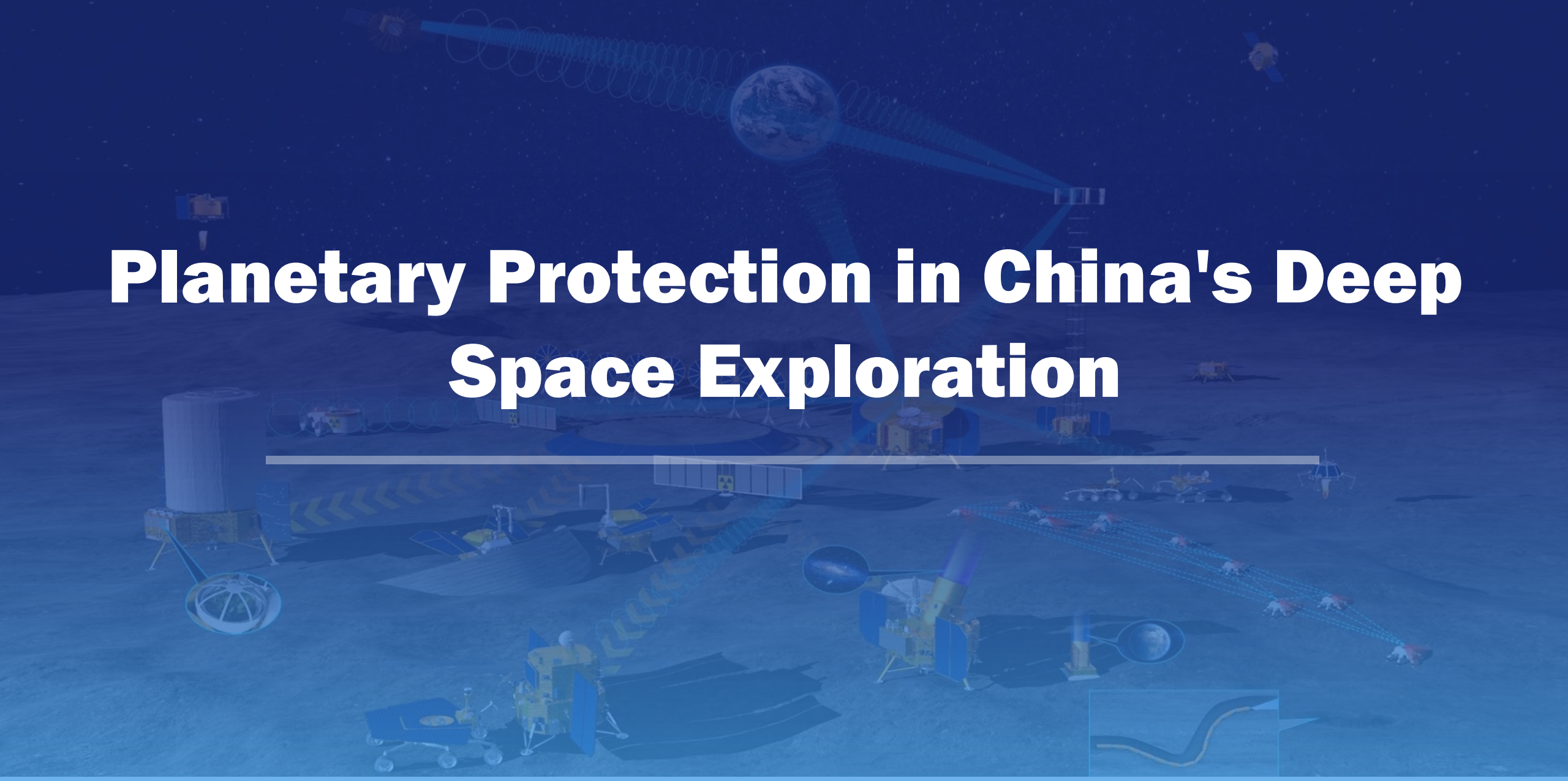


Planetary Protection in China's Deep Space Exploration

Kanyan Xu, IICPPW - April, 2024

Outline

- China's involvement in Planetary Protection
- Planetary Protection for China's Lunar Mission
- Planetary Protection for China's Mars Mission
- Research on Planetary Protection Technology in China
- Summary

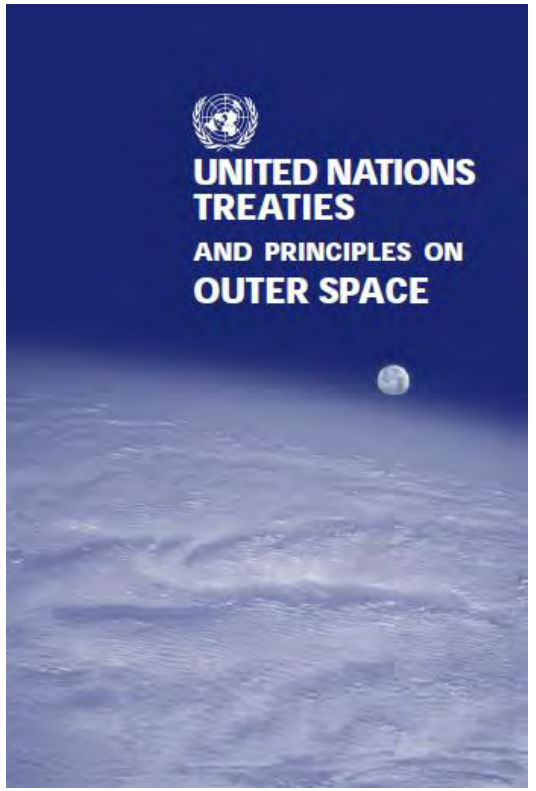
China's involvement in Planetary Protection

Planetary Protection: measures taken during the implementation of deep space exploration to avoid cross biological contamination between the Earth and other celestial bodies. Planetary protection includes two concerns: **forward contamination** and **backward contamination**.

The legal basis for planetary protection——**Outer Space Treaty**

The Committee on Space Research (COSPAR) is commissioned by the United Nations to develop international policies for planetary protection.

