0254-6124/2018/38(5)-650–06 *Chin. J. Space Sci.* 空间科学学报

JIA Yingzhuo, FAN Yu, ZOU Yongliao. Scientific objectives and payloads of Chinese first Mars exploration. *Chin. J. Space Sci.*, 2018, **38**(5): 650-655. DOI:10.11728/cjss2018.05.650

# Scientific Objectives and Payloads of Chinese First Mars Exploration

JIA Yingzhuo FAN Yu ZOU Yongliao

(*State Key Laboratory of Space Weather, National Space Science Center, Chinese Academy of Sciences, Beijing* 100190)

**Abstract** China plans to implement the first Mars exploration mission in 2020. It will conduct global and comprehensive exploration of Mars and high precision and fine resolution detection of key areas on Mars through orbiting, landing and roving. The scientific objectives include studying the Martian morphology and geological structure characteristics, studying the soil characteristics and the water-ice distribution on the Martian surface, studying the material composition on the Martian surface, studying the atmosphere ionosphere and surface climate and environmental characteristics of Mars, studying the physical field and internal structure of Mars and the Martian magnetic field characteristics. The mission equips 12 scientific payloads to achieve these scientific objectives. This paper mainly introduces the scientific objectives, exploration task, and scientific payloads.

**Key words** First Mars exploration, Scientific objectives, Scientific payloads

**Classified index** V 4, P 3

## 1 Overview of the First Mars Exploration

The first Mars exploration mission of China plans to implement orbiting, landing and roving on Mars by a single launch in 2020. It will conduct global and comprehensive exploration of Mars by orbiting detection and accomplish area survey of Mars surface by roving detection. The mission is composed by five parts: probe system, rocket system, launch system, telemetry, tracking, and command system and ground research and application system. The mission officially starts in January 2016, the first launch window is around July 2020.

The probe for the first Mars exploration mission is comprised of an orbiter and a lander/rover. The orbiter carries the landing/roving probe to complete the flight process of the Earth-Mars transfer and the Mars capture and orbit maneuver. After releasing the landing/roving probe will enter the Martian atmosphere at a preset altitude, land safely on the Martian surface after multiple deceleration stages and release the Mars rover for subsequent scientific exploration on the Martian surface. And the orbiter will then enter a higher orbit for relay communications.

After the landing/roving probe land softly on the Martian surface, the Mars rover will then leave the landing platform and begin its scientific exploration. Initially, the primary work of the orbiter is to provide a relay communication link to the Mars rover while performing scientific exploration. After operating for 90 Martian days, the orbiter will maneuver to enter a remote sensing orbit. The primary work of the orbiter then changes to scientific exploration while maintaining a relay communication link to the Mars rover. During the mission, the ground application system will receive scientific exploration data and perform data analysis and scientific research.

## 2 Scientific Objectives and Scientific Payloads

This mission will perform global and general exploration of Mars using orbiter exploration. By roving exploration, this mission will conduct detailed investigations of key areas with high accuracy and resolution. Specifically, the scientific objectives include the following aspects.

(1) It will study the morphology and geological structure of Mars. It will detect global topog-

Received 11 June 2018
E-mail: jiayingzhuo@nssc.ac.cn

raphy features of Mars, and obtain the high precision topography data of the typical area, study the evolution and the cause of Mars geological structure. Medium resolution camera and high resolution camera are configured to accomplish the scientific exploration of studying morphology and geological structure of Mars. Medium resolution camera can obtain about 100 m spatial resolution data of Mars global topography features. High resolution camera can obtain high resolution image for detailed investigation of the key area at the landing site, geomorphic feature data with a spatial resolution about meters. The data of the two payloads can be used to conduct a research of the Mars geological features forming process, such as water flow, volcanic landforms and wind erosion, impact crater landform, polar glacier geomorphology, and so on.

