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Exploration of the Planet Mars by Spacecraft

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Abstract. *The planet Mars is a terrestrial planet. The description of the current "desert planet" speaks of its current state, but the mineralogy of its surface reveals its much more geochemically active past. After extensive ground-based research, starting in the 1960s, increasingly reliable information about Mars began to be obtained using various spacecraft.*
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The planet Mars is classified as a terrestrial planet [9]. It is believed that it formed from a swarm of primary bodies and their fragments in a dust disk in the central plane around the Sun. After their merger into planets, their orbits became almost circular. The process of formation of the terrestrial planets shows that they included most of the solid matter that was in this region [10, 11]. Mars is characterized by a solid basaltic surface. After long-term ground studies of Mars, starting from the 1960s, increasingly reliable information about this planet began to be obtained using spacecraft [7]. Already on 01.11.1962, the spacecraft (SK) “Mars-1” was sent to Mars. But even when approaching this planet, contact with the spacecraft was lost. Later, the USSR and the USA, and starting from 2003, the European Community also performed many successful launches. Here is a list of them and some of their features. 07/15/1965 The “Mariner 4” spacecraft was able to fly within 13,200 km of Mars for the first time. The following equipment was installed on the spacecraft. Four detectors were used to record low-energy particles. Assuming that the shock wave fronts from the solar wind in front of the magnetopauses on Mars and Earth are the same, it was even possible to estimate the magnetic dipole of the planet Mars, approximately $5 \cdot 10^{-5}$ from the Earth value [1, 8]. To record charged particles with energies greater than 40 KeV, a telescope was used, with three electron detectors installed on it (however, they could not be registered), as well as with proton and α-particle detectors with possible energies from 1 to 170 MeV/nucleon (with their help, they were able to detect an increase in the concentration of protons). When the spacecraft entered the limb of Mars, they were able to determine the radius of the planet, atmospheric pressure, and some characteristics of the ionosphere from the radio eclipse. 22 images of the planet's surface were also obtained, covering almost 1% of the surface of Mars. They showed some similarity between the structure of the surfaces of Mars and the Moon, and allowed us to see 70 craters with diameters from 5 to 120 km.

In the summer of 1969, the spacecraft "Mariner 6" and "Mariner 7" were also able to fly at a short distance from the planet. The same equipment was installed on board. A wide-angle television camera began to receive photographs during the approach through light filters in the red, green, and blue regions of the spectrum with a resolution of 24 km; over an area of 625 thousand km^2, they were able to detect 156 craters of various sizes; During further approach, the next camera was turned on, and up to 200 images were obtained only in yellow rays with a resolution of up to 270 m; the craters discovered were even about 300 m in size [5, 13]. Infrared (IR) spectrometers installed on these spacecrafts in the range of 1.9-14.3 μm, in which there is a carbon dioxide absorption band at a wavelength of 2 μm, made it possible to study pressure drops (and height) over individual surface details with a resolution of 130×8 km with an error in height of ±1 km. And IR radiometers with a field of view of 7° in the wavelength ranges of 8.2-12.4 μm and 18-25 μm were paired with television cameras. With their help, it was found that at a latitude of 61°S the temperature decreased to 153 K. A spectrometer for the ultraviolet (UV) range of 110-340 nm, and devices for conducting radio obscuration experiments and bistatic radar were also installed there. On November 14, 1971, the "Mariner 9" spacecraft reached Mars. It became its first artificial satellite with a rotation period of 12h 34m and an orbital inclination to the equator of 64° 24′. The surface of Mars was studied using a wide-angle television camera, a Fourier spectrometer for the range of 5-50 μm, a spectrometer for the UV spectral range of 110-340 nm, and a device for conducting radio obscuration experiments; they showed large differences in the height of some parts with differences in atmospheric pressure values from 2.8 to 10.3 mbar [2, 12]. On November 27 and December 2, 1971, the "Mars-2" and "Mars-3" spacecraft reached the planet and became its artificial satellites. During the approach, capsules separated from each of them, and the capsule from the "Mars-3" spacecraft was able to make a soft landing for the first time. But the television signal was transmitted only in the first seconds. Both orbital modules had the following equipment: a television camera, a radiometer for the spectral range of 8-40 microns, filter photometers for λ=2 microns (CO_2 bands), λ=1.38 microns (H_2O), λλ≈121.5, 370, 420, 490, 560 and 690 nm; a 3.5 cm radio telescope, a magnetometer, ion traps, an electrostatic analyzer, and a special radio complex.