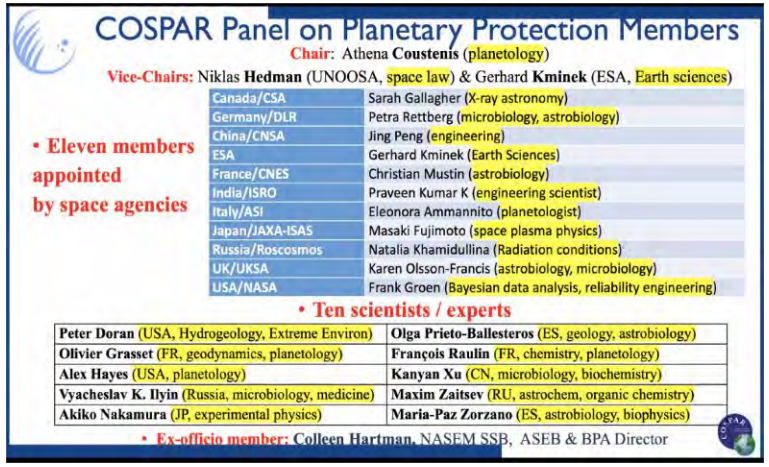
In 1999, COSPAR established the **Panel on Planetary Protection** (PPP), since then PPP updates planetary protection policies based on the latest scientific research progress.

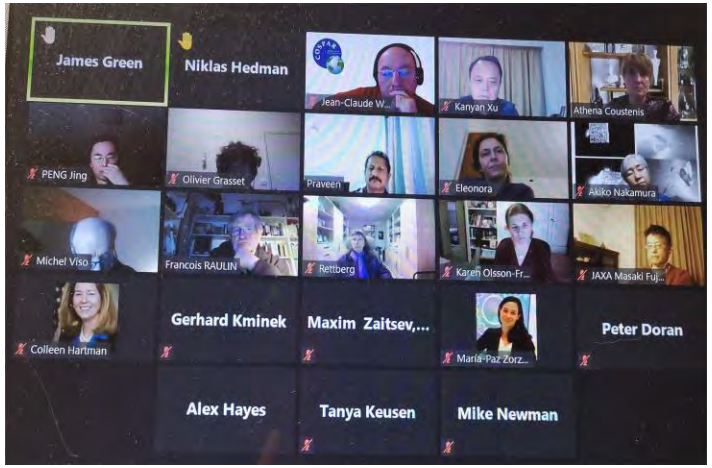


China's involvement in Planetary Protection

Involvement in COSPAR activities:

- ✓ China is actively involved in the activities of the Panel on Planetary Protection.
- ✓ China has two members in Panel on Planetary Protection and has been actively participating in PPP annual meetings since 2019.
- ✓ Member from the China Space Administration have introduced China's deep space exploration missions, including Tianwen-1, Chang'e-5 and China’ lunar exploration plan in PPP annual meetings.





China's involvement in Planetary Protection

Collaboration with Europe in PPOSS project:

- ✓ **Since 2015, the China Academy of Space Technology(CAST) has participated in the PPOSS (Protection of Outer Solar System Planets) project of the European Science Foundation.**
- ✓ **In October 2018, planetary protection experts from COSPAR, the European Science Foundation, TASI, and German Aerospace came to China for exchange and discussion with PP scholars in China, and gave training class on planetary protection policies and technologies.**
- ✓ **PPOSS has laid a solid foundation for further planetary protection technology cooperation between CAST, ESA, and TASI in the future.**

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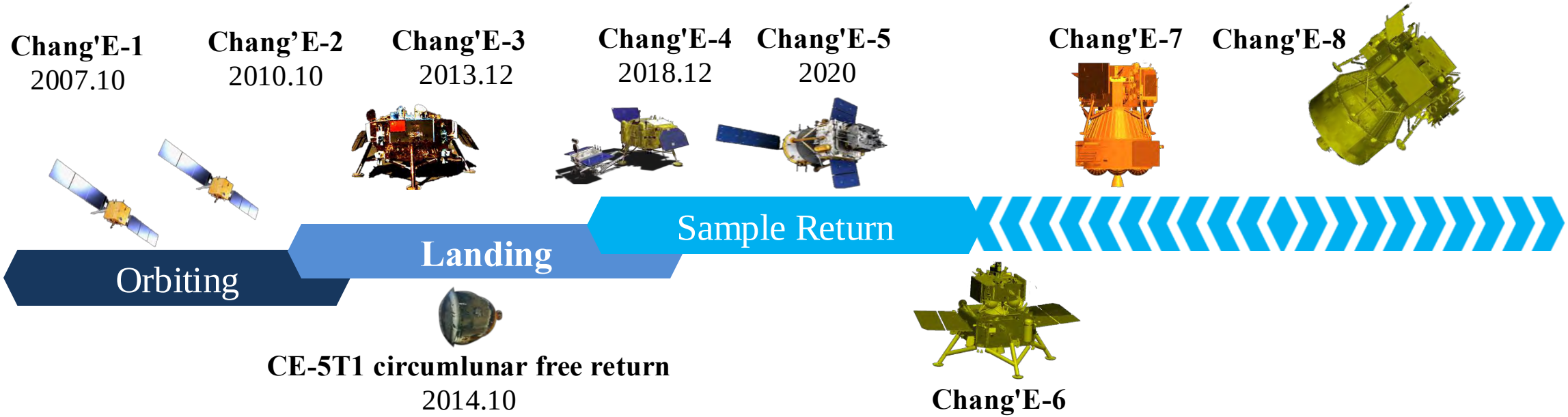
Planetary Protection for China's Lunar Mission

Strategic Plan of China Lunar Exploration Program (CLEP)

