China's Chang'E Program

--- Missions Objectives, Plans, Status, and Opportunity for Astronomy

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Three stages of the Chang'E Program

The Chang'E Program is China's Lunar exploration program envisaged to be carried out in three stages:

- **the lunar orbiter (Chang'E-1) stage**
- **the lander-rover stage**
- **the sample return stage**

The Lunar Orbitor Stage (Chang'E-1)

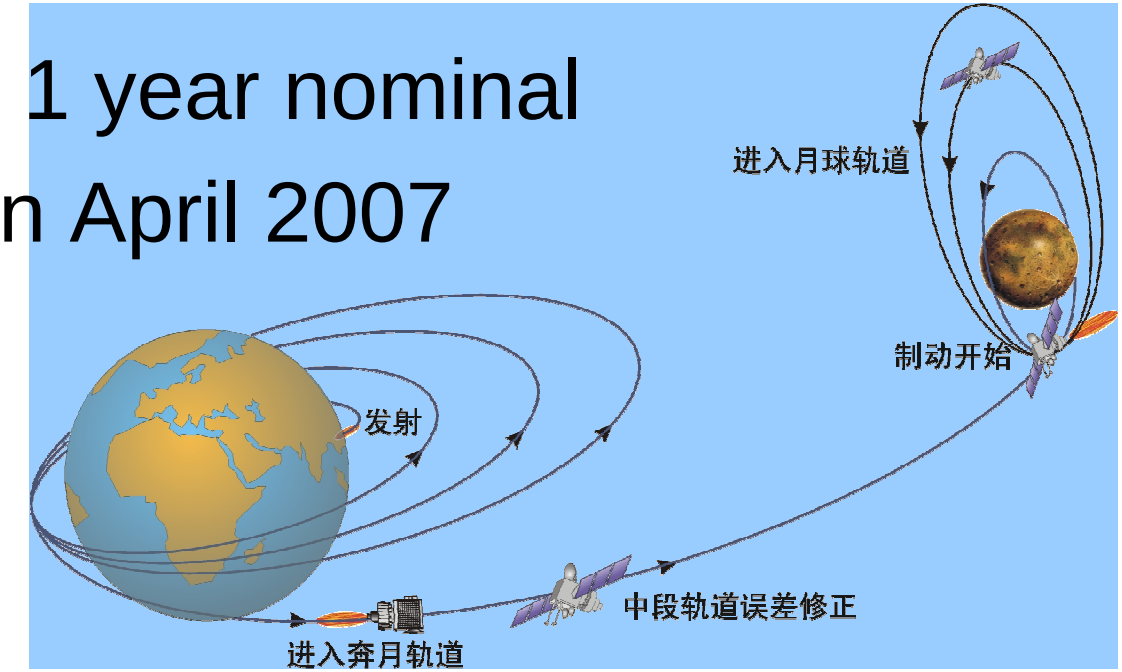
- has been approved by the Chinese government
  - Funded at ￥1,400m (~ $175m)
  - and ￥600m for a backup orbiter
- more than 100 institutes are involved
  - The Chinese National Space Administration (CNSA) as project lead
  - The China Aerospace Science and Technology Corporation (CASC) to provide LV and S/C
  - Chinese Academy of Sciences (CAS)
  - Other, including international collaborators

The four scientific objectives for CE-1

1. to study lunar surface topography;
2. to analyze abundance of elements and distribution of surface materials on the moon;
3. to survey the global properties of the lunar regolith;
4. to probe the space environments in the vicinity of the moon.