(2) It will study Mars surface soil characteristics and water-ice distribution. It will detect Mars soil types, weathering and deposition feature and their global distribution. It will search for water-ice and study Mars soil layered structure profile. Mars Subsurface Exploration Radar on the orbiter and Subsurface Detection Radar on the rover are configured to accomplish the scientific exploration of soil feature and water-ice distribution. It will detect the Martian surface and underground water-ice by the dual-polarization echo characteristics of radar, and solve the problem of multiplicity in water-ice detection. By using fully polarimetric radar, combined with orbiting detection, it will further the scientific understanding of Mars soil structure and ice water detection.

(3) It will study Mars surface material composition. It will recognize rock types on Mars surface, detect secondary mineral on Mars surface and analyze surface mineral composition. Mars Mineralogy Spectrometer, Multispectral Camera, and Mars Surface Composition Detection Package are configured to accomplish the scientific exploration of Mars surface material composition. Using the spectrum data of visible spectrum and near-infrared from Mars Mineralogy Spectrometer, the research of Mars surface material composition can be conducted; Using Mars Surface Composition Detection Package and Multispectral Camera, Mars surface element, mineral and rock types can be studied. Combined with ancient lakes, ancient channels, alluvial continents and other aqueous landscape, it will search carbonate minerals or weathering mineral such as hematite, layered silicate, hydrate sulfates, per chlorate minerals, and detect the effect of water deterioration on these minerals, and establish a relationship between the aqueous phase environment and secondary mineral species on the surface of Mars.

(4) It will study Mars atmospheric ionosphere and surface climate and environmental characteristics. It will detect Mars space environment and air temperature, air pressure, wind field on the surface of Mars, and conduct the research of Mars ionosphere profiles and the seasonal variation of the weather. Mars Weather Station, Mars Ions and Neutral Particle Analyzer and Mars Energetic Particles Analyzer are configured to detect Mars atmosphere, ionosphere and surface weather and environmental characteristics. Mars Weather Station can measure air temperature, pressure, wind speed and wind direction on the surface of Mars; Mars Ions and Neutral Particle Analyzer and Mars Energetic Particles Analyzer can detect Mars ionosphere and interplanetary environment. Mars Ions and Neutral Particles Analyzer also can measure ion flux in the Mars space environment, distinguish main ion species, obtain the density, speed, temperature and other physical parameters of the ion species; also, it can measure flux of neutral energetic particles, distinguish H, He, O and other major neutral particle species; Mars Energetic Particles Analyzer can obtain energy spectrum, flux and composition data of energetic electron, proton, alpha particle and other ions.

(5) It will study Mars physical fields and internal structure, detect Mars magnetic field characteristics and research the history of early geological evolution and internal mass distribution and gravity field of Mars. Mars Magnetic Field Observation Station and Subsurface Detection Radar on the rover, Mars Magnetometer and Mars Subsurface Exploration Radar on the orbiter are configured to detect Mars physical field and internal structure. Mars Magnetic Field Observation Station can detect magnetic field on Mars surface and identify the magnetic index. Cooperating with Mars Magnetometer on the orbiter, it can detect Mars space magnetic field, invert Mars ionosphere currents and determine parameters such as Mars ionosphere conductivity. Using natural magnetic field jump, it can detect internal large-scale configuration and local structure, invert the conductivity in depth, the thickness of the spheres and the temperature of Mars.

Scientific objectives and corresponding scientific payloads are shown in Figure 1.

## 3 Observation Tasks and Main Specifications of Scientific Payloads

The probe for the first Mars exploration is comprised of an orbiter and a lander/rover. The scientific payloads installed on the orbiter include Medium-resolution Camera, High-resolution Camera, Mars Subsurface Exploration Radar, Mars Mineralogy Spectrometer, Mars Magnetometer, Mars Ions and Neutral Particle Analyzer, Mars Energetic Particles Analyzer. The scientific payloads installed on the rover include Multispectral Camera, Subsurface Detection Radar, Mars Surface Composition Detection Package, Mars Magnetic Field Observation Station, Mars Climate Station. There are two payload controllers installed on the orbiter and the rover respectively, the controlling payload power supply, commands, data acquisition and data processing. Observation tasks and main specifications of scientific payloads are shown in Table 1.

