中国探月
C L E P

China Lunar Exploration Program

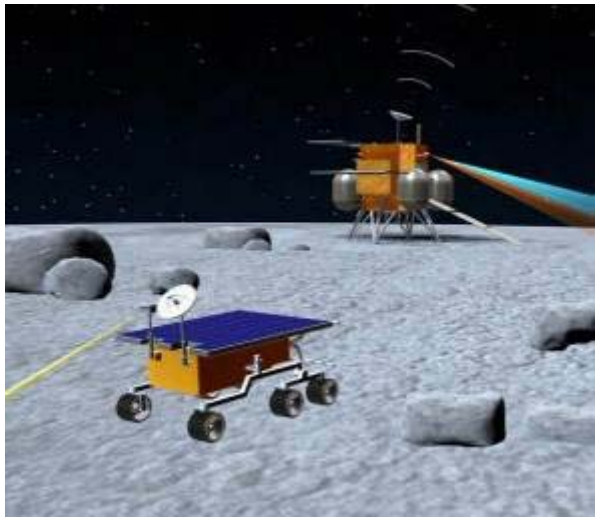
Global Space Development Summit

November, 2009

Plan of CLEP

Three phases in China Lunar Exploration Program (CLEP), or Chang'E program: orbiting, landing and sample returning.

Orbiting



Landing

sample returning

1. 1st Phase of CLEP

Engineering Goals of 1st phase of CLEP is to develop a lunar orbiter and perform lunar remote sensing:

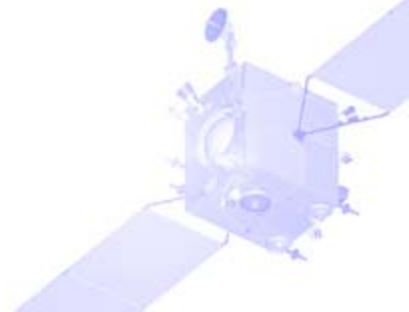
① To develop the first Chinese lunar orbiter

② To develop technology for lunar exploration

③ To develop research of lunar science

④ To build lunar exploration engineering system

⑤ To accumulate experience for further exploration



Scientific goals of 1st phase of CLEP

① To acquire 3 dimensional image of lunar surface;

② To analyze abundance and distribution of different elements on lunar surface;

③ To explore characteristics of lunar soil;

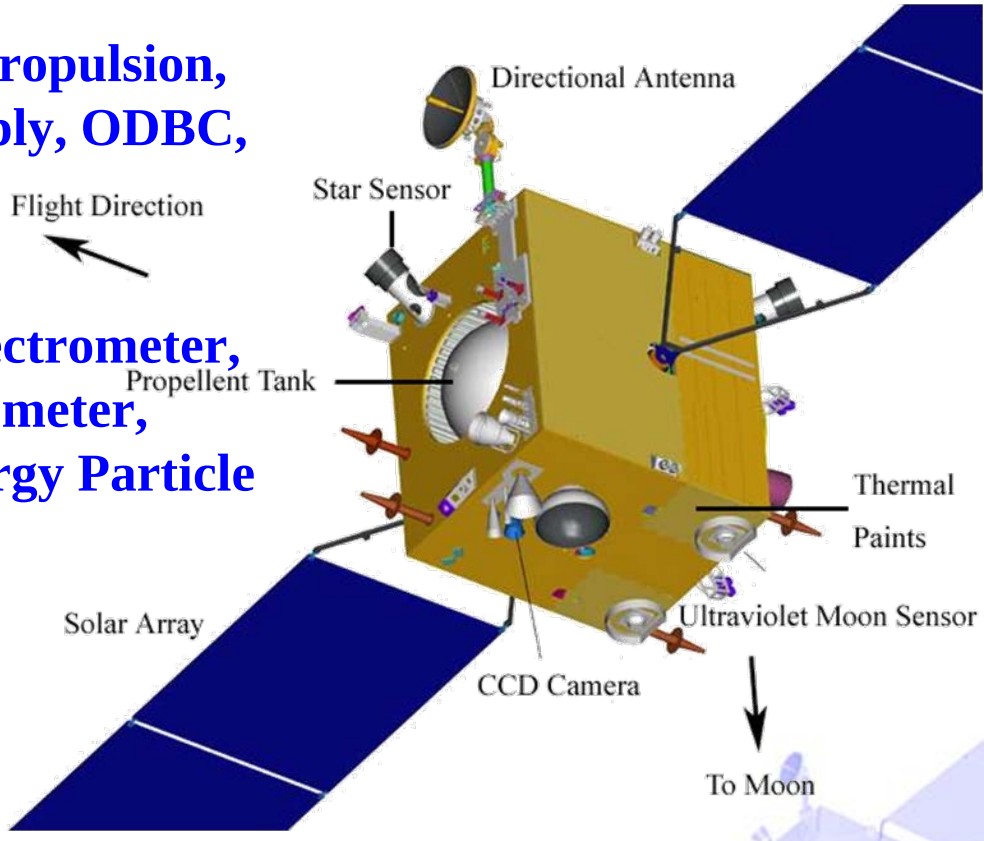
④ To explore the environment between the Earth and Moon.

Engineering System:

- Chang'E-1 orbiter
- CZ-3A Launch vehicle
- Xi'chang launch center
- ground telecommunication
- ground application

CE-1 Orbiter

- Based on DFH-3 bus
- Nine subsystems: structure, GNC, propulsion, TT&C, thermal control, Power supply, ODBC, directional antenna, payloads.
- Life: 1 year
- Payloads: CCD camera, Imager Spectrometer, Laser altimeter, γ-ray/X-ray spectrometer, Microwave detector, Solar high energy Particle detector, Low energy ion detector



Events of CE-1

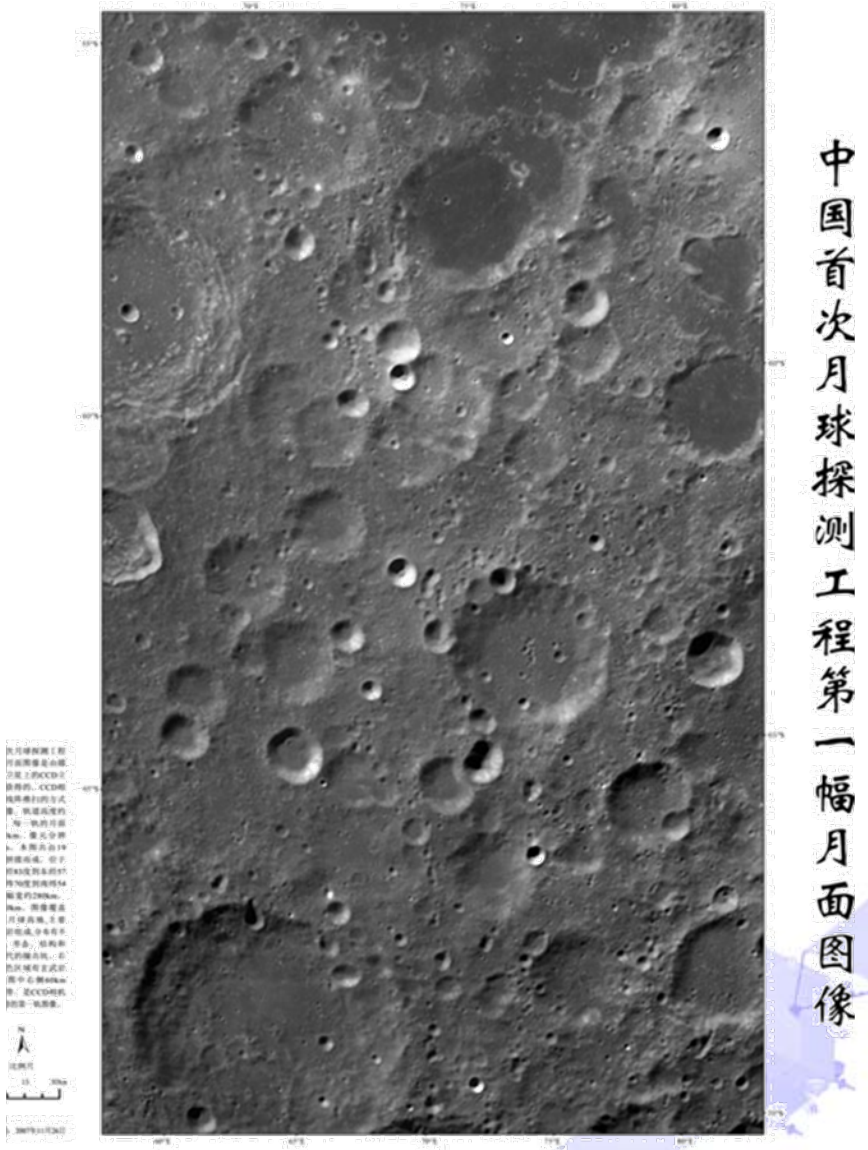
1. Oct. 24, 2007, successfully launched
2. Nov. 7, 2007, enter 200km normal operation orbit
3. Dec. 6, 2008, after one year around the Moon, went into 100km lunar orbit
4. Dec. 19, 2008, lower orbit into 15km×100km orbit
5. Mar. 1, 2009, impact lunar surface in 52.36°E，1.5°S by command, fulfilled 12 times coverage to the moon.

Achievement of CE-1

⇨ **Engineering goals are all accomplished.**

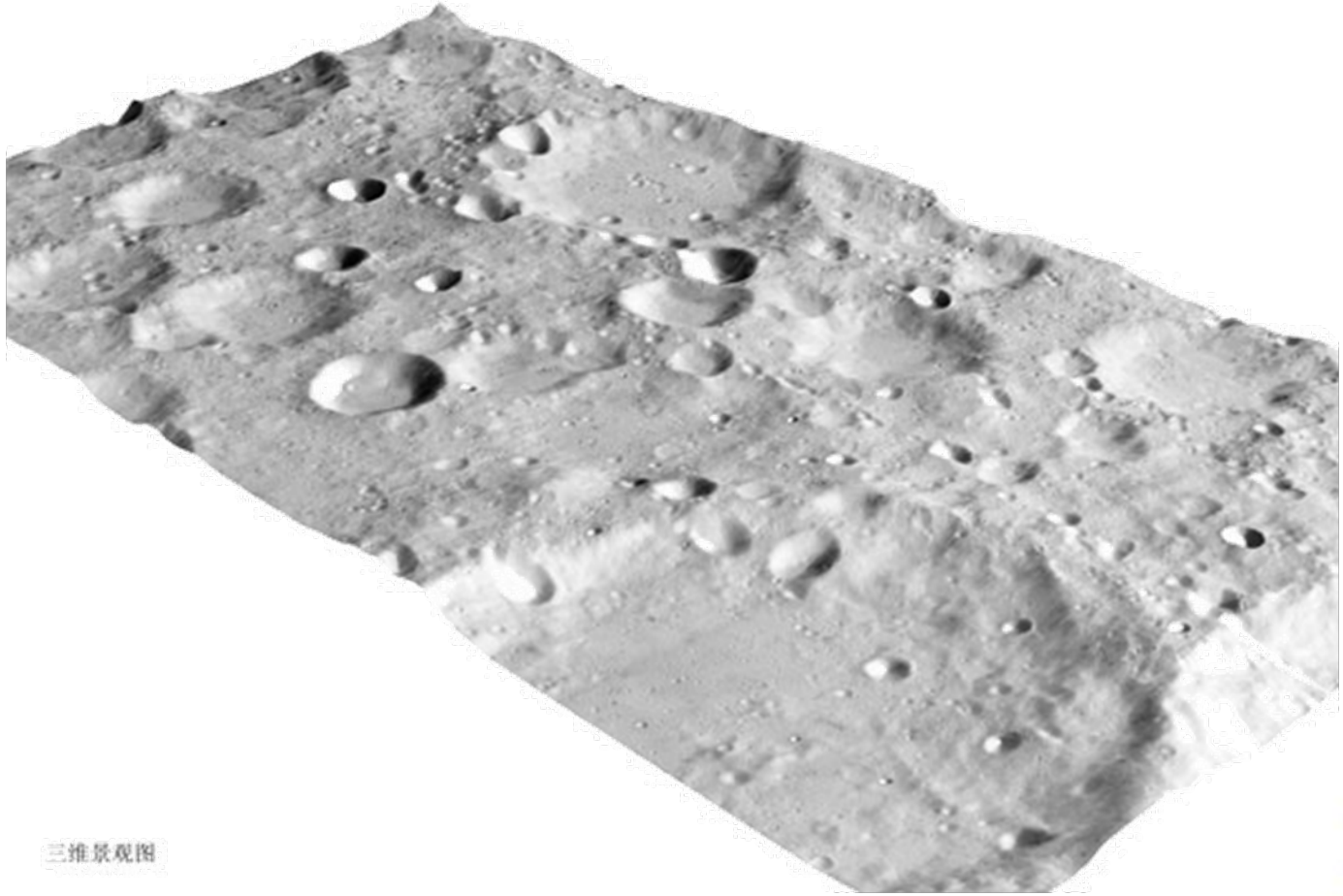
⇨ **Scientific achievements: acquire 1st image of lunar surface by China**

