Korean Pathfinder Lunar Orbiter (KPLO) Status Update

LEAG 2017

Oct 10, 2017

Gwanghyeok Ju
KPLO Program Office
KARI (Korea Aerospace Research Institute)
Agenda

• Korean Lunar Program Overview
• KPLO System & Instruments Overview
• Pre-phase A Study for Lunar Lander
• Project Status & Way Forward
Korean Lunar Program Overview

**Phase 1: Domestic Lead / International Collaboration**
- Technology demonstration for planetary exploration
- International cooperation
- Establishing deep-space network

**Payload [1st Phase]**
- Lunar science payloads (4)
- International payload (2-3)
- DTN (Delay Tolerant Network)

**Pre-phase A Study**
- Rover ground test model
- Landing site selection
- RHU/RTG for the lander mission
- Conceptual design for upper stage of launch vehicle

**Phase 2: Domestic Development**
- Science and/or Technology Demonstration?
- Landing Site Selection?
- International Collaboration still needed?
- Energy Source

**Deep Space Antenna /Ground Station**
- Deep-space antenna
- Science/Imaging data processing
- TM & TC Operation
- PDS compatible archive

**Payload [2nd Phase]**
- Space internet
- **Lunar rover**
- Scientific instruments

**LV Upper stage**
- Trans-lunar injection
- 550kg to trans-lunar orbit
1st Phase Overview

**Goal**: Enhancement of the lunar exploration technology and science

**Duration**: 2016 ~ 2020

**Budget**: 197.8B KRW (~170M USD)

**Orbit**: Polar orbit 100km

**Wet Mass**: 550kg

**Mission Life**: 1 year

**Launch**: End of 2020

**Tasks**
- System and Bus development
- Building DSN Ground-station
- Scientific Instruments (Domestic/International)
- Space Internet (DTN) demonstration
- Pre-phase A study including landing technology, rover, RTG, ISRU, site selection etc.

**KPLO Mission Objectives**

1. **Development of critical technologies for lunar exploration**
   - Developing lunar exploration technologies (Orbiter bus; Lunar orbit insertion and operation technologies; Communication and control; Navigation)
   - Construction of a ground station for the purpose of deep-space communications

2. **Scientific investigation on lunar environment**
   - Establishment of lunar topographic map for support to select future lunar landing sites
   - Survey of lunar resources and Investigation on the radiation environment and surface environment of the Moon

3. **Realization and validation of new space technology**
   - Technology demonstration and validation of space internet technology (DTN; Disruption Tolerant Network)
Collaboration with NASA

KARI
- Lunar exploration technology
- Tracking & operation technology
- Deep space communication
- Space internet

NASA
- Hosting Scientific Instruments
- Navigation & DSN support
- PDS System benchmarking

Mission Design

Launch & Tracking

Design, Development & Test

Spacecraft Control

Korean Deep Space Antenna Space Internet

NASA DSN & Operation Support

Science Instruments
- Space internet (DTN)