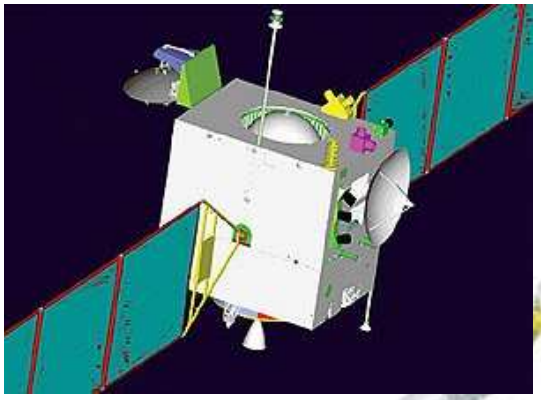
Mission outlines

- Lunar circular polar orbit
  - 200km above lunar surface
  - 127min orbit period
  - 90 degree inclination
- Mission life time: 1 year nominal
- To be launched in April 2007



Chang'E-1 subsystems

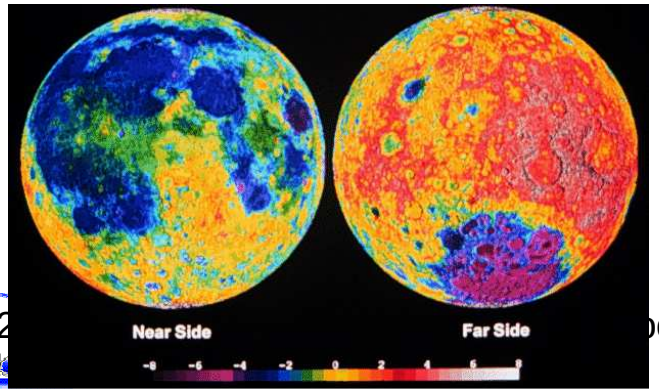
- LM3-A Launch vehicle
- Orbiter
  - DFH-1 bus
  - Payloads
- Launch site
  - Xichang

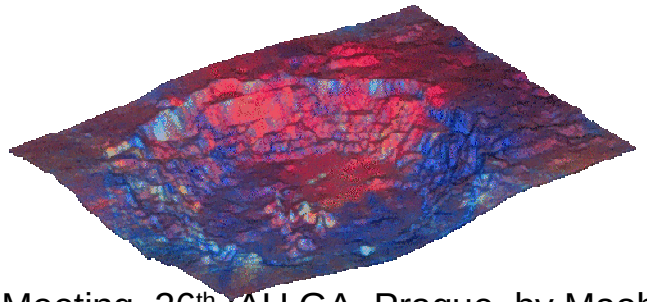


- Telemetering ,Tracking, and Command
  - USB networks (Chinese and Int'l)
  - Very Long Baseline Interferometry (VLBI) network
- Ground Segment for Data, Science, and Applications (GSDSA)

Payloads for topographical studies of global lunar surface

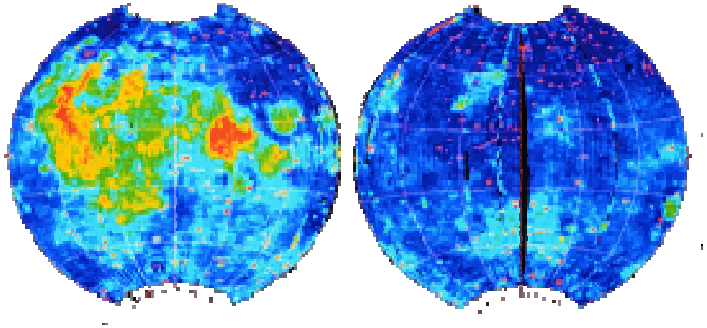
- Stereo CCD Camera
  - Three-line pushbroom CCD camera to obtain stereo images between N70 and S70 degrees latitude
- Laser altimeter
  - Direct measurement of S/C altitude above nadir point on lunar surface





Payloads for mapping abundance and distribution of elements and surface materials

- Imaging Interferometer in visible and near IR bands
  - 32-channel spectra for every 200m pixel
- and x-ray / Gamma ray detectors
  - elements Th,U, K, Fe,Ti ...

