The Science Objectives of the SELENE-II Lunar Landing Mission

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Key Questions to be Solved in Lunar Science

1. Chemical composition and mineral assemblage of the most ancient rock as a relict of hypothesized magma ocean (farside highland terrain: FHT)
2. Lunar crustal thickness and upper mantle structure and the extent of lateral variation, to estimate depth of magma ocean, efficiency of crust-mantle differentiation and style of mare volcanism
3. Derivation of the average composition of present lunar crust and mantle
4. Structure of deep mantle and central core, thermal and physical properties

Composition of highland meteorites

- D489 An. troctolite
- D489 Man
- Y-86032


Temperature profile of Apollo 17 probe

Ambient Temp. of each sensor, 17-1

(Langseth et al., 1977)

Newly discovered data (Saito et al., 2006)

Day from the first of 1972
How these questions to be resolved?

(1) In-situ precise chemical analysis and characterization for outcrops of pristine crustal rock and soil, as ground truths of global mapping data
(2) Access to a potential of upper mantle material as a window of deep interior
(3) High resolution chemical and isotopic analyses for samples of major geological units.
(4) Investigation of farside/nearside crustal dichotomy and difference in crustal structure of major geological units.
(5) Investigation of the deep interior by geophysical and/or geodetical methods

cf.) Major Geological Unit (Jolliff et al., 2000)
    PKT : Procellarum KREEP Terrane
    FHT : Feldspathic Highland Terrane
    SPA : South Pole Aitken

★Kaguya (SELENE) and other orbital missions, will provide us with new information to some extent. But, …..
Mission Description and Scenario

★Proposed Scientific Experiments on SELENE-2 Mission
- Surface geology and in-situ chemical analysis by lander/rover system
- Sub-surface installation of **geophysical package** by lander or rover
- Surface deployment for **geodesy** experiment and technological demonstration of **astronomical observatory**

Mission scenario of SELENE-2 (modified from Okada et al., 2006)
Surface Geology and In-situ Chemical Analysis

★Role of Surface Geology and Advantages
1. Near-field search and inspection (cm to 1m in area), and far field (1m to 10 km in area) traverse by a combination of intelligent Lander and autonomous Rover
2. Direct access to the outcrops of interest by mobile-rover and recovery to Lander
3. Characterization of the outcrops with much higher resolution (sub-mm to cm scale) and precision compared to remote-sensing (10 m to 10 km scale).
4. Control of the specimen’s surface condition with grinding/brushing.
   Free from contamination by surface bearing dusts and weathering process (cf. MER on Mars)

Route of exploration
500m
Crater Floor
Top of the Central peak
Copernicus Crater

Micro-texture of typical lunar rocks

- Basalt 70017
- Polymict Breccia 72275
- Norite 78235

Each composition of major elements is fairly similar and not discriminated from orbit.
## Proposed Instrument MIssion target and items

<table>
<thead>
<tr>
<th>Proposed Instrument</th>
<th>Mission target and items</th>
<th>Track record and/or space demonstration</th>
<th>New items to be developed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telescopic spectral camera (~ km scale)</td>
<td>Panoramic viewing and visible to near-infrared spectral profiling</td>
<td>Hayabusa/NIRS, Kaguya/LISM</td>
<td>2-axis gimbals system</td>
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<tr>
<td>Microscopic spectral camera (~ sub-mm scale)</td>
<td>Microscopic imaging by CCD and detailed description of sample texture and minerals</td>
<td>Hayabusa/ONC, Kaguya/LISM</td>
<td>Light source for landing on polar regions</td>
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<tr>
<td>X-ray fluorescence and diffractometer</td>
<td>Simultaneous in-situ chemical analysis of rock-forming elements and mineral assemblages</td>
<td>Hayabusa/XRS, Kaguya/XRS</td>
<td>Micro X-ray tube</td>
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<td>Multi-band and stereoscopic camera</td>
<td>Traverse of rover and finding of outcrops by multi-band spectroscopy</td>
<td>Hayabusa/ONC, Kaguya/LISM</td>
<td>Multi-color filter for identification of rock types</td>
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<td>gamma-ray spectrometer</td>
<td>In-situ chemical analysis of major and trace elements</td>
<td>Suzaku/HXD</td>
<td></td>
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<tr>
<td>Mid-IR spectrometer</td>
<td>Mid-infrared imaging and spectroscopy</td>
<td>Planet-C/LIR</td>
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<tr>
<td>Ground Penetrating Rader</td>
<td>Active sounding by RF pulses, investigation of sub-surface structures and regolith properties</td>
<td>Kaguya/LRS</td>
<td></td>
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</tbody>
</table>
Model Payload (1) Geology (contin.)