280km×460km
57°E ~ 83°E
54°S ~ 70°S



Achievement of CE-1

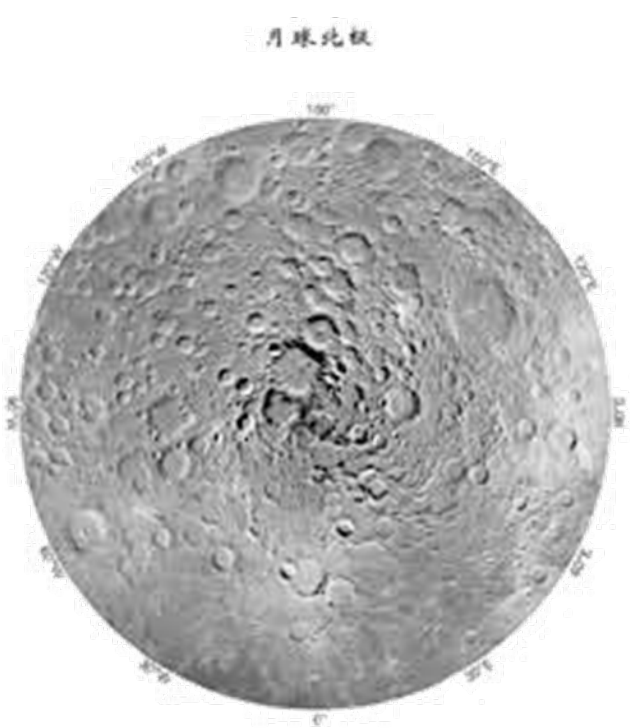
Acquire high quality 3-D image of lunar globe.

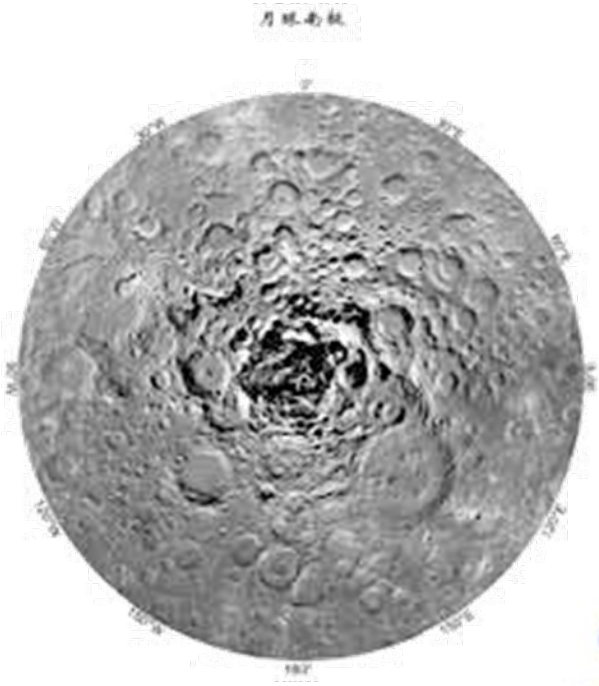


3-D composition of first lunar surface image

Achievement of CE-1

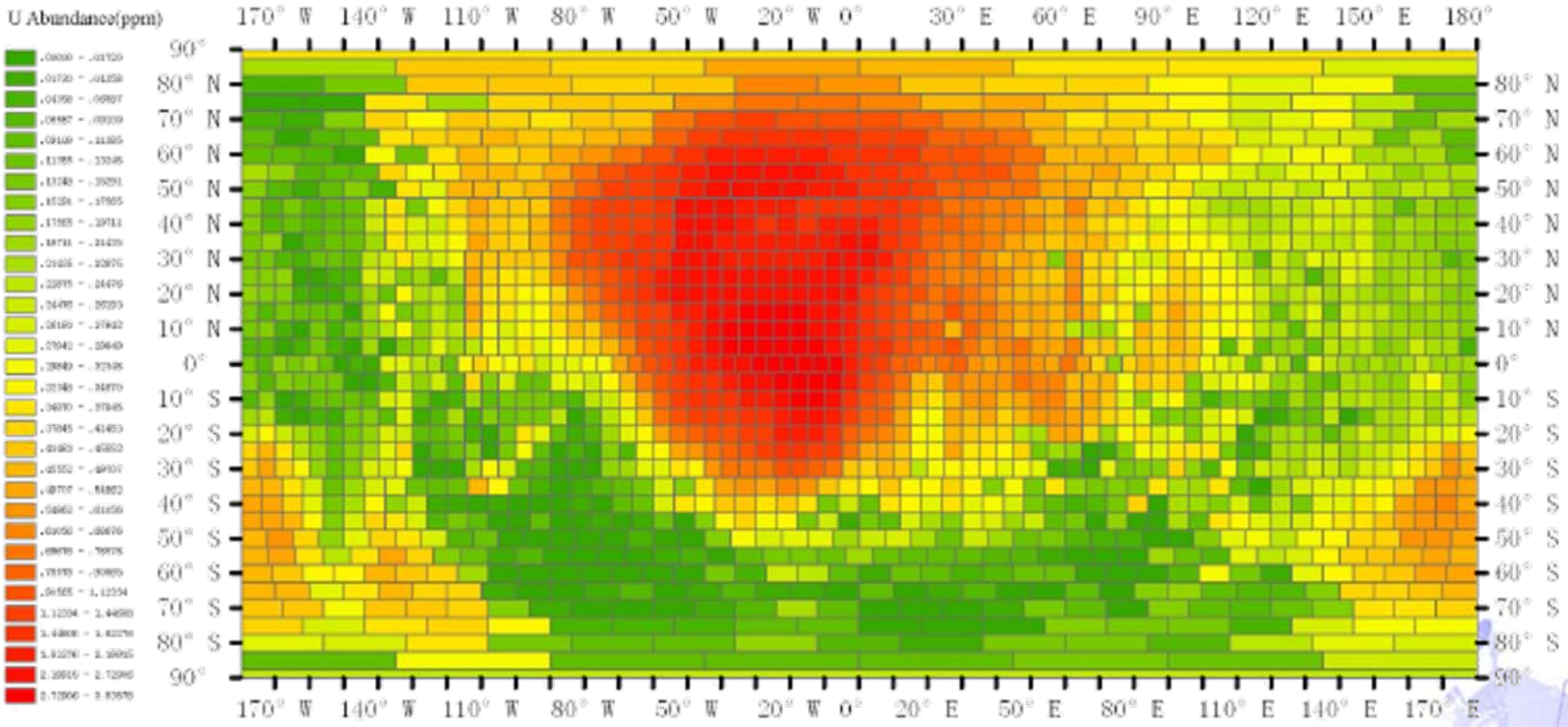
Image of lunar north and south pole.





Achievement of CE-1

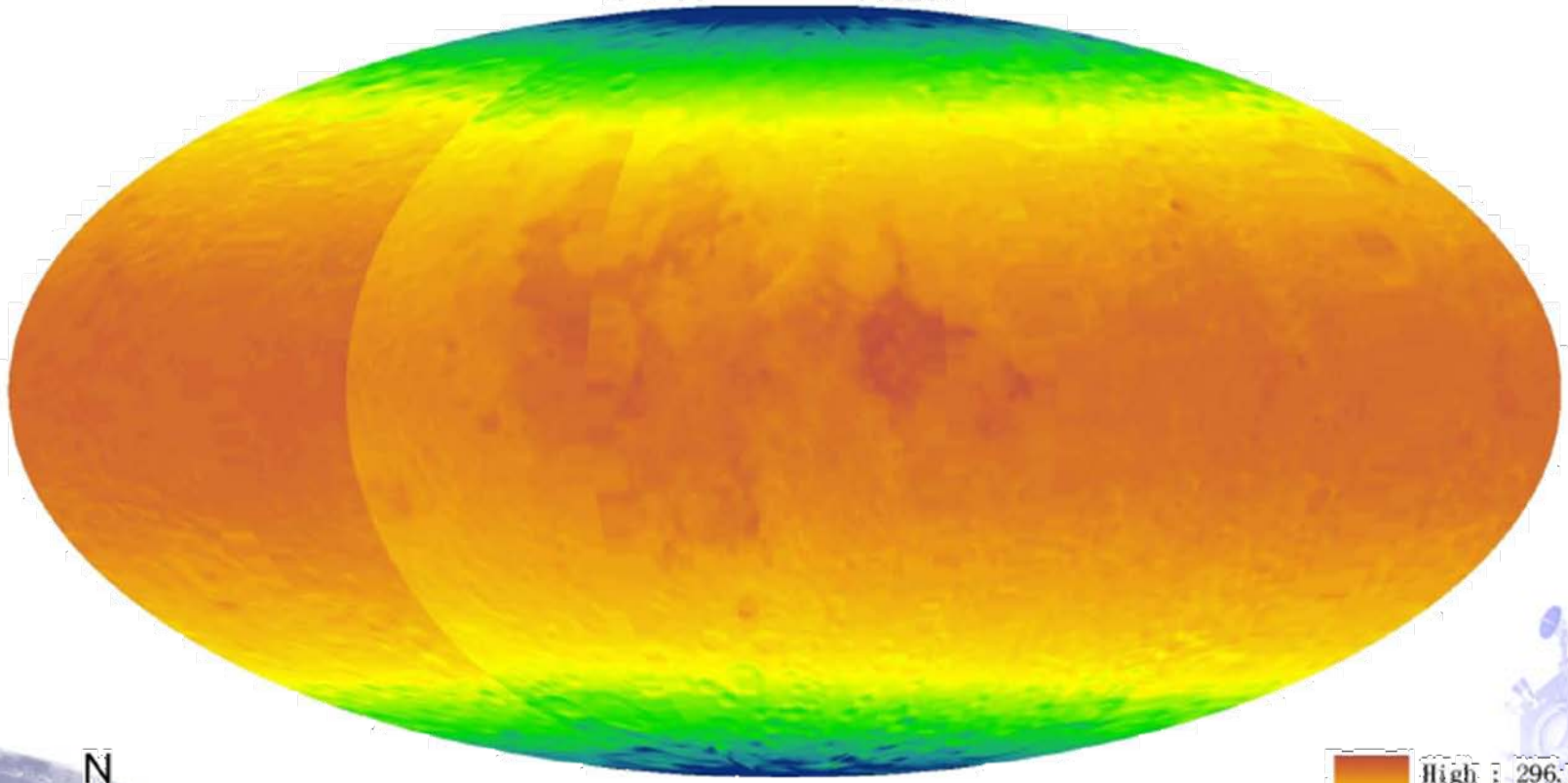
Distribution of elements of lunar globe.