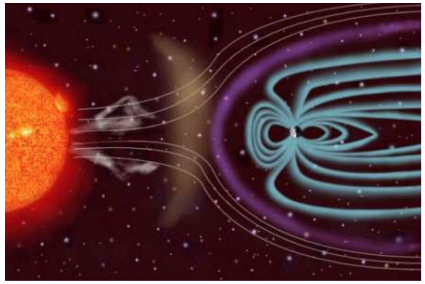


Payload to survey the global properties of the lunar regolith

- Microwave radiometer
  - Measure the brightness temperature at different frequencies to derive depth and other information of global properties.

Payload to probe the space environment between earth and the moon

- High energy solar particle detector
- Low energy solar wind ion detector



Ground Segment for Data, Science, and Applications

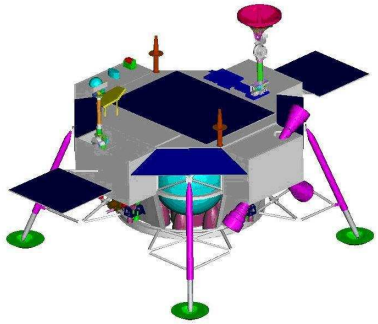
Being built and to be operated by the National Astronomical Observatories, CAS (NAOC) in Beijing

- Is the Science and Application Center for Lunar and future Deepspace Exploration
- Plans, executes, and coordinates CE-1 science ground operations
- Will process and archive more than 20TByte of data after one year of operation

Data downlink stations

- A 50-meter and a 40-meter antennas have been built for data downlinks

The lander-rover stage of Chang'E



- In definition stage
  - To be launched in the time frame of ~2011
- Scientific objectives envisaged:
  - to study the topography and selenology in the landing and roaming areas (~10km radius);
  - to conduct in-situ measurements of lunar minerals and resources, and to survey the composition of surface materials;
  - to probe the interior of the moon;
  - to study the space environment and perform moon-based astronomical research.

The sample return stage of Chang'E

- In preliminary definition stage
  - To be carried out before 2017
- preliminary scientific objectives
  - to return to earth lunar specimen sampled by drilling and collecting, and to study the returned samples systematically;
  - to study the extraction of resource materials and probe lunar dynamics in deep interior;
  - to investigate mineralogy, petrology and selenochemistry of the returned samples, and study the evolution of the Moon and Earth-Moon system;
  - to conduct long-term moon-based selenology, space science, and astronomy.

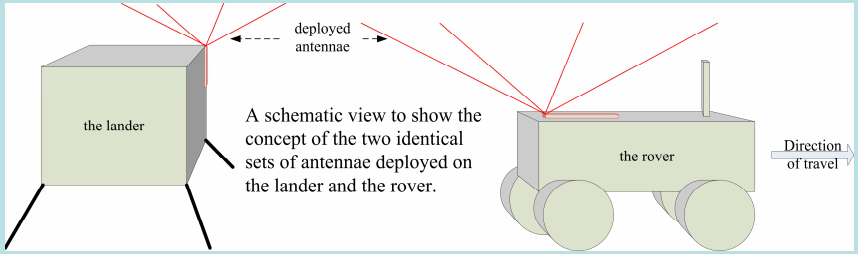
National Astronomical Observatory's role in Chang'e-2/3

