# China's Mars Exploration Mission and Science Investigation

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## Abstract

China's first Mars exploration mission (HuoXing-1) has been named as 'Tianwen-1' meaning Heaven Inquiry. Tianwen-1 was launched on July 23, 2020. In this paper, the scientific objectives of earlier and current Mars exploration missions worldwide are reviewed, and the scientific objectives, payloads and preliminary scientific investigation plan of China's first Mars exploration mission are introduced, and expected scientific achievements are analyzed.

**Keywords** Mars exploration · Payloads · Remote sensing exploration · In-situ exploration · Scientific investigation plan

## 1 Introduction

As the neighbor of the Earth, the Mars evolution is of significant importance for understanding the history and future evolution of the Earth. Since 1960s, more than 40 Mars exploration missions have been implemented, and some more are in progress. According to the collected data, there may have been life and liquid water on Mars, which makes the Mars a potential habitable planet in the solar system, providing new hope for human's migration to Mars and opening up new living space. Exploring information regarding life on Mars, whether life ever existed in the past, and the environment suited for living becomes hot topic of Mars exploration at present (Ouyang and Xiao 2011; Ouyang and Liu 2009). Scientific objectives in the past 20 years (Table 1) provide reference for China's Mars exploration. The scientific objectives and results of recent Mars missions are focused on the following aspects:

(1) Mars atmosphere characteristics and climate change: to examine the structure and composition of Mars neutral atmosphere, meteorology, climate characteristics and changes; to search for evidence on past climate change, and to study the evolution history and future trends of Mars meteorology and climate (Gómez-Elvira et al. 2012; Mahaffy et al. 2013; Barlow 2014; Jakosky et al. 2015).

**Table 1** Mars exploration missions and scientific objectives in the past 20 years

| Mission | Launch/end of mission | Scientific objectives |
|---|---|---|
| Mars Odyssey (Saunders et al. 2004) | 2001-4-7 in progress | (1) Globally map the elemental composition of the surface<br>(2) Determine the abundance of hydrogen in the shallow sub-surface<br>(3) Acquire high spatial and spectral resolution images of the surface mineralogy<br>(4) Provide information on the morphology of the Martian surface<br>(5) Characterize the Martian near-space radiation environment as related to radiation-induced risk to human explorers |
| Mars Express (Wilson and Chicarro 2004) | 2003-6-2 in progress | (1) Global color and stereo high-resolution imaging with about 10 m resolution and imaging of selected areas at 2 m/pix<br>(2) Global IR mineralogical mapping of the surface<br>(3) Global radar sounding of the subsurface structure down to 1–2 km depth<br>(4) Long term monitoring of atmospheric parameters: temperature, composition, dust loading<br>(5) Long-term monitoring of plasma environment and ion escape rate<br>(6) Global imaging and investigation of Phobos<br>(7) Infer critical information on the atmosphere, ionosphere, surface and interior |
| Spirit Mars Rover (Crisp et al. 2003) | 2003-6-10 2010-3-22 | (1) To investigate landing sites which have a high probability of containing evidence of the action of liquid water<br>(2) To search for and characterize a diversity of rocks and soils that hold clues to past water activity<br>(3) To extract clues related to the environmental conditions when liquid water was present and assess whether those environments were conducive for life<br>(4) To determine the spatial distribution and composition of minerals, rocks and soils surrounding the landing sites<br>(5) To determine the nature of local surface geologic processes from surface morphology and chemistry<br>(6) To calibrate and validate orbital remote-sensing data and assess the amount and scale of heterogeneity at each landing site |
| Opportunity Mars Rover (Crisp et al. 2003) | 2003-7-8 2019-2-13 | (7) To identify and quantify relative amounts of specific mineral types that contain $H_2O$ or OH, or are indicators of formation by an aqueous process<br>(8) To characterize the mineral assemblages and textures of different types of rocks and soils and put them in geologic context |

**Table 1**  (*Continued*)

| Mission | Launch/end of mission | Scientific objectives |
| --- | --- | --- |
| Mars Reconnaissance Orbiter (Graf et al. 2005) | 2005-08-12 in progress | (1) Characterize Mars's seasonal cycles and diurnal variations of water, dust, and carbon dioxide<br>(2) Characterize Mars's global atmospheric structure, transport and surface changes<br>(3) Search sites for evidence of aqueous and/or hydrothermal activity<br>(4) Observe and characterize the detailed stratigraphy, geologic structure, and composition of Mars surface features<br>(5) Probe the near-surface Martian crust to detect subsurface structure, including layering and potential reservoirs of water and/or water ice<br>(6) Characterize the Martian gravity field in greater detail relative to previous Mars missions to improve knowledge of the Martian crust, lithosphere, and potentially atmospheric mass variation<br>(7) Identify and characterize numerous globally distributed landing sites with a high potential for scientific discovery by future missions |
| Phoenix Mars Lander (Smith et al. 2008) | 2007-8-4 2008-11-2 | (1) To study the history of the ice and its emplacement mechanisms<br>(2) To address the affect that subsurface ice has on the local geomorphology of the surface and any layering beneath the surface<br>(3) To understand local climate and weather<br>(4) The question of the habitability of the icy soil |
| Mars Science Laboratory (NASA 2011; Webster et al. 2015) | 2011-11-26 in progress | (1) Determine the nature and inventory of organic carbon compounds<br>(2) Investigate the chemical building blocks of life (carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur)<br>(3) Identify features that may represent the effects of biological processes (biosignatures)<br>(4) Investigate the chemical, isotopic, and mineralogical composition of the Martian surface and near-surface geological materials<br>(5) Interpret the processes that have formed and modified rocks and soils<br>(6) Assess long-timescale (i.e., 4-billion-year) Martian atmospheric evolution processes<br>(7) Determine present state, distribution, and cycling of water and carbon dioxide<br>(8) Characterize the broad spectrum of surface radiation, including cosmic radiation, solar particle events and secondary neutrons |

**Table 1** (*Continued*)

| Mission | Launch/end of mission | Scientific objectives |
| --- | --- | --- |
| Mars Atmosphere and Volatile Evolution (Jakosky et al. 2015) | 2013-11-18 in progress | (1) Measure the composition and structure of the upper atmosphere and ionosphere today, and determine the processes responsible for controlling them<br>(2) Measure the rate of loss of gas from the top of the atmosphere to space, and determine the processes responsible for controlling them<br>(3) Determine properties and characteristics that will allow us to extrapolate backwards in time to determine the integrated loss to space over the four-billion-year history recorded in the geological record |
| Mars Orbiter Mission (MOM) (Kumar and Chauhan 2014) | 2013-11-5 in progress | (1) Exploration of Mars surface features, morphology,<br>(2) mineralogy and Martian atmosphere by five scientific instruments |
| ExoMars 2016 Trace Gas Orbiter (ESA 2014) | 2016-3-14 in progress | (1) Investigation of the water/geochemical environment as a function of depth in the shallow sub-surface<br>(2) Study of martian atmospheric trace gases and their sources<br>(3) Surface stereo and color imaging at $\sim$ 6 m/px resolution |
| InSight Mars lander (NASA 2018; Banerdt et al. 2020) | 2018-5-5 in progress | (1) Formation & Evolution: Understand the formation and evolution of terrestrial planets through investigation of the interior structure and processes of Mars<br>(2) Tectonic Activity: Determine the present level of tectonic activity and meteorite impact rate on Mars |
| Hope (Sharaf et al. 2020) | 2020-7-20 in progress | (1) characterize the weather system in the lower atmosphere of Mars, providing a comprehensive understanding of diurnal changes across the planet and across all seasons<br>(2) measure the distribution of hydrogen and oxygen in the highest portions of the atmosphere (the collisionless exosphere)<br>(3) correlate the processes within the lower atmosphere with rates of atmospheric escape from the exosphere |
| Mars 2020 (NASA 2020) | 2020-7-30 in progress | (1) Identify past environments capable of supporting microbial life<br>(2) Seek signs of possible past microbial life in those habitable environments, particularly in special rocks known to preserve signs of life over time<br>(3) Collect core rock and "soil" samples and store them on the Martian surface<br>(4) Test oxygen production from the Martian atmosphere |

(2) Ionosphere, aeronomy, plasma environment and escape processes: to measure the composition and structure of the upper atmosphere and ionosphere, and the rate of loss of gas from the top of the atmosphere to space (Jakosky et al. 2015; Pätzold et al. 2016).

