reference star. The reference star served only as a landmark in order to keep the telescope aimed at a given part of the sky where the stars, the spectrograms of which were of interest, are located. Then, the flight engineer in the orbital compartment aimed the telescope more exactly at the reference star by turning the telescope relative to the hull of the spacecraft using an optical viewer connected to the telescope by a remote servosystem. Then he switched on the automatic servosystem which did the final aiming and stabilization of the telescope in the direction of the star with an accuracy to several angular seconds. In order not to permit rotation of the telescope around its optical axis, which leads to "blurring" of the image on the photographs, the stabilization of the telescope takes place not only with respect to the basic reference star but also with respect to a second one located at a large angle to the first.

The radiation spectrograms of the stars of the given part of the sky obtained using the telescope were recorded on special highly sensitive film. Each section of the sky was photographed with different exposure times from one minute to 20 minutes. This made it possible to obtain spectrograms of a large number of bright and dim stars simultaneously on each photograph.

During the flight, the crew took spectrographs of stellar radiation in different parts of the sky 16 times. As a result, ultraviolet images of more than 3,000 stars were obtained. The total number of spectrograms suitable for processing is about 10,000. They belong to the wavelength band shorter than 3,000 Å and down to 2,000 Å. In individual cases, the radiation of highly remote heavenly bodies was recorded--to 12 stellar magnitudes and weaker. The photographs of the ultraviolet part of the spectrum of such weak stars were obtained for the first time.

The examination of the "Orion-2" spectrograms indicates, for example, that in the part of the sky around the star Capella there are many more hot stars than was known earlier. These hot stars are very weak. From the point of view of stellar cosmogony this fact can have important significance. The astrophysical experiment on "Soyuz-13" basically provided for studying the continuous stellar spectra. However, on the images of many objects individual spectral lines were noted belonging to different chemical elements. The lines with a wavelength of about 2800 Å belonging to ionized magnesium is very clearly visible. It is an important source of information on stellar atmospheres, and its study offers the hope of establishing the laws of the "behavior" of this line for stars having different temperatures, different mass, dimensions and other physical factors.

The scientific program of the "Soyuz-13" spacecraft also provided for performing an experiment for photographing the earth's surface in different parts of the solar radiation spectrum. A survey was made by a special nine-lens camera in which three films were used simultaneously. Three photographs were obtained simultaneously on each film through three lenses. The lenses were equipped with different light filters. All of this made it possible for each investigated section of the surface to be photographed simultaneously in nine spectral zones: from visible to near infrared. In addition, during the flight the cosmonauts used a manual spectrograph to record the spectra of natural formations on the earth's surface and also the twilight and day horizons of the earth.

Medical-biological studies were also performed under the scientific experiment program. They included the study of the nature of blood redistribution in the human body during spaceflight. In weightlessness, the blood leaves the legs and flows to the upper part of the body, in particular, to the head as a result of the absence of hydrostatic pressure. This can cause the cosmonauts to feel worse during the first days in orbit. The reaction mechanism and the mechanism of the adaptive capabilities of the circulatory system in the brain were studied using the "Levkoy" equipment with the cosmonauts at a state of rest and after doses of stress loads.

Onboard the "Soyuz-13" spacecraft a study was made of the effect of spaceflight factors on the development of lower plants, chlorella and duckweed. A study was also made of the peculiarities of the development of two types of microorganisms (hydrogen bacteria and urobacteria) under the conditions of weightlessness, and as a result of the experiment a protein mass was obtained for subsequent analysis of its biochemical composition. The experiment was performed using the "Oazis-2" system. A characteristic feature of the experiment was the fact that the feeding and multiplication of the bacteria, the formation of the protein mass took place in a system with a closed volume, in a closed cycle, with mutual enrichment of the two-types of bacteria as a result of the synthesis of certain materials and isolation of others. The biomass of the microbe culture in the "Oazis-2" system increased by more than 35 times during the flight.

Along with the scientific studies, the "Soyuz-13" crew performed a number of technical experiments, the purpose of which was to develop new devices for further use in the improved onboard systems. During the entire flight, the onboard systems, the units and mechanisms of the spacecraft operated normally. On 26 December, after completing their work on board "Soyuz-13," cosmonauts Klimuk and Lebedev returned to earth. At 1150 hours, the reentry vehicle of the "Soyuz-13" spacecraft completed a soft landing in the territory of the Soviet Union 200 km southwest of Karaganda.

Automatic Stations for Studying the Moon and Planets

"Luna-21." The "Luna-21" automatic station was launched on 8 January at 0955 hours. The "Lunokhod-2" self-propelled automatic moon rover was onboard (see Figure 1). The "Luna-21" automatic station was launched toward the moon from an intermediate orbit as an artificial earth satellite. In order to insure that the station would reach the calculated point in lunar space, on 9 January the flight trajectory was corrected. On approaching the moon on 12 January, the braking operation was performed, and the station was inserted into a selenocentric orbit with the following parameters: periselene 90 km, aposelene 110 km; lunar orbital inclination 60 degrees; orbital period 1 hour 58 minutes. In accordance with the flight program, corrections were made to the lunar orbit on 13 and 14 January. The "Luna-21" automatic station began an elliptic orbit with periselene 16 km. The station left its orbit and landed by using a unified landing stage. On 16 January at 0135 hours, the automatic "Luna-21" station made a soft landing on the surface of the moon on the eastern edge of the Sea of Tranquility inside the LeMonnier Crater. The landing site had the coordinates lat 25° 51' N and long 30° 27' E. At 0414 hours, the "Lunokhod-2" descended a ladder to the surface of the moon and proceeded with the scientific and technical research and experimental program. The "Lunokhod-2" weighed 840 kg The USSR flag, penants with a bas-relief of V. I. Lenin, the hammer and sickle and the inscription "50th Anniversary of the USSR" were installed on the "Lunokhod" [moon rover] and the landing stage.

The "Lunokhod" work program was in accordance with the main comprehensive scientific mission of joint study of the variations of the basic physico-chemical properties of the lunar surface as a function of geological-morphological conditions in the transition zone of the marine to continental relief. This mission included obtaining geological-morphological and topographic data and studying the magnetic field, the chemical composition of the surface layer and the physico-mechanical properties of the soil and also the optical properties of the surface. In order to obtain scientific information, a magnetometer, an x-ray spectral device for analyzing the chemical composition of lunar soil and an instrument for analyzing the physico-mechanical properties of the soil were installed on the moon rover; special photometric markers in the form of a plate with 39 fields having different reflectivity were introduced into the field of view of the panoramic cameras.

The geological-morphological and topographic studies of the terrain were made on the basis of surveying the lunar landscape which included the use of television panoramas and photographs and also data on the length of the path travelled and the position of the equipment on the lunar surface. Instruments designed for the solution of other scientific problems were also installed onboard the moon rover. These included an astrophotometer to measure the luminosity of the lunar sky, a radiometer which measures characteristics of cosmic radiation, the "Rubin-1" photoreceiver which was used to perform experiments in laser direction finding of the "Lunokhod" and the French laser radiation angular reflector.

The systems of "Lunokhod-2" included changes and improvements as compared to those which were used on "Lunokhod-1." In particular, the transmission frequency of images from the television cameras was increased. One of the cameras was raised on a bracket which improved the view of the terrain in front. The clarity of the images received was significantly higher. The procedure for studying the lunar surface with the "Lunokhod-2" was developed on the basis of experience accumulated during the operation of "Lunokhod-1." It combined detailed studies of individual sections of the surface and studies over the entire path travelled by the moon rover.

The "Lunokhod-2" initially performed a comprehensive study of the landing site. Analysis of television panoramas of the landing site transmitted to earth showed that the "Luna-21" station had landed on the wall of a crater about 40 meters in diameter inside the LeMonnier Crater. Measurements of the chemical composition and mechanical properties of the lunar soil were made on the wall of the crater. The magnetometer was switched on several times, and measurements were taken of the luminosity of the lunar sky in the visible and ultraviolet bands of the spectrum using the astrophotometer. After completing the study of the landing site, "Lunokhod-2" moved 1,050 meters southeast of the landing site. Here tests were made of the handling characteristics of the rover under various conditions of its movement and maneuvering. Maneuvers around obstacles without halting were completed for the first time. At the end of the session, the rover reached a comparatively "young" crater about 13 meters in diameter. The vicinity of this crater was selected as the second area for comprehensive studies of the surface. On 24 January the lunar night came to the area where the rover was operating. "Lunokhod-2" was stationary until 8 February, and on 9 February it began to examine the area where it was parked. The magnetization of the rock on the wall and slopes of the crater was measured in the vicinity of ejections from it and also at points 30 to 40 meters from the crater. A study was made of the physical-mechanical properties and the chemical composition of lunar soil. On 10 and 11 February, the "Lunokhod-2" continued its movement in a southeasterly direction toward the Tavr continental massif. As the rover travelled, scientific measurements were made, a panoramic survey was made of the surrounding terrain and the handling characteristics of the lunokhod were checked out. From 13 to 15 February, studies were made of the lunar surface with small movements of the lunokhod, and then the rover moved continuously. At night on 18 February, it approached a crater about 2 km in diameter. On 19 February, the lunokhod went around the crater, using the outside slope of its wall from the southwest. A detailed chemical analysis was made of the soil, the magnetization of the rock was measured and a panoramic survey was made of the slopes of the crater and the coastal regions of the LeMonnier Bay. The total distance traveled by "Lunokhod-2" in two lunar days was 11 km 67 meters.

During the lunar night from 22 February to 9 March "Lunokhod-2" was stationary. On the third lunar day (from 10 March to 23 March) "Lunokhod-2" conducted studies in the southern part of the LeMonnier Crater. The path travelled by the rover in this case began on the continent; it crossed the continental hilly region, ran along the south bank of the crater and ended 2.5 km from a circular tectonic fault in the eastern part of the LeMonnier Crater. The total distance travelled by "Lunokhod-2" in the three lunar days was 27 km 600 meters. The fourth lunar day (10 April to 22 April) of operating the moon rover was entirely devoted to studying the tectonic fault called the Straight Rille. The rille was 15 to 16 km long. Approaching the fault at the beginning of the lunar day, the rover moved to the south along its "west side," and then it went to the east slope and moved along it in a northerly direction. The depth of the fault in the various parts of the research area fluctuated from 30 to 80 meters. The total distance travelled by the rover in four lunar days was 36 km 200 meters.

"Lunokhod-2" operated for five lunar days. Sixty radio sessions were held with the rover, during which the operation of the onboard systems was monitored, the movement was controlled, scientific experiments were conducted and information was transmitted to earth. In the five lunar days, moving through complex relief, the rover travelled 37 km (a diagram of the path followed by "Lunokhod-2" is presented in Figure 2). The increased maneuverability and mobility of "Lunokhod-2" made it possible to travel 3.5 times farther than the distance travelled by the first "Lunokhod-1." More than 80,000 television pictures and 86 panoramas (see Figure 3) of the lunar surface were transmitted by the television equipment. During the survey, the stereoscopic images of the most interesting features of the relief were obtained making it possible to conduct a detailed study of their structure.

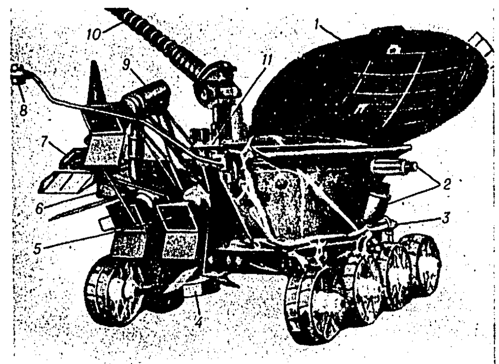

Figure 1. "Lunokhod-2" Automatic Self-Propelled Vehicle (moon rover): 1--Solar battery; 2--Telephotometers; 3--Instrument for estimating passability; 4--Remote unit of the Rifma equipment; 5--Television camera; 6--Astrotophotometer; 7--Angular reflector; 8--Magnetometer; 9--Remote television cameras; 10--Highly directional antenna; 11--Photoreceiver.

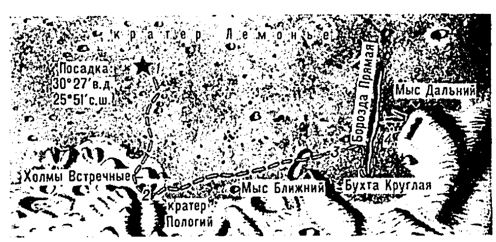

Figure 2. Schematic of the Path Travelled by "Lunokhod-2." The numbers mark the places where the moon rover spent the lunar night

Key:

1. LeMonnier Crater
2. Landing: long 30°27'E; lat 25°25'N
3. Kholmy Vstrechnyye
4. Pologiy Crater
5. Mys Blizhniy [Near Cape]
6. Bukhta Kruglaya [Round Bay]
7. Straight Rille
8. Mys Dal'niy [Far Cape]

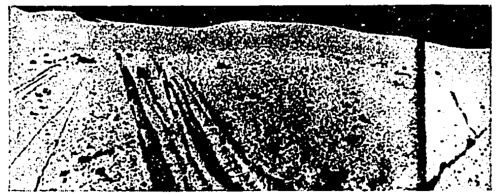

Figure 3. Fragment of the Panorama Transmitted from the Moon by "Lunokhod-2"

As the lunokhod travelled in the region of typically marine nature, known forms of the relief, small craters and in some cases the rock placers connected with them, were encountered. The highly smoothed ancient craters were hit most frequently. The relative number of so-called secondary craters, which were formed as a result of impact of the discharge from the larger craters on the surface was estimated. The number of such craters 0.5-2 meters in size does not exceed 0.25 percent of all of the craters of this size. The thickness of the regolith fluctuated from one to six meters. In the hilly continental zone, in the vicinity of the two-kilometer crater and near the crater 15-20 meters in diameter, landslip terraces up to 10-15 meters long were detected. In the same area, a decrease in the density of the small craters by two or three times by comparison with the normal "marine" density was noted. The thickness of the regolith within the limits of the hilly plain reaches 10 meters in places.

