月極域探査ミッション
仮称SELENE-R

2017年1月6日
橋本樹明, 星野健, 若林幸子, 大嶽久志, 大竹真紀子, 田中智, 森本仁,
増田宏一, 嶋田貴信, 須藤真緒, 井上博夏
(宇宙航空研究開発機構 国際宇宙探査推進チーム)
Lunar polar Exploration Mission

January 6 2017

Tatsuaki Hashimoto, Takeshi Hoshino, Sachiko Wakabayashi, Hisashi Otake, Makiko Ohtake, Satoshi Tanaka, Hitoshi Morimoto, Koich Masuda, Takanobu Shimada, Masataku Sutoh, Hiroka Inoue

(Japan Aerospace Exploration Agency)
Contents

- Objectives of Moon exploration
- Study of Lunar polar exploration mission
- Spacecraft design
- Technology development
- Summary
Contents

- Objectives of Moon exploration
- Study of Lunar polar exploration mission
- Spacecraft design
- Technology development
- Summary
Why do we go toward moon?

• Scientific interest and knowledge for future exploration
  – Detailed and subsurface geological observation
  – Geophysical observation to know internal structure
  – Volatile investigation
  – Moon surface environment (terrain, solar illumination, dust, radiation, soil mechanics)

• Technology demonstration
  – Safe and accurate landing
  – Surface mobility
  – Night survival
  – Return to earth (sample and return)

• Political, Outreach, Education
  – Contribute to international human moon exploration
  – HDTV, etc
Candidates of landing site

**Near side**

- **1. Pole**
  - Volatile including water
  - Human base candidate

- **2. SPA basin**
  - Lower crust and mantle material

- **3. Orientale basin**
  - Crust material

- **5. Aristarchus crater**
  - Heat source elements

- **6. Aristillus**
  - Absolute dating

**Far side**

- **1. Pole**
  - Low frequency radio astronomy

- **4. Central hill of Jackson crater**
  - Crust material

- **8. Far side**
  - Volatile including water
  - Human base candidate

**Geology**

- Suitable for geological observation to know surface material composition.
  - Sample and Return are required for detailed observation.

**Geophysics**

- Suitable for geophysical observation such as seismometer to know interior structure.

**Environment**

- Suitable for surface environment measurement and resource investigation.

**Utilization**

- Suitable for human base, astronomical observatory, or moon hotel.

---

This document is provided by JAXA.
The Global Exploration Roadmap

August 2013

ISECG
International Space Exploration Coordination Group
Common Goals and Objectives

The Global Exploration Roadmap is driven by a set of goals and supporting objectives that reflect commonality while respecting each individual agency’s priorities. They demonstrate the rich potential for exploration of each of the target destinations, delivering benefits to people on Earth. The definitions listed below remain largely unchanged and demonstrate the synergy between science and human exploration goals and objectives.

Develop Exploration Technologies and Capabilities
Develop the knowledge, capabilities, and infrastructure required to live and work at destinations beyond low-Earth orbit through development and testing of advanced technologies, reliable systems, and efficient operations concepts in an off-Earth environment.

Engage the Public in Exploration
Provide opportunities for the public to engage interactively in space exploration.

Enhance Earth Safety
Enhance the safety of planet Earth by contributing to collaborative pursuit of planetary defense and orbital debris management mechanisms.

Extend Human Presence
Explore a variety of destinations beyond low-Earth orbit with a focus on continually increasing the number of individuals that can be supported at these destinations, the duration of time that individuals can remain at these destinations, and the level of self-sufficiency.

Perform Science to Enable Human Exploration
Reduce the risks and increase the productivity of future missions in our solar system, characterizing the effect of the space environment on human health and exploration systems.

Perform Space, Earth, and Applied Science
Engage in science investigations of, and from, solar system destinations and conduct applied research in the unique environment at solar system destinations.

Search for Life
Determine if life is or was present outside of Earth and understand the environments that support or supported it.

Stimulate Economic Expansion
Support or encourage provision of technology, systems, hardware, and services from commercial entities and create new markets based on space activities that will return economic, technological, and quality-of-life benefits to all humankind.