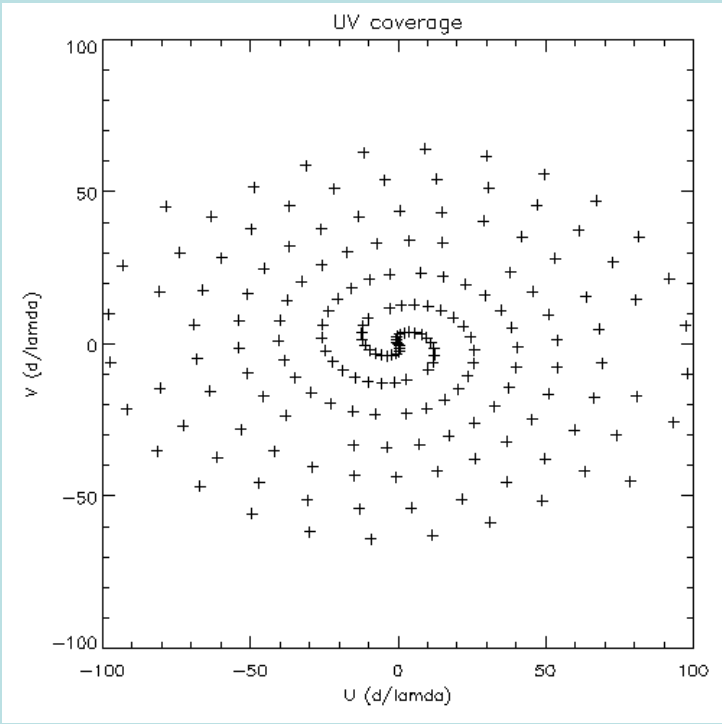
- Responsible for leading and coordinating the definition and justification of scientific objectives and payload requirements for Chang'e-2 and 3 stages
- Chinese astronomical community has been consulted and *preliminary* proposals have been formulated
  - Very low frequency interferometer experiment
  - small optical telescope

Astronomy from the moon 1

- ***Very low frequency interferometry pathfinder***
  - **Open up E&M spectral range from 0.03-30MHz**
  - **0.1 degree level angular resolution maximum**
  - **Demonstrate feasibility of lunar VLF observation**
    - Site characterization: lunar ionosphere, radio environment, electric properties of lunar surface
    - To show promise
    - With a scalable architecture to allow expanding
  - **Broad range of astronomical study possibilities**
    - Survey the Galactic ionized hydrogen distribution
    - Cosmic ray acceleration and Galactic magnetic field
    - Pulsars and transient phenomena
    - Coherent emission phenomena
    - Solar activities, planet sources
  - **Possible antenna configurations**
    - Interferometry between two antennas (Lander + Rover)
    - Interferometry between two antennas (Lander + Orbiter)
    - Single antenna