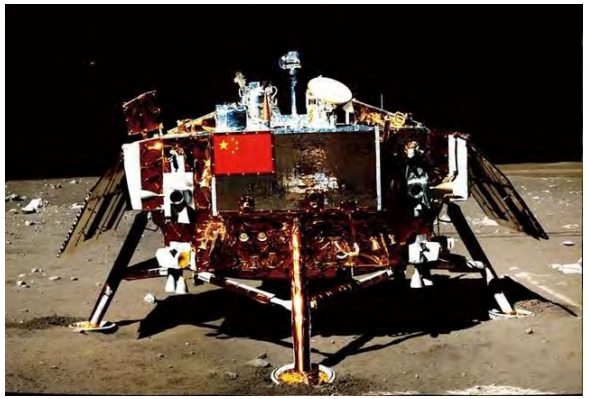
- ✓ **In 2004, 3-step strategic plan include "orbiting, landing, and sample return" were proposed.**
- ✓ **Before 2020, 7 lunar missions have been completed, successfully achieving all the goals as planned.**
- ✓ **At the end of 2021, 4th phase of CLEP was approved by Chinese Government, as well as PEC (Planetary Exploration of China) .**

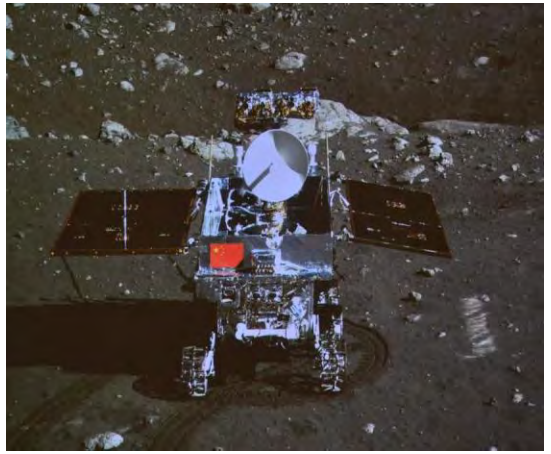


Planetary Protection for China's Lunar Mission

CE-3

- ✓ China’s first lunar lander and lunar rover.
- ✓ Development work started at 2008
- ✓ Launch date: 2nd Dec. 2013
- ✓ Landing date: 14th Dec. 2013
- ✓ Lunar rover deployment: 15th Dec. 2013
- ✓ Lunar landing site：19.51° W and 44.12° N
- ✓ The lander survived through lunar night.
- ✓ Planetary Protection Category：Cat. II

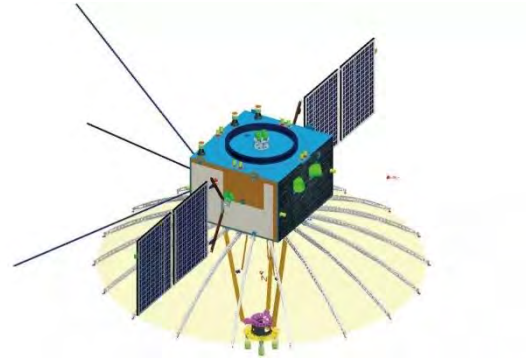


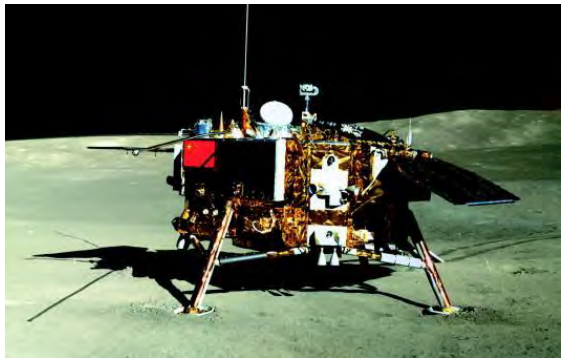


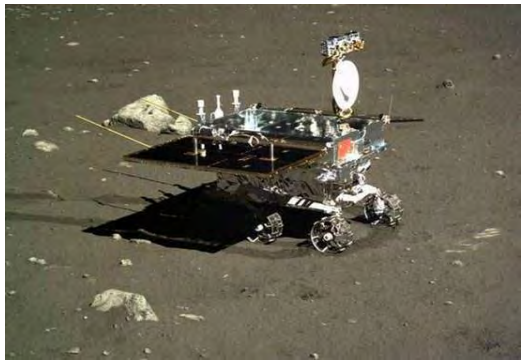
Planetary Protection for China's Lunar Mission

CE-4

- ✓ China’s first lunar lander and lunar rover on the far side of the Moon
- ✓ The hardware is the same as that of Chang'e-3
- ✓ Launch date: 8th Dec. 2018
- ✓ Landing on the far side of the moon: 3rd Jan. 2019
- ✓ Lunar landing site：177.6° E and 45.5° S
- ✓ The lunar rover was deployed on 3rd Jan. 2019, now the lander and the rover were still active after surviving through lunar nights.
- ✓ Planetary Protection Category：Cat. II



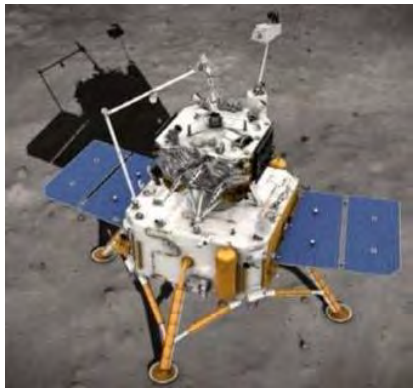




Planetary Protection for China's Lunar Mission

CE-5

- ✓ Launch date: 24th Nov. 2020
- ✓ Landing on the Moon: 1st Dec. 2020
- ✓ Lunar landing site: 51.8° W and 43.1° N
- ✓ Lift-off on the lunar lander: 3rd Dec. 2020
- ✓ Rendezvous, docking and sample transfer: 6th Dec. 2020
- ✓ Lunar sample return and recovery: 17th Dec. 2020
- ✓ Planetary Protection Category: Cat.V, unrestricted earth rueturn



Planetary Protection for China's Lunar Mission

Planetary protection requirement for lunar missions:

In the latest version of planetary protection policy, in order to protect the permanent shadow area(PSRs) of the moon, lunar exploration missions have been subdivided into subcategories as below:

- ✓ **Category II**. Orbiter and fly-by missions to the Moon. There is no need to provide an organic inventory.
- ✓ **Category IIa**. All lander missions to the surface of the Moon whose nominal mission profile does not access areas defined in Category IIb. An organic inventory limited to organic products that may be released into the lunar environment by the propulsion system is required.
- ✓ **Category IIb**. All lander missions to the surface of the Moon whose nominal profile access PSRs and the lunar poles, in particular latitudes south of **79° S** and north of **86° N**. An complete organic inventory including all organic materials carried by a spacecraft which are present in a total mass greater than 1 kg is required.