探査技術と能力の開発
先端技術、高信頼システム、および地球環境外での効率的な運用方法の開発・試験を通じて、地球外環境での探査目的で活動するための必要な知識、技術、およびインフラを提供する。

一般市民の探索への参加
一般市民が直接的に宇宙探査に参加する機会を提供する。

地球の安全性の向上
地球外の小惑星衝突と地球上の宇宙ゴミに関する国際協力による管理システムを構築し、地球の安全性を向上させる。

人類の探索領域の拡大
地球外環境での様々な目的での探査を行いながら飛行士の人数を増やし、滞在期間を延長し、自立レベルを強化する。

有人探査を可能にするための科学研究
宇宙環境での探究機に及ぼす影響を明らかにし、太陽系における将来の探査ミッションのリスクを軽減し、効率を向上させる。

宇宙科学、地球科学、および応用科学の研究
太陽系の様々な目的地での科学研究を行うとともに、その目的地に固有な環境での応用研究を実施する。

生命の探索
地球外生命が存在するか、または存在していたかを判断し、それらの生命を維持し、または維持していた環境を把握する。

経済拡大への刺激
民間財政からの技術、システム、ハードウェア、およびサービスの提供を支援または奨励することで、宇宙活動に基づいた新規市場を創出することになる。このような活動により、経済、技術、および生活の質に関する利益を人々に還元する。

ISS Commander Chris Hadfield communicates the significance of research activities on board the station.

Manufacturing has begun on the JAXA’s Hayabusa2 flight article that is scheduled to launch in 2014.

Robo-ops is an example of how planetary surface exploration challenges engage the minds of students around the world.

ESA’s Mars Express image of the Reull Vallis region of Mars, showing a river-like structure that stretches for almost 1,500 km and is believed to have been formed long ago by running water.
Outline of GER#2
SKG summarized by ISECG (Moon)

- Strategic Knowledge Gap (SKG), that is, knowledge to reduce the risk of human exploration, is summarized in Global Exploration Roadmap (GER) ver.2.