伽马谱仪获得的全月球U元素含量分布

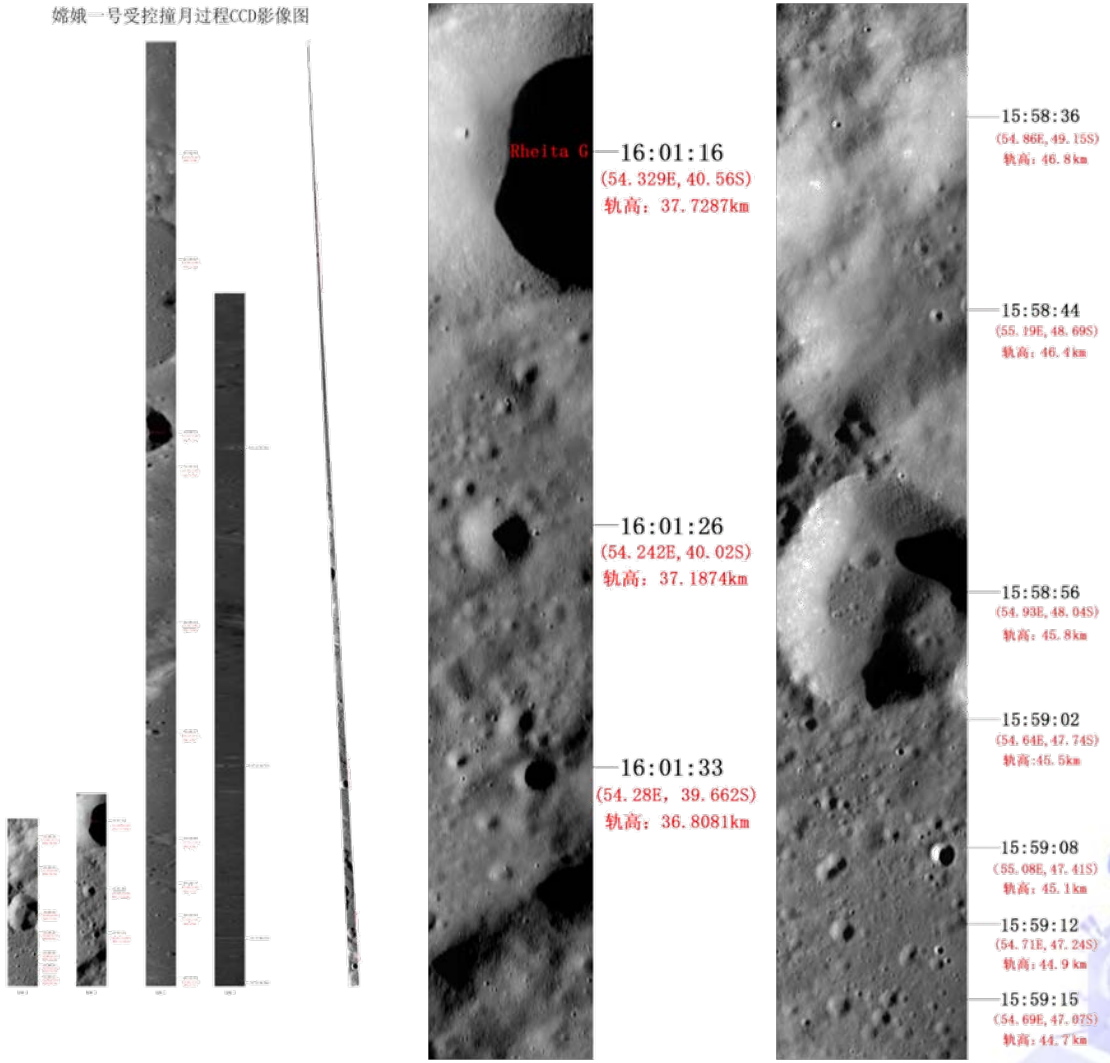
Achievement of CE-1

Brightness Temperature of lunar surface



Achievement of CE-1

Photos taken before Chang'E-1 impact on lunar surface.



2. 2nd phase of CLEP

- CE-2 orbiter will be launched in later 2010
- CE-3/4 lunar lander and rover will be launched after 2012. Lunar soft landing and IN-SITU exploration of lunar surface will be conducted.

CE-2 Orbiter is precursor orbiter of soft landing mission.

Mission objective:

key technologies such as LTO launch

X-band TT&C for deep space exploration

acquire high definition image of landing zone for CE-3/4 , improved from 120m to 10m.

Mission objectives of CE-3/CE-4

CE-3 is a lunar soft landing mission including a lander and a rover.

CE-4 is the backup of CE-3.

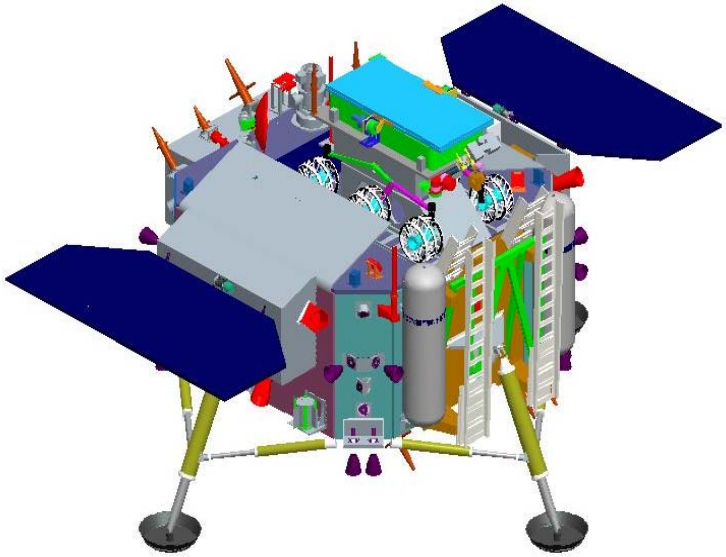
Objectives of CE-3/4:

- ⇨ **Perform lunar soft landing ,roving, and tele-operation.**
- ⇨ **Develop lunar soft lander and rover, build up deep space ground antenna, show Chinese capability to execute lunar exploration.**
- ⇨ **Build up lunar exploration engineering system.**

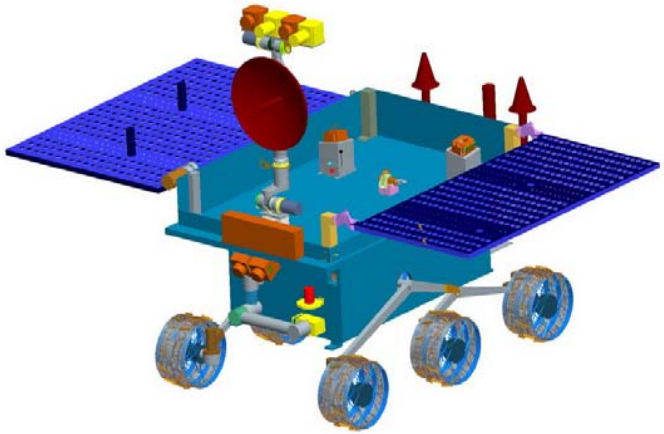
Scientific Objectives of CE-3/CE-4

- To study the landscape of lunar surface
- To study material composition and usable resources
- To study lunar internal structure
- To explore the environment among Sun, Earth and Moon and build up telescope based on Moon

CE-3/CE-4 Lunar Probe



Lunar soft lander



Lunar rover

CE-3/CE-4 Lunar Soft Lander

- **11 Subsystems : GNC, propulsion, power supply, power contribution, TT&C, data handling, structure and mechanism, landing cushion, directional antenna, thermal control and payload.**

- **Scientific Payloads: terrain camera, descent imager, telescope and ultra-violet camera.**

- **Engineering instruments: monitoring camera, lunar dust detector.**

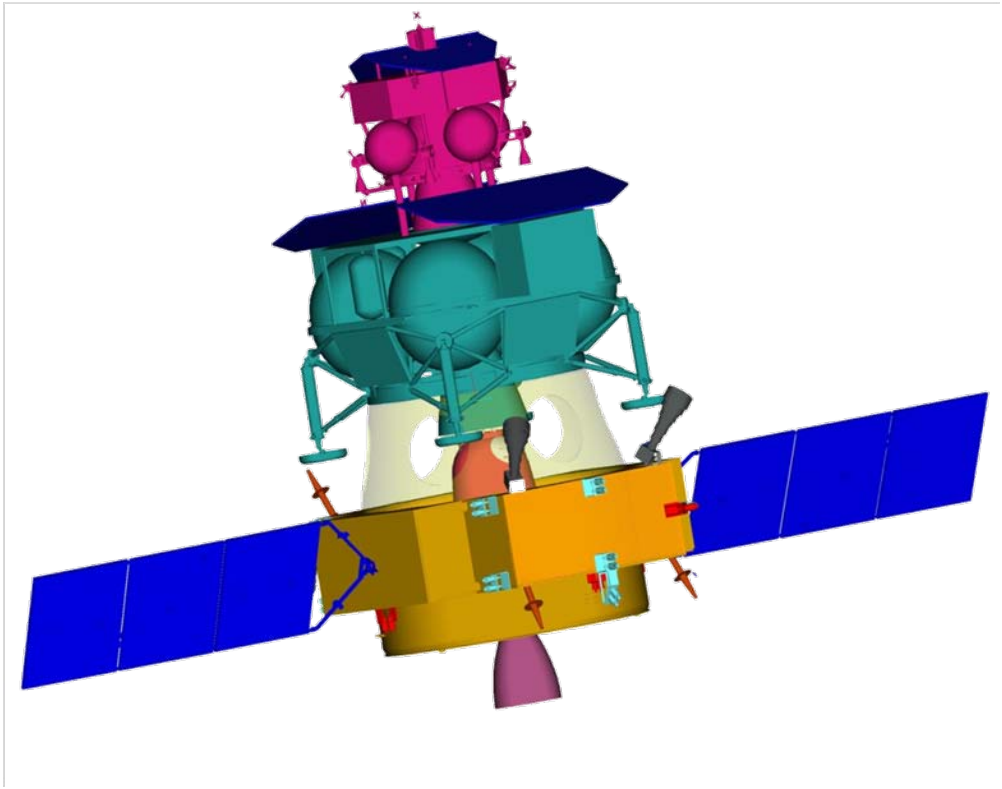
CE-3/4 Lunar rover

- **8 subsystems: payloads, GNC, thermal control , onboard data handling, power supply, TT&C, structure and mechanics, and locomotion.**

- **Payloads: pancamera, lunar subsurface penetration radar, APX and infrared imager spectrometer.**

3. 3rd phase of CLEP

⇨ **In the third phase of CLEP, a combined probe will perform lunar sample return task.**



4. Proposition

⇨ **Information exchange**

Exploration data of Payloads

3-D image of landing zone, such as rainbow, definition 1m or less

Lunar dust character

Lunar soil mechanical character

……

Academic Exchange Environment

4. Proposition

⇨ **Joint Exploration**

Different zone

Different payloads

Synergy exploration

interferometry, impact wave (moonshake)

……

4. Proposition

⇨ **International Lunar Lab**

Openness

Symbol

Union

Limited scale

Permanence

……

Conception Impetus

propositional companies

conception scheme

folk suggestion from countries

……

4. Proposition

Developing research on Lunar Lab supported by 863 plan

-Extensible structure

-Preparation method on H_2O and O_2

-Energy system of the Lab

-Temperature control (underground maybe)

The task will end in 2011.

The end .

Thanks for your attention!