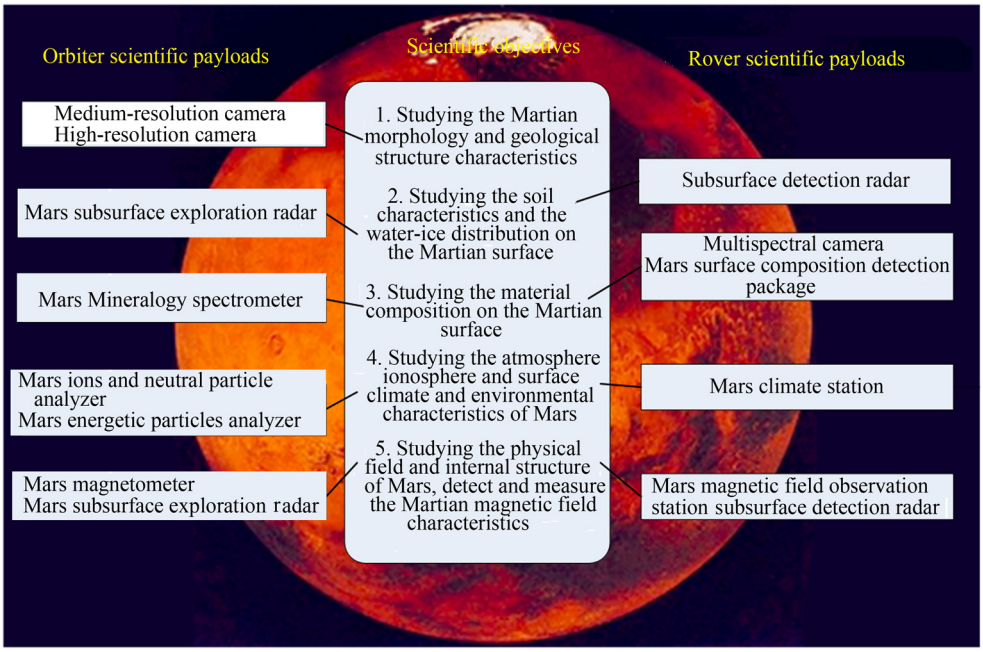


Fig. 1 Scientific objectives corresponding scientific payloads

**Table 1 Detection tasks and main specifications of scientific payloads**

| Scientific payloads | Detection tasks | Main specifications |
|---|---|---|
| Medium-resolution Camera | It will image Mars surface and obtain Mars global remote sensing image<br>It will image Mars topography and landscape, including Mars surface geological structure and topography and landscape | Spectral range: visible<br>Color: standard R, G, B<br>Resolution: better than 100 m@400 km<br>Imaging width: 400 km@400 km<br>Effective pixels: 4096×3072 |
| High-resolution Camera | It will obtain elaborated image on Mars surface key area<br>It will carry out high resolution imaging and detailed survey on areas which have dynamic change feature such as dunes, glaciers, avalanches, observe Mars surface topography and landscape | Pixel resolution (at 265 km orbit altitude)<br>Panchromatic: better than 2.5 m, a local key area better than 0.5 m<br>Color: better than 10 m, local key area better than 2.0m<br>Coverage width (at 265 m orbit altitude): 9 km |

(to be continued)