<table>
<thead>
<tr>
<th>Knowledge domain</th>
<th>Description and Priority</th>
<th>Required mission or ground activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource potential</td>
<td>Solar illumination mapping</td>
<td>Already enough data</td>
</tr>
<tr>
<td></td>
<td>Regolith volatiles from Apollo samples</td>
<td>Ground activity</td>
</tr>
<tr>
<td></td>
<td>Regolith volatiles an organics in mare and highlands.</td>
<td>Robotic mission, Sample return</td>
</tr>
<tr>
<td></td>
<td>Lunar cold trap volatiles (water, etc.) distributed within permanently shadowed area.</td>
<td>Robotic mission, Sample return</td>
</tr>
<tr>
<td></td>
<td>Resource prospecting in pyroclastic, dark mantle deposits, etc.</td>
<td>Robotic mission, Sample return</td>
</tr>
<tr>
<td>Environment and effects</td>
<td>Radiation at the lunar surface</td>
<td>Robotic mission</td>
</tr>
<tr>
<td></td>
<td>Toxicity of lunar dust</td>
<td>Robotic mission, Sample return, Ground activity</td>
</tr>
<tr>
<td></td>
<td>Micrometeoroid environment</td>
<td>Robotic mission</td>
</tr>
<tr>
<td>Live and work on lunar surface</td>
<td>Geodetic Grid and Navigation</td>
<td>Already enough data</td>
</tr>
<tr>
<td></td>
<td>Surface Trafficability</td>
<td>Robotic mission, Ground activity</td>
</tr>
<tr>
<td></td>
<td>Dust &amp; Blast Ejecta:</td>
<td>Robotic mission, Ground activity</td>
</tr>
<tr>
<td></td>
<td>Plasma Environment &amp; Charging</td>
<td>Robotic mission</td>
</tr>
<tr>
<td></td>
<td>Lunar Mass Concentrations and Distributions</td>
<td>Already enough data</td>
</tr>
<tr>
<td>Knowledge domain</td>
<td>Description and Priority</td>
<td>Required mission or ground activity</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td><strong>Resource</strong></td>
<td>Solar illumination mapping</td>
<td>Already enough data</td>
</tr>
<tr>
<td>potential</td>
<td>Regolith volatiles from Apollo samples</td>
<td>Ground activity</td>
</tr>
<tr>
<td></td>
<td>Regolith volatiles an organics in mare and highlands.</td>
<td>Robotic mission, Sample return</td>
</tr>
<tr>
<td></td>
<td>Lunar cold trap volatiles (water, etc.) distributed within permanently shadowed area.</td>
<td>Robotic mission, Sample return</td>
</tr>
<tr>
<td></td>
<td>Resource prospecting in pyroclastic, dark mantle deposits, etc.</td>
<td>Robotic mission, Sample return</td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td>Radiation at the lunar surface</td>
<td>Robotic mission</td>
</tr>
<tr>
<td>and effects</td>
<td>Toxicity of lunar dust</td>
<td>Robotic mission, Sample return, Ground activity</td>
</tr>
<tr>
<td></td>
<td>Micrometeoroid environment</td>
<td>Robotic mission</td>
</tr>
<tr>
<td><strong>Live and work</strong></td>
<td>Geodetic Grid and Navigation</td>
<td>Already enough data</td>
</tr>
<tr>
<td>on lunar surface</td>
<td>Surface Trafficability</td>
<td>Robotic mission, Ground activity</td>
</tr>
<tr>
<td></td>
<td>Dust &amp; Blast Ejecta:</td>
<td>Robotic mission, Ground activity</td>
</tr>
<tr>
<td></td>
<td>Plasma Environment &amp; Charging</td>
<td>Robotic mission</td>
</tr>
<tr>
<td></td>
<td>Lunar Mass Concentrations and Distributions</td>
<td>Already enough data</td>
</tr>
</tbody>
</table>
我が国の月探査戦略

～世界をリードするロボット月探査と有人宇宙活動への技術基盤構築～

平成22年7月29日
月探査に関する懇談会
Supplemental Figure 1  Image of Robotic Lunar Exploration

Image of Robotic Lunar Exploration in 2015

One of candidates of lunar landing sites in 2015 (Full view of Tycho Crater)

Image of explorer's soft landing

Laser reflector
Thermal flowmeter
Magnetometer
Small power supply system for providing power at night
Seismometer
Image of internal structure exploration using seismometer, etc

Image of Robotic Lunar Exploration in 2020

Earth's direction

Candidate of landing site in 2015 (large-size crater)
Candidate of landing site in 2020 (South Pole region)

South Pole
Shackleton Crater
Mulgari Mountain

One of candidates of landing site in 2020 (Region near Shackleton Crater)
Haruyama et al., (in prep.)

2020 Image of exploration base in the South Pole region and lunar exploration robot

Image of lunar rock collection
Image of sample return

(Image materials: courtesy of JAXA)
探査推進チームとしての月探査全体シナリオ(案)

2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 ～ 2035 ～ 2040

南極水探査ミッション(無人)

水資源が相当量あった場合

水資源がなかった場合でも獲得した着陸・探査技術で科学探査を行う。

有人月面探査 技術実証デモ(HLEPP)

水資源が相当量あった場合

有人月面探査 4人/42日滞在

有人基地(居住区+推薬生成設備)構築

SLIM

補給船

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion

補給船+
Orion
Effect of usage of moon surface water for propellant (LOX/LH2)

A Without water on moon surface (Disposal lander)

B With water on moon surface (Reusable lander)

- 3rd land
- 2nd land
- 1st land

4t

Reusable lander
Lox/LH2 propellant

Propellant generation plant

Earth
Earth return capsule

Ascending module

Disposal lander

Lunar orbit

This document is provided by JAXA.
月面往復ミッションに必要な総打上げ質量 (LEO) [t]

1. ISRU無
2. ISRU有 (0.1%)
3. ISRU有 (0.5%)
4. ISRU有 (1%)
5. ISRU有 (10%)

水含有率が0.5％から1％以上あれば、6-7回以上で水を利用しない場合に比べて合計質量は小さい。
Contents

• Objectives of Moon exploration
• Study of Lunar polar exploration mission
• Spacecraft design
• Technology development
• Summary
Why do we go toward moon?