On the eastern and western sides of the rille, zones 30 to 40 meters wide with one-way intensive shift of the lunar material in the direction of the fault were discovered. On approaching the rille the thickness of the regolith diminished, and on the lip of the fault, denuded rock of the foundation was detected in the form of a continuous rock "limb." The fragments of the denuded rock frequently were 1-2 meters or more. Below the rocky "limb" the steepness of the rille increases and reaches 30 to 35 degrees. Here the slopes are covered with talus made up of large lumps and rocks. The emergence of basement rock several tens of meters thick was established.

The mechanical properties of the soil along the path varied within broad limits. The bearing capacity fluctuated from 0.1 kg/cm^2 to 1-1.5 kg/cm^2. However, the general nature of the distribution of the mechanical characteristics of the soil with respect to the surface is quite close to the data obtained from onboard "Lunokhod-1." When measuring the mechanical properties of the soil, sections with increased sag and also with a small layer of loose material on the solid foundation were detected.

The first measurements of the chemical composition of the lunar soil were made at a short distance from the sagging stage on the wall of a crater 40 meters in diameter. The Si content here turned out to be 24 ± 4 percent, the Ca content--8+1 percent, the Fe content--6+0.6 percent, and the Al content--9+1 percent. (The measurement conducted by "Lunokhod-1" in the Mare Imbrium demonstrated an Fe content of 10 to 12 percent.) The studies of the crater 13 meters in diameter demonstrated that the soil in the second area 1.5 km from the landing site is similar with respect to composition to the first section investigated. As "Lunokhod-2" moved toward the hills located to the south, the Fe content began to drop, and at a distance of 5 km from the landing site it was 4.9±0.4 percent. In the session on 19 February, the lowest Fe content of 4.0±0.4 percent was recorded. Simultaneously, the Al content increased to 11.5±1.0 percent. These results indicate that changes in the chemical composition of this surface which are connected primarily with different rock in the "marine" and "continental" regions were recorded.

During the entire operating time of the lunokhod, the magnetic measurements were made continuously as the rover moved and when it stopped. The preliminary analysis of the data makes it possible to note that the magnetic field on the surface of the moon is highly nonuniform. In the magnetograms obtained when the lunokhod was at rest, certain characteristics of the field variation were discovered indicating the processes of current induction on the moon under the effect of the variable interplanetary fields. This makes it possible to calculate the conductivity of the moon at depths on the order of hundreds of kilometers and thus to establish certain concepts of its internal structure. It is possible to propose that up to a depth of about 200 km, the material of the moon is a dielectric, and at greater depths it has noticeable conductivity. A comparison of the results of similar measurements by American scientists provides a basis for considering that the nature of the electrical conductivity in the marine and continental regions is different. This, probably, indicates their different thermal history. While the moon rover was operative, the astrophotometer was switched on 14 times. The data obtained indicate that the sky above the moon is sufficiently "dark" to conduct ultraviolet astronomical observations from its surface both in the daytime and at night. As for observations in the visible range, the conditions during the lunar day and the lunar night are probably different.

The regular laser ranging measurements of the distance to the "Lunokhod-2" reflector were conducted with the telescope of the Crimean Astrophysical Observatory for several months. The statistical point of determination of the distance between the pulse source and the reflector installed on the moon is ±40 cm. During the lunar days continuous measurements were made from onboard the rover of the intensity of corpuscular radiation of solar and galactic origin. The radiation state in the vicinity of the moon was quiet.

The experimental program using "Lunokhod-2" was executed by the operations control group, which included the design engineering personnel, scientists and the lunokhod crew.

"Mars" Automatic Interplanetary Station. The "Mars-4," "Mars-5," "Mars-6," and "Mars-7" automatic interplanetary stations were launched on 21 July at

2231 hours, 25 July at 2156 hours, 5 August at 2046 hours, and 9 August at 2000 hours toward the planet Mars. The purpose of the space experiment was a study of Mars from artificial satellite orbit of it, from the flight trajectory and directly on the planet. For this purpose, the project called for the construction of the artificial Mars satellite and delivery of the landing vehicle to its surface. The "Mars-5" station (see Figure 4) is similar in structural design and purpose to the "Mars-4" station. The stations were designed for conducting scientific research from artificial Mars satellite orbit. The "Mars-7" station is similar in structural design and purpose to the "Mars-6" station. In accordance with the goals of the experiment, the "Mars-6" and "Mars-7" are somewhat different in design from the "Mars-4" and "Mars-5" stations. The structural design of the "Mars-6" and "Mars-7" stations included a descent vehicle (see Figure 5). It was proposed that the physical characteristics of the soil and nature of the surface rock be determined in the vicinity of its landing site, an experimental test be made of the possibility of obtaining television images of the terrain and also that a number of scientific studies be conducted.

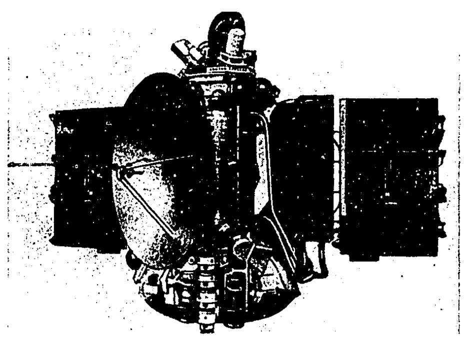

Figure 4. "Mars-5" Automatic Interplanetary Station

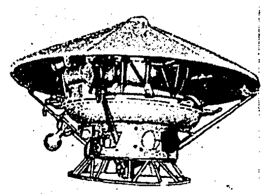

Figure 5. Descent Vehicle of the "Mars-6" Automatic Interplanetary Station

The automatic interplanetary stations were inserted into the flight trajectory to the planet Mars from an intei 'ediate artificial earth satellite orbit. During the flight, radio sessions were held regularly with the stations, during which trajectory measurements were taken, the condition of the onboard systems was monitored, the trajectories were corrected, and scientific information on the physical characteristics of outer space was transmitted to the earth.

The Mars-4 station approached the planet on 10 February 1974. As a result of a malfunction in the operation of one of the onboard stations, the braking engine did not come on, and the station passed the planet at a distance of 2200 km from its surface. Mars photographs were obtained by a phototelevision camera. The "Mars-5" station reached the vicinity of the planet on 12 February 1974. At 1845 hours, the braking engine was switched on to insert the station into Mars satellite orbit. All of the dynamic operations in the concluding phase of the flight were performed automatically using the onboard astronavigation system. As a result of the maneuver, the "Mars-5" station became an artificial satellite of the planet. On board the orbital station there were a number of devices for complex investigation of the atmosphere and surface of the planet by astrophysical methods. The optical axes of all of the instruments were oriented so that they "saw" the planet when the station passed through the pericenter. During the course of the experiment, data were obtained on the surface relief, temperature, thermal conductivity, structure and composition of the soil, the chemical composition of the lower atmosphere, and the structure of its upper layers. It was discovered that the water vapor content in the Martian atmosphere above individual sections of the surface reaches (according to the preliminary estimate) 60 microns of precipitated water. This exceeds by several times the maximum amounts of water vapor detected in 1972 by the photometer of the "Mars-3" station. The significant fluctuations in the atmospheric moisture along the flight path (by at least 5 times) can indicate different rates of water release from the depths in various parts of the planet. One of the ultraviolet photometers discovered traces of atmospheric ozone on Mars for the first time. The outermost part of the atmosphere of Mars is made up of atomic hydrogen which disperses the sunlight in a line with a wavelength of 1216 Å. The ultraviolet photometer recording the brightness of the atmosphere in this line indicated that the temperature of the hydrogen corona of Mars extending to an altitude of ~20,000 km is about 350 degrees K.

By using a magnetometer, the magnetic field nearest the planet exceeded the interplanetary field by 7 to 10 times. The new data confirm the results obtained in 1972 using the "Mars-2" and the "Mars-3" stations and indicating the presence on Mars of a natural magnetic field of the dipole nature of about 30 gamma in magnitude.

In the first half of February 1973, the "Mars-4" station photographed Mars from the flight trajectory, and the "Mars-5" station--from the artificial satellite orbit. The photography was carried out by two phototelevision units capable of distinguishing details on the order of 1 km and 100 meters in size from a distance of about 2,000 km. In addition, the image of a wider strip of the terrain along the flight paths was obtained using the scanning optomechanical devices. Surveying with the wide-angle camera was done through light filters so that after synthesis of the negatives, color images of various sections of the surface would be obtained. The survey paths lay in the southern hemisphere and extended from west to east for several thousands of kilometers, encompassing many different parts of the Martian surface with respect to structure. Traces of intensive erosion under the effect of surface dynamic processes are noted in the photographs. Sharply eroded, flat-bottomed craters with accumulations of sandy alluvium in various sections are widely represented. The sinuous cracks and canyons are possibly traces of ancient river valleys. Both ancient and comparatively fresh geological formations of the Martian surface are visible in the photographs. Figure 6 shows the western part of a Martian crater 150 km across and on the order of 3 km deep. A depression of irregular shape 25 km long can easily be seen. Figure 7 shows a crater with flat bottom 25 km across; the wall of the crater is very obvious, and another small crater is located on it. Numerous radial troughs can be seen on the inside slope of the large crater.

Figure 6. Segment of the Surface of Mars 100x100 km in size (the photograph was taken from on board the "Mars-5" automatic interplanetary station).

Figure 7. Crater on Mars (the photograph was taken from on board the "Mars-5" automatic interplanetary station).

The "Mars-6" and "Mars-7" automatic interplanetary stations reached the vicinity of the planet Mars on 12 and 9 March 1974, respectively. When the "Mars-6" station approached the planet, the final trajectory correction was made automatically using the onboard astronavigation system, and the descent vehicle separated from the station (at a distance of 48,000 km from the planet). At the calculated time, the engine was switched on insuring transfer of the descent vehicle to the rendezvous trajectory with Mars. Here, the station itself continued its flight in a heliocentric orbit with minimum distance from the surface of the planet of about 1,600 km. The descent vehicle entered the atmosphere of Mars and began aerodynamic braking. On reaching calculated g-loads, the parachute system was activated.

Instruments for measuring the pressure, temperature and chemical composition and g-load sensors were installed on the descent vehicle in order to examine atmospheric parameters. The information from the descent vehicle was received by the "Mars-6" station and was relayed to earth. And at the surface of Mars, radio communications with the descent vehicle ceased. The descent vehicle of the "Mars-6" station reached the surface of the planet in an area with coordinates lat 24°S and long 25°W.

After separation from the station, the descent vehicle of the "Mars-7" station passed the planet 1300 km from its surface because one of the onboard systems failed.

Instruments built by French specialists were installed on board the "Mars-6" and "Mars-7" stations in addition to the Soviet scientific equipment. The French scientists participated in the experiments for measuring the polarization of light reflected by the surface and atmosphere of the planet and the intensity of the glow of the hydrogen resonance line and for investigating the "solar wind" and cosmic radiation as well as in the radio astronomical experiment to investigate the radio wavelength emission of the sun in the meter wave band.

Artificial Earth Satellites for Scientific Purposes

"Prognoz-3." The "Prognoz-3" automatic station was launched on 15 February at 0412 hours. The station was inserted into a highly elliptic artificial earth satellite orbit from an intermediate low earth orbit. The station weighed 845 kg. The "Prognoz" automatic station, just as both preceding stations of this type (see YEZHEGODNIK BSE [Great Soviet Encyclopedia Yearbook], 1973, p 527) was designed for studies of corpuscular, gamma and x-radiation of the sun and of plasma fluxes as well as for the further study of magnetic fields in near-earth space in order to determine the effect of solar activity on the interplanetary medium and the magnetosphere of the earth.

The satellite orbit was selected so that for the greater part of the orbital period, information was obtained from the areas located outside the effect of the earth's magnetic field. Under such conditions, the interference from the particles captured by the geomagnetic field is noticeably reduced, and, in addition, the observation of the undisturbed "solar wind" is possible.

The data received from the "Prognoz," "Prognoz-2," and "Prognoz-3" satellites yielded a number of interesting results. Above all, the scientists got the possibility of regularly tracing radiation conditions in the interplanetary medium near the earth. Beginning on 14 April 1972 (with the launching of the "Prognoz" automatic station), there was continuous information on charged particle fluxes, the solar wind and solar x-radiation. This makes it possible to obtain a statistically reliable picture of the radiation conditions in near-earth space. For example, from April to November 1972 the interplanetary space was filled with intense solar proton fluxes with an energy to several Mev and electrons with an energy of Kev. This abundance of particles during minimum solar activity is extraordinary. Against this increased background, which is created by charged particles of relatively low energy, large solar flares were observed several times. The sun was especially active at the beginning of August 1972. On 2, 4 and 7 August, the largest flares in the last 20 years occurred, accompanied by intensive proton and electron fluxes. The instruments installed on the "Prognoz" and the "Prognoz-2" artificial earth satellites recorded this unique natural phenomenon in near-earth space. The dosimetric measurements demonstrated that the absorbed dosage inside a manned transport ship, had it been in orbit at that time, would have been dangerous to human health. The scientists also detected several very interesting phenomena accompanying this series of flares: for example, a narrow increase in particle flux with very steep leading and trailing edges in almost all of the energy ranges. This "tube" with a diameter of several millions of kilometers extended from the sun to the boundaries of our solar system and was formed by the lines of force of the interplanetary magnetic field connected obviously at one end to the flare region. The mechanism for confining the particles in this tube is still insufficiently clear. The profiles of the X-ray bursts of the flares have a periodic structure. It bears witness to the use of the model which considers the optical flare as a result of the interaction of accelerated particles with the matter in the atmosphere of the sun, that is, as a secondary phenomenon. During increased solar activity in August 1972, as a result of the effect of the accelerated solar particles and solar wind, the magnetosphere of the earth was strongly deformed. Initially in the compression phase of the magnetic storm, its radius was almost cut in half by comparison with the undisturbed state, and in the recovery phase, the magnetosphere expanded to almost twice its size in the direction of the sun. The data received from the "Prognoz" automatic station were compared with the results of the ground astronomical observatories and geophysical stations, the broad network of which encompasses almost the entire planet. Scientists are persistently looking for the possibility of predicting solar activity phenomena.