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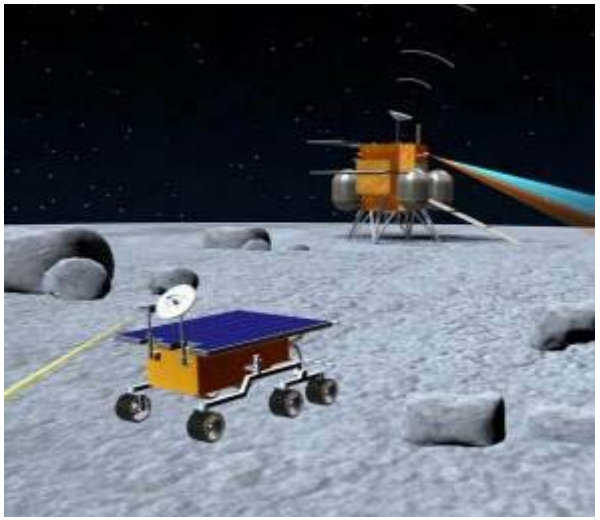
- ⇨ Strategic Plan of CLEP
- ⇨ Overview of CE-1
- ⇨ Scientific Achievements of CE-1 Orbiter
- ⇨ The Latest Updates of CLEP
  - – CE-2 Orbiter
  - – CE-3 Lander and Rover
  - – 3rd Phase of CLEP
  - – Application of CE-1/2 in Mars Exploration

Strategic Plan of CLEP

Orbiting

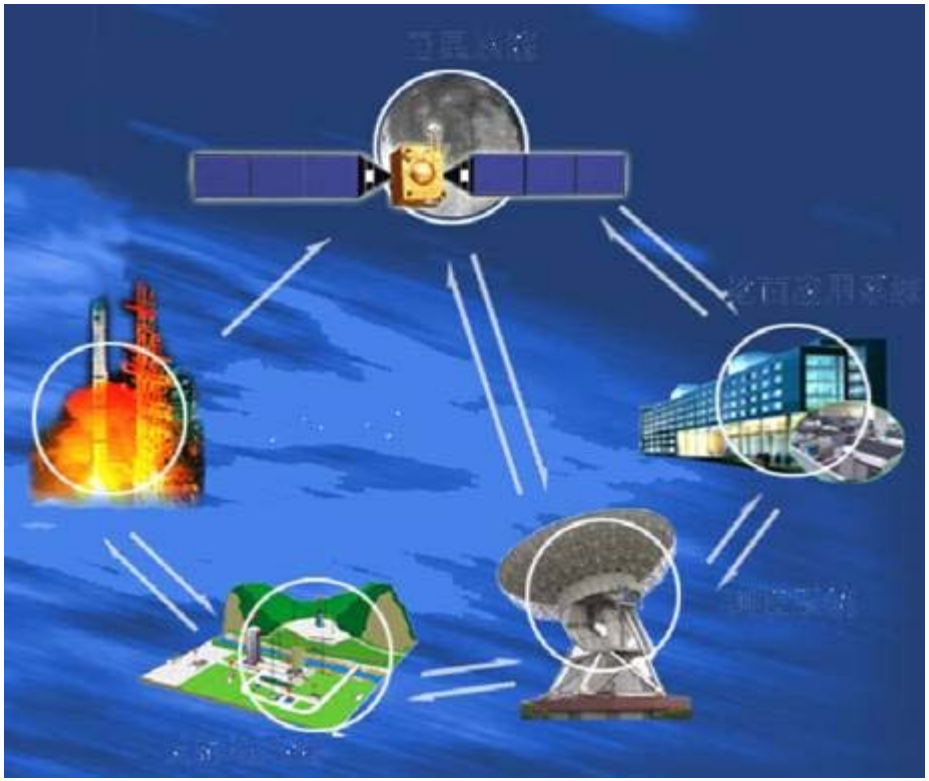


Landing

Sample and Return

- In 1991, Chinese space experts proposed lunar exploration program and conducted some research.
- In Nov. 2000, White Paper on China's Space Activities stated to carry out study for deep space exploration focusing on the Moon.
- In Jan. 2004, China State Council approved first Phase of China Lunar Exploration Program (CLEP), i.e. Lunar Orbiting Exploration (CE-1) Project.
- There are three Phases in CLEP: 2007(orbiting), 2012(landing), and 2016(sample and return).

Development history of CE-1



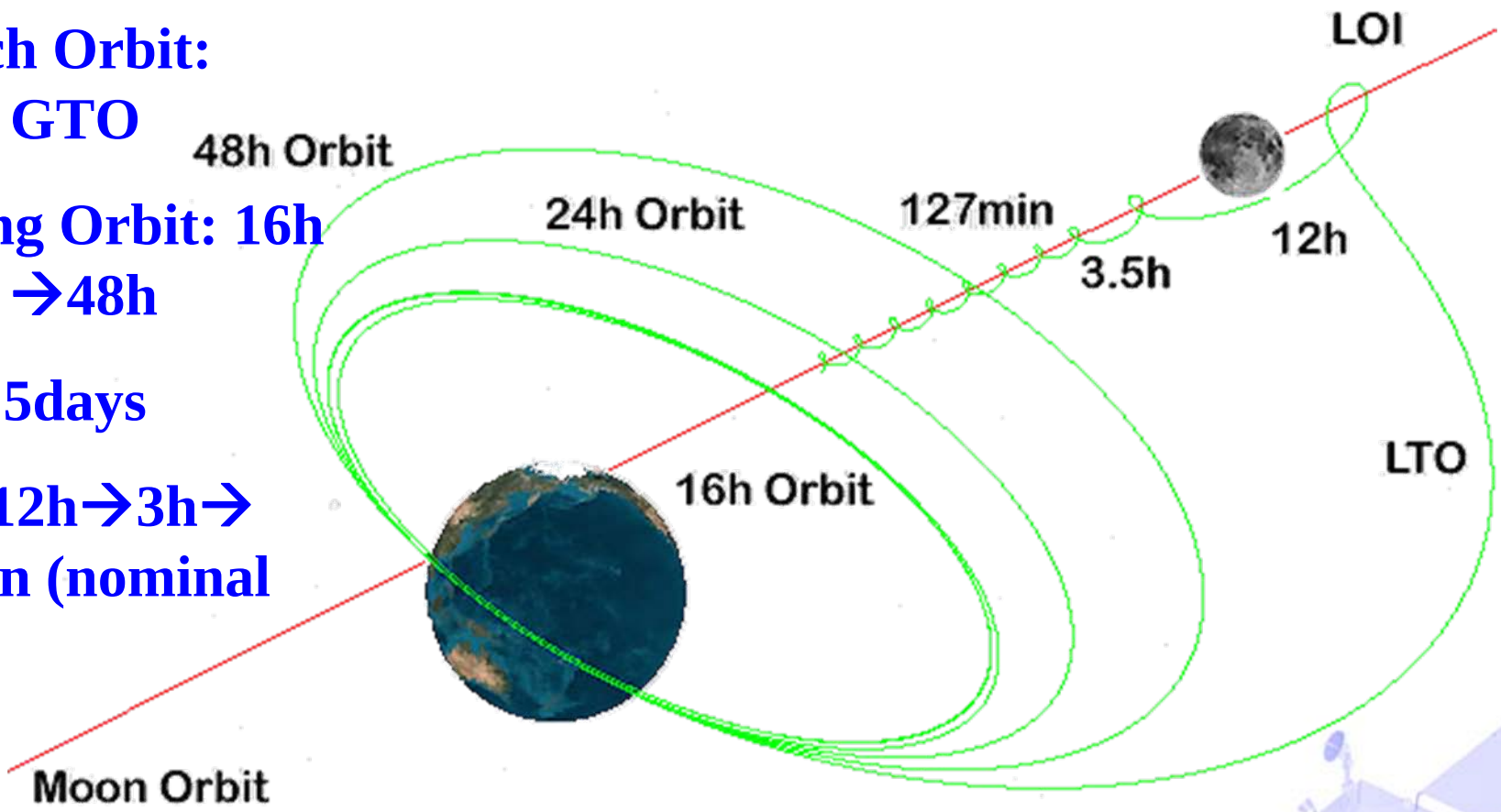
Engineering System of CE-1 Project

In Feb. 2004, development of Chinese first lunar orbiter CE-1 and Lunar Orbiting Exploration Project were initiated.

CE-1 orbiter was launched in Oct. 24, 2007, who became the third milestone of China space industry.

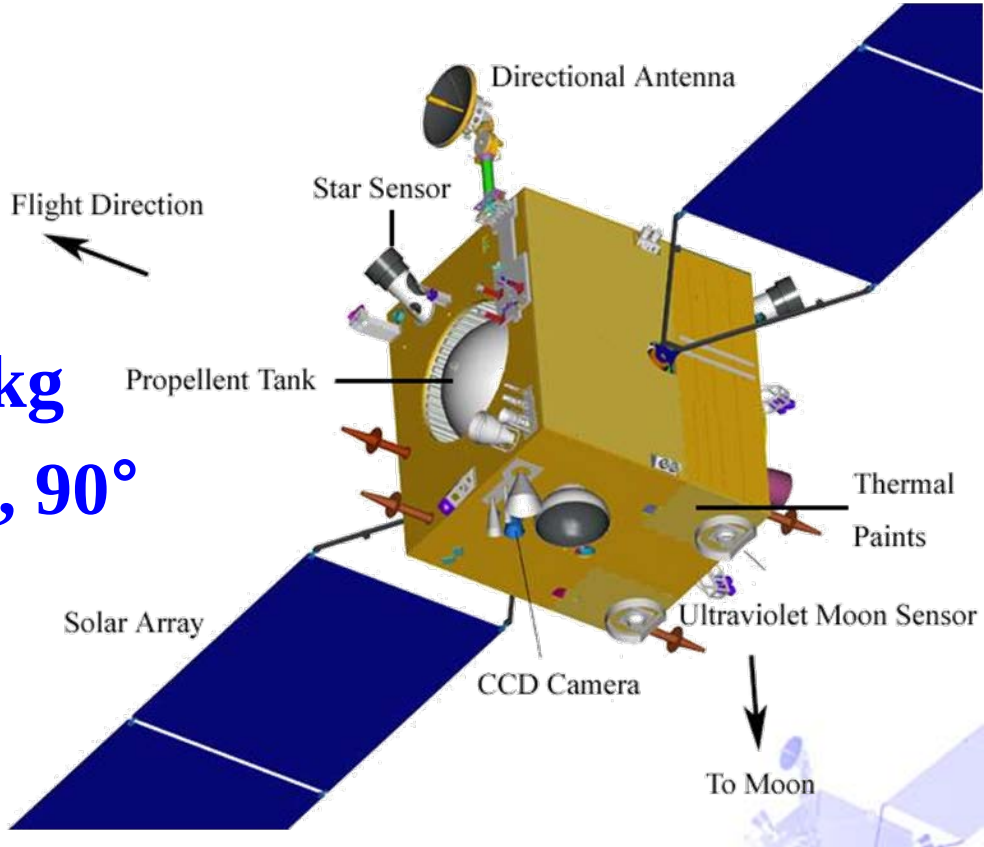
Flight Profile of CE-1 Orbiter

- ⇨ **Launch Orbit: Super GTO**
- ⇨ **Phasing Orbit: 16h →24h →48h**
- ⇨ **LTO: 5days**
- ⇨ **LOI: 12h→3h→ 127min (nominal orbit)**