• Scientific interest and knowledge for future exploration
  – Detailed and subsurface geological observation
  – Geophysical observation to know internal structure
  – Volatile investigation
  – Moon surface environment (terrain, solar illumination, dust, radiation, soil mechanics)

• Technology demonstration
  – Safe and accurate landing
  – Surface mobility
  – Night survival
  – Return to earth (sample and return)

• Political, Outreach, Education
  – Contribute to international human moon exploration
  – HDTV, etc
International volatile exploration study

- NASA RP (Resource Prospector) mission plans to find water ice on the moon surface and mine it. RP investigates volatiles such as hydrogen, oxygen and water. JAXA started the feasibility study of the collaboration with RP since 2013. The SELENE-2 team started the conceptual study to adapt the spacecraft configuration to the RP requirements.

- Lunar volatile exploration is studied not only by NASA but also ISECG including Roscosmos, ESA, DLR, JAXA, and KARI.

- Since Japanese budgetary environment for exploration is severe, NASA is currently considering collaboration with another international partner. Therefore, JAXA thinks about Japanese own spacecraft, though possibility of international collaboration is still considered.
SELENE/RP collaboration Mission

- Spacecraft mass: 5000 kg (Wet)
- Surface payload: 340 kg
- Launch target: 2020 (TBD)

Rover (NASA)
- Near Infrared Spectrometer
- Neutron Spectrometer
- Oxygen & Volatile Extraction Node
- Lunar Advanced Volatile Analysis
- Isotope Measurement of Volatile

Launch Vehicle (NASA)
Launch vehicle selection depends on the payloads.

Landing Module (JAXA)

Propulsion Module (JAXA)

Volatile observation in Polar region

Other instruments candidates

Radiation monitor
Seismometer
Heat flow measurement
Spectro-microscope camera
Active X-ray spectrometer
Contents

• Objectives of Moon exploration
• Study of Lunar polar exploration mission
• Spacecraft design
• Technology development
• Summary
Trajectory

Lunar Orbit Insertion LOI1

GTO
LTO1
LTO2
LTO2～3

Powered Descent
## Spacecraft configuration (tentative)

<table>
<thead>
<tr>
<th>Section</th>
<th>Component</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Propulsion Module</strong></td>
<td>Bus system</td>
<td>478</td>
</tr>
<tr>
<td></td>
<td>Fuel</td>
<td>2136</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2614</td>
</tr>
<tr>
<td><strong>Lander</strong></td>
<td>Bus system</td>
<td>807</td>
</tr>
<tr>
<td></td>
<td>Rover and instruments</td>
<td>309</td>
</tr>
<tr>
<td></td>
<td>Option instruments</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Fuel</td>
<td>1229</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2386</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>5000</td>
</tr>
</tbody>
</table>

Unit: kg

Compatible with H-II-A or Falcon 9 ver. 1.1
SELENE/RP collaboration Mission

- Spacecraft mass: 5000 kg (Wet)
- Surface payload: 340 kg
- Launch target: 2020 (TBD)

**Rover**
- Near Infrared Spectrometer
- Neutron Spectrometer
- Drill
- Oxygen & Volatile Extraction Node
- Lunar Advanced Volatile Analysis
- Isotope Measurement of Volatile

**Volatile observation in Polar region**

**Landing Module**
- Radiation monitor
- Seismometer
- Heat flow measurement
- Spectro-microscope camera
- Active X-ray spectrometer

**Propulsion Module**

Launch configuration

Lunar surface configuration
(Reference) Candidate payloads on SELENE-2

Instrument candidates on Orbiter
- Electro-magnetic Sounder : LEMS
- Radio source for VLBI : VLBI
- Lunar dust monitor : LDM
- Low frequency radio astronomy : LLFAST
- Radiation monitor : PRMD-Ⅲ
- High definition TV : HDTV