"Intercosmos-Kopernik 500." On 19 April in accordance with the program of cooperation of the socialist countries in the field of space exploration and utilization for peaceful purposes, the "Intercosmos-Kopernik 500," the ninth satellite in the "Intercosmos" series was launched. The space experiment prepared by Polish and Soviet specialists was devoted to the 500th anniversary of the great Polish scientist Copernicus. The scientific equipment installed on board the satellite was designed for investigating the radio wavelength emission of the sun in the frequency band of 0.6-6.0 megahertz and characteristics of the earth's ionosphere. The scientific equipment of the satellite includes the following: a radio spectrograph developed and manufactured in the Polish People's Republic; low-frequency and high-frequency ionospheric probes developed and manufactured in the USSR. The reception of information from on board the satellite was realized by receiving stations of the USSR and Czechoslovakia. The astrophysical and geophysical observatories of the socialist countries conducted synchronous observations of the sun in various wavelength bands and the state of the earth's ionosphere during the space experiment.

"Intercosmos-10." The "Intercosmos-10" artificial earth satellite (see Figure 8) was launched on 30 October. The satellite was designed for doing geophysical research in high latitudes in order to study the electromagnetic coupling between the magnetosphere and the ionosphere. Scientific equipment was installed on board the satellite to determine the concentration and temperature of ionospheric electrons. This equipment was manufactured jointly by specialists of the German Democratic Republic and the USSR. There was also equipment for measuring the variations of the magnetic field and for measuring the electrical field in the frequency range of 0.1 to 70 gigahertz, electron fluxes, ions and neutral atoms in the range of 0.05 to 20 Kev built by the USSR; equipment developed and manufactured in Czechoslovakia for studying the low-frequency electrical oscillations of plasma in the frequency band from 20 Hertz to 22 kilohertz; a special telemetry system built in Czechoslovakia for transmitting scientific data to ground stations; and a special unit developed in the USSR for storing telemetry data.

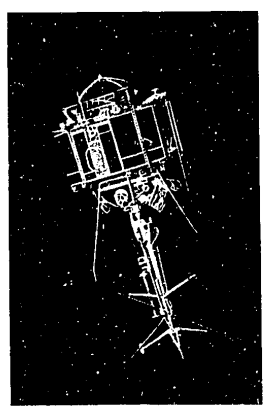

Figure 8. "Intercosmos-10" Artificial Earth Satellite.

For the comprehensive studies of the electromagnetic coupling between the magnetosphere and the ionosphere and its effect on the neutral atmosphere, the experimental program for the satellite mission provided for launching meteorological rockets with scientific equipment manufactured in the GDR and the USSR from the Soviet stations. Simultaneously with the operation of the scientific equipment of the "Intercosmos-10" earth satellite, ground measurements were made in a number of countries under a coordinated program. The information was received from on board the satellite by ground stations in the USSR, the GDR and Czechoslovakia.

"Oreol-2." In accordance with the program for cooperation between the USSR and France in the field of space exploration and utilization for peaceful purposes, the "Oreol-2" artificial earth satellite was launched on 26 December. The purpose of this experiment was to continue the studies of the physical phenomena in the earth's upper atmosphere in high latitudes and the study of the nature of the aurora polaris, which had started on the "Oreol" satellite in 1971.

Installed on board the "Oreol-2" satellite was scientific equipment designed to investigate the proton and electron spectra in a wide energy range, to measure the integral intensity of the protons and to determine the ion composition of the atmosphere. Service systems were also installed to provide for the carrying out of scientific experiments. Simultaneously with the measurements made on the "Oreol-2" satellite, ground observatories of a number of countries conducted coordinated geophysical studies under a joint program.

"Cosmos." The artificial earth satellites of the "Cosmos" series continued to be launched; in 1973, 85 satellites were launched (see the Table). White rats, turtles, insects, microorganisms and fungi were on board the unmanned "Cosmos-605" satellite. Conducting experiments with biological specimens required the creation of automatic equipment insuring normal vital activity of the animals and also providing for the measurement and transmission to earth of the data characterizing their state, the conditions of the environment and the operation of the corresponding systems. Each experimental animal (rat) was placed in a separate small chamber and was maintained in a free (unfixed) state. Inside the chamber were feeders and waterers, dome lights and a system of holes for air constantly ventilating the interior of a chamber by a directional flow that carried waste from the vital functions of the animals out of it. Each chamber was equipped with a special electronic measuring device permitting calculation and summation of the number of movements of the animal in two-hour intervals. The turtles, insects, microorganisms and fungi used in the experiments were placed in special containers insuring the corresponding living conditions.

Supplying the animals with oxyg· · and purifying the atmosphere inside the reentry vehicle to remove th· excess carbon dioxide and other harmful gaseous impurities were provided by the chemical air regeneration system. The required temperature and moisture regime was maintained by the thermal control system together with a device for drying the atmosphere. After 22 days of flight time, the "Cosmos-605" artificial earth satellite made a soft landing. A detailed examination of the animals using a complex of cytochemical, biochemical and morphological methods will permit us to obtain information on the mechanism of the effect of prolonged weightlessness on the tissue and cell levels. This will help us to come closer to an understanding of the mechanisms of the functional shifts observed during manned space flight. The basic purpose of the biological experiments on the "Cosmos-605" was the study of the effect of prolonged weightlessness on the development processes of the organisms. For this purpose drosophila, mealy bugs, bacteria and fungi imperfecti were used. The drosophilas which went into space two to three days old actually produced normal offspring. Some of the females and males developed in space subsequently also produced offspring. No differences in morphology and magnitude of the genetic load were detected between the parent generation and the offspring developed in weightlessness. The mealy bugs were placed on board the satellite in different stages of their life cycle: eggs, early larvae, late larvae, prepupa and pupa. The primary goal consisted in obtaining the transition from the lower stage of development to the higher one under weightlessness conditions. The development cycle went normally. The survival rate of all the species in all groups, both in orbit and in the control, was identical and amounted to about 100 percent.

The results of the experiment with fungi imperfecti clearly demonstrated how strongly weightlessness can influence the development of plants. Thus, for mushrooms grown under the conditions of weightlessness, the supporting tissues were much more poorly developed, and the stem supporting the cap was much thinner so that the mushroom was several times larger with respect to area than the "earth" mushroom.

Studies were also made on the "Cosmos-605" artificial earth satellite which were aimed at solving the problems of insuring the radiation safety of the crew and equipment during prolonged flights. An experimental study was made of the possible future form of radiation protection against the effect of charged particles--electrostatic protection. It is based on the creation and maintenance of an electric field near the protected compartments of the spacecraft which deflects the charged particle fluxes and lowers the radiation level inside the protected volume to the admissible limits. The measurements indicate the high "quality" of the space vacuum as an insulator in electrostatic protection even at altitudes of 200-400 km, in spite of the large number of charged and neutral particles here. In addition, the possibility for the automatic functioning of the electrostatic shielding in the radiation belt of the earth was confirmed experimentally for the first time.

Soviet spacecraft launched in 1973

Item No.	Launch date	Name of spacecraft	Apogee, (km)	Perigee, (km)	Orbital Inclination	Orbital period (min)	Frequency of radio transmissions (megahertz) Remarks
1	2	3	4	5	6	7	8
1	8 Jan	Luna-21					Completed a soft landing on the moon on 6 January. Delivered "Lunokhod-2" to the moon
2	11 Jan	Cosmos-543	333	211	65°	89.7	
3	20 Jan	Cosmos-546	561	513	74°	95.3	
4	25 Jan	Cosmos-545	521	279	71°	92.2	
5	26 Jan	Cosmos-546	630	585	51.7°	96.6	
6	Feb	Cosmos-547	330	208	65°	89.7	19.995
7	3 Feb	Molniya-1	39200	470	65°	11h,43m	
8	8 Feb	Cosmos-548	322	214	65.4°	89.6	
9	15 Feb	Prognoz-3	200000	590	65°	96h,23min	928.4
10	28 Feb	Cosmos-549	556	513	74°	95.2	
11	1 Mar	Cosmos-550	325	217	65.4°	89.6	
12	6 Mar	Cosmos-551	316	210	65°	89.5	
13	20 Mar	Meteor	903	882	81.2°	102.6	
14	22 Mar	Cosmos-552	337	211	72.9°	89.7	19.995
15	3 Apr	Salyut-2	260	215	51.6°	89.0	
16	5 Apr	Molniya-2	39100	500	65°	11h,42m	
17	12 Apr	Cosmos-553	519	282	71°	92.2	
18	19 Apr	Cosmos-554	318	212	72.9°	89.5	
19	19 Apr	Intercosmos-Kopernik-500	1551	202	48.5°	102.2	
20	25 Apr	Cosmos-555	253	216	81.3°	89.0	
21	5 May	Cosmos-556	252	209	81.3°	89.0	
22	11 May	Cosmos-557	266	218	51.6°	89.1	
23	17 May	Cosmos-558	526	279	71°	92.3	
24	18 May	Cosmos-559	345	217	65.4°	89.8	
25	23 May	Cosmos-560	336	211	72.9°	89.7	

Soviet spacecraft launched in 1973 (continued)

1	2	3	4	5	6	7	8
26	25 May	Cosmos-561	317	215	65.4°	89.5	19.995
27	29 May	Meteor	909	867	81.2°	102.5	
28	5 Jun	Cosmos-562	510	282	71°	92.1	
29	6 Jun	Cosmos-563	320	213	65.4°	89.5	
30	8 Jun	Cosmos-564-571	1507	1392	74°	114.5	Eight artificial earth satellites were inserted into orbit by one booster rocket
31	10 Jun	Cosmos-572	294	211	51.7°	89.3	
32	15 Jun	Cosmos-573	329.2	196.2	51.6°	89.5	20.008
33	20 Jun	Cosmos-574	1026	996	83°	105	
34	21 Jun	Cosmos-575	299	208	65.4°	89.3	19.995
35	27 Jun	Cosmos-576	356	212	72.9°	89.9	
36	11 Jul	Molniya-2	39280	480	65.3°	11h,45m	
37	21 Jul	Mars-4					The station passed near Mars at a distance of 2200 km from the surface
38	25 Jul	Cosmos-577	312	209	65.4°	89.5	
39	25 Jul	Mars-5	32500	1760	35°	25hours	
40	1 Aug	Cosmos-578	308	207	65.4°	89.4	19.995
41	5 Aug	Mars-6					Descent vehicle of the station reached the surface of Mars. Descent vehicle passed near Mars 1,300 km from the surface
43	21 Aug	Cosmos-579	315	209	65.4°	89.5	
44	22 Aug	Cosmos-580	518	283	71°	92.2	
45	24 Aug	Cosmos-581	303	211	51.6°	89.4	
46	28 Aug	Cosmos-582	559	521	74°	95.3	
47	30 Aug	Molniya-1	37970	480	65.3°	11h,19m	
48	30 Aug	Cosmos-583	316	208	65°	89.5	19.995

Soviet spacecraft launched in 1973 (continued)

1	2	3	4	5	6	7	8
49	6 Sep	Cosmos-584	360	213	72.9°	89.9	
50	8 Sep	Cosmos-585	1416	1385	74°	113.6	
51	14 Sep	Cosmos-586	1020	986	83°	105	
52	21 Sep	Cosmos-587	330	215	65.4°	89.6	
53	27 Sep	Soyuz-12	249	194	51.6°	88.6	
54	3 Oct	Cosmos-588-595	1512	1397	74°	115	Earth artificial earth satellites were inserted into orbit by one booster rocket
55	3 Oct	Cosmos-596	310	211	65.4°	89.4	19.995
56	6 Oct	Cosmos-597	312	212	65.4°	89.5	
57	10 Oct	Cosmos-598	360	213	72.9°	90	
58	15 Oct	Cosmos-599	294	206	65°	89.3	19.995
59	16 Oct	Cosmos-600	366	215	72.9°	90	
60	16 Oct	Cosmos-601	1561	210	82°	102.3	
61	19 Oct	Molniya-2	40600	630	62.8°	12h,16m	
62	20 Oct	Cosmos-602	365	213	72.9°	90	
63	27 Oct	Cosmos-603	380	213.5	72.9°	90.1	
64	29 Oct	Cosmos-604	647	624	81.2°	97.2	
65	30 Oct	Intercosmos-10	1477	265	74°	102	
66	31 Oct	Cosmos-605	424	221	62.8°	90.7	
67	2 Nov	Cosmos-606	39360	626	62.8°	710	
68	10 Nov	Cosmos-607	364	214	72.9°	90	
69	14 Nov	Molniya-1	39140	480	65°	11h,42m	
70	20 Nov	Cosmos-608	528	281	71°	92.3	
71	21 Nov	Cosmos-609	370	207	70°	90	
72	27 Nov	Cosmos-610	515	360	74°	95.2	
73	28 Nov	Cosmos-611	507	280	71°	92	
74	28 Nov	Cosmos-612	371	214	72.9°	90.1	
75	30 Nov	Cosmos-613	295	195	51.6°	89.1	
76	30 Nov	Molniya-1	40900	460	62.7°	12h,17m	

Soviet spacecraft launched in 1973 (continued)

1	2	3	4	5	6	7	8
77	4 Dec	Cosmos-614	830	770	74°	100.7	
78	13 Dec	Cosmos-615	859	280	71°	95.7	
79	17 Dec	Cosmos-616	355	214	72.9°	89.9	
80	18 Dec	Soyuz-13	272	225	51.6°	89.22	Orbital parameters after correction on the fifth orbit
81	19 Dec	Cosmos-617-624	1511	1404	74°	114.8	Eight artificial earth satellites were inserted into orbit by one booster rocket
82	21 Dec	Cosmos-625	346	214	72.8°	89.8	
83	25 Dec	Molniya-2	40865	466	62.8°	12h,17m	
84	26 Dec	Oreol-2	1995	407	74°	109.2	
85	27 Dec	Cosmos-626	280	257	65°	89.7	
86	29 Dec	Cosmos-627	1032	991	83°	105	

Artificial Earth Satellites for Applied Purposes

"Molniya." Four "Molniya-1" and four "Molniya-2" satellites were launched in 1973 in order to maintain long-distance telephone and telegraph radio communications, for the transmission of programs from the USSR Central Television to stations of the "Orbita" network and for international cooperation.