Simulation study: interferometry between a stationary and a mobile antenna

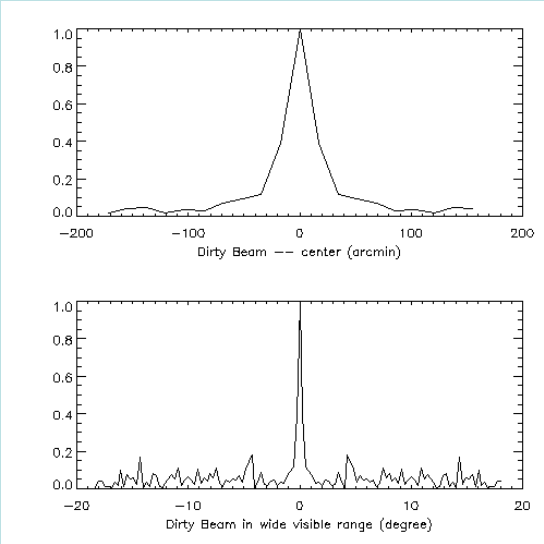


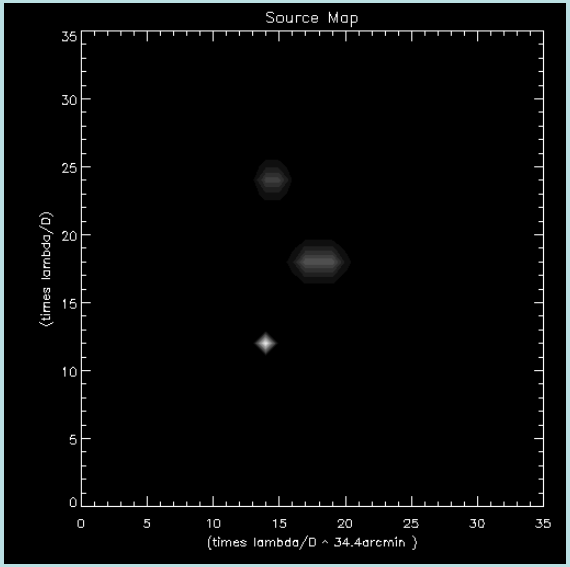


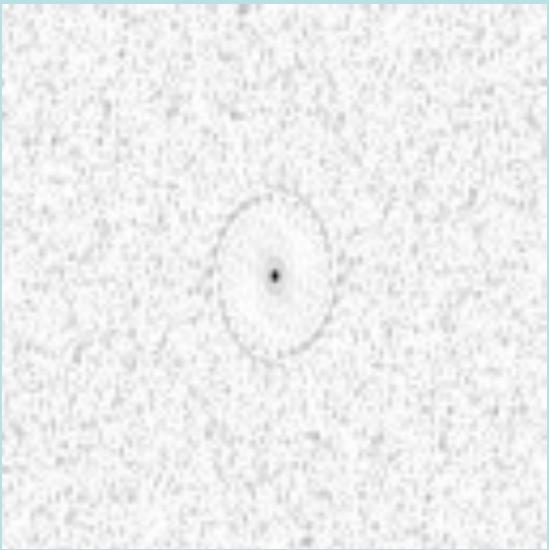
- One antenna is attached to the lander so is stationary .
- The other antenna is installed on the rover.
- Rover moves away from the lander at a constant speed over 6 months.
- The maximum distance between the two antennas is 3km.
- One measurement is made every day.
- Interferometry processing is done on the ground.
- Two possible ways are being studied to acquire signals:
  - RF or IF signal from each antenna is digitized, compressed and downlinked
  - RF or IF analogue signal is used to modulate downlink carrier signal, and is detected on the ground.
  - Using either method the phase information of signal is preserved, sophisticated processing on the ground can be possible, ultra high spectral resolution achievable
  - Scalable architecture, other antenna element can be added later, anywhere there is signal

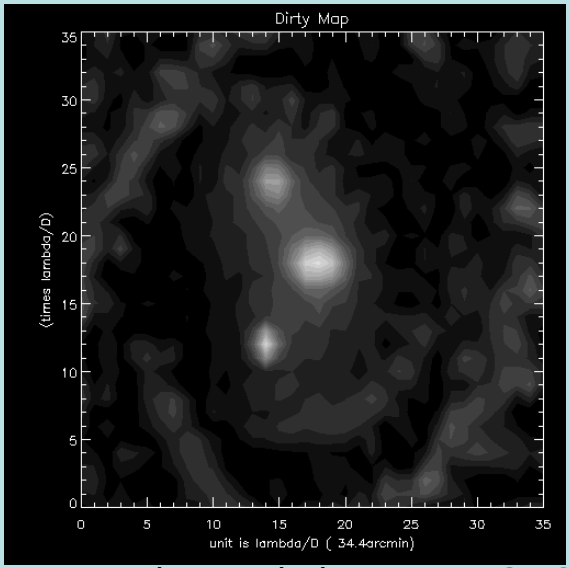
Simulated beam and observation

- 10 MHz
- 34’ angular resolution with 3km max baseline.
- Sensitivity is limited by downlink bandwidth.