Major features of CE-1 Orbiter

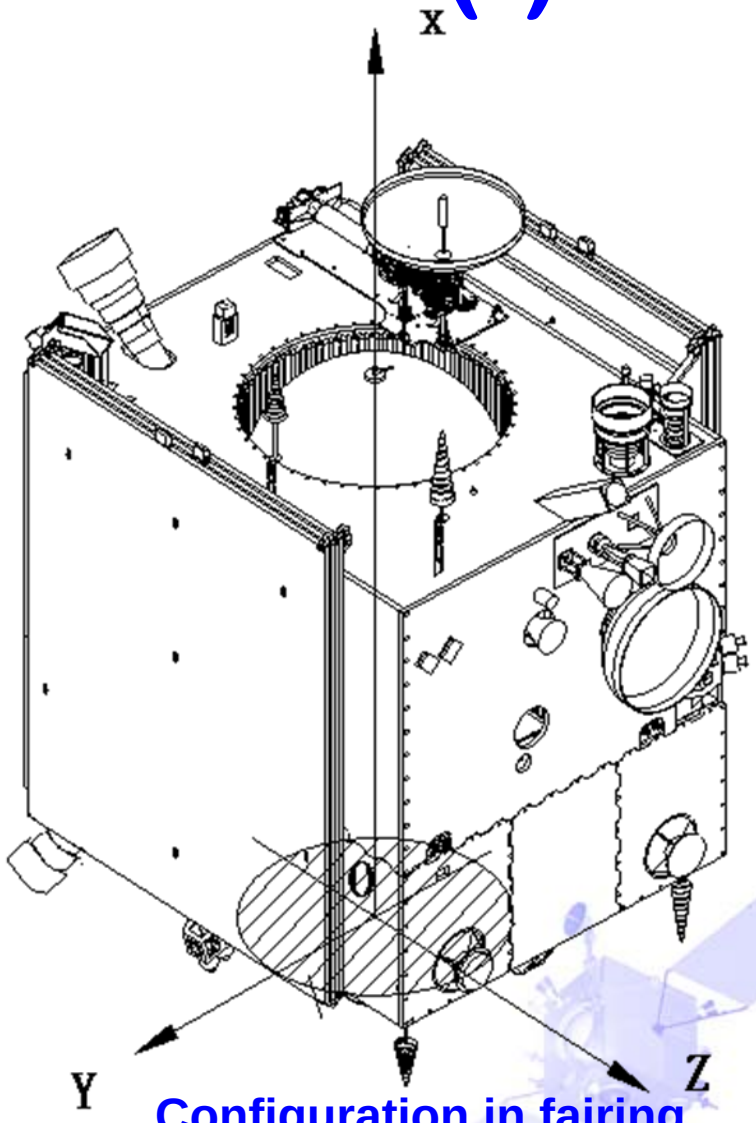
- ⇨ Launch Mass: 2350kg
- ⇨ Dry mass: 1150kg
- ⇨ Fuel mass: 1200kg
- ⇨ Scientific payloads: 140kg
- ⇨ Operation orbit: 200km, 90°
- ⇨ Life on orbit: 1 year



Flight Configuration

Major Subsystems of CE-1 (I)

- **Structure**: central bearing cylinder, honeycomb panel, box, upper module and bottom module, 2.2m×1.72m× 2.2m.
- **Thermal Control**: active + passive, thermal paint, multilayer thermal blankets and insulation material, heater, sensors, heat pipe and controller.
- **Power Supply**: single dimension symmetric solar panel, Si solar cell, 22.7m^2, Max output 1450W, Ni-H battery (output 48Ah@End Of Life)

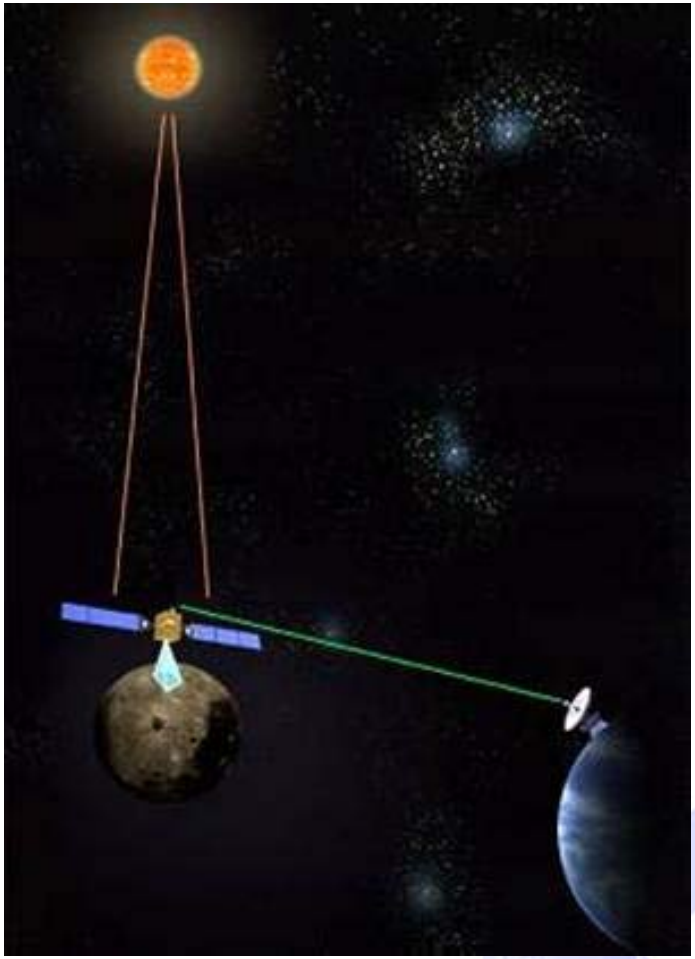


Configuration in fairing

Major Subsystems of CE-1 (II)

- **GNC:** solar sensor + star tracker + gyroscope + ultra violet sensor, zero moment, reaction wheel with thrusters, three-axis stabilized, pointing accuracy better than 1°(3σ), stabilization accuracy better than 0.01°/s

- **Thrusters:** Bi-propellant thrusters with MOH and N_2O_4 , for slow spin, angular rate damper, attitude control and orbit maneuver, 1×490N and 2×（6×10N）thrusters



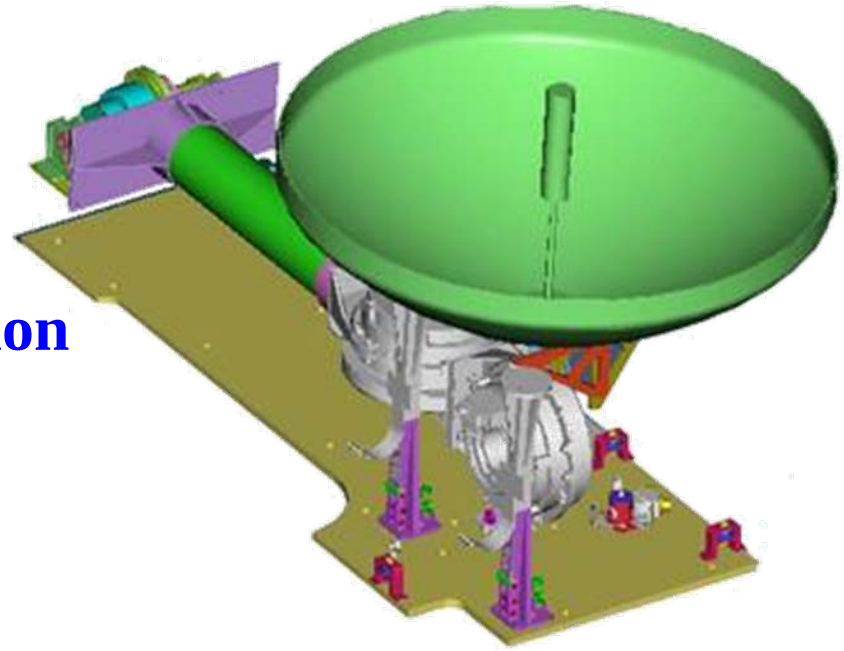
Attitude Control
3 Body Orientation

Major Subsystems of CE-1 (III)

- **TT&C:** S-band omni antenna for TT&C, directional antenna for downlink, BPSK, 3Mbps downlink rate, X-band beacon for VLBI

- **Directional antenna:** two dimension antenna for semi-sphere coverage, gain not less than +18dBi @±5°

- **OBDH:** two-level distributed redundant subsystem, CTU, 4 RTUs, one TCU, one set of redundant SDB.



Directional Antenna

Scientific Payloads of CE-1

- ⇨ CCD camera/Imager Spectrometer: 3-D images of lunar surface
- ⇨ Laser altimeter: surface topology
- ⇨ γ-ray/X-ray spectrometer: elements distribution ;
- ⇨ Microwave detector: thickness of lunar regolith, He-3;
- ⇨ Solar high energy Particle detector/Low energy ion detector: circumstance among Earth, Moon and Sun

CCD Camera

Laser altimeter

Microwave Detector

Major Events of CE-1

1. 2007-10-24, successfully launched in 0 window
2. 2007-10-31, enter LTO
3. 2007-11-2, en route correction
4. 2007-11-5, first LOI into 12h lunar polar orbit
5. 2007-11-7, enter 127min normal operation orbit
6. 2007-11-20, scientific payloads on
7. 2007-11-26, 1st image issued by Premier Wen Jiabao
8. 2008-2-21, pass first lunar eclipse
9. 2008-8-17, pass second lunar eclipse
10. 2008-10-24, one year after launched, accomplish all scientific and engineering mission goals