(3) Landform and geological structure: to investigate the Mars topography and geomorphology, geological structure, soil and rock composition and element, sediment rock distribution and relative age, polar water ice distribution and variation; to study the geological history and surface evolution (Carr 1981; Head et al. 1999; Smith et al. 1999; Gendrin et al. 2005; Bibring et al. 2005, 2006; Barlow 2014; Head and Pieters 2018).

(4) Magnetic fields, gravity fields and interiors: to explore Mars crustal and time-varying magnetic fields, Mars' core and magnetism, its gravity field; to comparatively study the interior structure of Mars and the Earth, and to explore the evolution of the earth-like planet (Stevenson 2001; Barlow 2014; Johnson et al. 2020).

(5) Water and life: to search for water on Mars; to study the water body evolution; to seek signs of habitable conditions on Mars in the ancient past, and to search for evidence of ancient life (Grotzinger 2014; Freissinet et al. 2015; Webster et al. 2015, 2018; Orosei et al. 2018; Salese et al. 2019).

(6) Mars science observation station and laboratory: to set up scientific observation station on Mars; to monitor and study the change of Martian surface and climate environment; to explore the possible resources on Mars and to provides scientific basis for the exploration and utilization of resources (Zeitlin et al. 2013; Hassler et al. 2014).

China announced its planetary exploration programme beyond the Earth–Moon system in 2016. Benefiting from the engineering heritage of China's lunar exploration programme, the Chinese national strategy sets Mars as the next target for planetary exploration. China's first Mars exploration mission (HuoXing-1) aims at completing orbiting, landing and roving in one mission, and has been named as Tianwen-1 (TW-1) which means Heaven Inquiry (Wan et al. 2020). TW-1 was launched on July 23, 2020. Here the scientific objectives of earlier and current Mars exploration missions worldwide are reviewed, and the scientific objectives, payloads and preliminary scientific exploration plan of China's first Mars exploration mission are introduced, and expected scientific outcomes are analyzed.

## 2 China's First Mars Exploration Mission

China's first Mars mission can be divided into launch phase, Earth–Mars transfer phase, Mars capture orbit phase, Mars parking orbit phase, EDL (Entry, Descent, Landing) phase and scientific exploration phase. The probe is launched into the Earth–Mars transfer trajectory and will travel for 6 and a half months in this transfer trajectory. After captured by Mars, the probe will enter an ellipsoid Mars orbit of 10 sols. After orbit maneuver at the apoareon, the probe will be adjusted to the circumpolar orbit and then enter the mars parking orbit with a period of about 2 days after three times of periareon braking. Two to three months later, the rover will be released by the orbiter and land on the surface to start in-situ exploration. After releasing of the rover, the orbiter will perform orbit maneuver, enter relay and survey orbit with a period of about 8.2 hours, communicate with the rover and start its scientific exploration. 90 sols later, global reconnaissance orbit phase will start after orbit adjustment and last for one martian year (Fig. 1).

Global reconnaissance orbit is a large ellipse with the altitudes of periareon and apoareon about 265 km and 11900 km, respectively. The orbit inclination is $90° \pm 5$, and the orbital period is 7.8 hours.
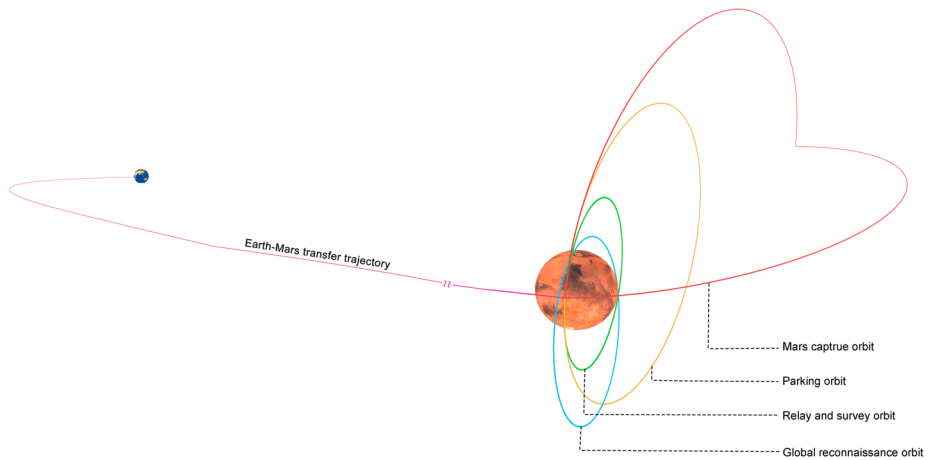
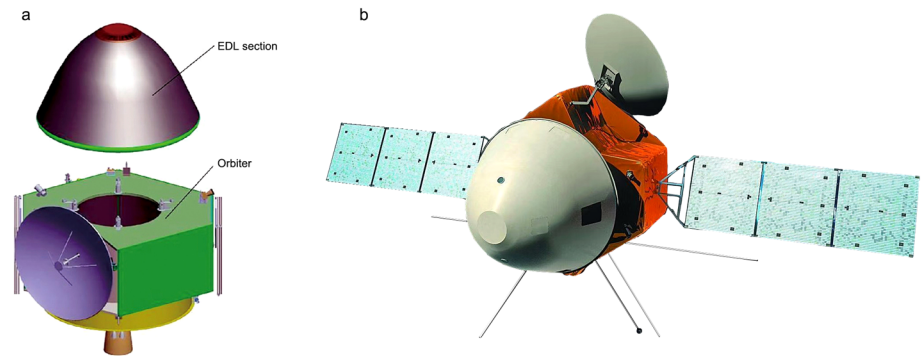**Fig. 1** China's first Mars Mission profile and flight orbit strategy



**Fig. 2** Configuration of TW-1 probe. (**a**) The TW-1 probe consists of an orbiter and an EDL section in which is the rover and landing infrastructure. (**b**) is the illustration of TW-1 probe model. Its size is 13.6 m × 4.2 m × 1.6 m with solar panels open. There are two pairs of radar antennas with 5 m length, a magnetometer boom with 3 m length and communication antenna with 2.5 m diameter, respectively. (Redraw according to Ye et al. 2017)

## 2.1 System Components

The mission consists of five systems: probe, launch vehicle, launch site, telemetry track and command (TT&C), and ground research and application system (GRAS).

The probe consists of an orbiter and an EDL section which is made up of an entry capsule, landing infrastructure and rover (Fig. 2). The orbiter transfers data to the Earth through X band signal with code rate of 16 kbps–4096 kbps. The communication between the orbiter and the rover are through UHF band and X band signals. The probe has been launched with Long March 5 carrier rocket at Wenchang launch site in Hainan province on July 23, 2020. The TT&C system is responsible for the measurement and control of the probe. The GRAS includes a headquarters and three ground stations at Miyun, Wuqing and Kunming. Its responsibility involves the formulation of in-orbit scientific exploration plan, payloads

operation, the receiving, processing, interpretation and management of scientific detection data, and the application and research of scientific data.

