Landing Targets and Technical Subjects for SELENE-2

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JAXA / JSPEC
JAXA’s Lunar Exploration

Hiten & Hagoromo 1990

SELENE ~ 2007.9

SELENE-B

JAXA 2025

SELENE-2 (Early 2010)

SAC-Lunar Explo. WG

NASA VSE

SELENE-X

Int’ Coop.

Lunar-A

Human Lunar Explo.

SELENE-2

ILEWG
Japanese Lander Concepts: SELENE-B to SELENE-2

• SELENE-B
  – Mission
    • Lunar science
  – Landing
    • Central peak of a large crater

• SELENE-2
  – Mission
    • Lunar science
    • Technology development
    • International cooperation
  – Landing:
    • Primary: ELR (Eternal Light Region) of polar region
    • Sub: Equatorial, or high latitudes

Copernicus
Central Peak

South Pole & Shackleton Crator
(D.B.J.Bussey et al)
Characteristics of new Landing Target
-- Quasi-ELR( eternal light region) --

• for long term lunar activity
  – Long term scientific observation
    – Seismology, libration, . . .
  – Future lunar activities
    – Outpost, Observatory

• Science
  – By : Long Term Seismometric Observation
  – of : Geology & Chronology, SPA
  – : Origin of Water/Ice
  – from : Astronomy

• Utilization
  – PSR is very close for water/ice ISRU
## Landing Targets for SELENE-2

<table>
<thead>
<tr>
<th></th>
<th>Polar Region (ELR)</th>
<th>Mid Lattice (Crater Central Hill)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tech. merits</strong></td>
<td>*Long term mission by solar power</td>
<td>*Direct link from ground</td>
</tr>
<tr>
<td></td>
<td>*Low temperature change</td>
<td>*Optical image role for Hazard Avoidance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>*Hot temperature during day time</td>
</tr>
<tr>
<td><strong>Science</strong></td>
<td>*Water/Ice possibility at PSR</td>
<td>*Material from lunar inside</td>
</tr>
<tr>
<td></td>
<td>*Samples from SPA</td>
<td>*SPA and far side</td>
</tr>
<tr>
<td><strong>Social</strong></td>
<td>*Inter. human lunar exploration &amp; outpost</td>
<td>*Science driven</td>
</tr>
<tr>
<td><strong>Subjects to be solved</strong></td>
<td>*Narrow Landing site</td>
<td>*Night survival for long Moon nights</td>
</tr>
<tr>
<td></td>
<td>*Low sun angle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>*Difficulty of direct comm.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>→Data relay Sat.</td>
<td></td>
</tr>
</tbody>
</table>
ELR -- what ELR is, for technology?

- Mountain top
  - Pin-point & Safe landing
    - Narrow(<1km) & Long(3,4km)
  - Rough terrain mobility
    - Slope with 15° Average
- Very low temperature thermal control
  - 100K (estimated)
- Long day time
- Low & sun angle (< 5°)

- Safe & precise landing
- Exploration around lander by rover
  - Slope Climbing
  - Survival in very low temperature
- Utilization of longer day time at ELR
  - Long term activities at landing site

2007.10.23
For Safe & precise landing

**Safe**
- Autonomous Obstacle Avoidance
  - Obstacle identification / recognition
    - Active image recognition
      » Rader altimeter & velocity meter
      » LRF
      » Flash, Star shell
  - Supervised landing control from ground

**Precise** — Navigation & Guidance
- Advanced N&G sensors
  - Image tracking
  - Altitude trace tracking
- Pin Point Control
  - Image tracking control
  - Sensors: Radio A&V
Simulated Image of Polar region

Effect of Rocks
*Surveyor 7 level rock distribution
*Sun angle : 1.5 deg
→ Shadow : 91.8%

Active sensors
Radar, LRF, Flash, Star shell
For Safe & precise landing  
-- Development of Landing RADAR

**Radar Type** | Pulse radar
---|---
**Function** | Altimeter  
| Velocitymeter  
| (Doppler RADAR)

**Range** | Altitude 30 - 10000m  
| Velocity 0 - 50m/s

**Accuracy** | 5% for Altimeter  
| 5% for Velocitymeter

**Data rate** | 5Hz

Now ready to move on to EM
For Safe & precise landing
-- Precise vertical descent control