Major Events of Extended Mission

1.2008-12-6, lower orbit into 100km lunar orbit

2.2008-12-19, lower orbit into 15km×100km orbit

3.2008-12-20, back into 100km orbit

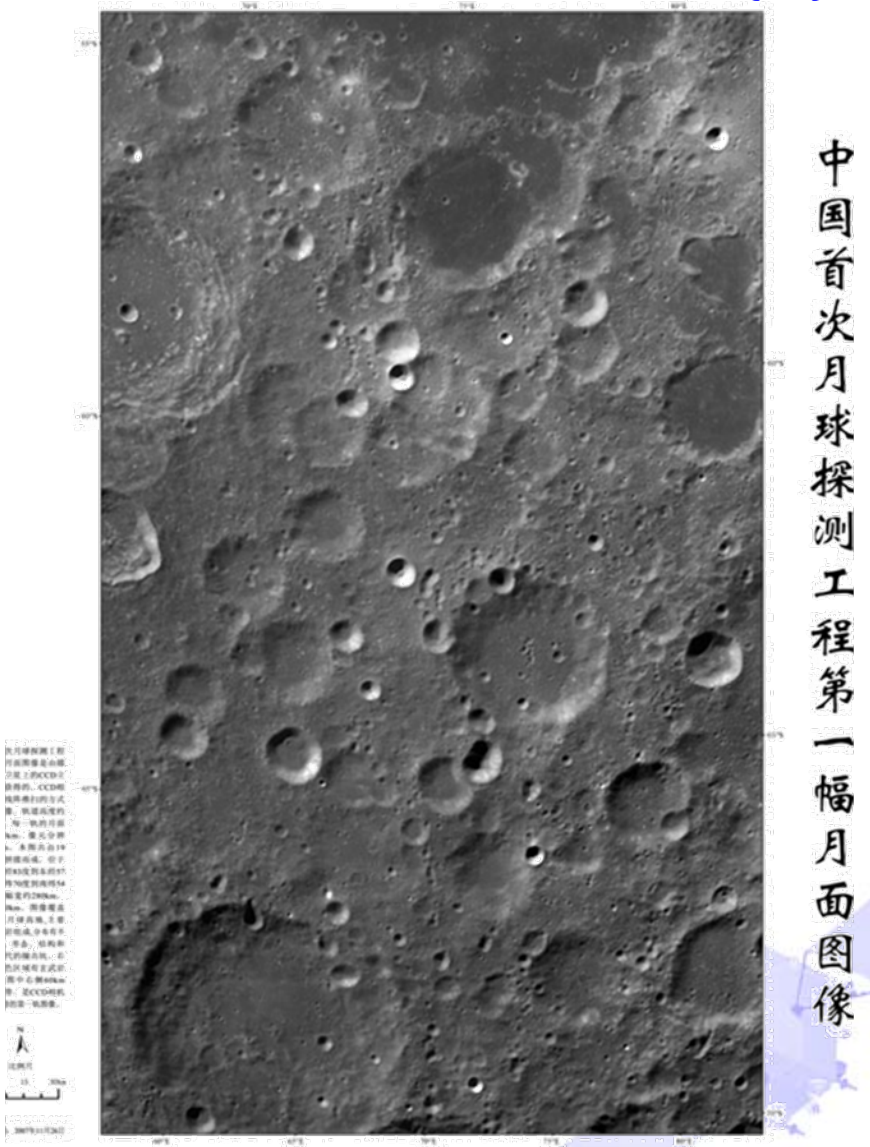
4.2009-2-9, pass third lunar eclipse

5.2009-3-1, impact lunar surface in 52.36°E，1.5°S by command

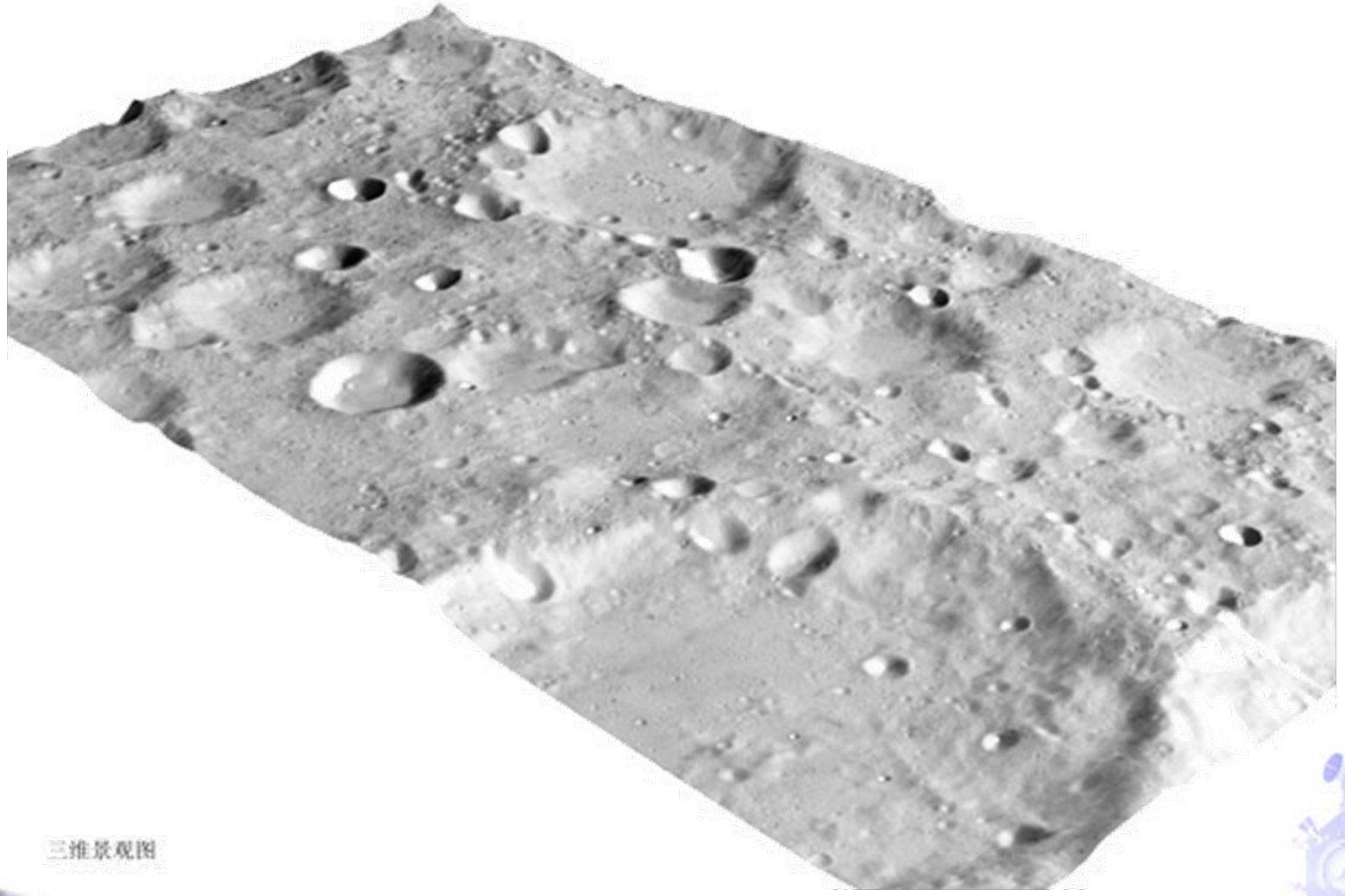
Experiments of CE-1 Extended mission gained more engineering experience for subsequent lunar missions.

Scientific Achievements of CE-1 (I)

- ⇨ 1st Lunar image by CE-1
- ⇨ Issued in Nov. 26, 2008
- ⇨ Image size: 280km×460km
- ⇨ Pixel resolution: 120m
- ⇨ Location on the Moon:
  57°E ~ 83°E，54°S ~ 70°S



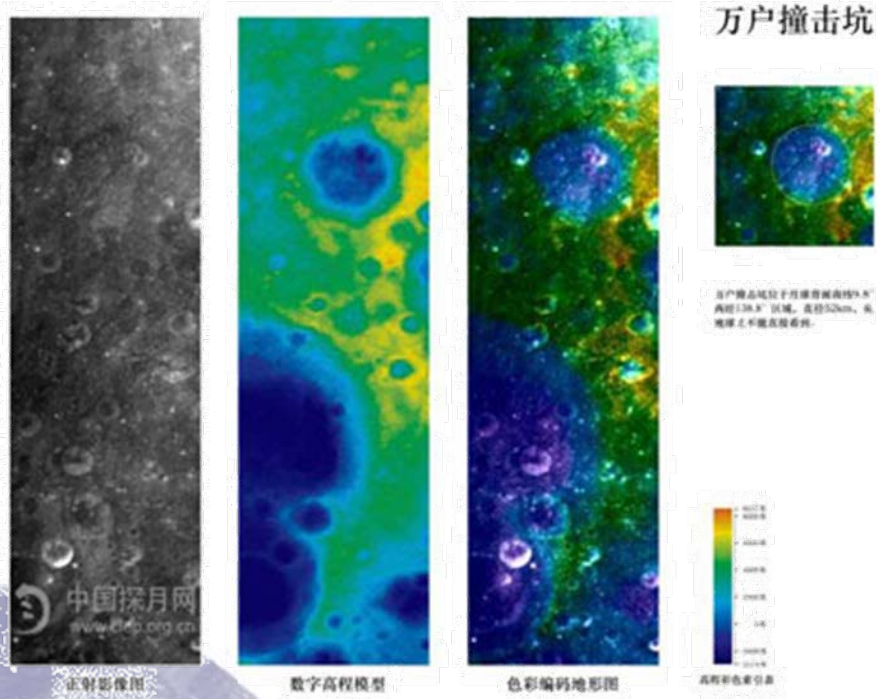
Scientific Achievements of CE-1 (II)

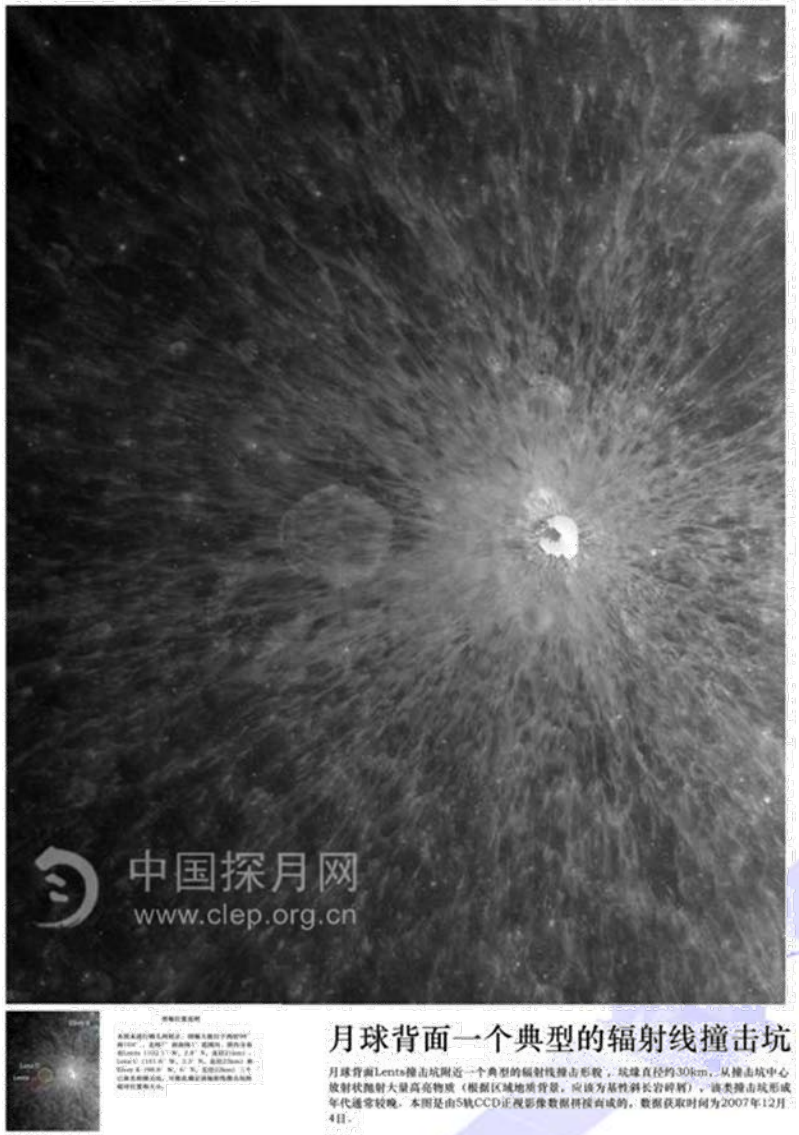


3-D composition of first lunar surface image

Scientific Achievements of CE-1 (III)

- ⇨ 1st Lunar far side image
- ⇨ Image of crater named by a Chinese Wan Hu who tried making rocket in 1400



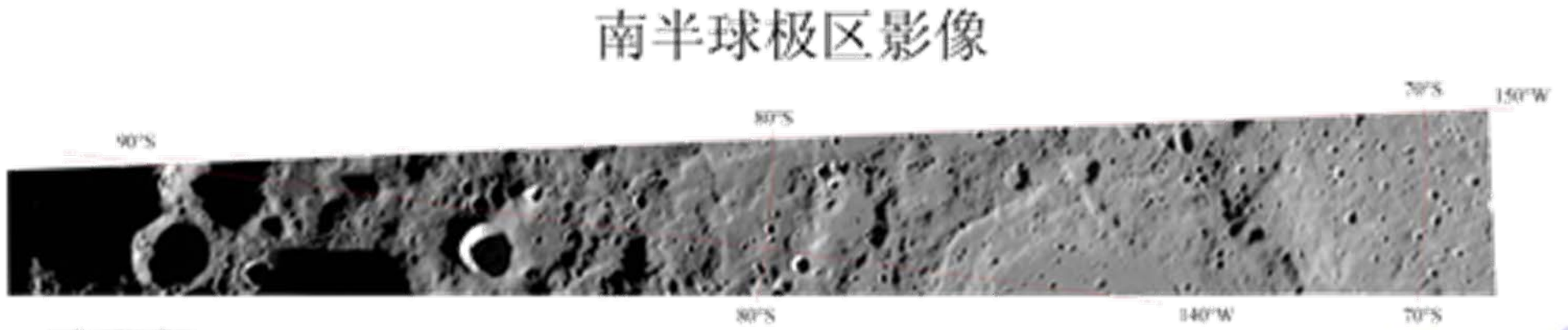


Scientific Achievements of CE-1 (IV)