The Advanced Science Research Team was formed by China National Space Administration (CNSA) to participate in the research on scientific objectives of Mars exploration mission. An academic seminar had been held every year to promote the communication between engineering team and science community from 2017.

## 2.2 Scientific Objectives

According to the general plan of China's deep space exploration and the progress of international Mars exploration, the scientific objectives of China's first Mars exploration mission include the following. The objectives will focus on two scientific problems regarding the environment in which the life existed, and the origin and evolution of Mars and the solar system.

(1) **To map the morphology and geological structure:** to map the global topography and geomorphology, to obtain the high-precision topography of typical regions, and to study the formation and evolution of the Mars geological structure. Geology and topography will be investigated by context imaging at 100 m/px resolution complemented by high-resolution imaging of key selected areas at 0.5 m/px resolution.

(2) **To investigate the surface regolith characteristics and water-ice distribution:** to investigate the regolith types, weathering and sedimentary characteristics and global distribution, to measure the subsurface structure, to search for the water and ice information, and to study the stratification structure of regolith profile. Subsurface structure and water ice distribution will be investigated by two sets of Radar on orbiter and rover. The orbiter subsurface penetrating radar sounding of the subsurface structure down to the depth of 100 m with vertical resolution of meter level will add the third dimension to the surface investigations. The rover subsurface penetrating radar sounding of the subsurface structure can down to the depth of 10 m and 3 m with vertical resolution of meter level and centimeter level, respectively.

(3) **To analyze the surface material composition:** to identify the rock types and the minerals on the Martian surface, and to analyze the mineral composition. The mineral and rock types and their distribution on the Mars' surface will be investigated by hyperspectral remote sensing in the wavelength range from 0.45 to 3.4 μm. The distribution of major mineral elements will be investigated by in-situ Laser-induced Breakdown Spectroscopy (LIBS) with the detection accuracy better than 10%.

(4) **To measure the ionosphere and the characteristics of the Martian climate and environment at the surface:** to measure the space environment, the temperature, pressure and wind fields. To study structure, composition dynamics of the neutral atmosphere; aeronomy, plasma environment and escape; seasonal changes of surface weather. Interplanetary space and plasma environment will be investigated by Ion and Neutral Particle Analyzer, Energetic Particles Analyzer and Very Low Frequency Radio Receiver. Ion energy range is 5 eV–25 KeV, neutral particle energy range is 50 eV–3 KeV, electron energy range is 0.1–12 Mev, proton energy range is 2–100 Mev, and heavy ion energy range is 25–300 Mev. Very Low Frequency Radio receiver frequency range is 10 kHz–10 MHz.

(5) **To perceive the physical fields (electromagnetic, gravitational) and internal structure of Mars:** to measure the Mars magnetic properties and study the early geological evolution history, the mass distribution and gravity field. The detection range of Mars
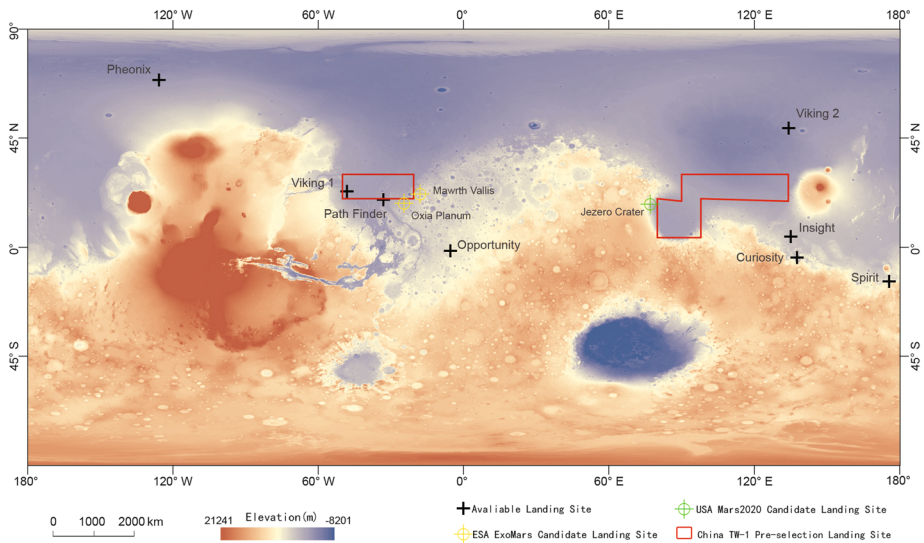
**Fig. 3** Candidate landing areas of China's Mars Exploration Mission. Base image is from MOLA DEM (https://astrogeology.usgs.gov/search/details/Mars/GlobalSurveyor/MOLA/Mars_MGS_MOLA_DEM_mosaic_global_463m)

space magnetic intensity is $\pm 10000$ nT with the resolution better than 0.01 nT. The detection range of Martian surface magnetic field measurement is $\pm 2000$ nT dynamic, and $\pm 65000$ nT compensation. The resolution is better than 0.01 nT.

The above five scientific objectives will be achieved by remote and in-situ investigations jointly. The investigations from orbit will focus on the integrated and comprehensive exploration of Mars, and to establish an overall scientific context of Mars. The investigations from rover will focus on the high precision and resolution detection and in situ analysis of the Mars key areas.

Through the synergistic exploration of the orbiter and the rover as well as simultaneous space-ground exploration, the Mars topography, regolith properties, material composition, water-ice distribution, ionosphere and magnetic field will be investigated.

## 2.3 Candidate Landing Area

Two landing areas for China's first Mars exploration mission are preselected based on the following engineering criteria and scientific objectives (Fig. 3).

Engineering criteria of landing site selection include (Ye et al. 2017):

(1) Latitude: landing area should be between 5–30 °N;
(2) Altitude: the lower the better, the elevation of landing site should be at least −2 km;
(3) Slope: avoid steep slopes area, choose relative flat area;
(4) Surface condition: should avoid dusty area and choose area with less dust cover;
(5) Rock distribution: should avoid area of abundant rocks, and choose area with less amount of rocks;
(6) Local wind speed: landing area with lower wind speeds are preferred;
(7) Visibility requirements during the landing process: the EDL process should be scheduled on the side of Mars that is visible from Earth at the time of landing.

Key scientific objectives required to be considered:

(1) Geology: the landing area should have as diverse geology as possible;
(2) Soil structure and water ice distribution: choose potential area that has the highest opportunity to find water ice or ground water;
(3) Surface elements, mineral, and rock distribution: choose potential area that has higher possibility to find diverse element, mineral and rocks;
(4) Magnetic field detection: choose the area favourable for Mars Magnetic field.

There are multiple rounds of selection during the landing area selection process to balance the technical feasibility and scientific interests. Firstly, landing areas meeting the strict criterion of engineering constraints would be selected and introduced. Then, the scientists would propose some interested landing sites from the selected areas according to the scientific objectives of the mission. After that, the proposed landing sites would be evaluated. In each round, the suggestion from the engineers and scientists will be thoroughly discussed.

**(1) Preselected landing area 1** The primary landing area 1 is located in the Chryse Planitia plain, close to dihotomy boundary. The landing site of Viking-1 is located in the west, while the landing site of Pathfinder, ESA pre-selected Oxia Planum and Mawrth Vallis landing zones are located in the south. The topography shows there may be water-formed channels. Geologic units Hto (Hesperian transition outflow unit), lHt (Late Hesperian transition unit) and lHl (late Hesperian lowland unit) are close to the pre-selected area 1.

