Progress and Prospects of Unmanned Deep Space Exploration in China

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Overview
Overview

Two Areas: Development in parallel.

CLEP
China Lunar Exploration Program
CE-1,2,3,4 5,6,7,8

Planetary Mission
Exploration beyond Moon
Mars, Asteriod, Jupiter
Mission Completed & in Development

- Mission Completed and in Operational
- Mission under Development
CLEP Robotic Exploration

**Orbiting**
- Chang'E-1
  - 2007.10
- Chang'E-2
  - 2010.10

**Landing**
- Chang'E-3
  - 2013.12
- Chang'E-4
  - 2018.12
- T1 Reentry Test
  - 2014.10

**Sample Return**
- Chang'E-5
  - Around 2020

Mission Completed & in Development
2007: Chang’e-1 achieved global remote sensing of the Moon
2010: Chang’e-2 achieved technology validations and multi-task multi-Objective exploration
2013: Chang’e-3 achieved soft-landing and rover survey on the Moon
2014: Chang’e-5 Flight Test Vehicle achieved high-speed reentry test validation
2020: Chang’e-4 achieved soft-landing and patrol survey exploration on the far side of the Moon
Mission in Operational-CE-4

CE-4 flight system consists of a lander, a rover and a relay satellite, which were launched separately. First, the relay satellite was launched and flew into its mission orbit about the Earth-Moon Lagrange point L2; Secondly, the lander and rover were launched together, flew to the Moon, and landed on the far side of the Moon, later the lander and rover were separated from one another, and started in-situ exploration and patrol survey respectively, with the relay link support from the relay satellite.
Powered Descent

Powered descent was initiated at Jan 3, 2019, 10:14:35.

At 10:26:02, the touch down sensor was triggered, signaling the safe landing of the lander on the Moon.
Mission in Operational-CE-4

Piggyback 4 international payloads

<table>
<thead>
<tr>
<th>Germany</th>
<th>Netherlands</th>
<th>Sweden</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLR</td>
<td>SRON</td>
<td></td>
</tr>
<tr>
<td>月球中子及剂量探测仪（着陆器）</td>
<td>低频射电探测仪（中继星）</td>
<td>中性原子探测仪（巡视器）</td>
</tr>
<tr>
<td>Germany</td>
<td>Netherlands</td>
<td>Sweden</td>
</tr>
<tr>
<td>月球轨道光学成像仪（KACST）</td>
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</table>

International cooperation according to principle of "free piggyback, data sharing".
Some scientific studies on the lunar far-side:

(1) Lunar based low-frequency radio astronomical observation
The low-frequency radio astronomical observation was carried out for the first time on the far side of the Moon.

(2) Detection and study of the morphology and mineral composition of the far side of the Moon.

(3) Detection and study of the shallow structure on the far side of the Moon

(4) Detection of Cislunar Space Environment
Detector has worked on the lunar surface of radiation dose data, neutron and charged particle energy spectrum data were obtained.

(5) Autonomous measurement of Lunar Soil Temperature at Lunar Night with RTG Power Supply

![Two spectral curves from the detection during 1st day on the Moon](image1)

![The spectral curves after filtering](image2)

![Time variation of background particles in neutral atom detector on February 10, 2019](image3)
Mission under Development

Chang'E-5

- Will be finished around 2020, automatic sampling and return of lunar sample.
- The first three phases of CLEP “Orbiting, Landing and Sample return” will be finished.
Mission under Development

The 1st Mars Exploration Mission

- **Objective**: orbiting and roving exploration of the Mars. To be launched in 2020.

- **Scientific Goal**
  - Global and comprehensive exploration of the Mars through orbiting exploration
  - High accuracy and high resolution refined exploration of the key areas of Martian surface through roving exploration
Mission under Development

The 1st Mars Exploration Mission

Probe = Orbiter + Decent Capsule (Landing platform, Mars rover)
Mission under Development

The 1st Mars Exploration Mission

Launch
Earth-Mars transfer and in parking orbit
Separation between the orbiter and the entry capsule