**Table 1 (continued)**

| Scientific payloads | Detection tasks | Main specifications |
|---|---|---|
| | It will give high resolution images on dry river bed, sedimentary rock strata districts where may exist water, and typical geomorphic features such as impact crater, volcano, canyon, hillock, rift valley edge, and other geomorphic features with special significance. It will recognize characteristic geomorphic features such as fluvial landscape, volcanic landscape, impact crater and wind-erosion landscape, for researches on Mars surface topography and landscape and geological structure | |
| Mars Subsurface Exploration Radar | It will obtain the surface and the subsurface radar echo data, detect Mars subsurface structure and underground water-ice distribution<br>On Earth-Mars transfer orbit, it will detect interplanetary very low frequency radio spectrum | Frequency: 10∼20 MHz, 30∼50 MHz<br>Receiver sensitivity: $\leqslant -87$ dBm<br>Detecting depth<br>Mars subsurface structure 100 m (Earth, $\varepsilon_\gamma = 3.0 \sim 4.0$)<br>Mars polar ice, about 100 m (ice, $\varepsilon_\gamma$ about 3.0)<br>Thickness resolution: meter level |
| Mars Mineralogy Spectrometer | It will analyze mineral composition and distribution<br>It will research Mars integral chemical composition and chemical revolution history<br>It will analyze Mars resources and distribution | Spectral region<br>visible-near infrared, 0.45∼1.05 $\mu$m<br>intermediate infrared and near-infrared, 1.00∼3.40 $\mu$m<br>Spectral resolution<br>visible-near infrared, better than 10 nm<br>intermediate infrared and near-infrared, better than 12 nm@1.0∼2.0 $\mu$m, better than 25 nm@2.0∼3.4 $\mu$m |
| Mars Magnetometer | It will detect Mars space magnetic field environment<br>Cooperating with Mars Magnetic Field Observation Station, invert currents of Martian ionosphere and research characteristics such as conductivity of Martian ionosphere<br>By detection of Mars magnetic field and Solar wind magnetic field, it will research interaction between Martian ionosphere, magnetosheath, and the solar wind | Measurement range: $\pm$2000 nT<br>Noise level: $\leqslant 0.01\ \text{nT}\cdot\text{Hz}^{1/2}$<br>Resolution: better than 0.01 nT<br>Precision: 0.1 nT |
| Mars Ion and Neutral Particle Analyzer | It will detect particle features of Mars plasma, to understand the escape of Martian atmosphere<br>It will study the interaction mechanism of solar wind and Martian atmosphere, and accelerate mechanism of neutral particles near the Martian bow shock | Low energy ions<br>Energy range: 5 eV∼25 keV<br>Energy resolution($\Delta E/E$): 15%<br>Mass: 1∼40 amu<br>Field of view: $90^\circ \times 360^\circ$<br>Angular resolution: $11.2^\circ \times 22.5^\circ$<br>Low energy neutral particles<br>Energy range 50 eV∼3 keV<br>Energy resolution ($\Delta E/E$): 100%<br>Mass: 1∼32 amu |

(to be continued)