"Meteor." Two "Meteor" artificial earth satellites were launched in 1973. The basic mission of the satellites was to obtain meteorological information required for use in the operational weather service. The meteorological equipment of the satellites provided for obtaining images of clouds and snow cover on the light and dark sides of the earth as well as data on the thermal energy reflected and emitted by the earth into the atmosphere.

Geophysical studies by rocket sounding of the atmosphere continued in 1973.

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NON-SOVIET SPACE RESEARCH IN 1973

Moscow YEZHEGODNIK BOL'SHOY SOVETSKOY ENTSIKLOPEDII in Russian No 18, 1974 pp 526-537

[Article by D. Gol'dovskiy]

[Text] Artificial Earth Satellites

In 1973 18 foreign artificial earth satellites were inserted into orbit including 16 American satellites (three in the "Explorer" series, one NOAA, one "Transit," two DSCS, one Air Force meteorological satallite and eight secret satellites for military purposes), one Canadian satellite ("Anik-2") and one satellite of the INTELSAT international consortium (the INTELSAT-4E). The "Anik-2" and INTELSAT-4E satellites were inserted into orbits by American booster rockets.

The basic information on the orbits of the enumerated satellites is found in the Table. A description of some of them is presented below.

"Explorer-49" (Table, No 5). The second American research satellite of the RAE[1] type (RAE-B, see Figure 1), designed for radio astronomical research: recording low-frequency (0.002-13 megahertz) radio wavelength emission of the Sun, Jupiter, the Milky Way and other galaxies. In contrast to the first satellite of this type (RAE-A, "Explorer-38," see YEZHEGODNIK BSE, 1969, p 500), the "Explorer-49" was inserted not into a geocentric orbit, but into a selenocentric orbit in order to avoid interference caused by radio noise of earth origin: when the satellite sets behind the moon, it is shielded from earth radiation. The satellite weighs 334 kg. In structural design and equipment, the RAE-B satellite is similar to the RAE-A satellite and, like it, it is equipped with two V-type antennas made up of four rods 230 meters long, each of which unfold after the satellite is inserted into selenocentric orbit. The rods are formed from prestressed tape wound from a drum and passed through a drawplate. In contrast to the RAE-E, installed on board the RAE-B satellite is an ejectable solid-fuel rocket engine (thrust 80 kg, operating time 20 seconds) which brakes the satellite in order to transfer it from the flight trajectory to the moon into selenocentric orbit, and the ejectable liquid-fuel engines (two liquid-fuel rocket engines with a thrust of 2.3 kg each and four spherical tanks with hydrazine) correct the flight trajectories on the "earth-moon" path and in selenocentric orbit.

"Explorer-50" (Table, No 12). The tenth and last American satellite of the IMP[2] series (IMP-J, Figure 2) is designed to investigate radiation, cosmic rays, the solar wind, and magnetic and electric fields. The satellite weighs 395 kg. In structural design and service equipment it is similar to the IMP-H satellite ("Explorer-47," see YEZHEGODNIK BSE, 1973, pp 529--30). The orbits of the "Explorer-50" and "Explorer-47" satellites almost coincide. The angular distance between the two satellites frequently is close to 180 degrees. This offers the possibility of simultaneously taking measurements at two points in space located on opposite sides of the earth. For example, it is possible simultaneously to investigate the effects of the solar flares on near-earth space on the day and night sides of the planet. The first IMP satellite was launched in 1963. The IMP-J satellite was designed to function for a year. Thus, by the end of the operational service of the IMP-J satellite, the studies using the IMP satellites would have encompassed the entire 11-year solar cycle (1963-1974).

"Explorer-51" (Table, No 18). The first satellite in the AE series (AE-C, Figure 3) of the "second generation"[3] for comprehensive studies of the upper layers of the atmosphere at altitudes of 120 km and higher. The satellite weighs 660 kg, including 95 kg of scientific equipment and 170 kg of onboard hydrazine reserves for correcting the trajectory. The hull has the shape of a regular 16-sided prism (height 1.14 meters, transverse dimensions 1.37 meters). The ~10,000 solar elements mounted on the hull provide a total power of 160 watts; for operation of the scientific instruments, a power of 114 watts is required. In the electric power supply system, nickel-cadmium batteries are also used. In orbit the satellite can be oriented with respect to three axes (orientation precision one angular minute) or stabilized by rotation (one to ten rpm). The axis of rotation must be perpendicular to the orbital plane.

The scientific equipment module includes ultraviolet spectrometers for recording solar radiation and radiation of the earth's atmosphere, a photometer for recording the luminosity of the sky and the aurora polaris, a mass spectrometer and a spectrometer for determining the concentration of neutral gases, an accelerometer for calculating atmospheric density with respect to decelerating the satellite, instruments for determining the ion and electron concentration in the atmosphere, and so on (a total of 14 instruments).

The satellite is inserted into an initial orbit with a perigee of 156 km and an apogee of 4,305 km. During the first five or six months, it must be transferred about five times to an orbit with a perigee of 180 km and, after a few days, returned to the initial orbit. These maneuvers as well as the compensation of the aerodynamic braking in the perigee of the initial and the low orbit are provided for by the onboard engine. When the hydrazine reserve is almost completely exhausted (approximately six months after the launch), the satellite must be moved to a circular orbit ~300 km high which will not be corrected. According to calculations, the satellite can stay in this orbit for approximately a year.

NOAA-3 (Table, No 14). The next American NOAA meteorological satellite (ITOS-F)[4]. The satellite weighs 340 kg. In structural design and service equipment the satellite is similar to the preceding ITOS satellites (see YEZHEGODNIK BSE 1971, pp 503, 504, 507 and 1973, p 531). The same scientific instruments were installed on it as on the NOAA-2 satellite (ITOS-D).

Transit (Table, No 13). The next satellite for use in the navigational satellite system of the U.S. Air Force which is called NAVSAT.[5] The system has been in operation since 1964. In recent years, five satellites have been used in it. On 29 October 1973 a satellite had to be launched to replace one of the five system satellites in which the stabilization system had failed (this satellite had operated since 1967). The operational model of the "Transit" satellite (see YEZHEGODNIK BSE 1964, pp 499, 500, 502) weighs ~60 kg. Its hull (see Figure 4) is a multifaceted prism (height 30.5 cm, transverse dimension 45.7 cm).

DSCS-3 and DSCS-4 (Tables, No 16 and 17). The second pair of satellites of the DSCS-2 model for use in the improved military communications system which must insure global continuous secret "strategic" and "tactical" communications (radio telephony, digital and video information transmission) with multistation access. The satellites weigh 558 kg each. They are an improved model of the DSCS-1 and DSCS-2 satellites (see YEZHEGODNIK BSE 1972, p 521).

Meteorological Satellite (without a designation) of the U.S. Air Force (see Table, No 8).[6] The next satellite for the meteorological data collection system in the interests of the U.S. Air Force and Navy. For the normal functioning of this system, there must be two operating satellites in orbit at any given time. The system was created in 1966, after which satellites have been launched periodically to replace those which fail.

The satellite weighs 195 kg. Its hull (see Figure 5) has the shape of a 12-sided truncated pyramid (height 1.64 meters, diameter of the large base 1.3 meters, diameter of the small base 1.1 meter). Solar cells are mounted on 11 out of the 12 faces of the hull; a turnstile antenna is mounted on the remaining face. Louvers are provided in the thermal control system. The triaxial orientation system uses an induction coil which interacts with the earth's magnetic field (bank, yaw) and a flywheel (pitch). In order to determine the earth's vertical, there is an infrared sensor. The output power of the onboard transmitter is 6 watts. The payload of the satellite is a four-channel radiometer built by Westinghouse and an eight-channel radiometer built by Barnes Engineering. With the first radiometer, images of the cloud cover were obtained during daytime and nighttime, both in the visible and in the infrared ranges of the spectrum, but it is possible to obtain images in the visible region of the spectrum at night only in moonlight. Two channels operating in visible light (0.4-1.1 micron) encompass the near infrared region which permits the clouds, the dry land and water surface to be better distinguished. The operating band of the two infrared channels (8-13 microns) is selected with consideration for the fact that they record cirrus clouds which can be transparent in visible light. The two visible channels provide resolutions of 0.63 and 3.7 km; the two infrared channels provide resolution of 0.67 and 4.4 km. Using the second radiometer (~15 microns), the vertical temperature profile of the atmosphere is obtained.

In the Air Force meteorological system, stationary and mobile (transported by aircraft) stations are used. The latter permit the troop soyedineniye commanders to obtain meteorological data of a tactical nature directly from the satellites in real time. These data were used, in particular, when planning the air operations in Vietnam.

Secret Satellites of the U.S. Air Force. No official information on the designations and missions of the secret satellites has been published. According to unofficial information, the following types of secret satellites were inserted into orbit in 1973:

1. Two satellites for detailed photo reconnaissance (Table, No 4 and 11). For information on such satellites (see YEZHEGODNIK BSE 1973, p 534). The first of these satellites ceased to exist on 13 June 1973, and the second on 29 October 1973. According to the suggestions of some reviewers, these satellites were used not for detailed photographic reconnaissance, but for testing experimental equipment which in the future is to be installed on satellites for observation of the ocean. This equipment, it is assumed, includes instruments which operate both in visible and in infrared regions of the spectrum. According to calculations, the scanning camera of the MSS type operating in the infrared part of the spectrum on the ERTS-1 satellite (see YEZHEGODNIK BSE 1973, p 531) would insure sufficient resolution for observation of large military ships. The onboard computer of the satellite could automatically identify ships by the characteristic emission of the ship itself and its wake. Then it would be possible to decrease significantly the volume of information transmitted from the satellite to earth.

2. Three "Big Bird" satellites ("Big Bird-4, -5 and -6," Table, No 2, 7 and 15) for surveying and detailed photo reconnaissance launched in accordance with program 467. For information on these satellites see YEZHEGODNIK BSE 1973, p 534). It is also reported that the Perkin-Elmer camera installed on the satellite for detailed reconnaissance when surveying from an altitude of 60 km insures resolution better than 0.3 meters. According to certain information, the camera is equipped with a 3-meter telescope. Six containers are used to return the film taken by this camera. When the satellite is in orbit for months, the containers can be returned to the earth at intervals of 2 or 3 weeks. It is possible that the satellite

equipment includes the television camera with a telephoto lens and variable focal length, cameras for infrared photography and also a side scanning radar (it has been reported that the signals from this radar has been picked up by certain telescopes). It is proposed that radio relays will later be installed on the "Big Bird" satellites to provide communications between ground media and strategic aircraft in the polar regions.

The first of three "Big Bird" satellites launched in 1973 ceased to exist on 19 May 1973, and the second on 12 October 1973. The third continued to operate in 1974.

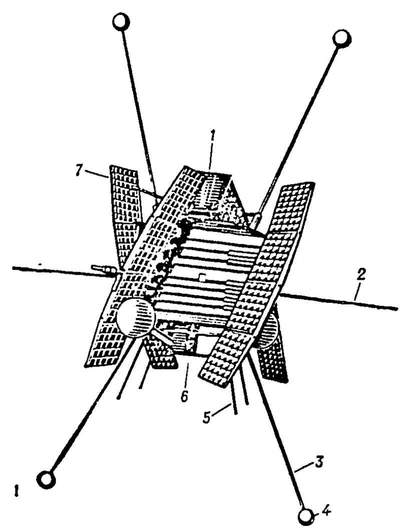

Figure 1. "Explorer-49" (RAE-B) Satellite

Key:
1. Onboard solid-fuel rocket engine
2. Dipole antenna rod
3. V-antenna rod (scale not maintained)
4. Weight on the end of rod
5. Telemetry system antenna (a total of 4)
6. Liquid-fuel engine
7. Solar panel (a total of 4)

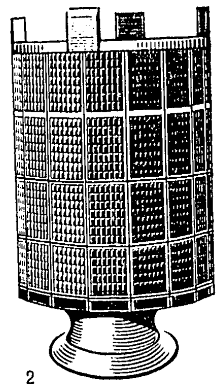

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Figure 2. "Explorer-50" (IMP-J) Satellite.

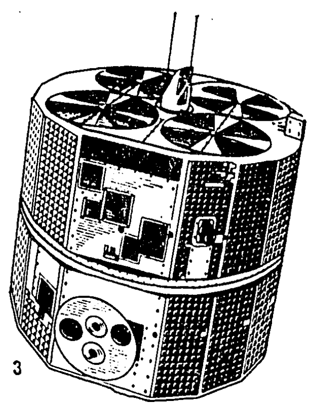

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Figure 3. "Explorer-51" (AE-C) Satellite.

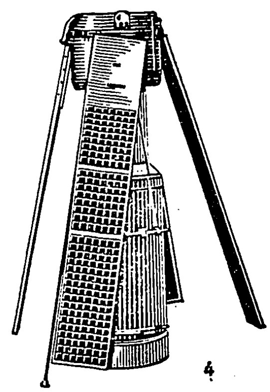

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Figure 4. Operating Model of the "Transit" Satellite (in the Last Stage of the Booster Rocket with Builtin Solar Panels).