Navigation Support & Data Archiving
## KPLO Baseline of SDR

<table>
<thead>
<tr>
<th>Item</th>
<th>Parameter (Baseline)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch Mass</td>
<td>550kg</td>
</tr>
<tr>
<td>Power @ EOL</td>
<td>760 Watt, (1-wing, 2-axis gimbal S/A) w/ unregulated 28V</td>
</tr>
<tr>
<td>Mission Life</td>
<td>1 Month (Trans-lunar) + 1 Year (on-orbit)</td>
</tr>
<tr>
<td>Lunar Transfer Trajectory</td>
<td>Phasing Loop Transfer</td>
</tr>
<tr>
<td>Propulsion System</td>
<td>Monopropellant System</td>
</tr>
<tr>
<td></td>
<td>OMT : 30N x 4</td>
</tr>
<tr>
<td></td>
<td>ACT : 5N x 4</td>
</tr>
<tr>
<td>Mission Orbit</td>
<td>Lunar Polar Orbit</td>
</tr>
<tr>
<td></td>
<td>100 ± 30km, Incl. 90° ± 1°</td>
</tr>
<tr>
<td>Communication</td>
<td>CCSDS compatible</td>
</tr>
<tr>
<td></td>
<td>S-band(uplink) : 500bps@LGA, 1kbps@HGA</td>
</tr>
<tr>
<td></td>
<td>S-band(downlink) : 512bps@LGA, 8.192kbps@HGA</td>
</tr>
<tr>
<td></td>
<td>X-Band(downlink) : 5Mbps@HGA (tbd)</td>
</tr>
<tr>
<td>Pointing Accuracy</td>
<td>0.1°</td>
</tr>
<tr>
<td>Ranging</td>
<td>OD: &lt; 660m/300m (RMS/radial) (1sigma)</td>
</tr>
<tr>
<td></td>
<td>OP: &lt; 6km/1km/1km (along/cross/radial) (1sigma)</td>
</tr>
<tr>
<td>Reliability</td>
<td>0.7[TBD]</td>
</tr>
</tbody>
</table>
KPLO Configuration

**Stowed**

**Deployed**

+X

+Y

+Z, Nadir (MOON)
KPLO Scientific Instruments: Scientific Objectives

- **LUTI**
  - Obtain high-resolution images (possibly stereo) of future landing sites (2nd stage lunar mission)
  - Target observation of interesting places on the Moon

- **PolCam**
  - Polarimetric imaging survey of the entire lunar surface except for the pole regions at various phase angles (0°~120°) and spectral bands (320, 430, 650nm) → First polarimetric map of near-/far-side of the moon
  - Investigate the characteristics of lunar regolith and Ti contents (varying latitude, longitude, mare & high-lands)

- **KMAG**
  - Investigate the origin of the crustal magnetism of the Moon (Impact/Dynamo etc)
  - Characteristics of the lunar magnetic anomalies

- **KGRS**
  - Map the distribution of major elements (Mg, Ni, Cr, Ca, Al, Ti, Fe, Si, O, U, He-3, Water) on the lunar surface and the beneath of the surface (up to 50cm)
  - Geological and geochemical activities of the Moon
  - Obtain radiation map of lunar environment

- **ShadowCam**
  - Map albedo patterns in PSRs and interpret their nature
  - Map the morphology of PSRs to search for and characterize landforms that may be indicative of permafrost-like features
  - Provide hazard and traversability information within PSRs for future landed elements
## KPLO Scientific Instruments: Features & Specifications

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Layout</th>
<th>Features</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUTI (KARI+)</td>
<td><img src="image1.png" alt="Image" /></td>
<td>High dynamic range EO Cassegrain type telescope Push broom camera w/ linear CCD (450-850nm)</td>
<td>Mass: &lt;15kg</td>
</tr>
<tr>
<td>PI: Haeng Huh</td>
<td><a href="image2.png">Image</a></td>
<td></td>
<td>GSD: 5m at 100km</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Swath: 8km</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MTF: 10%</td>
</tr>
<tr>
<td>PolCam (KASI+)</td>
<td><img src="image3.png" alt="Image" /></td>
<td>Push broom scanning Polarimetric &amp; photometric measurement</td>
<td>Mass: 3kg. FOV: 10deg</td>
</tr>
<tr>
<td>PI: Young Choi</td>
<td><a href="image4.png">Image</a></td>
<td></td>
<td>Polar: 430, 650nm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Photo: 320nm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Data: ~8Gbits/day</td>
</tr>
<tr>
<td>KGRS (KIGAM+)</td>
<td><img src="image5.png" alt="Image" /></td>
<td>Gamma-ray detector LaBr3 main detector BGO/PS shielding detector</td>
<td>Mass: 5kg</td>
</tr>
<tr>
<td>PI: Kyeong Kim</td>
<td><a href="image6.png">Image</a></td>
<td></td>
<td>Energy range: 0.03-10MeV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Energy res: &lt; 4% @ 661 keV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Data: 25.Gbits/day</td>
</tr>
<tr>
<td>KMAG (KHU+)</td>
<td><img src="image7.png" alt="Image" /></td>
<td>Boom/Hinge/Actuator Flux Gate Magnetometer sensor Measuring the magnetic field closer to lunar surface (&lt;70 km)</td>
<td>Mass: 3.5kg, Length: 1550mm</td>
</tr>
<tr>
<td>PI: Ho Jln</td>
<td><a href="image8.png">Image</a></td>
<td></td>
<td>Measure range: ± 1000 nT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Resolution: &lt; 0.05 nT at 10 Hz</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Data: &lt; 291Mbit/day</td>
</tr>
<tr>
<td>NASA ShadowCam</td>
<td><img src="image9.png" alt="Image" /></td>
<td>LRO NAC heritage w/ Ti adapter TDI detector(~3000 pixels with 1 28 TDI lines) 800x sensitivity</td>
<td>Mass: &lt;15kg</td>
</tr>
<tr>
<td>(ASU)</td>
<td><a href="image10.png">Image</a></td>
<td></td>
<td>Resolution: 1.7m@100km</td>
</tr>
<tr>
<td>PI: Mark Robinson</td>
<td></td>
<td></td>
<td>SNR: &gt;100</td>
</tr>
</tbody>
</table>