Planetary Protection for China's Lunar Mission

- The landing sites of CE-3, CE-4 and CE-5 are all located in the mid latitude region of the Moon, far away from latitudes south of 79° S and north of 86° N. According to the current knowledge of lunar PSRs, there is no PSR near the above landing sites.
- Based on the criteria for lunar landing missions categorization, Chang'e-3 and Chang'e-4 are Cat. IIa missions. Chang'e-5 is Cat.V unrestricted earth ruturn mission, the outbound phase is Cat.IIa.
- All three missions have met the COSPAR PP requirements including the organic inventory.

Orbiting

Landing

Sample return

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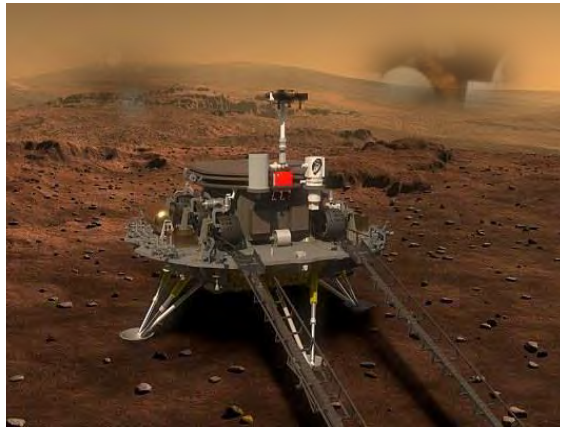
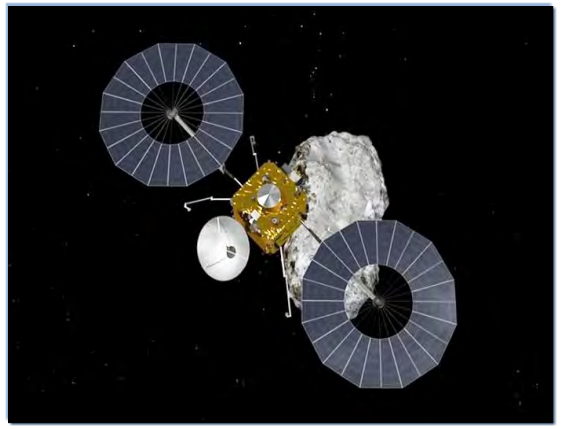
Planetary Protection for China's Mars Mission