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<tr>
<th>Supporting elements</th>
<th>Function and operation</th>
<th>Item</th>
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<tr>
<td>Manipulator with robotic arm</td>
<td>Collection and handling device of rock and soil samples, Installation and deployment of instruments</td>
<td>New development</td>
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<td>Cutting device</td>
<td>Preparation for Inspection of rock specimen and minerals</td>
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<td>Grinder/Brushing</td>
<td>Cross section of rock samples, Removal of regolith powder and cleaning of cutoff</td>
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<td>conveyance, safekeeping, and fixation</td>
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Supporting elements include:

- **Manipulator with robotic arm**
  - Function and operation: Collection and handling device of rock and soil samples, Installation and deployment of instruments
  - Item: New development

- **Cutting device**
  - Function and operation: Preparation for Inspection of rock specimen and minerals
  - Item: New development

- **Grinder/Brushing**
  - Function and operation: Cross section of rock samples, Removal of regolith powder and cleaning of cutoff
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- **Sample container**
  - Function and operation: conveyance, safekeeping, and fixation
  - Item: New development

In the image, the science instrument package (Mini-Labo) includes:

- Four fingers pick-up arm
- Three fingers pick-up arm
- Fixing by plate spring
- Fixing table

The diagram shows:

- Grinding
- Brushing
- Microscope Imagery
- X-ray Diffraction
- Recovery
- X-ray Fluorescence
- Sample Tray
- Rotary
- Ejection

Okada et al., 2006
Model Payload (2) Geophysics

(1) Broadband seismometer (See Poster ID101 and ID59 by Lognonne et al.)
   • Investigation of crust and upper mantle structure
   • Seismicity and focal mechanism of moonquakes
(2) Heat-flow probe
   • New data point far from the Apollo sites and on different geological unit
(3) Drilling mole
   • Instrumented autonomous drilling device deployed from Lander or Rover

⇒ Installation of geophysical instruments rigidly settled into lunar regolith
⇒ Long-lived observation and subsurface thermal stability
Model Payload (3) Geodesy

(1) **Differential VLBI**
- Radio-sources onboard Lander, Rover and Relay-satellite
- Detection by ground VLBI network stations ( Receivers )
- Precise measurement of **lunar spin motion and physical libration**

(2) **ILOM (In situ Lunar Orientation Measurement)**
- Optical telescope for astrometry and selenodesy
- Precise measurement of the **pole orientation and libration** relative to the fixed stars in the sky (free from the mean motion)

(3) **Active and Passive Laser Ranging**
- Precise measurement of **Earth-Moon distance and lunar mean motion**
- Revision of lunar ephemeris and verification of general theory of relativity

⇒ Alternative methods for investigation of physical properties of the deep interior.
   (liquid core or solid core?, mass of central core, thermal structure., etc.)

[Images of Iwata et al., 2007 and Hanada et al., 2005]
Model Payload (4) Astronomy

(4) LLFAST (Lunar Low Frequency Astronomical Telescope)
- Radio-wave interferometer and detection of radiation from Sun and Jupiter
- Pilot experiment for future astronomical observatory on the Moon
- Technological demonstration of deployment telescope, autonomous and remote-operation, high-speed telemetry and communication, etc.

★SELENE-2 Geophysical package, Geodesy and Astronomical experiment
- Heritage of LUNAR-A penetrator and Kaguya gravity experiments
- Advanced technology and development for the future missions (Thermal shield, Power supply, Long-lived operation and radiation damage, etc.)
- Requirement of international collaboration for share of landing sites for constitution of network in geophysical and geodetic observations.

Iwata, 2007
In Future

• After critical review process by JAXA and Japanese planetary science community, payloads will be selected in consideration for mission objectives, system configuration, technological requirements, and technological readiness level of instruments, etc.

• Detailed examination of observation targets, landing site selection and instrument performance will be made, based on Kaguya(SELENE) mapping data and others.