**Table 1 (continued)**

| Scientific payloads | Detection tasks | Main specifications |
|---|---|---|
| | | Field of view: $15^\circ \times 160^\circ$<br>Angular resolution: $10^\circ \times 25^\circ$ |
| Mars Energetic Particle Analyzer | It will research the character and changes of the energy spectrum of energy particles, elementary composition and flux in the near-Mars space environment and earth-Mars transfer orbit<br>It will mapping the spatial distribution of the energetic particle radiation from different species on Mars global and earth-Mars transfer orbit<br>Together with Mars Ion and Neutral Particle Analyzer and Mars Magnetometer, it will study the relationship between near the energetic particle radiation and atmosphere, SEP event's influence on Mars atmosphere, particle acceleration, transport and escape process | Energy range<br>Electron: 0.1∼12 MeV<br>($\geqslant$ 16 channels, logarithmic division)<br>Proton: 2∼100 MeV<br>($\geqslant$ 16 channels, logarithmic division)<br>$\alpha$-particle, heavy ion: 25∼300 MeV<br>($\geqslant$ 16 channels, logarithmic division)<br>Energy resolution ($\Delta E/E$): 15%<br>Flux range: $0\sim10^5 \mathrm{cm}^{-2}\cdot\mathrm{s}^{-1}$<br>Species: H∼Fe ($1 \leqslant Z \leqslant 26$)<br>Heavy ion mass resolution ($\Delta m/m$)<br>$\leqslant 25\%$ ($Z \leqslant 9$, 25∼300 MeV)<br>$\leqslant 25\%$ ($10 \leqslant Z \leqslant 26$, 100∼300 MeV)<br>$\leqslant 60\%$ ($10 \leqslant Z \leqslant 26$, 25∼100 MeV) |
| Multispectral Camera | It will obtain multispectral image of landing and roving area<br>It will obtain the material type distribution on Mars surface | Spectral range (nm): 9 spectrum, 480 (20), 525 (20), 650 (12), 700 (15), 800 (25), 900 (30), 950 (50), 1000 (50)<br>Color: multispectral<br>Normal imaging distance: 1.5 m∼ $\infty$<br>Pixel: 2048×2048 |
| Subsurface Detection Radar | It will detect covering area of Mars surface soil thickness and ice structure, obtain Mars surface and subsurface ultra-wideband full polarized echo data<br>It will detectcovering area subsurface structure, obtain subsurface geologic structure data | First channel<br>Center frequency: 55 MHz<br>Operation bandwidth: 40 MHz<br>Resolution of ice thickness: meter level<br>Investigation depth<br>$\geqslant$ 100 m (ice, $\varepsilon_\gamma = 3.0$)<br>$\geqslant$10 m (soil, $\varepsilon_\gamma = 3.0\sim4.0$)<br>Second channel<br>Center frequency: 1300 mHz<br>Bandwidth: 1000 mHz<br>Resolution of thickness: cm level<br>Detection depth<br>$\geqslant$ 10 m (ice, $\varepsilon_\gamma = 3.0$)<br>$\geqslant$3 m (soil, $\varepsilon_\gamma = 3.0\sim4.0$) |
| Mars Surface Composition Detection Package | It will analyze chemical elements of Mars surface material<br>It will analyze Mars surface mineral and analyze rocks | LIBS detection<br>Number of elements: $\geqslant$ 10<br>(Si/Al/Fe/Mg/Ca/Na/O/C/H/Mn/Ti/S, *etc.*)<br>Detection distance: 2∼5 m (best detection distance), up to 10 m<br>Micro image Angle resolution: $\leqslant 100\,\mu$rad<br>(0.20 mm@2 m, 0.50 mm@5 m)<br>Short-wavelength infrared spectroscopy<br>Spectral range: 850∼2400 nm |

(to be continued)

**Table 1 (continued)**

| Scientific payloads | Detection tasks | Main specifications |
|---|---|---|
| | | Spectral resolution: $\leqslant 12$ nm<br>Field of view: $\geqslant 1$ mrad |
| Mars Magnetic Field Observation Station | It will detect Mars magnetic field in the landing area, determine Mars magnetic field index<br>Cooperating with orbit Mars space magnetic field measurement, invert Mars ionosphere currents, study Mars ionosphere characteristics such as conductivity<br>It will detect Mars internal local structure by using natural magnetic field jump | Measure range: $\pm 2000$ nT<br>Resolution: better than 0.01 nT<br>Noise level: 0.01 nT·Hz$^{1/2}$<br>Magnetometer stability: $\leqslant 0.01$ nT·K$^{-1}$ |
| Mars Climate Station | It will conduct in-situ detection on Mars surface wind field parameters<br>It will monitor the sound of Mars surface<br>It will measure Mars surface environment temperature and air pressure | Temperature<br>Range: $-120\sim+50$°C<br>Resolution: 0.1°C<br>Pressure<br>Range: 1∼1500 Pa<br>Resolution: 0.1 Pa<br>Wind speed<br>Range: 0∼70 m·s$^{-1}$<br>Resolution: 0.1 m·s$^{-1}$<br>Wind direction<br>Range: 0°∼360°<br>Resolution: 5°<br>Sound<br>Frequency range:<br>20 Hz∼2.5 kHz, 2.5∼20 kHz<br>Sensitivity: better than 50 mV·Pa$^{-1}$<br>Dynamic range: $\geqslant 90$ dB |

# 4 Summary

The Chinese first Mars exploration mission will implement orbiting, landing and roving on Mars by a single launch. Scientific payloads will conduct global and comprehensive orbiting detection and regional roving detection on Mars surface. During the mission, the ground application system will receive science data and perform data analysis and scientific research.