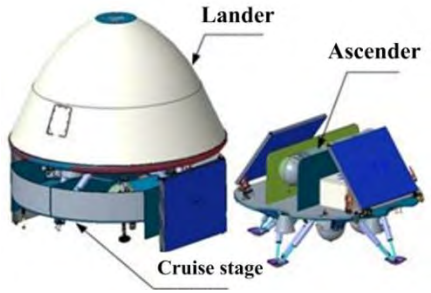
Planetary Exploration of China

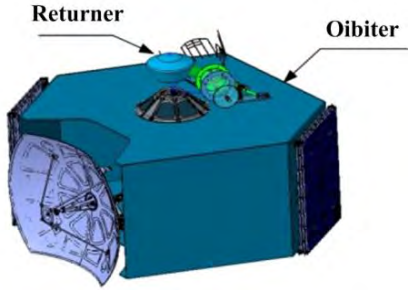


Mars exploration mission（Tianwen-1）

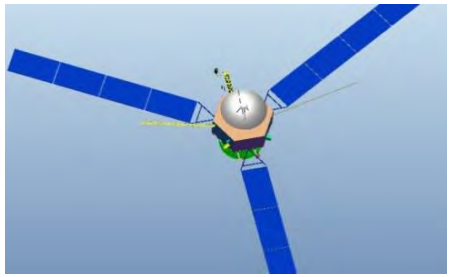


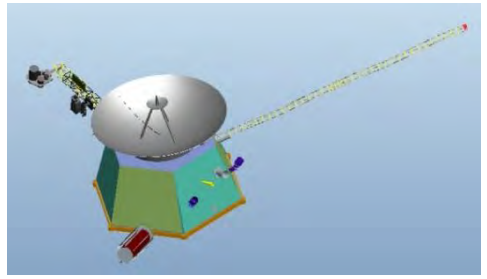
Asteroid exploration mission（Tianwen-2）





Mars sample return mission（ Tianwen-3 ）



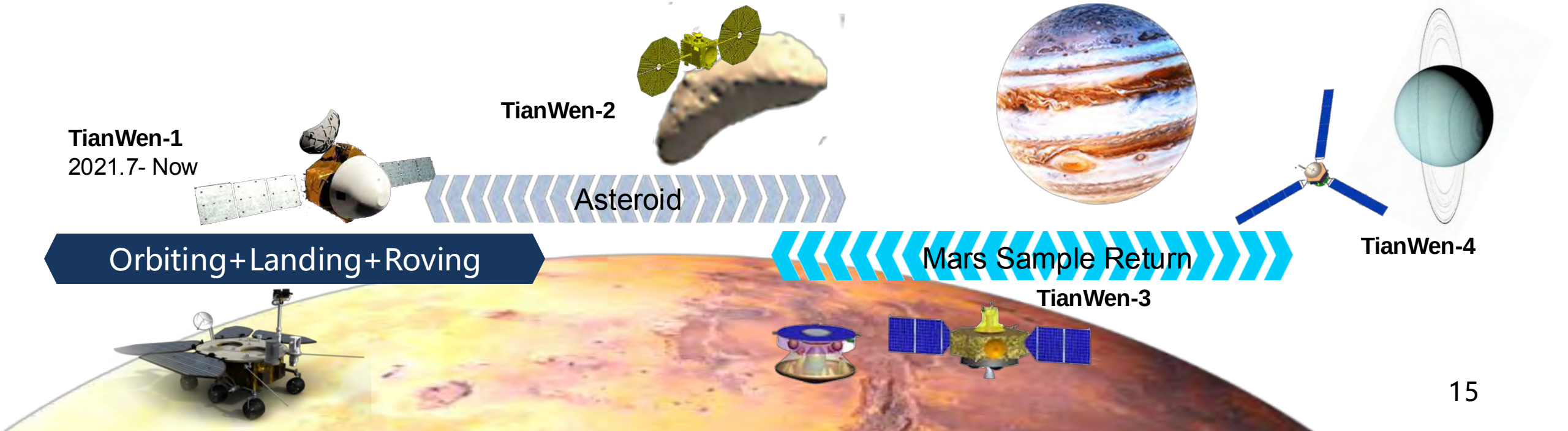


Juvian system and Interplanetary exploration mission（Tianwen-4）

Planetary Protection for China's Mars Mission

Planetary Exploration of China

- ✓ **TianWen-1 was approved in 2016 as the first China's planetary mission, to implement Mars orbiting, landing and roving in a single mission. In 2021, TianWen-1 achieved its expected objectives perfectly.**
- ✓ **In the future, subsequent planetary missions will explore the whole Solar System including small bodies exploration, Mars sample return, Jovian system exploration and Uranus flyby.**



Tianwen-1 Mission Review

Mission Objective

- ✓ **Achieve orbiting, landing and roving exploration of Mars through one mission.**

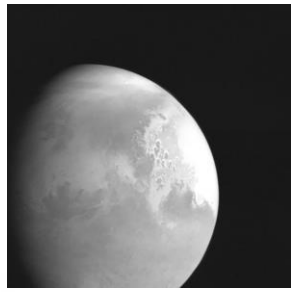
Scientific Objective

- ✓ **Morphology and geological structure.**
- ✓ **Surface soil characteristics and water-ice distribution.**
- ✓ **Surface material composition.**
- ✓ **Atmospheric ionosphere and surface climate and environmental characteristics.**
- ✓ **Physical field and internal structure.**

Planetary Protection for China's Mars Mission

Tianwen-1 Mission Review

- ✓ **The Tianwen-1 probe was successfully launched at 12:41:05 on July 23, 2020.**
- ✓ **The flight process: Including launch, Earth-Mars transfer, Mars capture, Mars parking, Mars landing and scientific exploration.**



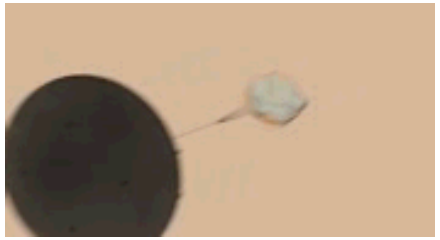
Planetary Protection for China's Mars Mission

Tianwen-1 Mission Review

- **Mars Landing: the whole EDL process was about 9 minutes.**

Aerodynamic deceleration 90.417%

- Deceleration capabilities: 4.8km/s → 460m/s
- Duration: ~330s



Parachute deceleration 7.604%

- Deceleration capabilities: 460m/s → 95m/s
- Duration : ~120s

Power deceleration 1.948%

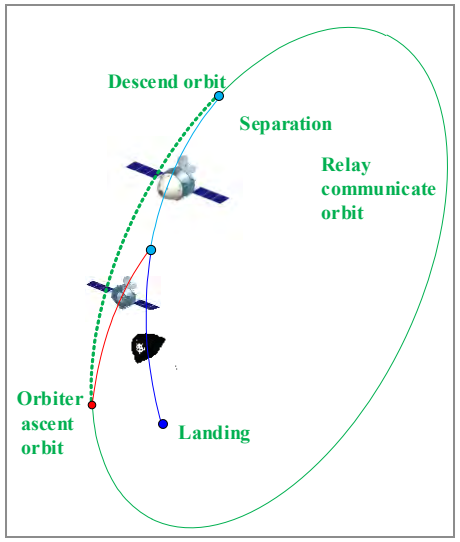
- Deceleration capabilities: 95m/s →1.5m/s
- Duration : ~90s

Soft landing and buffering 0.031%

- Deceleration capabilities: 1.5m/s →0m/s
- Soft landing and buffering mechanism action

Tianwen-1 Mission Review

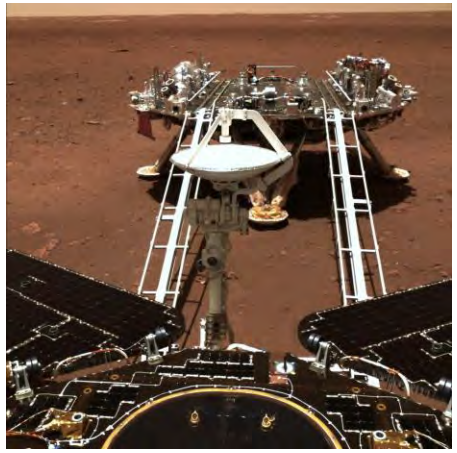
- **Mars Landing**
  - ✓ **The lander-rover complex combination soft-landed in the pre-selected landing zone of the southern Utopia Planitia at 7:18 a.m. on May 15.**
  - ✓ **Landing Site: 109.9°E, 25.1°N**