Instrument candidates on Rover
- Multi-band camera : LMUCS
- Macro spectral camera : LUMI
- Science integrated package : R-SIP
- Gamma-ray and neutron spectrometer : GNS
- Active X-ray spectrometer : AXS
- Laser-induced breakdown spectrometer : LIBS
- High definition TV : HDTV

Instrument candidates on Lander
- Observation onboard lander -
  - Multi-band panoramic camera : ALIS
  - High definition TV : HDTV
- Observation on lunar surface -
  - Broadband seismometer : LBBS
  - Heat flow probe : HFP
  - Electro-magnetic sounder : LEMS
  - Radio source for VLBI : VLBI
  - Laser reflector for lunar ranging : LLR
  - Soil mechanics measurement : LSM
Site Selection Criteria for RP

- Likely subsurface volatiles
  - Sustained low subsurface temperatures conducive to volatile retention
  - Orbital neutron spectrometer hydrogen signature
- Sufficient daylight illumination
  - More than 4 Earth days of solar power for rover operations
  - Clement surface temperature for rover survival
- Suitable for Direct to Earth (DTE) communication
  - DSN stations clear the horizon
- Traversable terrain
  - Slopes < 10 deg
  - Limited density of rocks
Site Selection Criteria for SELENE-R

- For volatile investigation
  - Existence of Subsurface volatile
  - Sunlit at least several days for rover activity
  - Direct communication to Earth
  - Limited obstacles, slope < 10 deg

- For geological and geophysical observation
  - Geological interest such as ejecta from South Pole Atkin basin
  - Sunlit for several month for long time observation

Area which meets those conditions is very limited. Only a few hundred meters diameter area.
Landing site selection: Slope

Slope map

Radius 100m

1,280m

1,280m
Landing site selection: Solar illumination

- **2022 South pole** (Shorter sunshine)
- **2022 North pole** (Longer sunshine)

This document is provided by JAXA.
Contents

• Objectives of Moon exploration
• Study of Lunar polar exploration mission
• Spacecraft design
• Technology development
• Summary
Landing technology

100 x 15 km orbit

Powered descent phase

Guidance, Navigation and Control Algorithm

Propulsion system with precise control

Landing radar

Obstacle detection Hazard avoidance algorithm

Final descent control Landing gears

Vertical descent phase

Touch-down phase

This document is provided by JAXA.
## Landing technologies

<table>
<thead>
<tr>
<th></th>
<th>Heritage</th>
<th>Newly developed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propulsion system</td>
<td>Experienced 500 N</td>
<td>10 or 12 clusters of 500 N thruster</td>
</tr>
<tr>
<td>GNC algorithm</td>
<td>Basically demonstrated by SLIM</td>
<td>Modification for polar lander</td>
</tr>
<tr>
<td>Landmark navigation</td>
<td>100 m accuracy</td>
<td>Modification for weak solar illumination</td>
</tr>
<tr>
<td>Landing radar</td>
<td>Developed and demonstrated by SLIM</td>
<td>N/A</td>
</tr>
<tr>
<td>Hazard avoidance</td>
<td>Developed and demonstrated by SLIM</td>
<td>Flash LIDAR?</td>
</tr>
<tr>
<td>Landing gear</td>
<td></td>
<td>Shock absorption plate?</td>
</tr>
</tbody>
</table>
Propulsion system

• Large and accurate-controlled thrusters are required for the propulsion system of the lander.
• 12 of flight-proven 500 N thrusters are used for descent.
• Bipropellant (MON3, N2H4), Isp = 325 sec.
• Pulse firing tests are being conducted.
Laser altimeter and Landing Rader

- For vertical descent phase of landing, precise speed and altitude measurements are required.
- JAXA has the heritage of laser altimeters.
  - LALT on Kaguya: 50km～150km
  - LIDAR on Hayabusa: 50m ～50km
- JAXA has been developing a landing radar with one beam altimeter and four beams of speed meter.
  - Altitude: 10m-3.5km (precision: 0.3m or 5%)
  - Velocity: 0～50m/s (precision: 0.3m/s or 5%)
- Landing Rader will be demonstrated by SLIM project.