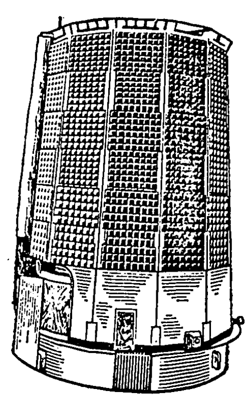

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Figure 5. U.S. Air Force Meteorological Satellite

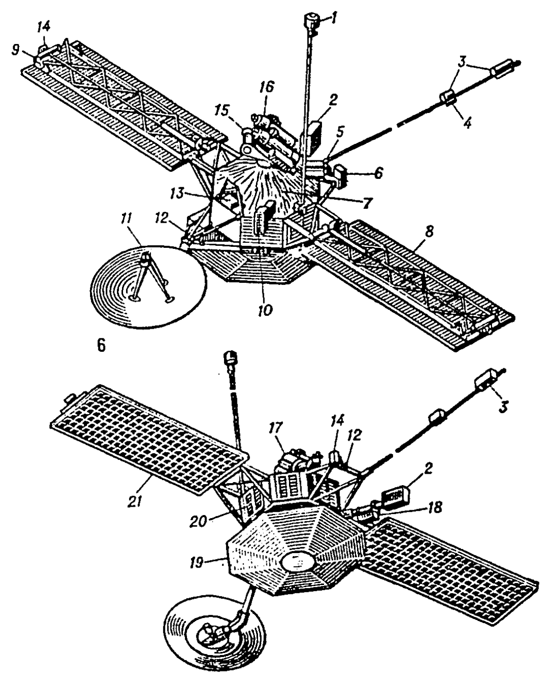


Figure 6. "Mariner-10" Automatic Interplanetary Station. 1--Omnidirectional antenna; 2--Device for investigating solar plasma; 3--Tri-axial induction magnetometers; 4--Sound protective shields of the magnetometers; 5--Set of sensors ("telescope") for recording charged particles; 6--Ultraviolet spectrometer on the hull of the station; 7--Heat insulation; 8--Solar panels (reverse side); 9--Microengines for orientation with respect to bank and yaw (on the ends of the panels 8); 10--Stellar sensor; 11--Reflector of the unidirectional antenna; 12--Microengines for orientation with respect to pitch (on the hull of the station; 13--Radio transmitter in the X band; 14--Sun sensor; 15--Scanning platform; 16--Television cameras; 17--Ultraviolet spectrometer on the scanning platform; 18--Infrared radiometer; 19--Station's sun shield; 20--Louvers for the thermal control system; 21--Solar cells.

3. One IMEWS operational satellite (IMEWS-4, Table, No 6) for early detection of the launching of strategic satellites from ground launch sites and from submarines, recording nuclear blasts as well as other missions of a military nature. For more information about the satellites launched in accordance with program 647, see the YEZHEGODNIK BSE, 1973, p 534. It has been reported that the infrared sensors on the IMEWS satellites have gradually begun to lose their sensitivity for an unexplained reason. It is proposed that this is the result of nuclear blasts in the atmosphere by France and China.

4. One experimental BMEWS satellite (BMEWS-7, Table, No 1) for developing equipment to detect strategic rocket launching. For more information on these satellites see the YEZHEGODNIK BSE, 1973, pp 534, 535. It has been proposed that the BMEWS satellites launched in recent times are being used to discover why the infrared sensors on the IMEWS satellites have lost their sensitivity sensors. It is also assumed that a new type of detectors are being tested on the BMEWS satellites which will not only detect rocket launchings but also track their nose cones in the middle part of the trajectory, permitting calculation of the strike point.

5. The experimental satellite (Table, No 9) launched in accordance with program 711 for testing equipment and solving the technical problems of communications with strategic bombers on flights in polar regions. In contrast to all the remaining modern foreign communications satellites for civilian and military purposes inserted into stationary or near stationary orbit, this satellite is in an elliptic orbit with an inclination of 63.2 degrees. This orbit, in contrast to the stationary orbit, permits communications coverage of the polar regions. The sharply elongated elliptic orbit with the apogee over the northern hemisphere provides a prolonged visibility zone for the users located there. This is the second such satellite launched in the United States (for information about the first one, see the YEZHEGODNIK BSE, 1972, p 529, Table, No 11).

"Anik-2" (Table, No 3). The second "Anik" communications satellite for the commercial communications system servicing the territory of Canada. It was manufactured in the United States with the participation of Canadian companies. It is completely like the "Anik-1" satellite (see the YEZHEGODNIK BSE, 1973, p 535). Several of the radio relays of the satellite are leased by American companies for communications servicing of United States territory.

INTELSAT-E (Table, No 10). The fifth satellite of the INTELSAT-4 series for use in the global commercial communications system. It was inserted into stationary orbit above the Atlantic Ocean where it plays the role of a reserve for the INTELSAT-4A and INTELSAT-4B satellites in operation there at the present time. The INTELSAT-4E satellite is completely like the previously launched satellites of the INTELSAT-4 series (see the YEZHEGODNIK BSE, 1972, p 525 and 1973, p 536).

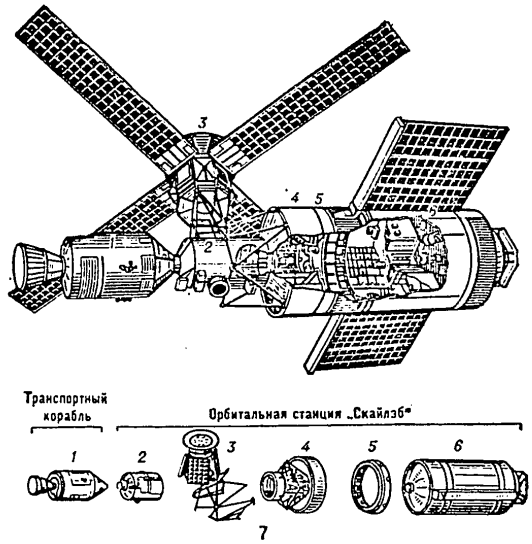


Figure 7. Basic components of the "Skylab" Station, including the "Apollo" Transport Ship Docked with It (for the description see pp 532-533): 1--Transport ship; 2--Docking unit; 3--ATM set of astronomical instruments; 4--Lock; 5--Equipment compartment of the "Saturn-5" booster rocket structurally entering into the composition of the station; 6--Station module.

Key: (A) Transport ship (B) "Skylab" orbital station

Automatic Interplanetary Stations

At the beginning of December 1973, the "Pioneer-10" automatic interplanetary station launched in 1972 completed its flight past Jupiter. On 6 April 1973, the "Atlas-Centaur-Werner-2" booster rocket was used to launch the "Pioneer-11" automatic interplanetary station for studies of Jupiter and Saturn from a fly-by trajectory. On 3 November 1973, the "Atlas-Centaur" booster rocket was used to launch the "Mariner-10" automatic interplanetary station for studying Venus and Mercury from a fly-by trajectory.

"Pioneer-10." This station des gned for surveying and sounding Jupiter was inserted into the flight trajectory to Jupiter on 3 March 1972 (see the YEZHEGODNIK BSE 1973, pp 536, 537). On completing the flight by this trajectory, on 15 February 1973 the station left the belt of asteroids between the orbits of Mars and Jupiter.

Studies on the interplanetary trajectory demonstrated that the concentration of meteor particles ~ 1 micron in size diminishes on going away from the sun, and at a distance of 3.5 astronomical units, that is, at the outer edge of the asteroid belt, it drops almost to zero. Contrary to expectations, the concentration of particles ~ 10 microns in size, which are the greatest danger to spacecraft, did not increase in the asteroid belt. There were almost three times more particles 100-1,000 microns in size in the asteroid belt than between the orbit of the earth and this belt. No particles greater than 1,000 microns in size were detected by the onboard complex of "Sizif" optical telescopes designed to record asteroids and meteor bodies. The intensity of the solar magnetic field, the density of the solar wind and the number of high-energy particles of solar origin decrease approximately proportionately to the square of the distance from the sun. Aluminum and sodium atoms were detected in the cosmic radiation for the first time. Helium atoms which obviously belonged to the interstellar gas were recorded in the interplanetary medium.

The surveying of Jupiter (using a photopolarimeter) began on 4 November 1973. From 4 to 25 November, surveying sessions were held for 3 to 6 hours each day, and beginning on 25 November, round the clock.

On the photographs it is obvious that Jupiter is covered with concentric stripes of grey, orange, red brown, yellow and blue. The "red spot" which has several points is clearly isolated. The outer edge of the spot are sharply outlined and are darker than the inner part.

Picture of Jupiter taken by the "Pioneer-10" automatic interplanetary station (the "red spot" and the shadow of the satellite Io on the surface of the planet are visible).

On 4 December at 0225 hours Greenwich time, the "Pioneer-10" automatic interplanetary station passed its minimum distance from Jupiter--131,000 km from the tops of the clouds or 2.85 times the radius from the center of the planet. The automatic interplanetary station passed over the eastern or right hard (for the earth observer) limb of Jupiter and flew around the planet counterclockwise (if we consider from the direction of the north pole of the ecliptic), that is, with respect to rotation of the planet. The inclination of the bypass trajectory to the Jupiter equator was 14 degrees. Under the effect of the gravitational field of the planet, the trajectory of the automatic interplanetary station was twisted almost at a right angle and the automatic interplanetary station began to move along the tangent to the orbit of Jupiter.

At 0239 hours on 4 December the automatic interplanetary station passed behind the Jupiter satellite Io (the cover lasted 91 seconds) and then it set behind Jupiter (the cover lasted 64 minutes) and flew in the shadow of Jupiter (for 50 minutes).

According to calculations, continuing its flight, the automatic interplanetary station will intersect the orbit of Saturn in 1976, the orbit of Uranus in 1979, the orbit of Neptune in 1983 and the orbit of Pluto in 1987. It is hoped that communications with the automatic interplanetary station will be maintained approximately until 1978 (to the time that it is approximately 3 billion km from the earth).

Some highly preliminary results of the study of Jupiter, its satellites and near-planetary space using the instruments of the "Pioneer-10" automatic interplanetary station are presented below.

The magnetometer showed that the axis of the magnetic field of Jupiter is inclined 15 degrees to the axis of rotation of the planet. The source of the magnetic field is asymmetric with respect to the center of the planet and is somewhat shifted toward the north from the equatorial plane. The intensity of the magnetic field on the surface of the planet is defined as 4 gauss. The most important discovery is the strong concentration of captured radiation around the plane of the magnetic equator of Jupiter (see the figure). In the opinion of some scientists, in the magnetosphere of this planet other electrodynamic processes are more decisive than in the magnetosphere of the earth. The radiation concentration in a limited zone explains the fact that the intensity levels of the fields and particles recorded by the instruments of the automatic interplanetary station varied with a 10-hour period. Obviously, as a result of the inclination of the magnetic axis to the axis of rotation of the planet, the equatorial peak intensity passed through the automatic interplanetary station approximately synchronously with the period of rotation of the planet around its axis (10 hours). The radiation concentration is an important factor for planning future flights, in particular, the flight path of the "Pioneer-11" automatic interplanetary station past Jupiter. The interplanetary stations can approach relatively close to the planet, passing the equatorial zone and at the same time without subjecting the onboard equipment to the danger of radiation damage.

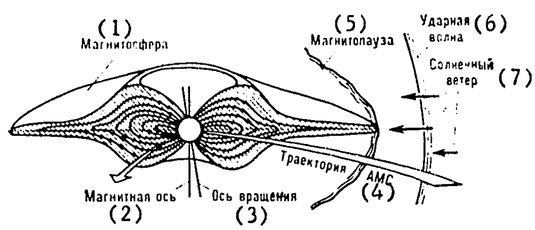
Radiation detectors demonstrated that in a zone extending 35 degrees from the center of Jupiter, the fields and particles rotate with the same velocity as the planets. The energy of the captured particles is especially high in the 10 degree zone. At a distance of 3 radii, the electron flux with an energy of more than 3 Mev is $5 \cdot 10^8$ particles/cm^2-sec, the proton flux with an energy of more than 30 Mev is $4 \cdot 10^6$ particles/cm^2-sec. The automatic interplanetary station received a radiation dose of approximately 500,000 rad (at the critical limit for some onboard equipment).

The ultraviolet spectrometer recorded the Lyman-alpha hydrogen line (1216 Å) and the corresponding helium line (584 Å). The presence of helium on Jupiter was detected for the first time, although it had been theoretically predicted earlier. The ratio of hydrogen to helium still has not been calculated for this is a very difficult problem.

By using an infrared radiometer in the ranges of 20 and 40 microns, the temperature distribution over the disc of the planet was obtained. The total thermal flux from Jupiter exceeds by 2.5 times the energy obtained by the planet from the sun. In the opinion of a number of scientists, the planet obviously is still passing through the stage of gravitational compression in which the potential energy is converted to thermal energy.

Radio sounding when the automatic interplanetary station set behind the planet demonstrated that it has a multilayered ionosphere.

Celestial mechanical studies by the trajectory measurements gave the following preliminary values for the density of the Jupiter satellites (in g/cm^3): Io 3.48, Europa 3.07, Ganymede 2635, and Callisto 2500. A characteristic feature is noted: the farther the satellite is from Jupiter, the smaller its density. The mass of Jupiter only very insignificantly exceeds the value determined by ground observations. According to the trajectory measurement data, it was calculated that the ratio of the mass of the sun to the mass of Jupiter is 1047.341. The compression of the planet on the basis of these data was defined as 0.065.



Magnetosphere of Jupiter, according to the data of the "Pioneer-II" Automatic Interplanetary Station.

[Key on following page]

[Key for figure on preceding page]

(1) magnetosphere
(2) magnetic axis
(3) axis of rotation
(4) automatic interplanetary station trajectory
(5) magnetopause
(6) shock waves
(7) solar wind

The meteor particle detectors have demonstrated that their density on Jupiter is 300 times higher than in interplanetary space: of the interplanetary trajectory the particles were recorded on the average every 600 hours; when flying past Jupiter, every two hours.