**(2) Preselected landing area 2** The pre-selected area 2 is located partly in Isidis Planitia and partly in Utopia Planitia. Isidis Planitia is the third largest basin on Mars, formed in the Noachian geological era 3.9 billion years ago. This area is covered by Martian dust and brighter in telescope image, making it as a typical reflectance feature on the Martian surface. Geologic units lHl (late Hesperian lowland unit) and AHv (amazonian and Hesperian volcanic unit) are close to the preselected landing area 2. Landing site of ESA's Beagle 2 in the late Hesperian era is also located in this preselected landing area. The eastern side of landing area is located in the volcanic region, a transition zone from Hesperian to Amazonian, with relatively younger strata.

According to the current orbit design, we are more inclined to land on the surface of southern Utopia planitia, adjacent to the west of Elysium Mon, where many water/ice related landforms have been found such as domes/pitted cones, rampart crater, mound, and lava flow front. This landing area was selected because we aim to conduct scientific exploration regarding whether ancient ocean ever exist on the northern part of the Mars and the geological evolution history of the Mars volcanos.

# 3 Payloads and Scientific Tasks

## 3.1 Payloads on the Orbiter

Remote sensing is an important exploration method which helps to obtain the global exploration data and to construct the global conception for Mars studies. Therefore, the investigations from orbit is the preferred at the beginning stage of planetary exploration.

According to the scientific objectives of TW-1 mission, the experiences of international Mars explorations and the scientific research progress, as well as the development of the China's aerospace science and technology, the scientific objectives of Mars orbiter include the following five aspects: to analyze Martian ionosphere, plasma environment and escape

**Table 2** The designated payloads for the orbiter investigations and their corresponding scientific tasks

| Scientific tasks | Payloads |
| --- | --- |
| Martian ionosphere, plasma environment and escape processes | Mars Orbiter Magnetometer (MOMAG) |
| | Mars Ion and Neutral Particle Analyzer (MINPA) |
| | Mars Energetic Particles Analyzer (MEPA) |
| | Very Low Frequency Radio Receiver (VLFRR) of Mars Orbiter Scientific Investigation Radar (MOSIR) |
| Martian surface and subsurface water-ice | Mars Orbiter Scientific Investigation Radar (MOSIR) |
| Martian regolith types distribution and structure | Mars Orbiter Scientific Investigation Radar (MOSIR) |
| | Mars Mineralogical Spectrometer (MMS) |
| | Moderate Resolution Imaging Camera (MoRIC) |
| Martian topography characteristic and their changes | Moderate Resolution Imaging Camera (MoRIC) |
| | High Resolution Imaging Camera (HiRIC) |
| Martian surface material composition | Mars Mineralogical Spectrometer (MMS) |
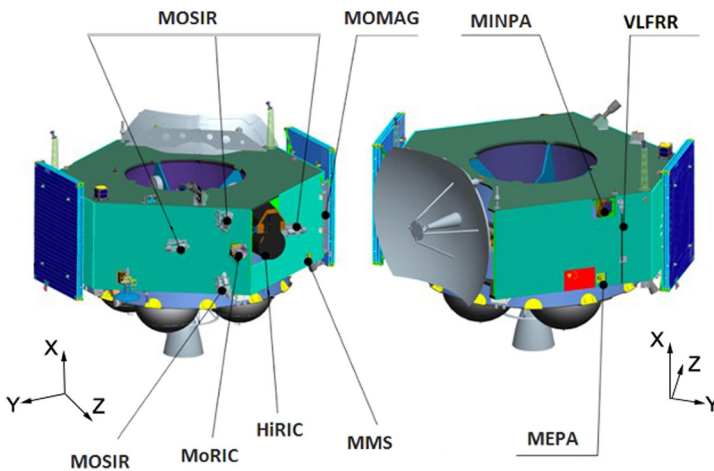


**Fig. 4** The configuration and layout of payloads onboard Orbiter. The orbiter coordinate system X-axis, Y-axis, and Z-axis form a right-hand system, with the X-axis is the flight direction and the Z-axis is direct toward the Mars at the periareon. Cameras (MoRIC and HiRIC), spectrometer (MMS), radar (MOSIR), magnetometer (MOMAG) are installed in the Z-axis direction. MINPA, MEPA and VLFRR are installed in the negative Z-axis direction

processes, to investigate Martian surface and subsurface water-ice, to investigate Martian regolith types distribution and structure, to map Martian topography characteristic and their changes, and to characterize Martian surface material composition.

To achieve the scientific objectives of orbiter investigation, the Mars orbiter is equipped with seven types of payloads including moderate resolution imaging camera, high resolution imaging camera, mars orbiter scientific investigation radar, Mars mineralogical spectrometer, Mars orbiter magnetometer, Mars ion and neutral particle analyzer and Mars energetic particles analyzer (Table 2, Fig. 4). The main technical parameters of these payloads are shown in Table 3.

**Table 3** Payload configuration and main technical parameters of TW-1 Mars Orbiter

| Payloads | Technical parameters |
|---|---|
| Moderate Resolution Imaging Camera (MoRIC) | (1) Color: RGB |
| | (2) Imaging Band: Visible |
| | (3) Spatial resolution: 100 m@400 km |
| | (4) Frame Width: 400 km@400 km |
| | (5) Pixel: 4096 × 3072 |
| | (6) Field of View: 53.1° × 41.1° (diagonal 64°) |
| High Resolution Imaging Camera (HiRIC) | (1) Resolution (@265 km altitude) |
| | Panchromatic: better than 2.5 m, in key areas better than 0.5 m |
| | Color: better than 10 m, in key areas better than 2.0 m |
| | (2) Swath Width: 9 km@265 km |
| Mars Orbiter Scientific Investigation Radar (MOSIR) | (1) Mars subsurface structure and water ice exploration |
| | Frequency: 10 MHz–20 MHz, 30 MHz–50 MHz |
| | Polarization: HH, HV |
| | Transmitter power: $\geq$ 100 W |
| | Receiver sensitivity: $\leq -87$ dBm |
| | Detecting depth: Mars subsurface structure, $\sim$ 100 m (regolith, $\varepsilon\gamma = 3.0$–4.0), Mars polar ice, $\sim$ 1000 m (ice, $\varepsilon\gamma = 3.0$) |
| | Thickness resolution: meter level |
| | (2) Ranging precision: better than 10 m |
| | (3) Interplanetary very low frequency radio spectrum detection |
| | VLF receiver frequency: 10 kHz–10 MHz |
| | VLF receiver resolution: better than 1 KHz (10 KHz–500 KHz), better than 20 KHz (500 KHz–10 MHz) |
| Mars Mineralogical Spectrometer (MMS) | (1) Spectral range (μm): |
| | Visible-near infrared, 0.45–1.0 μm, intermediate infrared and near-infrared, 1.00–3.40 μm |
| | (2) Spectral resolution: visible-near infrared, better than 10 nm, intermediate infrared and near-infrared, better than 12 nm@1.0 μm–2.0 μm, better than 25 nm@2.0 μm–3.4 μm. |
| Mars Orbiter Magnetometer (MOMAG) | (1) Measurement range: ±10000 nT |
| | (2) Resolution: better than 0.01 nT |
| | (3) Precision: 0.1 nT |
| | (4) Noise level: $\leq 0.01$ nT/$\sqrt{\text{Hz}}$ |
| | (5) Stability: $\leq 0.01$ nT/°C |
| Mars Ions and Neutral Particle Analyzer (MINPA) | (1) Low energy ions: |
| | Energy range: 5 eV–25 KeV |
| | Energy resolution ($\Delta E/E$): 15% |
| | Mass: 1–70 amu |
| | Field of view: 90° × 360° |
| | Angular resolution: 11.2° × 22.5° |
| | (2) Low energy neutral particles: |
| | Energy range: 50 eV–3 KeV |
| | Energy resolution ($\Delta E/E$): 100%, Mass: 1–32 amu |
| | Field of view: 15° × 160° |
| | Angular resolution: 10° × 25° |
| | Time resolution: 4 s |