⇨ Jan. 31, 2008 image of lunar south pole

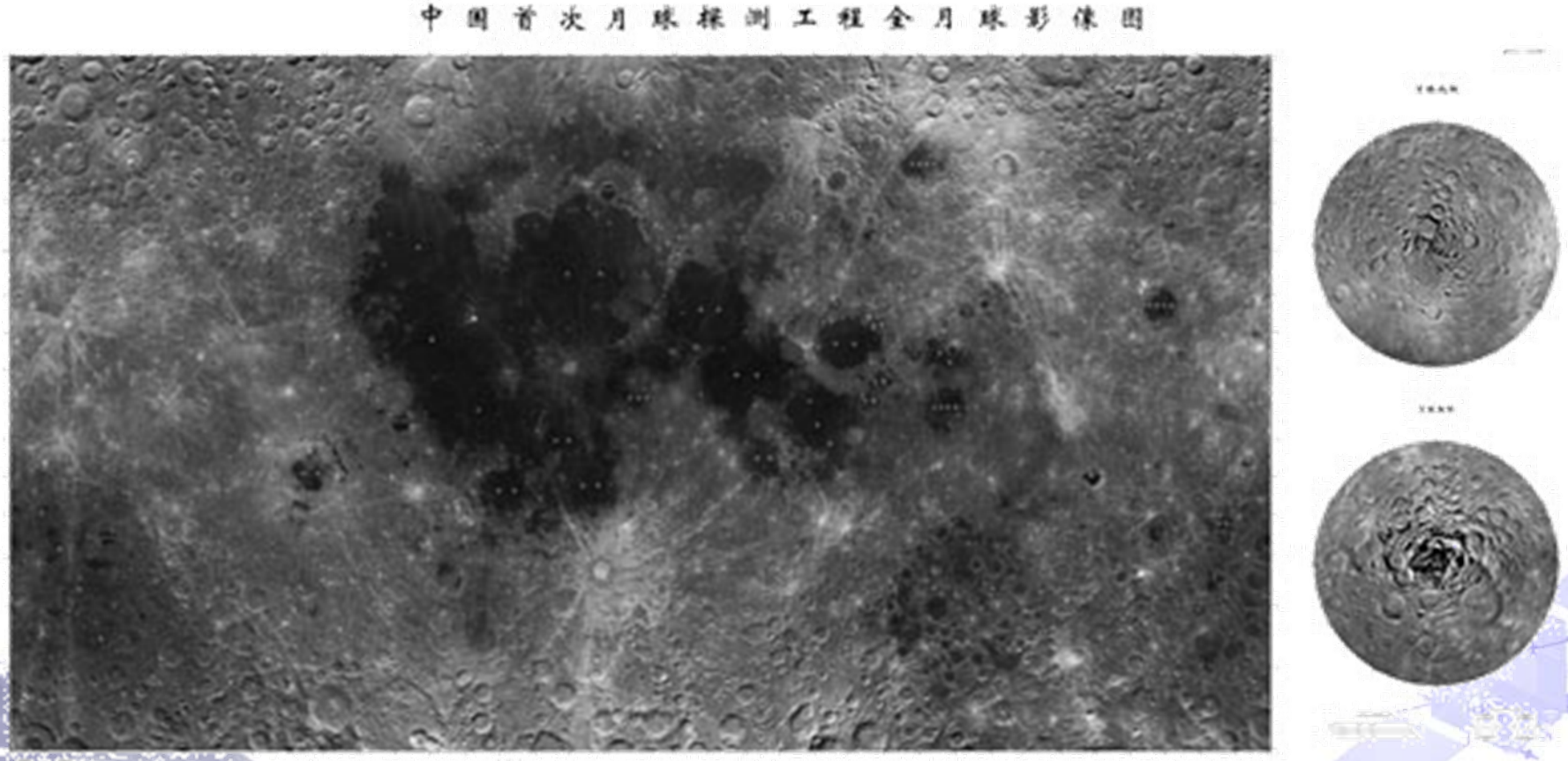
⇨ Latitude higher than 70°S

⇨ Image quality better than expected



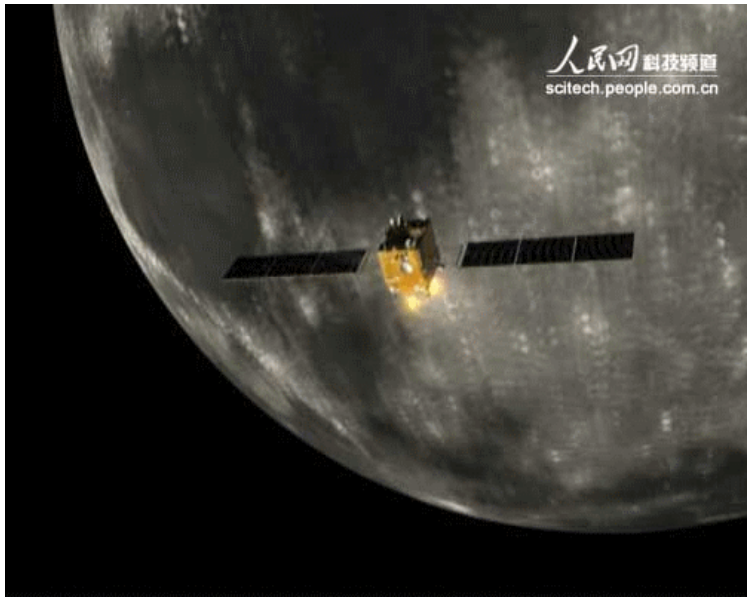
Scientific Achievements of CE-1 (V)

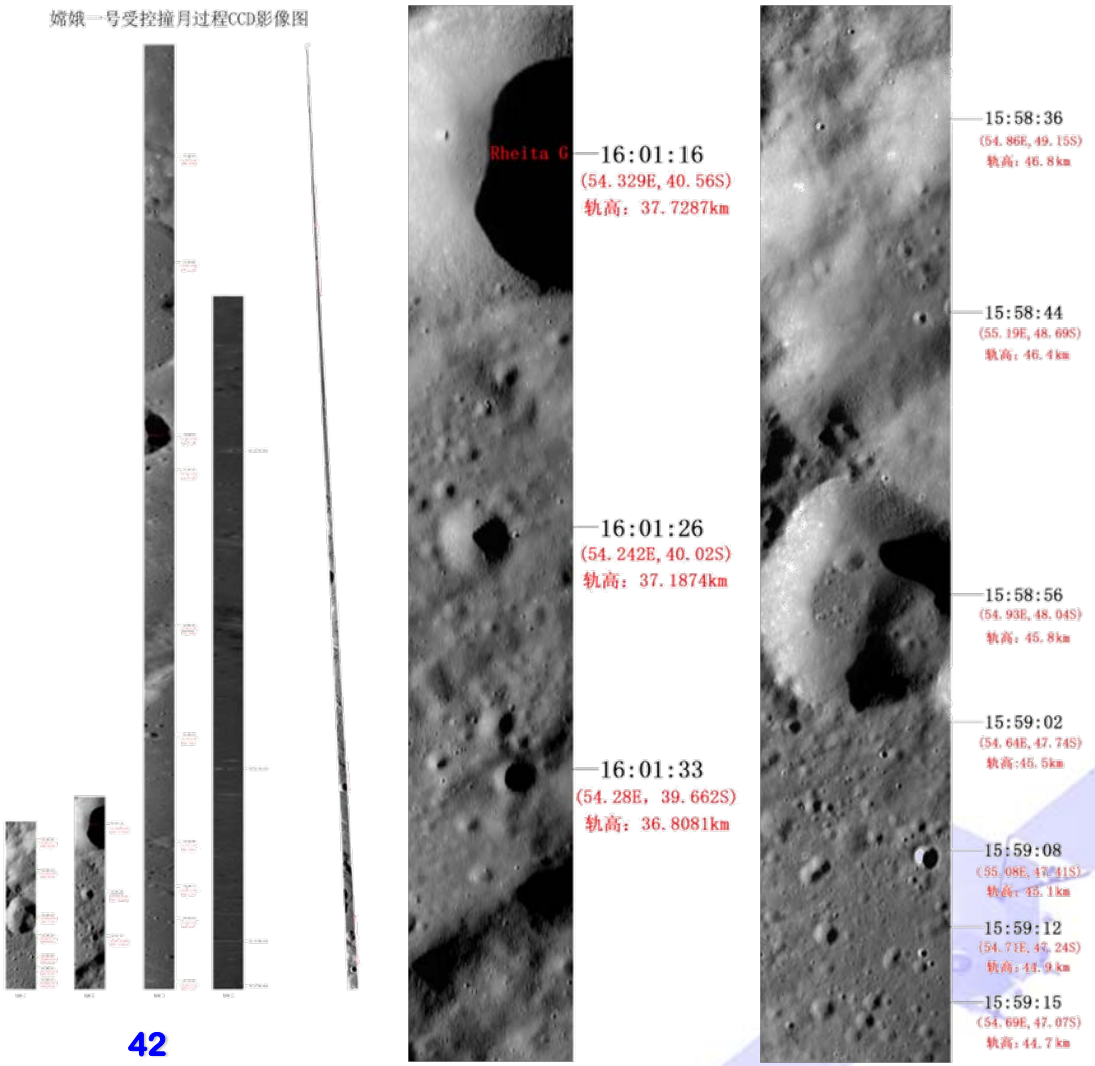
⇨ **Nov. 12, 2008, lunar global image issued, while first package of scientific data was transferred to scientists**



Scientific Achievements of CE-1 (VI)

⇨Mar. 1, 2009, CE-1 impact the Moon by command





The Latest Updates of CLEP

Coming soon after CE-1 success ……

- ⇨ **CE-2 Orbiter**
- ⇨ **CE-3 Lander and Rover**
- ⇨ **3rd Phase of CLEP**
- ⇨ **Application of CE-1/2 in Mars Exploration**