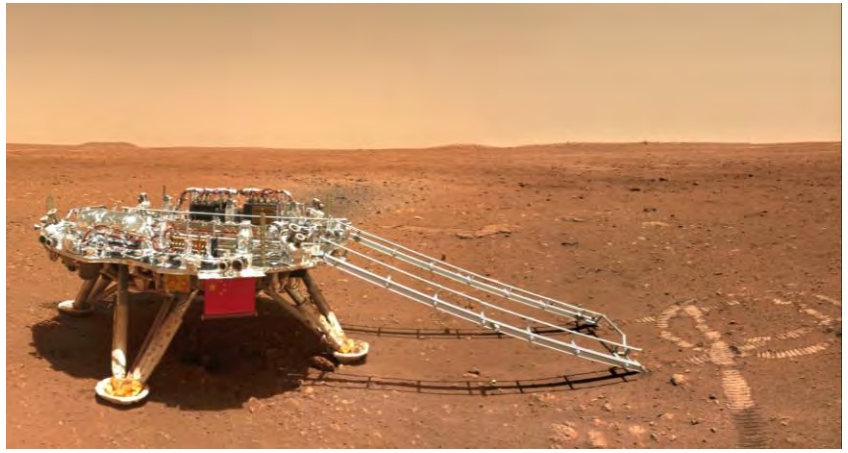


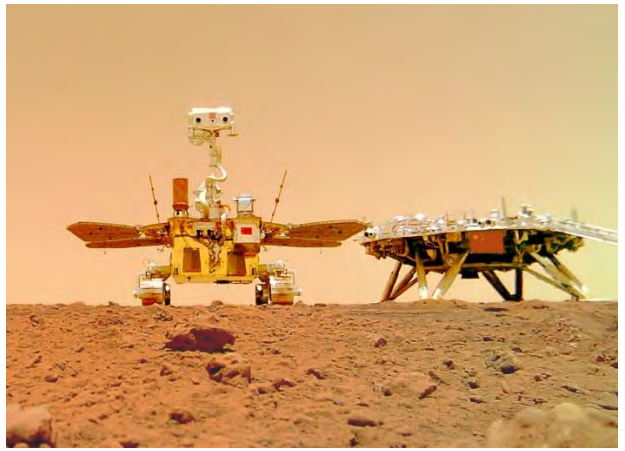
Planetary Protection for China's Mars Mission

Tianwen-1 Mission Review

- **Rover reached Mars Martian Surface**
  - ✓ **The Zhurong rover reached the Martian surface at 10:40 a.m. on May 22 and began to patrol and explore.**
  - ✓ **The China National Space Administration released four images taken by the Zhurong rover which showed the panorama of landing site, terrain and landform, landing platform and the selfie of landing platform and rover, marking a complete success of China's first Mars mission.**







Planetary Protection for China's Mars Mission

Planetary protection requirement for Mars missions:

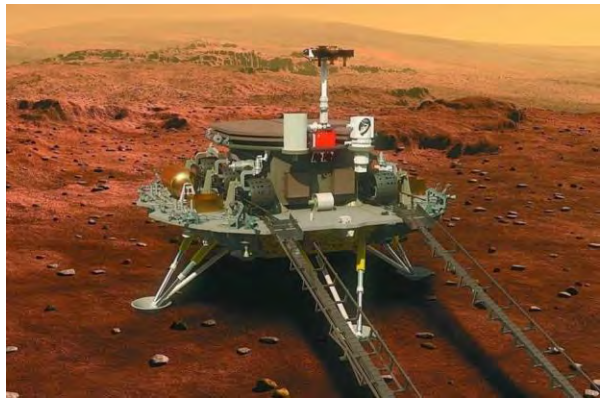
Category IV for Mars is subdivided into IVa, IVb, and IVc:

- ✓ **Category IVa: Lander systems not carrying instruments for the investigations of extant Martian life.**

  Requirement: total surface bioburden level ≤ 3 x 10^5 spores, and surface bioburden density ≤ 300 spores per square meter.

- ✓ **Category IVb: For lander systems designed to investigate extant Martian life.**

  Requirement: The entire landed system is restricted to a surface bioburden level of ≤ 30 spores, or The subsystems which are involved in the acquisition, delivery, and analysis of samples used for life detection must be sterilized to these levels, and a method of preventing recontamination of the sterilized subsystems and the contamination of the material to be analysed is in place.



Tianwen-1 Lander and Cruiser

Planetary Protection for China's Mars Mission

Planetary protection requirement for Mars missions:

✓ **Category IVc: For missions which investigate Mars Special Regions even if they do not include life detection experiments.**

Requirement:

Case 1. If the landing site is within the special region, the entire landed system is restricted to a surface bioburden level of ≤ 30 spores.

Case 2. If the special region is accessed through horizontal or vertical mobility, either the entire landed system is restricted to a surface bioburden level of ≤ 30 spores, or the subsystems which directly contact the special region shall be sterilized to these levels, and a method of preventing their recontamination prior to accessing the special region shall be provided.

Special regions: a region within which terrestrial organisms are likely to replicate or have a high potential for the existence of extant martian life forms.