**Table 3**   (*Continued*)

| Payloads | Technical parameters |
|---|---|
| Mars Energetic Particles Analyzer (MEPA) | (1) Energy range:<br>Electronic: 0.1–12 MeV<br>Proton: 2–100 MeV<br>$\alpha$-particle, heavy ion: 25–300 MeV<br>(2) Energy resolution ($\Delta E/E$): 15%<br>(3) Flux range: 0–$10^5$ cm$^{-2}$ s$^{-1}$<br>(4) Elementary composition: H–Fe ($1 \leq Z \leq 26$)<br>(5) Heavy ion mass resolution ($\Delta m/m$):<br>$\leq 25\%$ ($Z \leq 9$, 25–300 MeV)<br>$\leq 25\%$ ($10 \leq Z \leq 26$, 100–300 MeV)<br>$\leq 60\%$ ($10 \leq Z \leq 26$, 25–100 MeV)<br>(6) Field of view: 60°<br>(7) Time resolution: 4 s (proton, electron, alpha particle), 60 s (heavy ion) |

**(1) Analyze Martian ionosphere, plasma environment and escape processes** The orbiter is equipped with Mars orbiter magnetometer, Mars ion and neutral particle analyzer, Mars energetic particles analyzer and very low frequency radio receiver to explore the ionosphere and interplanetary environment. Mars orbiter magnetometer is used to map Martian magnetic field. The Mars ion and neutral particle analyzer measures the flux of ions in space environment, distinguishes the main ions and obtains their physical parameters such as the density, velocity and temperature. In addition, it measures the flux of neutral energy particles and distinguishes the main neutral particle components such as H, He and O. Mars energetic particles analyzer obtains the energy spectrum, flux and elemental composition of energy electrons, protons, $\alpha$ particles and ions. Very low frequency radio receivers acquire the very low frequency radio spectrum data in the interplanetary space during the cruise phase.

A highly elliptical orbit will be adopted by the mission with a periareon of 265 km where the orbit enters the Mars ionosphere (110 km–400 km) and an apoareon of 11900 km which crosses the complex and variable magnetic field boundaries such as the bow shock wave (towards the sun), the magnetosheath layer, the boundary of the magnetic accumulation zone, the magnetic accumulation zone and the induced magnetic tail (back of the sun). It is expected to obtain the space magnetic field survey data at 2.8–4.3 Rm (Radius of Mars) to fill the gap in existing Mars exploration (MGS/MAVEN) in the far magnetic tail region, and to partially fill the gap of observation in the position of bow shock wave. New data of the ionosphere ions of 5 eV–several KeV will be obtained to fill in the blank of 50 eV–3 KeV ions detection of MAVEN ionosphere mode.

**(2) Investigate Martian surface and subsurface water-ice** The orbiter is equipped with Mars orbiter scientific investigation radar to investigate the Martian surface and subsurface water-ice. It aims to explore water-ice by means of the dual-polarization echo characteristics of radar. When the radar is below the 800 km orbital altitude during the Mars-orbiting phase, the altimetry mode, ionospheric detection mode and subsurface detection mode will be used.

**(3) Investigate Martian regolith types distribution and structure** The orbiter is equipped with Mars orbiter scientific investigation radar and Mars mineralogical spectrometer. The

**Table 4** Scientific tasks and the designated payloads for in-situ exploration

| Scientific tasks | Payloads |
| --- | --- |
| Surface morphology and geology | Navigation and Terrain Camera (NaTeCam) |
| Subsurface structure and water ice distribution | Mars Rover Penetrating Radar (RoPeR) |
| Surface elemental composition and mineralogy | Mars surface Composition Detector (MarSCoDe) |
| | Multispectral Camera (MSCam) |
| Magnetic field | Mars Rover Magnetometer (RoMAG) |
| Atmospheric properties and meteorology | Mars Climate Station (MCS) |

Mars orbiter scientific investigation radar data, combined with the optical image and compositional information acquired by Mars mineralogical spectrometer, will be used to investigate the distribution of regolith types and subsurface structure of Mars.

**(4) Map Martian topography characteristic and their changes** The orbiter is equipped with moderate resolution imaging camera, high resolution imaging camera and Mars orbiter scientific investigation radar to characterize the topographic and geomorphological features of Mars and their changes. Moderate resolution imaging camera can obtain the global geomorphic data with a spatial resolution of about 100 m. The images overlap along the flight direction is up to 60%, and the side overlap between adjacent orbits is up to 15%, satisfying the need of three-dimensional imaging. High resolution imaging camera can acquire high-resolution images and perform detailed surveys on key areas and landing area, and obtain the landform data with spatial resolution of 0.5 m. The elevation can be measured by the Mars orbiter scientific investigation radar. Based on these three payloads, the formation process of Mars geological features, such as geomorphology of landing site, flow, volcano, erosion, impact crater and polar glacier will be studied.

**(5) Characterize Martian surface material composition** The orbiter is equipped with Mars mineralogical spectrometer, which utilizes the visible and near infrared imaging spectrometer with detection wavelengths ranging from 0.45 to 3.4 μm to investigate and analyze the Martian surface composition.

## 3.2 Payloads on the Rover

The mission will combine remote sensing and detailed in-situ exploration to advance our scientific understanding of Mars. The rover will undertake the following four scientific tasks in landing sites: to map morphology and geology, to investigate subsurface structure and possible water-ice, to analyze surface elements, minerals and rock types, and to measure atmosphere physical characteristics and surface environment.

In order to complete these scientific tasks, the Mars rover is equipped with six instruments (Table 4, Fig. 5) including the Mars surface composition detector, multispectral camera, navigation and terrain camera, Mars rover penetrating radar, Mars rover magnetometer, and Mars meteorological instrument. The technical parameters of these payloads are shown in Table 5.

**(1) Surface morphology and geology of landing sties** High-resolution 3D panoramic images will be obtained with two navigation topography cameras onboard the rover. These data will be used to construct topography maps, extract parameters such as slope, undulation
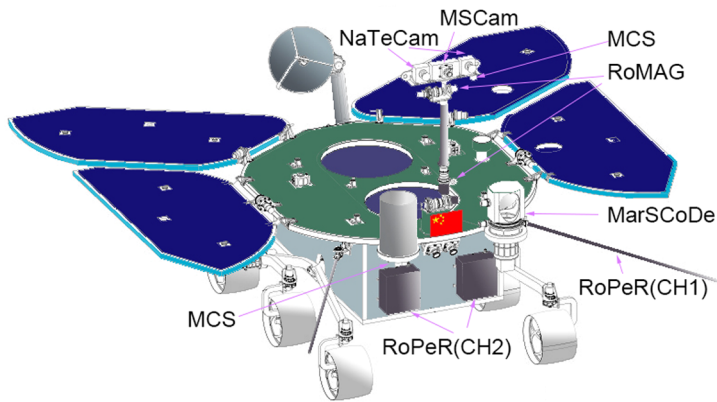
**Fig. 5** The configuration and layout of payloads onboard the Rover. The NaTeCams are binocular stereo cameras. NaTeCams and MSCam are mounted on the mast. Two tri-axial magnetometers (RoMAG) are mounted on the top and bottom of the mast, respectively. The distance between them is 67.5 cm. The RoPeR two low frequency channel (CH1) antennas are respectively mounted on two bottom sides of the top board of the rover. The length of each CH1 antenna is 1350 mm. The RoPeR two high frequency channel (CH2) antennas are mounted on the front board of the rover. The wind sensor and microphone unit of MCS are mounted on the mast. The air temperature and pressure sensor unit of MCS is mounted at the bottom of the UHF band relay antenna. MarSCode is mounted on the left top board of the rover

and roughness, investigate geological structures, and conduct comprehensive analysis on the geological structure of the surface parameters. Based on the investigated topography, geomorphology and geological structures, the local morphologic and geological evolution models will be established.