### Notes:
- **PI** denotes the Principal Investigator.
- **GSD** stands for Ground Sample Distance.
- **MTF** stands for Modulation Transfer Function.
- **FOV** stands for Field of View.
- **Data** refers to the daily data transmission rate.
Space Internet

Objective

- Establish DTN (Delay Tolerant Network) for Space Internet between GS, Orbiter, Lander & Rover
- Apply Mobile/Satellite Communication Network Standard to Lunar Network
- Maximize IT-based Strong Potentials from Mobile Communication Industry

Diagram:

- International Space Station node
- Earth
- DTN
- DSN
- MOC DTN node
- International Spa Verification Env
- Orbiter
- DTN+Proximity-1
- DTN nodes
  - DTN Control Center (DCC)
  - DTN Payload (DTNPL)
  - Lander Communication Model (LCM)
  - Rover Communication Model (RCM)
- Non DTN nodes
  - Mission Operation Center (MOC)
  - Korea Deep Space Antenna (KDSA)
Ground Segment

KARI Ground System

KDSA

Planning & Dynamics Element (PDE)
- Mission Planning Subsystem (MPS)
- Flight Dynamics Subsystem (FDS)
- Dynamic System Simulator (DSS)

Image Cal & Sci. Management Element (ISE)
- Planetary Data Subsystem (PDS)
- Science Data Management (SDM)
- Image Calibration and Analysis (ICA)

Comm. & Operation Element (COE)
- TT&C
- Real Time Operation Subsystem (ROS)

External Ground Station
- DSN
- NEN
- USN

ETRI
- DTN Node(s)

USERs
Keumsan Satellite Communication Center

- KTSat Satellite communication Center (50km South-East from KARI, Daejeon)
- 27.4m Antenna with Cassegrain Optic
  - Since 1976
  - Manufacturer: Philco Ford
Conceptual Design by Pre-phase A Study

RHU Design/Analysis

- Preliminary Design
- Structural Optimization
- Impact Analysis
- Thermal Analysis
Research Topics supported by Pre-phase A Study

**Lunar Mapping Tool & Archive**
- Lunar Image Generation Tool Development
- Korean PDS Buildup compatible with NASA PDS & ESA PSA

**Landing Site Selection**
- Illumination & Communication Conditions Analysis for Target Site Using the Previous Lunar Images from KPLO, LRO & KAGUYA, or its combinations
- Finding Ideal Site for proper scientific objectives
- Finding optimal imaging area in order to obtain the optimum imaging schedule with high res.
- Landing Site Risk Analysis