<table>
<thead>
<tr>
<th>Type</th>
<th>Pulse Doppler Radar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 beams for velocity</td>
</tr>
<tr>
<td></td>
<td>1 beam for altitude</td>
</tr>
<tr>
<td>Altitude</td>
<td>10m～3.5km</td>
</tr>
<tr>
<td>Velocity</td>
<td>10m～3.0km</td>
</tr>
<tr>
<td></td>
<td>0～50m/s</td>
</tr>
</tbody>
</table>

Field tests of landing radar using helicopter
Landmark optical navigation

- Landmark navigation is planned to be used for accurate pin-point landing.
- The navigation algorithm is now under study. Similar ground-based method was demonstrated while Hayabusa landing navigation.
- The landmark navigation will be demonstrated by SLIM project.
Simulated images for the landmark navigation

Landing to North Haworth (86.33S, 14.19W)

Optical landmark Nav. timing (TBD)
0. Start powered descent (15 km)
1. Waypoint (9.8 km)
2. Waypoint (5.9 km)
3. End powered descent (3.5 km)

Landing site is dark.
Simulated images for the landmark navigation
Landing to North Haworth (86.33S, 14.19W)

2020/04/09  00:00:00

Landing site is sunlit but optical nav. is difficult.

2020/04/10  00:00:00

Optical nav. is OK.
# Surface exploration technologies

<table>
<thead>
<tr>
<th>Heritage</th>
<th>Newly developed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload deployment mechanism</td>
<td>Development of slope Low-floor lander</td>
</tr>
<tr>
<td>Exploration rover</td>
<td>SELENE-2 study</td>
</tr>
<tr>
<td>Solar cell tower</td>
<td>Thin film solar cell</td>
</tr>
<tr>
<td>High performance Li ion battery</td>
<td>SELENE-2 study</td>
</tr>
<tr>
<td>Wireless power transmission</td>
<td>SSPS study</td>
</tr>
<tr>
<td>Drill</td>
<td>SELENE-2 study</td>
</tr>
<tr>
<td>Instruments</td>
<td>SELENE-2 study</td>
</tr>
</tbody>
</table>

International partners

Most of instruments must be newly developed.
# Rover deployment mechanism

## Table of Deployment Types

<table>
<thead>
<tr>
<th>#</th>
<th>Deployment type</th>
<th>Schematic picture</th>
<th>Reachable area</th>
<th>Complexity</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Slopes</td>
<td><img src="image" alt="Slopes Schematic" /></td>
<td>Good</td>
<td>Good</td>
<td>Average (Good)</td>
</tr>
<tr>
<td>2</td>
<td>Top Crane</td>
<td><img src="image" alt="Top Crane Schematic" /></td>
<td>Good</td>
<td>Average</td>
<td>Average</td>
</tr>
<tr>
<td>3</td>
<td>Elevator</td>
<td><img src="image" alt="Elevator Schematic" /></td>
<td>Poor</td>
<td>Good</td>
<td>Average</td>
</tr>
<tr>
<td>4</td>
<td>Skycrane</td>
<td><img src="image" alt="Skycrane Schematic" /></td>
<td>Excellent</td>
<td>Poor</td>
<td>Heavy</td>
</tr>
</tbody>
</table>

This document is provided by JAXA.
Rover deployment using slopes

- For redundancy, a couple of slopes are required.
- To reduce mass of the slopes, the bottom plate should be placed as low as possible.
- Reliable and light weight mechanism should be studied.
## Deployment mechanism tradeoff