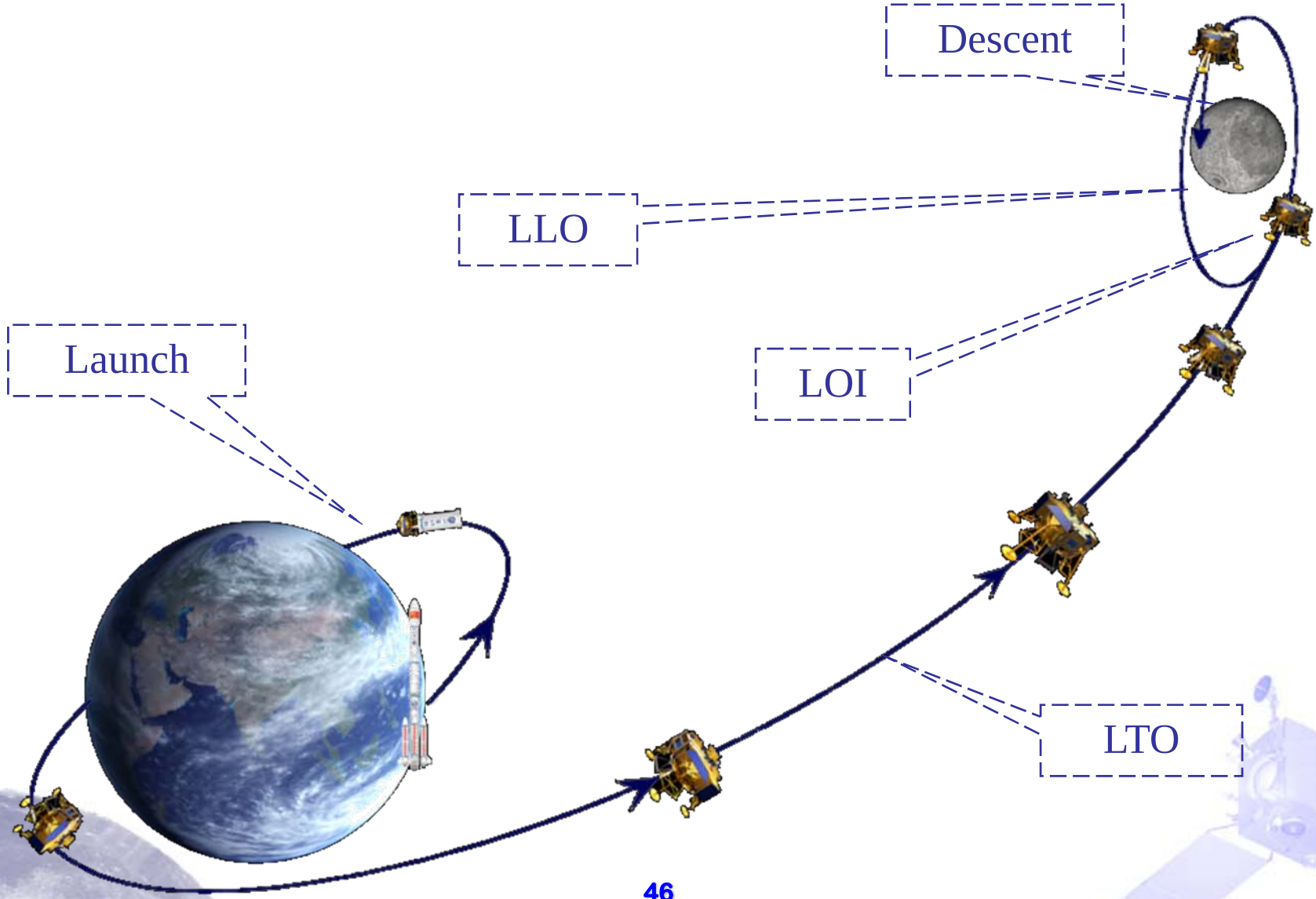
CE-2 Orbiter

- ⇨ Once was a backup of CE-1
- ⇨ CE-2 will be launched in Oct. 2010
- ⇨ Different payloads and orbit from CE-1
- ⇨ Demonstrate technologies for subsequent deep space exploration

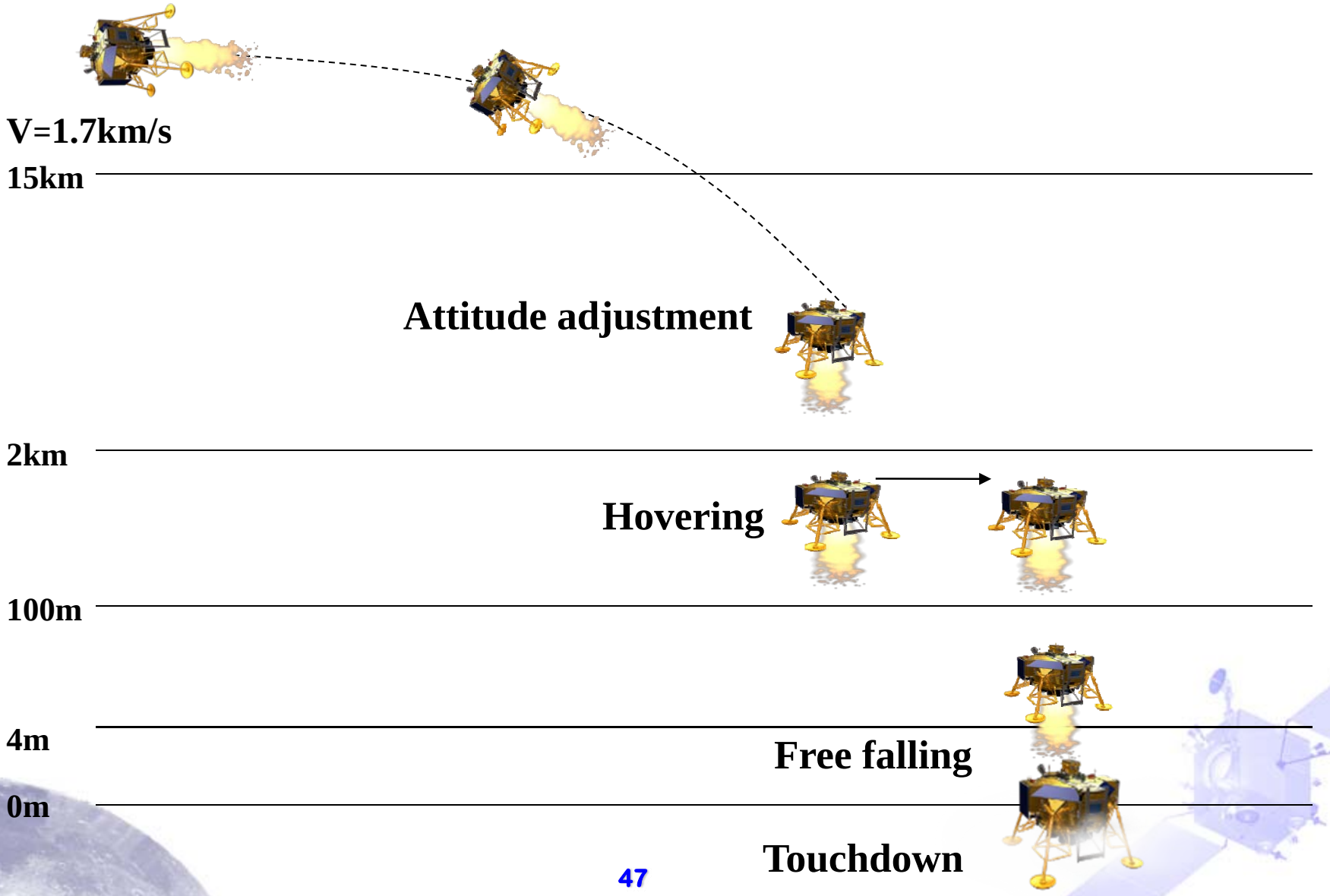
Scientific Objectives of CE-3

- ⇨ To investigate the landscape of lunar surface and geological structure of Moon
- ⇨ To investigate material composition and usable resources of lunar surface
- ⇨ To study lunar internal structure
- ⇨ To build up an observatory based on Moon

Flight Profile Of CE-3



Power Descent of CE-3 Lander



Engineering System of CE-3 mission

Lander + Rover

64m/35m/50m +VLBI

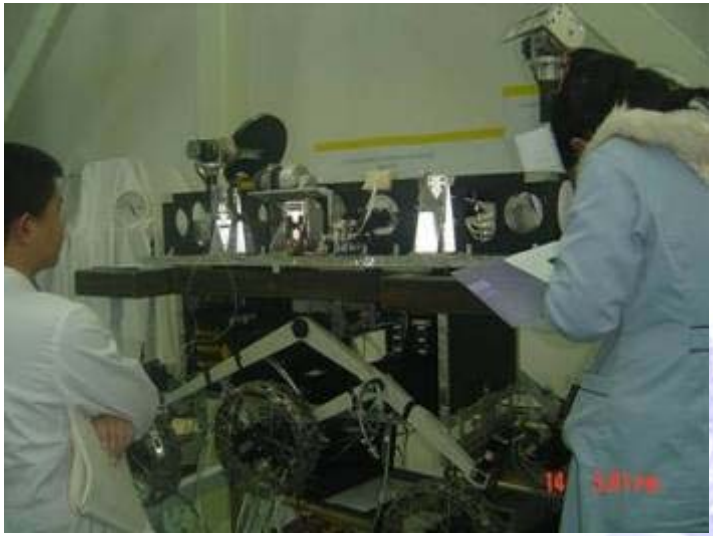
CZ-3B，Xichang

Developments of Lander & Rover

Structure model

Wheels of the rover prototype

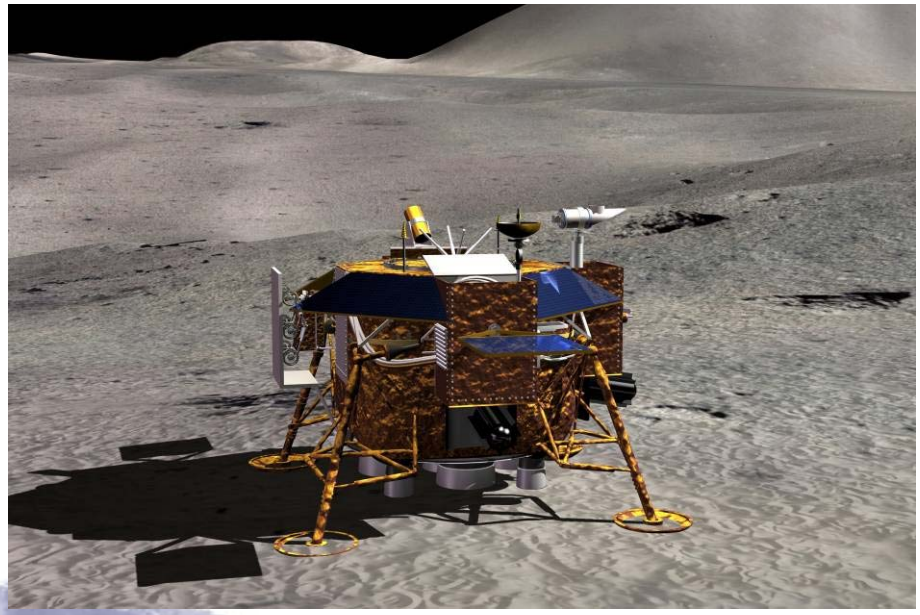
Impact test of landing leg



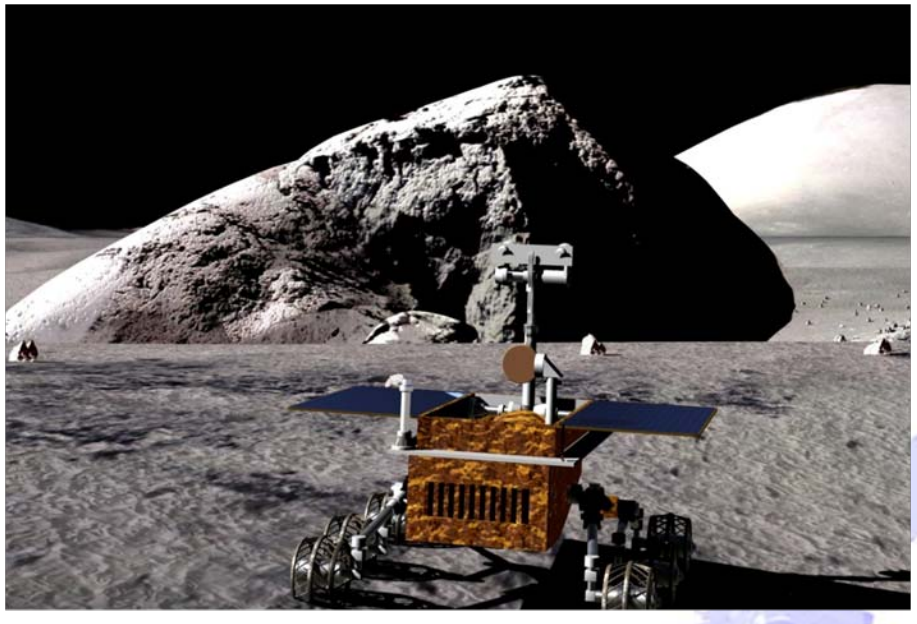
Rover prototype under test

Overview of CE-3 Lander & Rover

- ⇨ Launch date in schedule: later in 2012
- ⇨ Launch mass: 3750kg
- ⇨ Landing site: Rainbow (near side)



Lander



Rover

3rd Phase of CLEP

- ⇨ Ascending stage, return capsule, orbiter
- ⇨ Launch rockets: CZ-5E
- ⇨ Robotic sample and return

- ⇨ Performed in 2016
- ⇨ Key technologies for sample and return

- ⇨ Study lunar sample in ground lab
- ⇨ Learn technologies necessary for robotic exploration and future more deeper space exploration even manned lunar exploration

The End

Thanks for your attention