"Pioneer-11." The basic missions of this station were to study the magnetic field of Jupiter and its radiation belts, to investigate the heat balance and the temperature distribution in the outer atmosphere of the planet, to obtain images of the planet and some of its satellites in visible light, more precisely to define the ephemeris and mass of the planet. On the flight trajectory to Jupiter and after flight past the planet, provision was made for studying the solar wind, the interplanetary magnetic field, cosmic radiation as well as the meteor material in the asteroid belt for the first time. The station must fly past Jupiter on 2 December 1974 at a distance of about 42,000 km and under the effect of the gravity of this planet go into the trajectory toward Saturn. The flight past this planet will take place in October 1979.

The "Pioneer-11" automatic interplanetary station weighs 258.5 kg, including 30 kg of scientific instruments. In its structural design and service and scientific equipment, the "Pioneer-11" automatic interplanetary station is similar to the "Pioneer-10" automatic interplanetary station (see the YEZHEGODNIK BSE, 1973, pp 536, 537), but an induction magnetometer is also installed on it to measure the intense magnetic fields near Jupiter (the measurement range of the instrument is up to 10^6 gammas).

"Mariner-10." The basic missions of this station are to survey and sound Venus and Mercury from flight trajectory (in the gravitational field of Venus the station will complete a perturbation maneuver and transfer to the flight path to Mercury). By using the television cameras of the station it is proposed that 5,700 picture of Venus and ~2,740 pictures of Mercury will be obtained. Special attention has been given to the studies of Mercury: in addition to the survey, provision has been made for measuring the thermal radiation of the surface, the search for hot sections, determining the composition of the planet's atmosphere if it exists, the search for the magnetosphere, recording the shockwave and particles captured by the magnetic field of the planet, the "tail" of the magnetosphere, more precisely calculating the mass and radius of Mercury as well as the harmonics of the gravitational field of the planet.

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The "Mariner-10" automatic interplanetary station (see Figure 6) weighs 526 kg, including 77 kg of scientific instruments. The hull has the shape of an octahedral prism (transverse dimension 1.3 meters). The solar panels are 8 meters long. The thermal control system uses heaters, louvers, heat shielding made of "beta" fiberglass, thermal insulation as well as a sun shield of "beta" fiberglass and capton film with aluminum coating. This shield is needed because the trajectory of the station passes very close to the sun. Sun sensors, a stellar sensor which locks on Canopus or Vega and gyrostabilized platform are used in the orientation system, and two (one spare) sets of 6 microengines operating on compressed gas are used as the servoelements. The precision of the orientation with respect to pitch and yaw is 0.25 degrees. The nitrogen reserve for the microengines is 3.6 kg. Four solar panels (total area 5.25 m^2) provide a power of 475 watts when flying past Mercury. In order to prevent heating of the solar cells above 100 degrees C on approaching the sun, the panels gradually rotate with respect to the longitudinal axis until they establish an angle of 70 degrees to the direction of the sun. Before unfurling the panels and also during the trajectory corrections when the panels are not turned towards the sun, the electric power is provided by a storage battery. An S-band receiver, two (or one spare) S-band transmitters (2113 megahertz) and an X-band transmitter (8415 megahertz) have been installed on the station. The omnidirectional antenna of the station operates in the S-band; the highly directional rotating antenna operates both in the S-band (amplification factor 28 db) and in the X-band (38.5 db). The sharply directional antenna has a reflector 1.37 meters in diameter which is on a rod 1 meter long. The formation content when transmitting television images is up to 117,600 bits/sec, the telemetry information is up to 2,450 bits/sec. The capacity of the onboard memory is 1.6×10^8 bits. The correcting engine (thrust 23 kg) operates on the products of the breakdown of hydrazine, the reserve of which is 27.2 kg and insures a total increase of velocity of 115 m/sec.

The scientific equipment includes two identical television cameras each with a telephoto lens (focal length 1,500 mm, viewing angle 0.5 degrees) and a wide-angle lens (68 mm, 11-14 degrees). The survey is made in the visible and ultraviolet ranges. The latter is especially important for obtaining images of the cloud cover of Venus. The cameras are installed on a scanning platform which can rotate with respect to two axes (255 degrees with respect to one and +58 degrees to -180 degrees with respect to the other). One ultraviolet spectrometer is installed on the same platform, and a second one is mounted on the hull of the station. In addition, an infrared radiometer, a solar plasma detector that includes a scanning spectrometer and a scanning electrostatic analyzer as well as a set ("telescope") of Geiger-Mueller counters for recording charged particles are mounted on the hull. Two magnetometers are placed on a rod 7 meters long.

The "Mariner-10" station was launched on 3 November 1973, and it was inserted in the flight trajectory to Venus. In the near-earth segment, the onboard television cameras were used to obtain several hundred pictures of the earth and the moon basically to calibrate the cameras. On 13 November 1973, the first correction was made to the trajectory of the station on the "Earth-Venus" flight path; on 21 January 1974, a second correction was made. The station flew past Venus on 5 February and Mercury on 29 March 1974. The correction to the heliocentric orbit of the station after the first pass near Mercury provided for a repeated pass near this planet on 21 September 1974 at a distance of 50,000 km.

Orbital Station and Manner Transport Ships

The "Skylab" orbital station (unmanned) was launched in 1973 in the United States. Three crews of three astronauts each were delivered to it by the "Apollo" manned transport ships. The first crew spent 28 days in the station (from 25 May to 22 June); the second crew spent 59 days (from 28 July to 25 September), and the third and last crew spent 84 days (from 16 November 1973 to 8 February 1974). The basic missions of the "Skylab" program were to study the effect of prolonged weightlessness on the physical condition and fitness of the astronauts, medical experiments, observations of the sun, studies of the earth's natural resources, technological experiments, testing various equipment and a number of other studies and experiments. The "Skylab" station is experimental. It was proposed that it could be used to obtain information important for the creation in the future of long-term manned orbital stations as well as for future prolonged manned flights to the planets.

On launching from the earth the "Skylab" station weighs 88.9 tons; in orbit (after separation of the ejectable section of the nose cone) it weighs 77.1 tons. The length of the station in orbit is ~ 25 meters. It is made up of the following basic components (see Figure 7, page 529):

1. A station module (14.66 meters long, 6.6 meters in diameter, a sealed volume of 292 m^3 weighing 35.38 tons with artificial atmosphere). The module was created on the basis of the S-4V rocket developed in its time as the third stage of the "Saturn-1B" and "Saturn-5" booster rockets. The hydrogen tank of the rocket (Figure 8, see page 529) has been partitioned into two compartments: the living quarters and laboratory. In the living quarters there are four areas partitioned off: for sleeping, for personnel hygiene, for leisure, the preparation and eating of food, for setting up and conducting experiments. The oxygen tank of the rocket (volume 80 m^3) is evacuated and is used to collect waste which is discharged into it from the living quarters through a lock.

2. The air-lock module (536 meters; 1.6-3.0 meters; 17.4 m^3; 22.2 tons). A hatch for exiting to open space is located in it. Many units of the life-support system and storage batteries are placed inside the lock. The oxygen and nitrogen storage tanks are placed on the outside.

3. The docking adapter (5.27 meters; 3.0 meters; 32.3 m^3; 6.26 tons). It is equipped with two berths with docking units. The axial berth is the basic one, and the side berth, the spare. The docking adapter has control panels for the set of ATM astronomical instruments for observations of the sun and the EREP instrument set for studying the earth's natural resources. The EREP instruments are placed inside and outside the docking adapter.

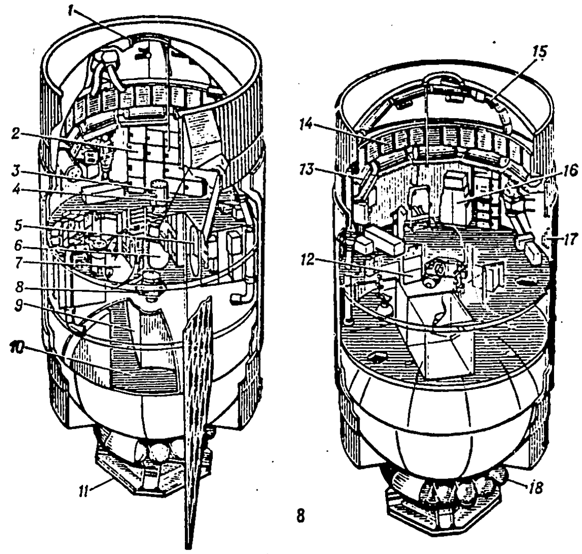


Figure 8. Diagram of the Station Module (for the description see pp 532-533): 1--Hatch; 2--coolers, freezers, and uncooled containers for food products in the laboratory compartment; 3--fan in the personal hygiene facilities; 4--bracket for fastening the solar panel; 5--sleeping cubicle in the living quarters; 6--Facility for personal hygiene; 7--facility for leisure time, preparation and eating of food; 8--lock for discharging waste; 9--grid holding back solid waste; 10--evacuated tank for collecting waste; 11--radiator; 12--facility for setting up and conducting experiments; 13--water tanks; 14--storage; 15--air duct; 16--storage for film; 17--lock for putting scientific equipment into outer space; 18--tanks with compressed nitrogen for the TACS orientation system engines.

4. The set of ATM astronomical instruments (4.4 meters; 3.3 meters; 11.8 meters). It is placed on a girder type structure which is titled by 90 degrees after the station goes into orbit. In addition to the astronomical instruments, the set includes onboard digital computers, power gyroscopes of the orientation system, four out of the six solar panels, storage batteries and a number of other units of the station service systems.

The life support system of the station is designed to create an oxygen-nitrogen atmosphere (74 percent oxygen and 26 percent nitrogen) at a pressure of 0.35 kg/cm^2. The comfortable air temperature is 21$\pm$5° C. The onboard oxygen reserve when launching the station was 2.23 tons, and the nitrogen reserve was 0.6 tons (not considering the nitrogen reserve for the TACS orientation system engines), there were 2.7 tons of water and 0.67 tons of food products. All of the consumable materials were calculated to maintain three crews in the station for a total of 140 days.

The thermal control system uses a liquid cooling system where the coolant circulates, giving off heat in a radiator, heating elements, special paint and thermal insulation. A decisive role in the thermal control system must be played by the meteor shield surrounding the station module. It is made up of aluminum alloy panels 0.6 mm thick which are pressed against the hull in the remote section and, after the station goes into orbit, are moved 12 cm away from it.

The electric power supply system uses two solar panels on the station module and four panels on the ATM complex. The size of the panels on the station module is $\sim$ 30 meters, the total area is 110 m^2, the guaranteed average power was no less than 3,800 watts, the peak power was 11,900 watts. Eight storage batteries in the air-lock module were charged from the solar cells of these panels. The capacity of each battery was 33 amp-hours. They can provide a power of 3,830 watts in one orbit. The size of the panels on the ATM complex is also $\sim$ 30 meters. The total area is 110 m^2, and the guaranteed average power is no less than 3,700 watts. The peak power is 10,500 watts. Eighteen storage batteries in the ATM set are charged from the solar cells of these panels. The capacity of each battery is 20 amp-hours. They can provide 3,700 watts of power in one orbit. Provision is made for the possibility of transferring power between the electric power supply systems of the station, the ATM set and the "Apollo" transport ship when it is docked to the station.

The station has three orientation and stabilization systems: TACS, CMG and EPC. The TACS system is used to keep the station quiet and provide initial orientation, and later it is used only in the case of saturation of the power gyroscopes of the CMG system. The TACS system operates both on command from on board and on command from the earth. As servoelements the system uses six motors of 68 kg each operating on compressed nitrogen which is stored under a pressure of 218 kg/cm^2 in 15 spherical tanks mounted by a ring on the rear of the station module. The total nitrogen storage ($\sim$4.4 m^3) for the engines of the TACS system provides a total impulse of 27 ton/seconds. The CMG system is used to stabilize the station in a given position with a precision of 3'. The system uses a sun sensor, a stellar sensor and high-speed gyroscopes, and as actuators it uses three power gyroscopes operating from an asynchronous motor. The weight of each power gyroscope is 189 kg, the rotor weight is 65.8 kg, the rotor diameter is 0.56 meters, the speed is 9,100 rpm. The EPC system provides for aiming the astronomical instruments of the ATM set at the selected section of the solar disc or at another heavenly body with the precision of $\pm$2.5". The system uses sun sensors and precision gyroscopes, and it uses electric engines as the actuators.

The interaction of three orientation systems and also the solution of a number of other problems are provided by two onboard digital computers (one reserve) in the ATM complex. Each digital computer weights 44 kg, the overall dimensions are 19x48x77 cm, the intake power is 165 watts, the memory capacity is 16,000 16-bit words, the reference time is 2.5 microseconds, and the average speed is 60,000 operations per second.

The radiotechnical system includes a large number of receivers and transmitters in the meter and decimeter bands for communications with the earth and also radio teletype by which instructions to the astronauts and various information are transmitted on board. The transmission of television from on board is provided by the radio technical system of the "Apollo" transport ship docked to the station. Means of intrastation communications, devices for video recording and memories for storing information from the scientific instruments are provided. The radio technical system includes the transponder and the meter band used in combination with the range meter on the "Apollo" transport ship when rendezvousing in orbit.

The payload of the "Skylab" station includes the astronomical instruments of the ATM complex, the instruments of the EREP complex for studying natural resources, a number of devices for medical experiments, the means for conducting technological experiments and also several dozens of other instruments, devices and means for conducting the most varied studies. In addition, on the "Apollo" transport ship when delivering the crew to the station, there were various biological subjects for studying the effect of weightlessness on them. The ATM complex includes a coronograph, an x-ray spectrograph, spectroheliometer, an x-ray telescope, an ultraviolet x-ray spectroheliograph, an ultraviolet spectrograph and two telescopes for observing the sun in the H-alpha line. The EREP complex includes six frame television cameras, a topographic camera, an infrared spectrometer, a multirange scanning television camera, a microwave sonde and the L-band radiometer. In order to conduct medical experiments, in particular, a bicycle ergometer, a device for creating negative pressure on the lower half of the body, a rotating coulometric chair, a scale, a treadmill, and so on are provided. In order to perform technological experiments, a spherical chamber (0.4 meters in diameter) with a cathode-ray gun and an electric furnace are used.