<table>
<thead>
<tr>
<th>Concept</th>
<th>Wire controlled</th>
<th>Spring development</th>
<th>Sliding type</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Wire controlled concept" /></td>
<td><img src="image2" alt="Spring development concept" /></td>
<td><img src="image3" alt="Sliding type concept" /></td>
<td></td>
</tr>
<tr>
<td>mass</td>
<td>43 kg</td>
<td>60 kg</td>
<td>50 kg</td>
</tr>
<tr>
<td>Motor</td>
<td>4</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Adaptability</td>
<td>Good</td>
<td>Poor</td>
<td>Very good</td>
</tr>
<tr>
<td>Simplicity</td>
<td>Good</td>
<td>Very good</td>
<td>Medium</td>
</tr>
<tr>
<td>Total</td>
<td>Good</td>
<td>Poor</td>
<td>Good</td>
</tr>
</tbody>
</table>
• At the polar region, solar illumination depends on local terrain. Sunlit at 2 or 5 meters level is much longer than the surface.
• Light weight deployable solar cell tower is required.
Extendable solar cell tower

A. Flat panel type (need sun tracking)

B. Cylindrical type
## Laser power transmission

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission range</td>
<td>100 to 1000 m</td>
</tr>
<tr>
<td>Transmitter</td>
<td>Laser (800nm)</td>
</tr>
<tr>
<td>Diameter of Transmitter</td>
<td>Φ 100 mm class</td>
</tr>
<tr>
<td>Transmission power</td>
<td>10 to 100 W</td>
</tr>
<tr>
<td>Receiver</td>
<td>GaAs commonly used for Solar cell</td>
</tr>
<tr>
<td>Receiving power</td>
<td>More than 20 W</td>
</tr>
<tr>
<td>Diameter of receiver</td>
<td>Φ 300 mm class</td>
</tr>
</tbody>
</table>

This document is provided by JAXA.
Contents

• Objectives of Moon exploration
• Study of Lunar polar exploration mission
• Spacecraft design
• Technology development
• Summary
Summary

• JAXA thinks that the existence of lunar water ice affects exploration scenario. Therefore, measuring the existence of water ice on the surface is the top priority.

• Expanding landing technologies developed and demonstrated by SLIM, lunar polar mission is studied.
Reference (1/2)

- ISECG website: http://www.globalspaceexploration.org/
- ISECG Lunar Volatiles website: https://lunarvolatiles.nasa.gov/
- 月探査に関する懇談会: 我が国の月探査戦略
- 文部科学省宇宙開発利用部会 国際宇宙ステーション・国際宇宙探査小委員会（第16回）配付資料16-1, 第2次とりまとめ（案）, 2015/6/25,
  http://www.mext.go.jp/b_menu/shingi/gijyutu/gijyutu2/071/attach/1358968.h
- 坂井 真一郎, 澤井 秀次郎, 福田 盛介, 櫛木 賢一, 佐藤 英一, 上野 誠也, 鎌田 弘之, 北薗 幸一, 小島 広久,高玉 圭樹, 能見 公博, 樋口 丈浩,小型月着陸実証機「SLIM」プロジェクトの概要, 第60回宇宙科学技術連合講演会3C01, 函館, 2016
Reference (2/2)


- 嶋田貴信, 星野健, 若林幸子, 須藤真琢, 増田宏一, 橋本樹明, 坂本文信, 黒瀬豊敏, 久保田伸幸, 小野ゆかり, 前田修, 武内由成:月極域探査ミッション:機構系システム技術の検討状況, 第60回宇宙科学技術連合講演会2C12、函館アリーナ、函館、2016年

- 須藤 真琢, 若林 幸子, 星野 健: 月極域探査ミッション:ローバの移動機構に関する検討, 第60回宇宙科学技術連合講演会2C11、函館アリーナ、函館、2016年

- 後藤大亮、鈴木拓明、大橋一夫、田中孝治、星野健、若林幸子、大嶽久志、田中智、宗正康、西城邦俊、橋本樹明:月面極域探査ミッションにおけるレーザーエネルギー伝送システムの有効性に係わる検討, 第35回宇宙エネルギーシンポジウム、宇宙研、相模原、2016

- 若林 幸子, 星野 健: 月極域探査ミッション:月面掘削の実験的検討, 第60回宇宙科学技術連合講演会2C10、函館アリーナ、函館、2016年