Deploy the trim wing
Open the parachute
Deploy the landing system
After landing
Mars rover drives away
<table>
<thead>
<tr>
<th>Orbiter payload</th>
<th>Scientific target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-resolution camera</td>
<td>Exploration of geological conditions and their changes</td>
</tr>
<tr>
<td>High-resolution camera</td>
<td>Exploration of geological conditions and their changes</td>
</tr>
<tr>
<td>Subsurface exploration radar</td>
<td>Exploration of geological conditions and their changes</td>
</tr>
<tr>
<td></td>
<td>Exploration of surface and underground water-ice</td>
</tr>
<tr>
<td></td>
<td>Exploration of soil type distribution and structure</td>
</tr>
<tr>
<td></td>
<td>Analysis of atmospheric ionized layer and exploration of extraterrestrial environment</td>
</tr>
<tr>
<td>Mars mineral spectrometer</td>
<td>Exploration of soil type distribution and structure</td>
</tr>
<tr>
<td></td>
<td>Surface material composition investigation and analysis</td>
</tr>
<tr>
<td>Mars magnetometer</td>
<td>Analysis of atmospheric ionized layer and exploration of extraterrestrial environment</td>
</tr>
<tr>
<td>Mars ions and neutral particle analyzer</td>
<td>Analysis of atmospheric ionized layer and exploration of extraterrestrial environment</td>
</tr>
<tr>
<td>Mars energetic particles analyzer</td>
<td>Analysis of atmospheric ionized layer and exploration of extraterrestrial environment</td>
</tr>
</tbody>
</table>
## Payloads on Mars Rover

**Mission under Development**

**The 1st Mars Exploration Mission**

<table>
<thead>
<tr>
<th>Payloads on Mars rover</th>
<th>Scientific target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mars Surface Composition detector</td>
<td>Exploration of surface elements, minerals and rock type in the roving area</td>
</tr>
<tr>
<td>Multispectral Camera</td>
<td></td>
</tr>
<tr>
<td>Topography Camera (Navigation camera)</td>
<td>Exploration of landform and geologic structure in the roving area</td>
</tr>
<tr>
<td>Subsurface exploration radar</td>
<td>Exploration of soil structure (section plane) and water-ice in the roving area</td>
</tr>
<tr>
<td>Mars magnetic field detector</td>
<td></td>
</tr>
<tr>
<td>Mars climate detector</td>
<td>Exploration of atmospheric physics features and surface environment in the roving area</td>
</tr>
</tbody>
</table>
Mission Planned

- CLEP follow-on Mission
- Planetary Exploration
Three Transitions in China’s Deep Space Exploration

Development modes: From independence exploration to cooperation.

Exploration destinations: From earth-moon system to planetary space.

Exploration purposes: From mastering space technology to developing space technology, space science and space application.
Mission Planned

China's contribution to ISECG road map (2018.2)
There are three missions have already been planned after CE-5. In January 2019, Wu Yanhua, deputy director of CNSA said: Chang'e-6 plans to do sample return from the lunar Antarctic; Chang'e 7 will carry out a comprehensive exploration mission on the lunar landform, material composition and space environment; Chang'e 8 will also carry out a comprehensive exploration mission, and execute some key technical demonstration on lunar surface.
Planetary Exploration Before 2030

- First Mars exploration (2020)
- Mars sample and return (2029)
- Asteroid exploration (2022)
- Jovian system exploration (2036)
- Arrive Jupiter in 2036
- Arrive Uranus in 2036
- Further robotic deep space exploration (2046)
- Arrive MBC
- Arrival in the main belt comets (2031)
- Jovian system exploration (2030)
**Mission concept of CAST**

- Target selection: Constellation of heterogeneous wide-field NEO surveyors
- **Exploration: Sample return and main-belt comet investigation**

- Phase 1: NEA, quick outcome
- Phase 2: MBC, high value (long distance)
- Multi-task, multi-target, multi-function
- Validation of new technology
- International cooperation
Phase 1: NEA
- Sample return
- In-situ analysis & Remote sensing

Phase 2: MBC
- Investigation
## Asteroid Exploration

### Science Target

<table>
<thead>
<tr>
<th>NEA</th>
<th>MBC</th>
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</table>
| **Remote sensing**<br>(Document the sampling site)<br>
- X-ray/NS<br>- W/NAC<br>- Volume<br>- LFR<br>Elements<br>Morphology<br>Gravity field<br>Internal structure | **Connections, Clues & evidences**
- Global surface characteristic
- Global physical properties
- Subsurface constrain
- Sample site Special materials • Water • Volatile • Organic • Dust grain | **In-situ measurement**
- Original Bulk Sample
- MS
- D/H ratio of water
- GIA&DA
- Dust grain<br>Thermal measurement<br>Micro imaging... |
| **earth co-orbital objects dynamics**<br>the role of NEA and MBO impacts in the origin of life | **Activity mechanism**
- Direct detect the Water |
| **origin of the earth quasi-satellite**<br>the solar system small bodies dynamics formation |
## Payloads