**(2) Subsurface structure and water-ice distribution of landing sties**   The full-polarization radar on the rover is used for the first time, which in combination with other payloads on the orbiter can further enhance the depth of scientific research of subsurface structure and possible water-ice.

**(3) Surface elemental composition and mineralogy of landing sties**   The elements, minerals and rocks are studied in details using the Mars surface composition detector and multispectral camera. Combined with water related landscape such as ancient lake, ancient river and alluvial island, weathering formed minerals will be searched such as carbonate minerals or hematite, layered silicate, hydrated sulfate, and perchloric minerals. Metamorphism effect of water on these minerals will be investigated to establish the relationship between Martian surface water environment and secondary mineral types, and to search for historical environmental conditions for the presence of liquid water.

**(4) Magnetic field, atmospheric properties and meteorology of landing sties**   The fine-scale structures of crustal magnetic field is obtained with Mars rover magnetometer based on mobile measurements on the Martian surface. Combining with orbiter observation, the ionospheric conductivity by inverting the ionospheric dynamo current will be studied. In addition, we will explore the local interior structure using magnetic field variations.

The temperature, pressure, wind velocity and direction of the surface atmosphere, and sounds will be measured with Mars meteorological measuring instrument.

**Table 5** Payload configuration and main technical parameters of Mars rover

| Payloads | Main technical parameters |
|---|---|
| Navigation and Terrain Camera (NaTeCam) | (1) Color: RGB<br>(2) Spectral range: visible<br>(3) Normal imaging distance: 0.5 m–∞<br>(4) Pixel: 2048 × 2048 |
| Multispectral Camera (MSCam) | (1) Spectral range (nm): there are 9 bands, which are 480(20), 525(20), 650(12), 700(15), 800(25), 900(30), 950(50), 1000(50), and panchromatic<br>The figures in brackets are the filters bandpasses (full width at half maximum)<br>(2) Color: multi-spectral<br>(3) Normal imaging distance: 1.5 m–∞<br>(4) Pixel: 2048 × 2048 |
| Mars Rover Penetrating Radar (RoPeR) | (1) The first channel (CH1):<br>Frequency: 15–95 MHz<br>Polarization: HH<br>Penetration thickness: meter level<br>Detection depth: ≥ 100 m (ice, $\varepsilon r = 3.0$), ≥ 10 m (regolith, $\varepsilon r = 3.0$–4.0)<br>(2) The second channel (CH2):<br>Frequency: 450–2150 MHz<br>Polarization: HH, HV, VH, VV<br>Penetration thickness: centimeter level<br>Detection depth: ≥ 10 m (ice, $\varepsilon r = 3.0$), ≥ 3 m (regolith, $\varepsilon r = 3.0$–4.0) |
| Mars surface Composition Detector (MarSCoDe) | (1) LIBS detection<br>Element type: no less than 10 elements (Si, Al, Fe, Mg, Ca, Na, O, C, H, Mn, Ti, S, etc.)<br>Detection distance: 2–5 m (best detection distance), with the largest distance of 10 m<br>(2) Microscopic camera<br>Image resolution: ≤ 100 μrad (0.20 mm@2 m, 0.50 mm@5 m)<br>Field of view: ≥ 1 mrad<br>Short-wave infrared spectral detection<br>Spectral range: 850–2400 nm<br>Spectral resolution: ≤ 12 nm<br>Band: no less than 130 bands |
| Mars Rover Magnetometer (RoMAG) | (1) Measurement range: ±2000 nT dynamic; ±65000 nT compensation<br>(2) Resolution: better than 0.01 nT<br>(3) Precision: 0.1 nT<br>(4) Noise level: ≤ 0.01 nT/$\sqrt{Hz}$<br>(5) Stability: ≤ 0.01 nT/°C<br>(6) sampling rate: 1 Hz, 16 Hz, 32 Hz, 128 Hz |
| Mars Climate Station (MCS) | (1) Temperature: range −120 °C–+ 50 °C; resolution 0.1 °C;<br>(2) Air pressure: range 1–1500 Pa; resolution 0.1 Pa;<br>(3) Wind speed: range 0–70 m/s; resolution 0.5 m/s;<br>(4) Wind direction: range 0–360°; resolution 5°;<br>(5) Sound: frequency range: 20 Hz–2.5 kHz, 2.5 kHz–20 kHz; sensitive: better than 50 mV/Pa; dynamic range: ≥ 90 dB |

# 4 Preliminary Scientific Investigation Plan

## 4.1 Scientific Investigation Plan of the Orbiter

The orbiter will begin scientific investigation during the Earth–Mars transfer. The rover will be released after Mars orbit insertion and 2–3 months of the orbit adjustment in the parking orbit. After that, the orbiter performs maneuver, enters relay orbit, communicates with the rover, and conduct scientific exploration at the same time. After 90 sols of the rover mission, the orbiter enters the reconnaissance orbit for the orbiting investigations and rover data relay. The scientific investigation plans of the orbiter are presented in Table 6.

The payloads of the orbiter do not work in the launch phase, capture phase, and off-orbit landing phase.

**Earth–Mars transfer orbit** Mars orbiter scientific investigation radar (very low frequency detection), Mars ions and neutral particle analyzer, and Mars energetic particle analyzer continuously operate during Earth–Mars transfer. Moderate resolution imaging camera will work at selected time to image the Earth, the Moon and Mars. Other payloads will choose time to carry out self-check.

**Mars parking orbit, relay and survey orbit** After captured by Mars, the payloads on obiter will start on-orbit test work. The moderate resolution imaging camera, high resolution imaging camera and Mars mineralogical spectrometer will focus on investigation of pre-selected landing areas. The rover will start a 90 sols in-situ exploration after the lander is released. The orbiter will perform orbit maneuver and enter one Martian year global reconnaissance orbit after the rover works on Mars for 90 sols.

**Global reconnaissance orbit** Moderate resolution imaging camera, high resolution imaging camera, Mars orbiter scientific investigation radar and the Mars mineralogical spectrometer will operate below the 800 km altitude. The Mars orbiter magnetometer, Mars ion and neutral particle analyzer and the Mars energetic particles analyzer work continuously.

## 4.2 Scientific Investigation Plan of the Rover

The working life of the rover on the Martian surface is designed to be 90 sols. After landing, the rover will extend its solar panels, establish direction control of the Earth-point antenna and report its initial status. The orbiter will be located in a relay and survey orbit to support the rover's scientific investigation of Mars. The Mars rover penetrating radar works during the roving. The Mars surface composition detector, Multispectral Camera, Navigation and Terrain Camera begin to work when the rover stops after reaching the study target. Both the Mars rover magnetometer and Mars climate station work during the roving or when it stops.

Every three sols are defined as one operation period. The basic process of each operation period is as following (Fig. 6):

(1) On the first sol of operations period, the Navigation and Terrain Camera obtains the stereo image pairs of the study target and downlinks them for operations plan of the rover and the selection of the next study target;
(2) On the second sol of operations period, each payload performs scientific exploration on the study target according to the operations plan, and downlinks the data;
(3) On the third sol, the rover moves to the next study target, and Mars Rover Penetrating Radar, Mars Climate Station work until it arrives at the next study target. The rover payloads complete a operations period and downlinks the data.