On February 10, 1974, the "Mars-4" spacecraft flew 2,200 km from the planet and transmitted several images of its surface. On February 12, 1974, the Mars-5 spacecraft entered the orbit of the artificial satellite of Mars. The orbit was chosen so that during the day it would pass over the area where the probes of the next two spacecraft were planned to land. But on March 9, 1974, "the Mars-7" spacecraft passed 1,300 km from the surface of Mars. While "Mars-6" reached Mars three days later and was able to lower the probe to a point with a longitude of 25°E and a latitude of 24°S. This spacecraft was the first to determine the chemical composition of the atmosphere, atmospheric pressure and temperature on the descent route, and then on the surface of the planet [4, 16].

On June 19 and July 7, 1976, respectively, the “Viking 1” (V1) and “Viking 2” (V2) spacecraft entered Mars orbit. On July 20 and August 3, 1976, both probes landed at the following coordinates: latitude 22.7°N, longitude L=47.94°E (V1) and latitude 47.67°N, longitude L=225°E (V2) [6]. Both orbital modules carried traditional instruments, while the landing modules were equipped with instruments for optical observations around the modules, for observations of the Sun and Martian satellites, for measurements of seismic activity [3], magnetic activity of the soil, chemical analysis of the soil and atmosphere, for determination of pressure, temperature, wind direction and speed, etc. During the mission, the seismometer operated for almost 2,100 hours, but no noticeable seismic activity was detected. 07/04/1997 the “Pathfinder” spacecraft landed on the surface of Mars and released the small Mars rover “Sojourner”. It transmitted images of the environment, studied the chemical composition of the surface using α-proton and X-ray spectrometry, conducted meteorological observations of the atmosphere and a number of technological experiments. 09/11/1997 the “Mars Global Surveyor” spacecraft reached Mars and became its next satellite, equipped with several cameras, radio equipment, a thermal spectrometer, a laser rangefinder, two magnetometers and an electronic reflector. 10/24/2001 The “Mars Odyssey” spacecraft also became its satellite and lowered a probe to the surface at the border of the northern polar region. In 2003, the Japanese interplanetary station "Nozomi" ("Hope") flew within 1000 km of the surface of Mars but was unable to enter the planet's orbit. On 19.12.2003, the European Space Agency (ESA) spacecraft "Mars Express" was able to reach Mars and become its satellite. But the landing of the British module "Beagle 2" was unfortunately unsuccessful. Two spacecraft "Mars Exploration Rover" with the Mars rover "Spirit" and the practically identical "Opportunity" 3 and 23.01.2004 landed on opposite sides of Mars. Their goal was to answer the question: "Is there water on Mars?". In March 2006, the “Mars Reconnaissance Orbiter” reached Mars, and then spent several months braking in the upper atmosphere and conducting a detailed study of the planet's surface in different spectral ranges [15, 17] in order to search for possible landing sites for future expeditions, search for areas of geothermal or water activity for climate research [18]. It was also planned to conduct soil sounding to a depth of 1 km using the Subsurface Sounding Radar to detect liquid, or at least frozen, water. In 2007, NASA launched the “Phoenix” spacecraft. It landed near the north pole on the polar cap of Mars to study the geological history of water, which is a key element for a better understanding of past climate changes [14], and to search for regions favorable for the emergence of possible life forms in "biologically suitable soil." The next NASA mission was the launch of the Mars Science Laboratory spacecraft with the “Curiosity” rover on November 26, 2011. On August 6, 2012, it landed on the surface of Mars in Gale Crater. The rover has instruments for studying possible existing or previously existing forms of life on Mars. During the Martian year, the results of “Curiosity” allowed us to assert that the environment on Mars once had conditions that could support microbial life. On November 18, 2013, the MAVEN (Mars Atmosphere and Volatile Evolution) spacecraft was launched, which reached the planet on September 22,

2014. The purpose of the orbital station was to study the upper atmosphere of Mars and serve as a transmitter module for rovers and vehicles that will subsequently descend to the surface of Mars. On November 5, 2013, the Indian Space Research and Development Organization launched the “Mangalyaan” mission, and on September 24, 2014, the spacecraft entered Martian orbit. This mission became a testbed for testing technologies for subsequent launches of similar missions. The mission's instruments studied the Martian atmosphere. It became India's first mission to Mars, and India itself became the fourth organization whose spacecraft successfully reached Mars after NASA, the USSR, and ESA. ESA, together with Roscosmos, built the ExoMars Trace Gas Orbiter, which entered Mars orbit on October 19, 2016. It studied the nature of the appearance of methane, water vapor, and other gases in the Martian atmosphere, the content of which on Mars has been known since 2003.

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