Vertical descent scenario

- Initial error: 500m
- Rough AHA: 150m
- Precise AHA: 40m
- Constant V: 10m
- Free Fall: 2m
- Lunar Surface

Simulation
Improved vertical descent control
Results: $< \pm 4m \; 3 \sigma$

- Hovering: 10 sec at 40m altitude
- N&V sensor
  - Image Tracking
  - Touch down sensor
Rover: Exploration around lander

- **ELR area characteristic**
  - Rough terrain like mountain top
    - Surface: covered by thick regolith
    - Slope: Average 15°
    - Rock: Ejector zone of a Crater
      - Surveyer-7 level as worst case

- **Technical subjects of rover**
  - Running mechanism
    - Crawler
    - Low pressure ring tire
  - Supervised vs Autonomy
    - Little comm. time delay
    - Technology & future planet explo.
  - Moon night survival
Rover: Exploration around lander

-- Running Mechanism--

- Crawler type rover and Wheel type rover BBM is under developing

Crawler for
*next exploration
*future outpost

![Graphs showing Hill Climbing and Power Requirement for Crawler and Wheel types with load and slope inclination data.](image)
Explo

• Before landing
  – Penetrator
    • High penetrating G (>10000G)
  – Capsule with Air Bag
    • Single point of PSR surface

• After landing
  – Hopping exploration
    • Amount of fuel
  – Rover exploration in PSR
    • Survivability in PSR
  – RSIM observation from Rover on the end of Rim
    • RSIM sensor
Solar Tower: Utilization of longer day time at ELR

- **Feasibility of Solar Tower Concept**
  - Tower Height
    - Against Ground relief
    - (Against rock obstacles)

Tower Height

\[ \text{Height} = L \times \tan 3.5\text{deg} \]

- Max 3.5deg for 88 deg latitude
- Possible Objects: 15 to 30m Tower Height
- Landing Point: L: Width of ELR (250m to 500m)
## Power system: Utilization of longer day time at ELR

### Electrical Specification

<table>
<thead>
<tr>
<th></th>
<th>Power Req. kw/h</th>
<th>Total Power for a Night kw/h</th>
<th>Fuel Cell (kg)</th>
<th>RTG (kg)</th>
<th>Nuclear (kg)</th>
<th>Solar Paddle on Lunar Pole (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrical Specification</strong></td>
<td></td>
<td>400 WH/kg</td>
<td></td>
<td></td>
<td></td>
<td>11w/kg ~ 150w/kg</td>
</tr>
<tr>
<td>Unmanned Explorer (No activities in Night)</td>
<td>0.1</td>
<td>36</td>
<td>200</td>
<td>20</td>
<td>_</td>
<td>10</td>
</tr>
<tr>
<td>Unmanned Explorer (Active in Night)</td>
<td>0.5</td>
<td>180</td>
<td>400</td>
<td>100</td>
<td>_</td>
<td>50</td>
</tr>
<tr>
<td>Manned Outpost (JEM Size)</td>
<td>21</td>
<td>7560</td>
<td>(18900)</td>
<td>(4200)</td>
<td>1000</td>
<td>280 ~ 1900</td>
</tr>
<tr>
<td>Manned Base (ISS Level)</td>
<td>75</td>
<td>27000</td>
<td>(67500)</td>
<td>(15000)</td>
<td>1000</td>
<td>1000 ~ 7000</td>
</tr>
</tbody>
</table>

**Promissing Solar Paddle Tower**
-- Major technological subjects to be solved – as Concluding Remarks

• **Safe & Precise**
  – Active sensors for Obstacle recognition
  – Reliable N&G algorithm/software

• **Rover**
  – Night survival without RTG
  – Activities under very low temperature

• **Night survival**
  – Parts development & verification for –200°C to –240°C
  – Effective power resource for lunar exploration
Rover: Exploration around Lander
-- Survivability in PSR --

- **PSR is close to landing zone**
  - Long traverse from lander to PSR
    - > 10km
    - Steep slope from crater rim to floor > 30°
  - Survivability of Small rover in PSR
    - Thermal Control in ELR & PSR
    - 2 to 5 hours survival in PSR
      - with 40W continuous power consumption