**Table 6**   Scientific investigation plans by the orbiter payloads

| Payloads | Earth–Mars transfer orbit | Mars parking orbit, relay and survey orbit | Global reconnaissance orbit |
|---|---|---|---|
| MoRIC | (1) Self-check once a month<br>(2) Select the time to start working, imaging the Earth, the Moon and Mars | (1) On-orbit calibration at the apoareon once a month, and data downlink<br>(2) 3D images of the landing area from periareon | (1) On-orbit calibration at the apoareon once a month<br>(2) Images are captured when the orbit altitude is below 800 km and sun elevation angle is larger than 5 degree, with the average work time of 26 minutes and the imaging interval of 20 s–66 s<br>(3) In order to achieve the coverage, the images can be obtained with off-nadir pointing of the spacecraft |
| HiRIC | Self-check once a month | (1) Self-check once a month<br>(2) 3D images of the landing area from periareon | (1) High resolution imaging when the orbit altitude is below 800 km and sun elevation angle is larger than 10 degree<br>(2) In order to achieve the coverage, the images can be obtained with off-nadir pointing of the spacecraft |
| MOSIR | After the separation of satellite and rocket, the VLF antenna selects time to explore the interplanetary radio | (1) Select time to deploy the radar antenna including the transmit antenna and receive antenna<br>(2) Subsurface investigations of the landing area from periareon<br>(3) Subsurface investigations of polar ice caps and other areas of interest when the orbit is higher than 800 km and the requirements are satisfied | (1) Calibration of equipment lasts about 70 s before the probe enters the periareon section above the orbit altitude of 800 km<br>(2) After the calibration, the radar starts to work with the mode selected from the on-orbit working mode list (with average working time of 26 minutes) |
| MMS | Self-check once at selected time | (1) Self-check once at selected time<br>(2) Spectral observation of the landing area from periareon<br>(3) On-orbit calibration at the apoareon | (1) Continuous multi-unit spectral observation. The spectral data are obtained at an altitude below 800 km, and MMS work for 21 minutes each time<br>(2) Investigation of interested regions<br>(3) On-orbit calibration at the apoareon and work once to twice each month |
| MOMAG | Self-check twice at selected time | Select time to deploy the boom, same working mode as that used in the global reconnaissance orbit | Works continuously<br>(1) Work with the 32 HZ sampling rate 0.5 h before and after reaching the apoareon<br>(2) Work with the 32 HZ sampling rate 1 h before and after reaching the periareon<br>(3) Work with the 1 HZ sampling rate in other orbit sections |

**Table 6** (*Continued*)

| Payloads | Earth–Mars transfer orbit | Mars parking orbit, relay and survey orbit | Global reconnaissance orbit |
|---|---|---|---|
| MINPA | After entering the Earth–Mars transfer orbit, the high-voltage debugging starts in the first month, after which the payload carries out the interplanetary solar wind detection continuously | (1) After entering the parking orbit, working continuously, and turned off before the separation of the lander<br>(2) Work continuously after entering the relay and survey orbit and powers off before the end of the mission | Works continuously<br>(1) Work with the ionospheric mode below the orbit altitude of 800 km<br>(2) Work with the default mode above 800 km<br>(3) Switch to magnetic-tail mode 30 minutes before the apoareon and switch back to the default mode 30 minutes after the apoareon as required |
| MEPA | Continuous working | Continuous working | Continuous working |

**Table 7** Scientific data products categorization

| Data level | | Data description |
|---|---|---|
| Level 0 | Level 0A | Source packet data that are generated after ground demodulation, frame synchronization, descrambling, channel decoding, demultiplexing and other processing of the data sent back from a spacecraft and received at a single ground station for each payload |
| | Level 0B | Data collected by each payload, which are generated after package structure removing and decompressing (where applicable) of the source packet data; those source packet data are, on the basis of Level 0A, generated after combining (where applicable), sorting and deduplicating of the data from multiple ground receiving stations |
| Level 1 | Level 1 | Data that are generated, on the basis of Level 0B, after numerically converting temperature, voltage, current and other instrument parameters, and reorganizing according to observation periods |
| Level 2 | Level 2A/2B/2C | Data in physical units that are generated, on the basis of level 1, after applying calibration, and provide geometric positioning information. Level 2 data products are divided into several sub-levels, level 2A, level 2B and level 2C (where applicable) |
| Level 3 | | Digital orthophoto maps, digital elevation models, mineralogical maps, etc. |

### 4.3 Data Products

Focusing on the five scientific objectives of China's first Mars exploration mission, the orbiter is equipped with 7 instruments and the rover is equipped with 6 instruments for scientific exploration. The obtained exploration data will be preprocessed according to the following levels (Table 7). Level 0 data products are stored in binary file format, while level 1 and level 2 data products are stored in standard PDS4.0 format. Levels 3 is high level science maps, including digital orthophoto maps, digital elevation models and mineralogical maps, etc.

GRAS and the instruments teams will expect to follow the data release policy proposed by CNSA based on an official 5–6 months' proprietary period that is used by the teams to validate, calibrate, and perform preliminary scientific data exploration. After all the proce-
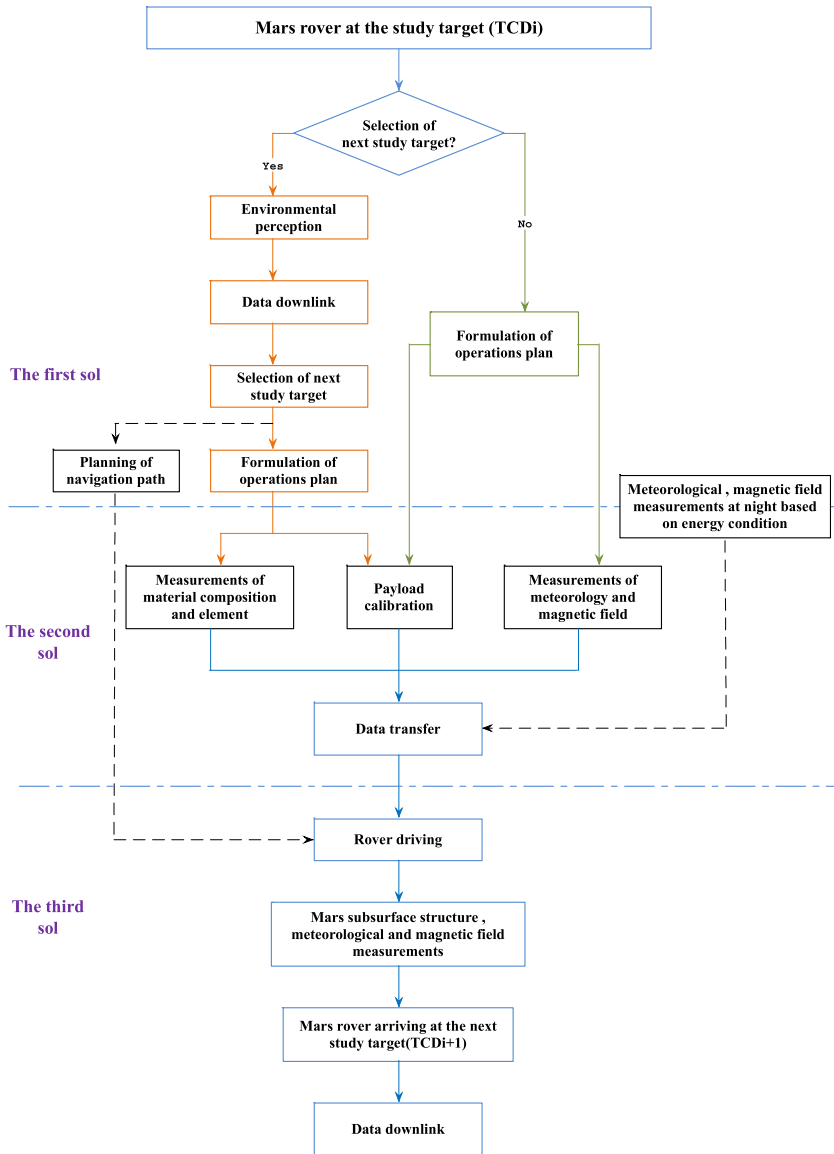
**Fig. 6** Process of rover scientific investigation

dures are complete, the data will be released to the scientific community from the website (http://moon.bao.ac.cn/index_en.jsp).