Planetary Protection for China's Mars Mission

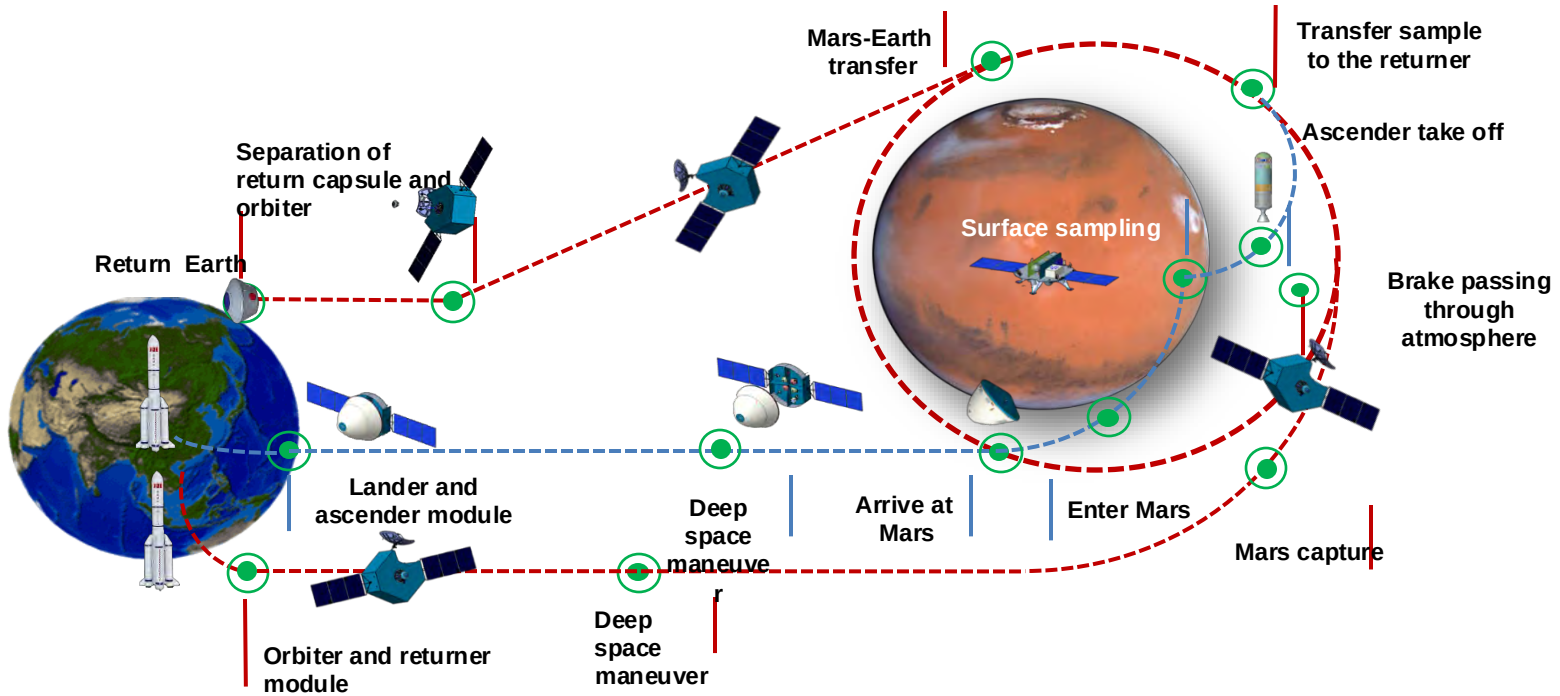
Overview of planetary protection for Tianwen-1 mission:

- ✓ The Tianwen-1 mission does not carry Mars life detection instruments, does not come into contact with Martian special regions, thus its mission Category is IVa;
- ✓ The Tianwen-1 mission is China's first planetary protection Cat. IV mission, we have established a planetary protection team and clarified the requirements for planetary protection including bioburden control, probability of Mars impact, organic inventory, etc.
- ✓ Major planetary protection measures include: cleanroom for AIT; microbial examination; cleaning, disinfection and sterilization; recontamination control and organic inventory.
- ✓ The pre-launch bioassay result showed the bioburden level of the probe met the requirements for Cat. IVa missions.

Planetary Protection for China's Mars Mission

Mars sample return mission:

- ✓ The category for Mars sampling and return mission is **Cat. V restricted earth return**, the outbound leg of the mission needs to meet the requirements of **Cat. IVb.**
- ✓ China fully recognizes the importance of planetary protection in achieving the scientific goals of the Tianwen-3 mission and ensuring the biosafety of the Earth. Strict forward and backward planetary protection measures will be taken.



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Research on Planetary Protection Technology in China

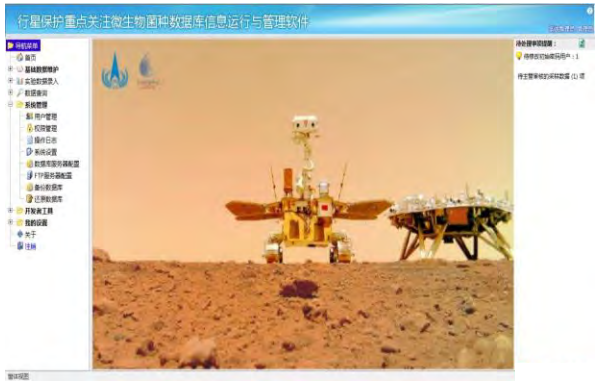
A large amount of research works have been conducted on planetary protection techniques through both international cooperation and independent study and development, and a series of research and technological development achievements can support planetary protection requirements of Cat. IV and V missions.

Microbial database and strain storage center:

Through long-term monitoring and sampling of AIT and launch site cleanroom environments in various parts of China, a microbial database and strain storage center have been set up and can be used for future planetary protection technology development and positive control for space mission.

Strain storage center

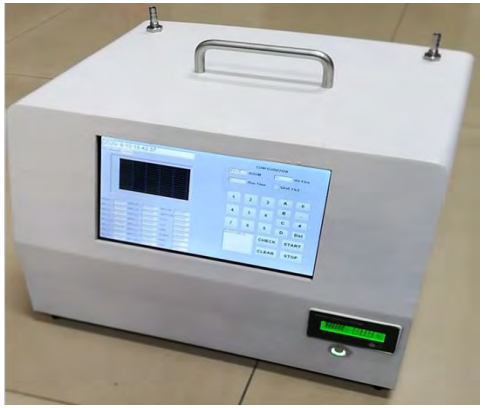
Storing microbial strains



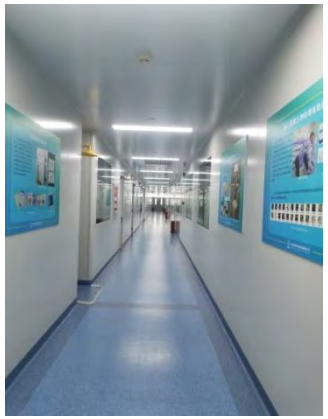
Database interface

Qualified team and laboratory for microbial examination:

- ✓ We have an experienced and professional microbial examination team, which have participated in multiple space missions such as space station, lunar and Mars missions.
- ✓ We have a microbiological testing laboratory which meets CNAS standards.
- ✓ We have a set of standard microbiological sampling and testing facilities.
- ✓ We have developed operational and data analysis protocols for deep space exploration missions, by studing publicly available documents from NASA and ESA.