**Landing GNC & Rover Technology**
- Sensing & Perception : 3D Sensing, Onboard Mapping, Onboard Science Data Analysis
- Mobility & Manipulation : Extreme-Terrain Mobility, Robot Navigation with Localization
- Autonomy : Autonomous Targeting, ALHAT(HAD, TRN), Activity Planning, Scheduling & Execution
- Modeling & Simulation : Touchdown Dynamics, Landing Modeling & Simulation

**Evaluation Platform**
- Lunar Lander Demonstrator Setup
- Landing Site General Assessment Software Tool Development
- End-to-End Performance Simulator Setup for KPLO & Lunar Lander
- Lunar Science Research & Strategic Knowledge Gap Formulation
Landing Site Survey associated w/ Instrument Candidates

**Lunar Characterization & History**

- **Mineralogical Composition and Tetrology & Chronological Measurement (VIS/IR Hyperspectral Camera, X-ray Spectrometer):** Nectaris basin (35°S, 42°E), Orientale impact melt (South pole), Copernicus floor (10°N, 20°W), King rim (5.5°N, 121°E), Ancient crust (30°N, 160°E), Aitken basin (21.5°S, 160°W)

- **Lunar Volatile Investigation:** (MWIR Spectrometer): Orientale impact melt (South pole)

- **Meteorite Impact Study (Camera):** Tsiolkovskiy (20°S, 130°E)

**Lunar Science & Environments**

- **Terrain Investigation (Panoramic Camera):** Landing Sites incl. Apollo Sites

- **Lunar Dust & Water Study (LIDAR, Spectrometer):** Polar shadows (near each pole), dawn/dusk

- **Lunar Surface Environment Change Study by Solar & High Energy Particles**

- **Magnetic Field Investigation & Plasma & Radiological Environment Measurements:** Reiner Gamma (7.5°N, 59°W), Marginis swirls (15°N, 90°E)

**Investigation on Lunar Mineral Resources**

- **Uranium (gamma ray spectrometer):** KREEP Enriched region, high abundance of U, Th, K

- **He-3 (wide band & gamma-ray spectrometer):** Exploration of He-3 at the region where high deposition of Solar particles, measurement of Ilmenite mineral abundance

- **Lunar Volatiles:** Utilization of gases, which are accumulated at the lunar surface by solar wind, for construction of a lunar base

- **Si, Al (XRS, GRS):** Obtaining Si and Al from feldspar enriched area in the highland region

- **REE (XRS, NS, GRS):** Exploration of KREEP material enriched region
## KPLO Programmatic Status Update

### Milestone
- KPLO Program Plan Approval (Dec 2014)
- Program Start (Jan 2016)
- Kick-Off Meeting (Mar 2016)
- Science Payload Selection (Apr 2016): 3 Scientific Instruments + 1 KARI camera
- Mission Design Review (Apr 2016)
- System Requirements Review (July 2016)
- System Design Review (Dec 2016)
- System Preliminary Design Review (Sep 2017)

### International Collaboration
- KARI-JPL TAA Signup (Oct 2015)
- KARI-NASA SSERVI Agreement Signup (Dec 2015)
- KARI-NASA LOI (May 2015) & MOU Signup (Dec 2016)
- NASA Instrument AO (Sep 2016), RFI (Dec 2016) & Final Selection (Spring 2017)
- KARI-NASA Face-to-Face Meeting (March 2017, JSC)
- KARI-NASA Instrument PI Meeting (June 2017, KARI)
Way Forward

- Optimize the operational schedule to meet requirements and scientific objectives of all scientific instruments.
- Try to implement additional collaborative framework in terms of image processing and science data archiving with international compatibility and interoperability such as PDS & SPICE, etc.
- Pursue to keep pace with Lunar Strategic Knowledge Gaps (STGs) through ISECG.
- Keep up with landing site selection study.
- Develop design & analysis tool based on open sources as possible.
- Hope to develop future collaborative exploration (or planetary science) mission.
- Try to reflect Korean lunar landing mission and international collaborative exploration mission(s) to the National Space Development Plan to be updated by the end of 2017.
Fly to the Moon