## 4.4 Expected Scientific Achievements

According to the preliminary scientific investigation plan, the expected scientific achievements of China's first Mars exploration mission are as following (Table 8).

**Table 8** Expected scientific achievements and scientific objectives of China's first Mars exploration mission

| Payloads | Expected scientific data | Expected scientific achievements | Scientific objectives |
|---|---|---|---|
| MoRIC | 1. Global orthophoto images with spatial resolution of 66 m–200 m/pixel<br>2. Global DEM with spatial resolution of 200 m–600 m/pixel | Global topography and geomorphology as well as their variations, such as polar cap, sand dunes, layered deposit | To map Martian topography, landform and their changes, and to obtain the basic information on Mars evolution |
| HiRIC | The key area images with spatial resolution of 0.5 m–1.5 m/pixel | Detailed investigation of key areas, such as geomorphology of flow, volcano, erosion, impact crater and polar glacier | |
| NaTeCam | Stereo images, panoramic mosaic and 3D topographic map of landing areas | 1. Geomorphology of landing areas<br>2. High-resolution digital elevation models of landing areas<br>3. Geology characteristic | |
| RoPeR | 1. Acquire subsurface echo data of low-frequency channel radar (15–95 MHz) and high-frequency channel full-polarization radar (450–2150 MHz) in landing areas<br>2. Obtain the subsurface structure and possible water-ice of landing areas | 1. Subsurface structure of landing areas<br>2. Possible water-ice of landing areas | To investigate the regolith characteristics and water-ice distribution on the Martian surface, and to obtain the conditions and environmental information of life |
| MOSIR | 1. Acquire echo data of dual-frequency dual-polarization radar of Martian surface and subsurface (10–20 MHz, 30–50 MHz)<br>2. Obtain the subsurface structure and possible water-ice of exploration areas | 1. Subsurface water-ice distribution at Mars medium and high latitudes<br>2. Water-ice exploration in the Mars polar regions<br>1. Regolith type and distribution<br>2. Regolith subsurface structure | |
| | 1. Spectral data of ultra-low frequency detection in the Earth–Mars transfer orbit section (10 KHz–10 MHz)<br>2. Detection data of ionosphere (TEC) in the Mars-orbiting section (10–20 MHz, 30–50 MHz) | 1. Mars atmosphere escape processes<br>2. Interplanetary very low frequency radio<br>3. The conductivity and vertical structure and variability of the ionosphere | To measure the characteristics of Mars ionosphere, plasma environment and escape processes, surface atmospheric properties and meteorology; |
| MINPA | 1. The data of Mars ions and neutral particles<br>2. Physical parameters of Mars space environment such as density, velocity and temperature of main ion components<br>3. Distinguish the main neutral particle components such as H, He and O | plasma environment | To study the Mars magnetic field and interior structure and obtain the law of interaction between solar activity and Mars |
| MEPA | The data of interaction between solar wind, high-energy particles and Mars | 3D spatial distribution of radiation energy spectrum and components of high-energy particles | |

**Table 8**  (*Continued*)

| Payloads | Expected scientific data | Expected scientific achievements | Scientific objectives |
|---|---|---|---|
| MOMAG | magnetic field data within 3.5 Rm above the Martian surface, and to make a spatial distribution map of Mars magnetic field | Based on the positions of the orbiter and the rover as well as the measured magnetic field, Mars ionosphere height, current strength, distribution and other characteristics are to be retrieved | |
| RoMAG | Mars surface magnetic field | | |
| MCS | Basic characteristics and time variation of atmospheric temperature, pressure and wind field. Meteorological parameters and acoustic data at particular times (such as dust storms) | Martian surface wind field and air pressure measurement | |
| / | Mars orbit data | Mars gravity field | |
| MMS | 1. 72 bands spectral images with spatial resolution of 1.06 km–3.2 km/pixel and spectral range of 450 nm–3400 nm 2. 72 bands and full bands spectral images covering the interested regions with spatial resolution of 265 m–3.2 km/pixel and spectral range of 450 nm–3400 nm 3. Mineral type and distribution of the whole Mars and regions of interest | 1. Large-scale survey of major minerals 2. Major type and distribution of Mars rocks types 3. Mineral resources and enrichment areas on the Martian surface | To analyze the Martian surface materials composition and to obtain the basic information on the chemical evolution |
| MSCam | 1. Multi-spectral data of 8 bands visible near-infrared spectra of the landing area 2. True color and false color images of the landing area from 1.5 m to infinity | 1. Martian surface rock lithology 2. Martian surface minerals 3. Martian surface secondary minerals | |
| MarSCoDe | 1. High-resolution LIBS spectral data of study targets of the landing area from 240 nm to 850 nm 2. Elemental composition identification and their content, major minerals of the landing area | | |

# 5 Summary

With the development of science and technology, especially the space technology, solar system has been explored by many countries using a variety of methods, including the Moon, terrestrial planets and their satellites, asteroids, comets and etc. The geological background and space environment of celestial bodies in the solar system are deeply investigated to study the formation and evolution history of solar system which are the most fundamental scientific problems of planetary research.

China's first Mars exploration mission focuses on the investigation of Mars magnetosphere, ionosphere and atmosphere as well as the changes and evolution of Mars climate by measuring the structure, composition and characteristics of Mars magnetosphere, ionosphere and atmosphere. It will investigate the distribution, composition and characteristics of Mars surface, especially the distribution of aqueous minerals, and study the environmental evolution of Mars. Besides, the topography and geomorphology of the Mars will be mapped to study the role of wind, water-ice, volcano, impact and tectonic activities in the formation and transformation of Mars surface topography, which also helps to reveal the geological features and evolution history of the Mars. Comparative planetary studies will be carried out, the global image will be acquired, and the preferred sampling and landing areas will also be selected. The mission will analyze the content and distribution of major elements on Martian surface, the distribution of various minerals and rocks, especially sedimentary rocks on Martian surface, and study the geological evolution history of the Mars. It will explore the distribution and storage of ground water and study the water escape and transfer process. Mars magnetic field and gravity field will be characterized and compared with other terrestrial planets. On the basis of these investigations, the mission will the study of the living environment and the evolution history of Mars as well as the origin and evolution of the solar system, which can provide clues and support for the most basic scientific problems faced by planetary exploration.

Tianwen-1 is going to orbit, land and release a rover all on the very first try, and coordinate observations with an orbiter. If successful, it would signify a major technical breakthrough. Scientifically, Tianwen-1 is a comprehensive mission to investigate the Martian morphology, geology, mineralogy, space environment, and water-ice distribution. There are some complementarity and uniqueness of Tianmen-1 with other missions, for example MoMAG and RoMAG can measure Mars space and surface magnetic field, MOSIR and RoPeR can investigate water-ice by means of the dual-polarization and full-polarization radar, respectively. Similar instruments such as MarSCoDe can measure different representative results of Mars on the different landing site. HiRIC can provide high resolution images and DEM where other missions have not been imaged.

China's first exploration of Mars will be another important landmark project after lunar exploration, which will advance our understanding of the origin, evolution and characteristics of the Earth, solar system and the universe and promote the development of space science and planetary science.

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