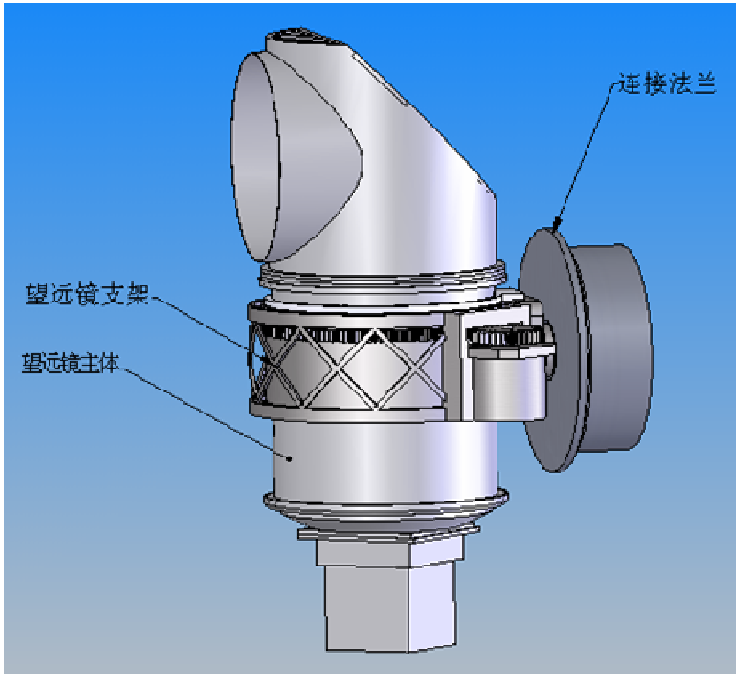


Astronomy from the moon 2

- ***A Lunar-based Optical Telescope (LOT)***
- A small (~300mm diameter) optical telescope to conduct continuous precision photometry study. It aims at two major scientific objectives:
  1. studying properties of stellar interiors through observations of oscillations in stellar luminosity and surface temperature.
  2. Search for extrasolar planets, particularly the telluric planets.
  3. Observe meridian transits of stars to study selenodesy.
  4. Public outreach

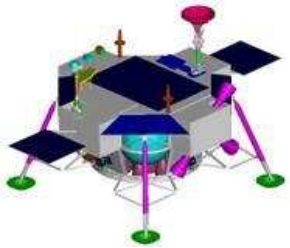
Preliminary Specifications of the telescope

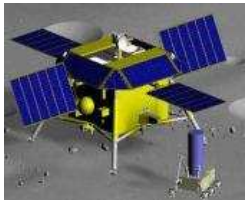
Parameters	**Specifications**
Diameter	300mm
f-ratio of the primary mirror	f/1.5
Optical design	Ritchey-Chretien reflector
system f-ratio	f/8
scale at Cassegrain focus	85.9arcsec/mm
mount	modified Az-Alt mount, automatic pointing and tracking, tracking accuracy is better than 10 arcsec/sec
Detector	Marconi 47-20 frame transfer CCD, 1024x1024, back illuminated, pixel size 13x13micron
field of view	19.1 x 19.1 arcmin (with Marconi 47-20)
working wavelength	380 – 700 nm

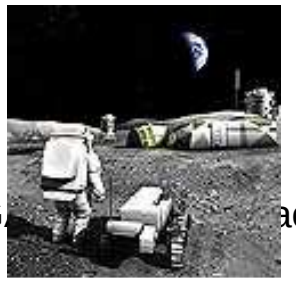


Opportunities ahead

- Despite uncertainties in government policies and technical risks associated with lunar astronomy, there is now unprecedented opportunities in the incoming wave of international lunar exploration to conduct astronomy from the moon
  - Chinese Chang'e-2 (2011-2013)
  - Japanese Selene-II (2013-2014)
  - the USA (2015+)
  - ESA, Russia, India, Italy, other countries ?
  - Private Lunar missions (International Lunar Observatory)

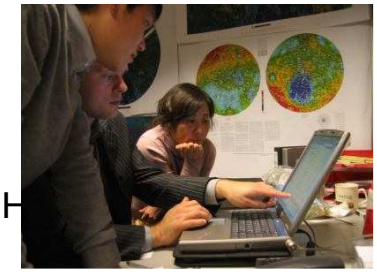






Take action now

- The astronomical community should seize incoming opportunities and give support to lunar astronomical initiatives so that funding bodies could
  - realize the importance of lunar astronomy compared with other disciplines of science from/on/of the moon
  - feel tangible endorsement if astronomical payloads and sub-programs are selected
  - more resource is allocated to astronomical payloads (power, bandwidth, operation priorities)
- Steps should be taken to create collaboration frameworks so that lunar astronomy proposals of individual missions could contribute to sustainable lunar astronomical build-up
  - Frequencies and other interferences
  - Interferometry framework
  - coordinated observing campaigns



Thank you

Information and contact

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