The "Apollo" transport ship is a modified basic unit of the "Apollo" lunar spacecraft (the command module, see the YEZHEGODNIK BSE, 1968, page 519). The rated launching weight of the transport ship is $\sim$ 14 tons; it is 11 meters long; and the diameter is 3.9 meters. The maximum weight of the payload (not considering the astronauts) delivered to the station by the transport ship is 880 kg; the maximum payload returned in the transport ship to Earth is 900 kg.

The proposed program provided for launching the unmanned "Skylab" station on 14 May 1973 by the two-stage "Saturn-5" booster rocket into a circular orbit 435 km high with an inclination of 50 degrees. On the next day, 15 May, the "Saturn-1B" booster rocket launched the transport ship with the first crew, which stayed 28 days on the station and returned in the same transport ship to Earth. It was proposed that the second crew be delivered to the station on 25 July, and the third on 26 October 1973. These two crews were to stay 56 days on the station. In the interval between running the station, and after the third crew left the station, it was to be used for conducting certain experiments in the automatic mode by command from the earth.

Launching the "Skylab" station. The "Skylab" station (unmanned) was launched by the two-stage "Saturn-5" booster rocket on 14 May 1973, and it was inserted into orbit with a perigee of 434 km, an apogee of 437 km and an inclination of 50 degrees. The orbital period was 93.2 minutes. The mass of the object inserted into orbit (the station and the second stage of the booster rocket with residual fuel) was 112 tons. In the insertion segment a 63 second flight, the meteor shield surrounding the station module was broken under the effect of dynamic pressure. This shield, as was discovered later, was not tight enough against the hull. The broken shield damaged the coupling of one of the two solar panels to the hull (panel No 2) of the station module. In orbit, upon separation of the second stage from the station, the exhaust of the braking engines of the stage broke panel No 2. The second panel (panel No 1) on the station module opened only partially: it was wedged by a piece of the meteor shield. There was no other damage to the station.

The four solar panels of the ATM complex remained the only sources of electric power, providing only half the calculated power. Under these conditions, it was still possible to perform part of the planned studies under a highly abbreviated program and with the required use of the batteries of the hdryogen-oxygen fuel elements of the transport ship to power the station equipment.

A more serious problem than the shortage of electric power was the absence of the meteor shield, which plays an important role in the heat regulating system of the station: on 15 May the temperature in some of the compartments of the living quarters had already risen to 38°C, and the temperature of a number of sections of the outer wall was up to 82°C. On 16 May the temperature rose to 65.6°C and 163°, respectively. The heating was dangerous for the electronic equipment, the film, food and medicines on board. In addition, at high temperature some of the plastic materials inside the station could give off toxic gases. In order to decrease the concentration of such gases, the air in the station facilities was periodically purged, and the quarters were again filled with oxygen and nitrogen.

In order to decrease the overheating, it was decided to change somewhat the station's regular "solar-inertial" orientation in which the longitudinal axis is perpendicular to the direction of the sun and certain sections of the hull are constantly exposed to solar rays. After a number of tests, the orientation in which the longitudinal axis of the station was at an angle of 40 degrees to the direction of the sun was recognized as the most expedient. Thus, the angle of incidence of the solar rays on the hottest sections was diminished, but other sections began to overcool. The later was no less dangerous than the superheating: a temperature drop below 0°C could lead to freezing of the water in the tanks and lines and destruction of them. By again changing the orientation, it was possible to prevent the temperature from dropping below 2.8 degrees. The orientation of the station had to be changed many times, "balancing on the hot wire," which led to the high consumption of the compressed nitrogen for the TACS system engines.

The launching of the transport ship with the first crew to the station was delayed from 15 May first to 20 May and then to 25 May (launches were possible every 5 days when the path of the station passed over Cape Canaveral). It was decided that the astronauts could take several emergency heat shields and, depending on the circumstances, install one of them to replace the broken meteor shield inasmuch as there was no other way of restoring a comfortable temperature on the station. The astronauts took with them certain instruments to try to open the partially open panel No 1 all the way.

The "Apollo" No 116 transport ship with the first station crew was launched on 25 May 1973 by the "Saturn-1B" booster rocket. The first crew included Charles Contrad (commander), Joseph Kerwin (physician) and Paul Weitz (co-pilot). Only Conred had experience with space flight (on the "Gemini-5" and "Gemini-11" satellites and also on the "Apollo-12" spacecraft as commander of the second American lunar expedition). The weight of the transport ship into which the equipment was loaded to repair the station reached 14.19 tons. The booster rocket inserted the transport ship into an initial orbit with an apogee of 352 km, a perigee of 156 km and an inclination of 50 degrees (the calculated values of 350 km, 150 km and 50 degrees). As a result of six maneuvers, at 7 hours 40 minutes after launch the transport ship rendezvoused with the station. The astronauts began to fly around it for inspection and examination of the damage. An effort was made to open panel No 1. For this purpose, Weitz, hanging with his shoulders out of the hatch of the transport ship manipulated a hook on a long handle and Conrad held the transport ship at a distance of one or two meters from the panel. The effort did not succeed.

The transport ship was docked with the station 15 hours 52 minutes after launch only on the 10th attempt. After the ninth unsuccessful attempt the astronauts unsealed the cabin of the transport ship and examined the docking unit where a short circuit was detected in one of the electric circuits. The short circuit was bypassed by using a connecting cable.

On 26 May, the astronauts in gas masks and with toxic gas detectors moved from the transport ship to the station. The detectors found no toxic gases. The temperature in some of the station facilities had reached 55 degrees. First the astronauts installed the heat shields. The "umbrella" was selected from among the three shields taken with them (an "umbrella," a "canopy" and a "sail"). It was extended from the station on a rod through the airlock for putting the scientific equipment out in space, and it was opened by springs, although partially. The temperature in the station almost immediately began to drop (by approximately 0.5 degrees per hour). On 27 May the astronauts began to activate the station.

On 28 May the crew proceeded with the scientific program; in particular, the astronaut Doctor Kerwin began regular medical examinations of his colleagues and himself. On 29 May the first observations of the sun were made using the ATM complex and the first studies were made of natural resources using the EREP complex. On 31 May during the next session of the study of natural resources, there were failures immediately in several of the storage batteries of the ATM complex, which further complicated the critical situation with respect to electrical power. The scientific program, in particular the study of natural resources, had to be curtailed. The decision was made on 7 June to go out into open space and repeat the effort to open panel No 1, this time using shears which were available among the repair tools on the station to cut the metal.

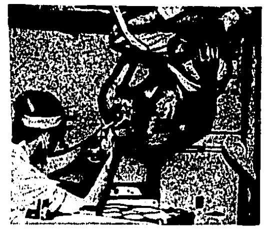
Conrad and Kerwin participated in the 7 June walk which lasted 4 hours 15 minutes. Conrad, holding onto an improvised railing, moved along the hull of the station to panel No 1. Using the scissors, the fragment that had jammed the panel was cut away, and the panel was freed. After a few hours it opened completely and provided a power of approximately 3,000 watts, and together with the panels of the ATM complex, 6,500 to 7,000 watts. The "energy crisis" in the station was over.

Beginning on 9 June, the operations of the station developed in accordance with the complete program. Even on the free days provided by the schedule, the astronauts refrained from rest.

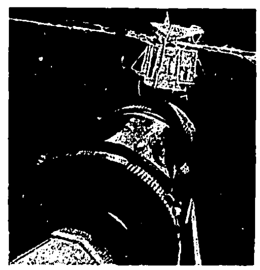
On 19 June, the second and last walk of the astronauts of the first crew into open space took place basically to replace the film holders in the ATM complex. Conrad and Weitz participated in the walk which lasted 1 hour 36 minutes.

On 22 June the astronauts returned to the earth in the transport ship. The flight lasted 28 days 000 hours 50 minutes. The crew compartment with the astronauts was lifted to the deck of the "Ticonderoga" aircraft carrier, and the crew members independently stepped out of the compartment onto the deck. Conrade had lost 1.7 kg of weight, Kerwin 2.9 kg, and Weitz 3.7 kg. The calf muscles in all three had shrunk by approximately 2.5 cm.

The flight of the first crew of the "Skylab" station was characterized by unexpectedly fast and sickness-free adaptation of the astronauts to the condition of weightlessness and comparatively easy readaptation to the earth's gravitational conditions especially for Conrad. Obviously the latter was promoted by the regular, long exercises on the bicycle during the flight. In spite of the fact that the first crew was forced to devote a great deal of time to repair operations, the flight program was approximately 80 percent completed, including the medical experiments--90 percent; solar



Kerwin examining Conrad's oral cavity.



"Skylab" station in orbit (the arrow indicates the broken wires at the place where the No 2 panel was torn away). The picture was made from the transport ship after rendezvous with the station.

observations--81 percent; studies of natural resources--88 percent. Using the ATM complex. 30,200 photograph were taken, and with the EREP, 16,700 photographs and 13,700 meters of magnetic tape recordings.

The "Apollo" No 117 transport ship with the second crew for the station was launched on 28 July 1973 using the "Saturn-1B" booster rocket. The second crew included Allen Bean (commander), Owen Garriott (scientist and astronaut) and Jack Lousma (copilot). Only Bean had had spaceflight experience (on the "Apollo-12" spacecraft when he landed on the Moon together with Charles Conrad). The transport ship weighed ~ 14.2 tons, including 862 tons of payload (the equipment for repairing the station and performing various experiments). The equipment for repair included a new "umbrella" shield (it was not required), a set of six spare gyroscopes, a spare heat exchanger, a television monitor and two tape memories. The equipment for the experiments included an aquarium with two gudgeons and 50 gudgeon eggs, a cage with two spiders, containers with drosophila and mice, and so on.

Provision was made for the study of the effect of weightlessness on the state and the behavior of these biological subjects.

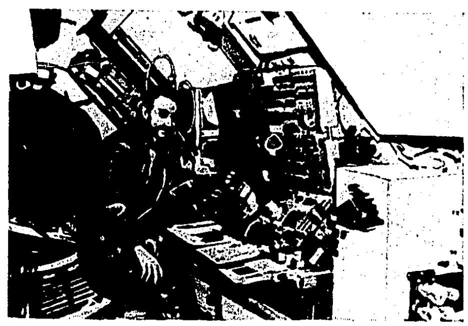
The booster rocket inserted the transport ship into the initial orbit with a perigee of 155 km, an apogee of 232 km and an inclination of 50 degrees. As a result of nine corrections, the transport ship rendezvoused with the station and 8 hours 29 minutes after launch, it docked with it on the first attempt. During insertion, a leak occurred in one of the four auxiliary engine blocks of the transport ship, and this block was shut down.

During the first days at the station all three crew members experienced severe motion sickness symptoms; they frequently could not eat; their physical fitness declined, and the station was demothballed significantly behind schedule. The first walk in open space planned for 31 July was put off until the astronauts felt better.

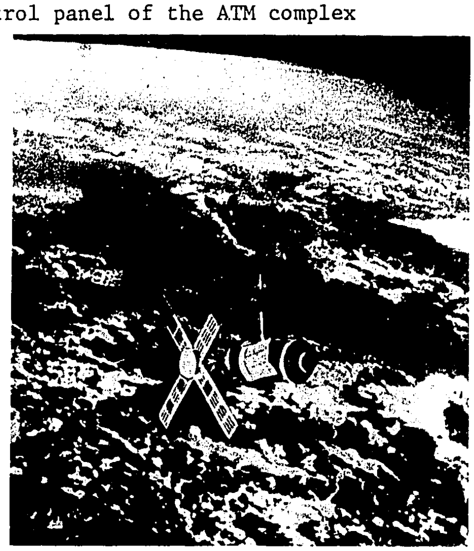
On 1 August the scientific experimentation began. The observations of the fish demonstrated that they had lost orientation: they swam in a spiral head down in the aquarium. Later, when the young fish were hatched from the eggs, no disorientation was observed. During the return to earth, the fish died so that it was not possible to study their readaptation to gravitational conditions. The first spider forced into the container where he could spin a web initially spun it randomly in the corners of the container, but then he created a web of proper geometric shape. Later, the same thing occurred with the second spider. Initially no provision had been made to feed the spiders in flight, but later the decision was made to feed them so as to return them live to the Earth and study the readaptation process. The spiders gradually learned to eat pieces of beefsteak. However, the spiders did not survive. One of them died in flight, and the other during return to earth. The drosophila and mice died as a result of equipment failures.

On 2 August a leak was detected in the oxygen unit in one of the auxiliary engine blocks of the transport ship. Even the problem of expediency of an emergency return of the astronauts to the earth was considered while the remaining two modules functioned. Then it was decided that this was not necessary inasmuch as the astronauts were not threatened with any immediate danger. In case the remaining auxiliary engine blocks failed, which would make it impossible to use the No 117 transport ship docked to the station to return the astronauts to Earth, the preparation of the booster rocket with No 118 transport ship would have been accelerated to deliver a third crew to the station in case it was necessary to use this spacecraft as a rescue vehicle for emergency evacuation of the astronauts. In this case two additional chairs would have been installed in the No 118 transport ship, and the crew would have been reduced from 3 to 2: the three free chairs would have been planned for the astronauts evacuated from the station. The two remaining auxiliary engine block of the No 117 transport ship docked to the station remained fit until it was time for the second crew to leave the station, and it was not necessary to launch the rescue ship.