sampling and testing facilities



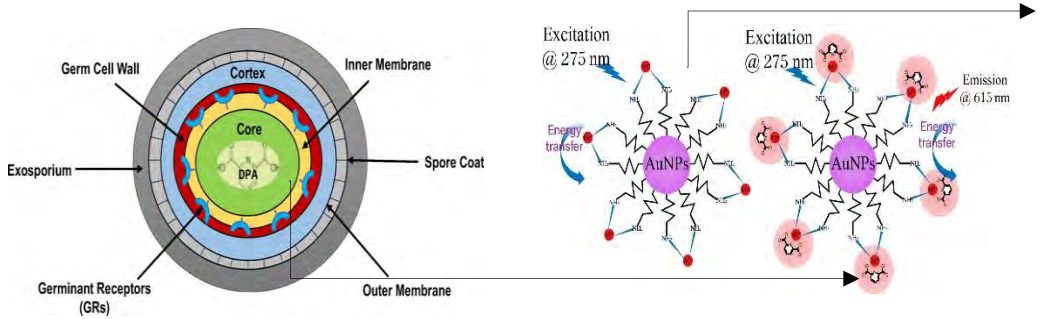
microbiological testing laboratory

Research on Planetary Protection Technology in China

Rapid Microbial Examination Technology:

- ✓ Traditional heat shock culture methods for bioburden assay takes normally 3 days to get result, To avoid delays of AIT processes, two rapid spore detection techniques is being developed as a supplement to culture methods.
- ✓ Quantitative and rapid detection of spores in samples is achieved through (1) image recognition and interpretation of spores and (2) DPA fluorescence detection technology, which can shorten the examination time from 3 days to a few hours.

Rapid spore detection based on image recognition



UV excitation of DPA to generate fluorescence

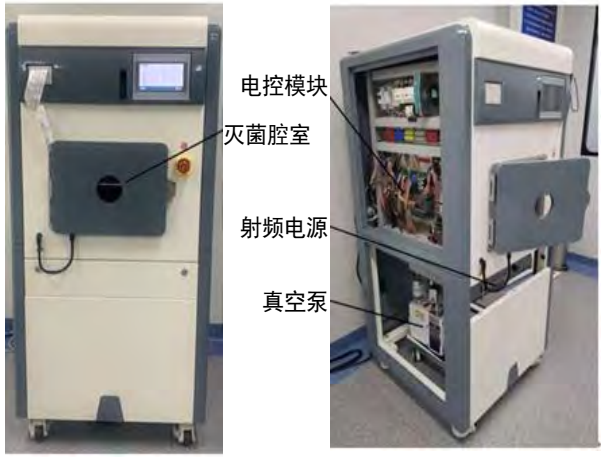
rapid Microbial examination process

Research on Planetary Protection Technology in China

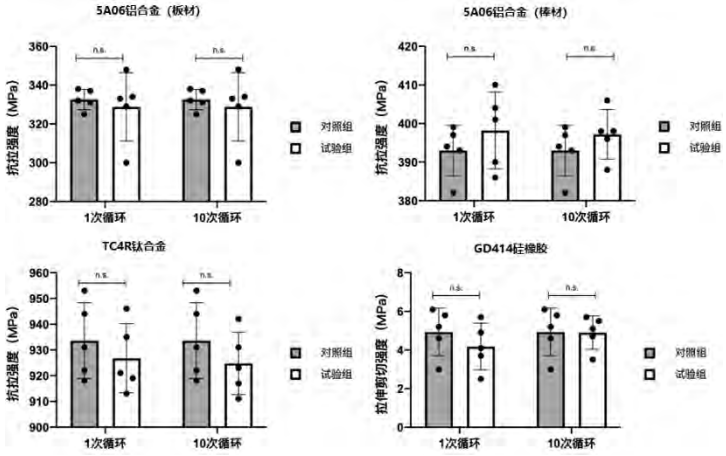
Bioburden reduction technology and their compatibility studies:

- ✓ We have various bioburden reduction and sterilization technologies which can be used for PP purpose, including dry heat sterilization, UV sterilization, hydrogen peroxide gas sterilization, cold plasma sterilization, alcohol/Isopropanol wiping, and so on.
- ✓ UV sterilization and hydrogen peroxide/cold plasma sterilization device have been developed for flight hardware materials which are not resistant to high temperatures.
- ✓ For years, a number of compatibility studies for defferent bioburden reduction technologies have been conducted at the material level.

UV/infrared sterilization device



H_2O_2 /cold plasma sterilization device



compatibility study results

Research on Planetary Protection Technology in China

Portable clean environments:

- ✓ Through cooperation with TASI, we have set up small ISO7 tent and portable ISO5 tent.
- ✓ By implementing bioburdern control procedures such as cleaning, disinfection, and bioburdern assay monitoring, the clean level of the above environment can reach bioburdern controlled ISO7 and ISO5.
- ✓ Simulated AIT test were conducted to verify the effectiveness of the aboved small clean environments on bioburden control during AIT process.

ISO7 cleanroom environment

portable ISO5 clean tent

cleanroom maintenance

Research on Planetary Protection Technology in China

Cleanroom operation and recontamination control

- ✓ Through cooperation with TASI, We now have formed a series of planetary protection documents, especially for cleanroom operations and recontamination control for AIT activities.
- ✓ Members of the planetary protection team have passed training classes on planetary protection, cleanroom operations and recontamination control.
- ✓ During simulated AIT test, cleamroom operation and recontamination control protocols have been followed and confirmed effective.

Planetary protection documents

simulated AIT test followed cleanroom operation procedure

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Summary

- ✓ **The goal of planetary protection is not only to protect the effectiveness of research on major scientific issues in deep space exploration, but also to protect the Earth and the safety of human.**
- ✓ **It is necessary to take planetary protection measures for ensuring the achievement of scientific goals of deep space exploration missions.**
- ✓ **China has complied with the outer space treaty and the planetary protection policies formulated by COSPAR, and has conscientiously carried out planetary protection work during both lunar and Mars exploration missions.**


Thank you for your attention!