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide/Narrow angle camera</td>
<td>Perform global and local characterization of the target</td>
</tr>
<tr>
<td>Visible/Near-Infrared imaging spectrometer</td>
<td>Perform global and local characterization and distribution of the mineralogy (including water-altered minerals) and organics</td>
</tr>
<tr>
<td>Thermal emission spectrometer</td>
<td>Provide key information on the nature of the surface and near subsurface (the thermal inertia) and composition</td>
</tr>
<tr>
<td>Radar</td>
<td>Provide a detailed understanding of the internal structure at a variety of scales</td>
</tr>
<tr>
<td>Dust analyzer</td>
<td>To detect the physical and dynamic characteristics and the distribution of the dust on the asteroid belt and main-belt Comet.</td>
</tr>
<tr>
<td>Charged and neutral particle analyzer</td>
<td>To measure the neutral gas composition and its isotopes and the cold plasma ions and their isotopes near the main comet, in combination of the measurement to the dust particle environment Through measure the plasma environment of the main-belt Comet and the asteroid, in combination of the measurement of the spatial magnetic field</td>
</tr>
</tbody>
</table>
Other Missions

Mars sample and return:
Under concept studies.

Jovian system exploration:
Under concept studies.
Cooperation Opportunities
Cooperative Ways:

- **Different levels**: Task level, system level, data/sample type.
- **At mission stages**: Pre-study, project demonstration, task design, development and construction, implementation and operation, data research.
- **Contributions**: Physical, non-physical.

Cooperation Mode:

- Planning docking
- Joint formulation
- Sharing achievements
- Mission design
- Joint implementation
- Technical cooperation
Opportunities for Two Exploration Missions

**Asteroids Exploration Mission**
- Near-earth asteroid 2016HO3 exploration
- Main-belt comet 133P exploration
- Call for 8 types of payloads with total mass of 200 kg
- Encourage to jointly develop the payload with Chinese academy, like CAST.
- Call for onboard project schemes

**Chang’E-6 Exploration Mission**
- Return lunar samples
- Call for 20kg payloads

For more information:
- [www.cnsa.gov.cn](http://www.cnsa.gov.cn)
- [www.clep.org.cn](http://www.clep.org.cn)
Cooperation in mission level:
Each side carries out relevant exploration missions independently, and in-orbit Probes coordinate with each other for exploration activities to obtain the scientific data unobtainable in an individual mission or improve the mission's efficiency.

Cooperation in system level:
Both or several parties define the responsibility in the mission and are responsible for developing respective functional modules; the Chinese side is responsible for integration; for example, one party provides the launch vehicle, or carries scientific payloads or a small-scale Probe with independent functions.
Call for papers

Journal of Deep Space of Exploration
Special Issue on Planetary Science 2061

The special issue will include contributions in this emerging field including but not limited to:
- major scientific questions on planetary systems;
- the different types of space missions;
- the key technologies which need to be mastered to make these missions flyable;
- the ground-based and space-based infrastructures needed in support to these missions.

Manuscript Submission Information
Manuscripts should be submitted online at http://jdse.bit.edu.cn/index.htm. Manuscripts can be submitted until the deadline. All papers will be peer-reviewed. Accepted papers will be published continuously in the journal (as soon as accepted) and will be listed together on the special issue website. Research articles, review articles are invited. Only the English language will be accepted.

Date:
Submission deadline: 01 Nov. 2019
Final Manuscripts: 30 April 2020

Guest Editors:
Michel Blanpain (lead guest editor), Planetary scientist, Space plasmas physicist, Astronomer, Institut de Recherche en Astrophysique et Planetologie (IRAP), Toulouse, France; Academic affiliate, Climate and Space Department, University of Michigan, Ann Arbor, USA. Visiting Professor, State Key Laboratory of Space Weather, NSFC, Chinese Academy of Sciences, Beijing, China.
Email: michel.blanpain@irap.omp.eu

Guo Lin, professor, Vice Chief Engineer, Science and Technology. Satellite System Engineering Department, DFH Satellite Co., Ltd, China Academy of space technology (CAST). More than 50 articles in China are refereed journals and publications (approximate number). Officially published 3 academic monographs, and 2 academic treatises are being signed. 
Email: gulin@spacechina.com

Yang Xiaoqian, the editor of JDSE office, is responsible for the editing and publishing for the special issue of the journal.
Email: jdse@bit.edu.cn
5 Summary
• Exploration of the unknown world is the eternal power to promote the development of mankind.

• Exploration of the vast universe is the inevitable course in expanding living space of human being.

• CAST will, and is willing to make contribution to the deep space exploration, with her partners.
LET’S WORK TOGETHER
CREATING A BETTER FUTURE

Thanks!

www.cast.cn/en

Some pictures are from the source of CNSA.