The first walk in open space was on 6 August when the disorientation symptoms ceased altogether in the astronauts. The walk lasted 6 hours 31 minutes, and it was performed by Garriott and Lousma. Their basic mission was to install the second heat shielding mechanism ("canopy") above the umbrella shield opened by the first crew which, first of all, had not opened fully and which, secondly, under the effect of the sun's ultraviolet radiation had begun to lose its heat protective properties. In order to install the "canopy" shield the astronauts needed 4 hours, twice the calculated time. In addition, they replaced film holders in the ATM astronomical instrument complex.



Garriott at the control panel of the ATM complex



"Skylab" Station after Unfolding Panel No 1 (Panel No 1 and the umbrella shield are visible). The picture was taken from the transport after undocking from the station.

Beginning on 7 August, the astronauts set about doing the scientific research in accordance with the complete program. The basic mission of the second crew was observation of the sun using the ATM complex. In spite of the quiet period of the solar cycle, the activity of the sun was unexpectedly high, which made these observations especially valuable. In addition to them, studies were made of the natural resources of the earth, and medical experiments were carried out as well as meteorological observations, tests (in the laboratory compartment of the station) of several types of units for travel in open space, technological experiments and so on. The fitness of the astronauts reached a very high level, exceeding the planned fitness by almost 50 percent. The crew members, overcome by the enthusiasm of the researchers, gave up their rest time provided for by the schedule and persistently asked ground control to develop additional experiments for them.

On 24 August a second walk in open space took place, the basic mission of which was the connection of a cable to the hull of the docking structure and to the split in the ATM complex. This cable joined the spare gyroscopes installed by the astronauts in the docking structure and the digital computer in the ATM complex. The basic missions of the space walk were replacement of the film holders in the ATM complex and some small repair operations. The EVA was made by Garriott and Lousma and it lasted for 4 hours 21 minutes.

On 25 August, the second crew broke the space flight time record which belonged to the first crew of the "Skylab" station. Then on the basis of the results of the medical examination, the astronauts were given permission to stay in space for another week. Initially it was planned that the second crew would spend 56 days at the station; then the time was increased to 59 days, which made it possible to land the astronauts returning from the station in the Pacific Ocean closer to the coast of the United States (350 km instead of 1,930 km fron San Diego and western California), and, likewise, to deliver the crew faster to the Johnson Center in Houston, where the most refined equipment exists for complete medical examination and to give medical aid if this turns out to be necessary.

On 22 September, the third and last EVA of the astronauts of the second crew took place, basically to replace the film holders in the ATM complex. Bean and Garriott participated in the walk lasting 2 hours 49 minutes.

Lousma testing the space walk equipment.

On 25 September, the astronauts returned to earth in the transport ship. The flight lasted 59 days 11 hours 9 minutes. The crew compartment with the astronauts was lifted onto the "New Orleans" helicopter carrier. Bean, Lousma, and Garriott stepped independently from the capsule to the deck. The astronauts lost 3.2 to 3.6 kg of weight each. Their condition after returning to the earth was better than the medical specialists expected and better than the condition of the members of the first crew (including Conrad).

The second crew astronauts overfulfilled the flight program by approximately 50 percent. Observations of the sun using the ATM complex were made for 305 hours (instead of 205 hours according to plan). During this time 77,600 photographs were obtained, in particular, photographs of more than 100 flares and large protuberances (21 August). The EREP complex was used for 39 study sessions of natural resources instead of 26 according to plan; 16,800 pictures and 29 km of magnetic tape recordings were obtained. The members of the second crew performed 12 unplanned experiments.

The "Apollo" No 118 with the third station crew was launched on 17 November 1973 by the "Saturn-1B" booster rocket. The third crew included Gerald Carr (commander), Edward Gibson (scientist and astronaut) and William Pogue (copilot). None of the crew members had had any spaceflight experience. The flight of this crew was initially calculated at 56 days. Later, after studying the post-flight medical indicators of the first and second crews, the medical specialists considered it possible to increase the stay of the third crew on the station to 84 days. After 56 days the astronauts were given a weekly medical examination, and permission to extend the flight for the next week was granted on the basis of its results. Initially the primary mission for the third crew was to study the earth's natural resources, but later the primary mission was defined as observations of the comet Kohoutek. The launching of the third crew was delayed from 26 October to 10 November 1973 in order that the manning of the station would fall into the period in which the comet would come closest to the Sun and the earth. The third crew devoted two of the four planned walks in open space to observations of the comet: directly before the directly after it passed through the perihelion (28 December 1973). No significant repair operations were planned for the third crew. The payload of the No 118 transport ship (990 kg) basically included equipment and specimens for scientific research. The transport ship was loaded with food stores (27 kg of especially high-calorie powdered sticks used in the production of candy with an aromatic glaze) inasmuch as the stores on board the station were not sufficient for the prolonged stay. The transport ship also carried a tank with coolant to replenish the cooling system in which a leak had occurred. The delay in launching the No 118 ship from 10 to 16 November was caused by failure of the booster rocket.

The perigee of the initial orbit of the transport ship with the third crew was 153 km, and the apogee was 324 km. As a result of five maneuvers the transport spacecraft rendezvoused with the station, and eight hours after launching, having flown around the station for examination and television survey, the astronauts docked with it. Docking was successful on the second attempt. All of the astronauts experienced symptoms of motion sickness. Pogue vomited. The crew devoted the first days on the station to demothballing the equipment and preparing for scientific research. All of the operations took place somewhat behind schedule.

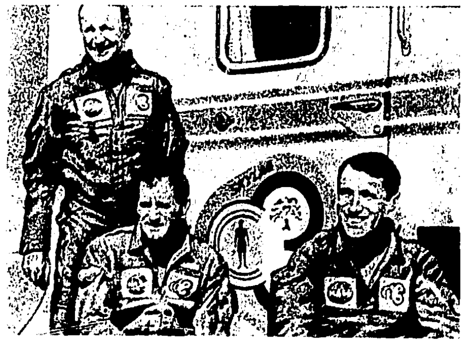
The delay was observed during the entire flight (the fitness of the astronauts approached the calculated level only in the second half of the flight). Obviously, the individual peculiarities of the members of the third crew were expressed. They were slow; they rather frequently made errors; they requested additional rest periods; and they did not work with any zeal or enthusiasm like the preceding crews. Possibly one of the reasons for being behind schedule was the absence of a demanding commander with spaceflight experience such as Conrad and Bean who commanded the first and second crews. However, it turned out that the work schedules for the third crew were based on the achievements of the second, which obviously set a record and were not the norm.

On 19 November Pogue put the coolant brought from earth in the cooling system. To do this, it was necessary to punch a hole in the main line using a device resembling a syringe. A valve was seated in the opening, and the coolant was introduced through it.

On 22 November, Pogue and Gibson completed a walk in open space lasting 6 hours 35 minutes. They replaced five film holders in the ATM complex. They repaired the antenna drive of the microwave probe for investigating natural resources, and they mounted samples of heat shielding coatings on the girder structure outside the station in order to investigate the effects of cosmic and solar radiation on them.

On 23 November, as a result of the overheating of bearings, it was necessary to shut down the No 1 power gyroscope in the CMG orientation system. Accordingly, it was necessary to use the TACS system for subsequent changes in orientation of the station, which led to highly significant overconsumption of the compressed nitrogen for the engines of the system. Subsequently failures also began to be observed in the No 2 power gyroscope. This made it necessary to refrain from natural resources observation sessions for several days because they required a change in orientation of the station. There was a danger of having to shut down power gyroscope No 2. Then a premature return of the crew to the earth would have become unavoidable, for orientation could be maintained only by using the TACS system engines, and the compressed nitrogen reserve was extremely limited for this. In spite of the failures, power gyroscope No 2 operated to the very end of the crew's missions on board the station. The compressed nitrogen also lasted the entire time.

On 23 November, the crew began its observations of the sun using the ATM complex; they began studies of natural resources with the EREP complex; they took photographs with manual cameras and performed other experiments,



Third Skylab Crew: (left to right) Carr, Pogue, Gibson

including visual recording of the beam from a ground laser and observation of the flight of the "Minuteman" strategic missile. Most importantly, they took pictures of the comet Kohoutek--first by handheld cameras, then on 19 December when the comet approached the sun (and the earth), with ATM instruments. The astronauts devoted a great deal of time to exercises on the bicycle and the treadmill (the first and second crews did not have this treadmill), studies in the lower body negative pressure device, tests in the cupolometric chair, and so on.

The second and third walks in open space were performed on 25 and 29 December to photograph the comet Kohoutek using two cameras loaded with film and sensitive to ultraviolet radiation. On 25 December, Carr and Pogue took a 7 hour walk; on 29 December Carr and Gibson took a 3 hour 28 minute walk.

On New Year's Eve some of the results of the work of the astronauts were summed up. Out of the 24 sessions studying natural resources planned for November-December 1973, only 19 were performed; 196 hours were spent on medical experiments instead of the 228 proposed under the program; 140 hours were spent on other scientific experiments (in addition to the observations using the ATM complex) instead of 235. The only area in which the astronauts overfulfilled the initial program was in observing the sun and the comet Kohoutek using the ATM complex. In November-December the astronauts worked an average of 24 man-hours a day instead of 26-29 man-hours as planned.

In January 1974, the fitness of the astronauts was improved. For example, on 8 January they worked more than 30 man-hours.

Non-Soviet spacecraft launched in 1973

Item No.	Satellite name	Booster rocket	Date of launch	Satellite wt, kg.	Parameters of initial orbit			Initial orbital period min
					Perigee, km	Apogee, km	Incli- nation	
1	Secret[2]	"Atlas-Agena"	6 Mar	680	32106	39638	10.1°	1441
2	Secret[2]	"Titan-3D"	9 Mar	11300	151	270	95.7°	88.76
3	"Anik-2"[2]	"Torad-Delta"	20 Apr	530	35775	36483	0.4°	1445.5
4	Secret	"Titan-3B"	16 May	~ 3000	135	351	110.49°	89.39
5	"Explorer-49"(RAE-B)[2]	"Torad-Delta"	10 Jun	334	Selenocentric orbit			221.8
					1016	1030	38.72°	
6	Secret	"Titan-3C"	12 Jun	> 800	35565	35887	0.53°	1431.9
7	Sec[illegible]	"Titan-3D"	13 Jul	11300	143	291	96.2°	88.8
8	Air Force Meteorological Satellite	"Thor-Boerner 2"	17 Aug	195	807	854	98.8°	101.5
9	Secret	"Titan-3B"	21 Aug	No information	459	39300	63.2°	11.8h
10	INTELSAT-4E[2]	"Atlas-Centaur"	23 Aug	1387	Stationary orbit			
11	Secret	"Titan-3B"	27 Sep	~ 3000	137	390	110.48°	89.8
12	"Explorer-50"(IMP-J)[2]	"Torad-Delta"	26 Oct	395	141000	289000	28.7°	~ 12 days
13	"Transit"	"Scout"	29 Oct	~ 60	907	1136	90.2°	105
14	NOAA-3 (ITOS-F)	"Torad-Delta"	6 Nov	340	1500	1509	102.1°	116.1
15	Secret	"Titan-3D	10 Nov	11300	159	269	96.9°	88.8
16	DSCS-3[2]			558				
17	DSCS-4[2]	"Titan-3C"	14 Dec	558	35799	36123	2.4°	1445
18	"Explorer-51"(AE-C)	"Torad-Delta"	16 Dec	660	156	4305	68.1°	132.4

1. The mass of the secret satellite was taken from unofficial sources.
2. Elements of the final orbit are indicated.

The second of February was the last day wholly devoted to scientific research. On 3 February Carr and Gibson completed the fourth and last walk in open space to retrieve the film holders from the ATM instruments. The walk lasted 5 hours 15 minutes. Mothballing of the station and preparation to return to earth began on 4 February. On 7 February a correction was made to the station orbit to increase its ballistic existence to 7-10 years. The correction was made by the main engine of the transport ship docked to the station. On 8 February the transport vehicle undocked from the station and after approximately 5 hours, the landing module of the spacecraft landed in the Pacific Ocean 280 km southwest of San Diego, 5 km from the helicopter carrier "New Orleans."

The flight of the third crew had lasted 84 days 1 hour 16 minutes. The crew was lifted on board the helicopter carrier 39 minutes after landing, and the astronauts stepped independently out on the deck. According to the claims of the medical specialists, the members of the third crew felt even better after 84 days of flight than the members of the second crew after 59 days in space.

The payload delivered by the third crew from the station to the ground was approximately 900 kg. The film holders from the ATM instruments contained 75,000 pictures of the sun and the comet Kohoutek. The film holders from the EREP cameras contained 19,400 photographs of the earth. More than 30 km of recorded tapes were obtained from the EREP probes.

On 8 February the ground crews made a remote check of the onboard systems of the "Skylab" station orbiting at an altitude of 450 km. On 9 February, the onboard power supplies of the station were shut down on command from the ground. Work with it was completely discontinued; no further trips to the station were planned.

FOOTNOTES

1. Radio Astronomy Explorer

2. Interplanetary Monitoring Platform

3. For information on the "first generation" AE satellites see YEZHEGODNIK BSE 1967, p 506.

4. These satellites are launched by NASA, and after insertion in orbit they are transferred to the NOAA [National Oceanic and Atmospheric Administration]. In the NASA documents, the satellites are called ITOS (Improved Tiros Operational Satellite). On 16 July 1973, the ITOS-E satellite was launched, but as a result of failure of the second stage of the booster rocket, it was not inserted into orbit. The ITOS-F satellite is carrying out the missions planned for the ITOS-E satellite.

5. NAVSAT (Navigation Satellite).

6. Previously these satellites were included in the Great Soviet Encyclopedia Yearbook in the section on "Secret Satellites of the U.S. Air Force," and they were called "Meteorological Reconnaissance Satellites" (see the YEZHEGODNIK BSE, 1973, p 535). In 1973 these satellites were declassified, and it was discovered that their functions were much broader than meteorological reconnaissance.

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