Korean Pathfinder Lunar Orbiter (KPLO) Status Update

LEAG 2017

Oct 10, 2017

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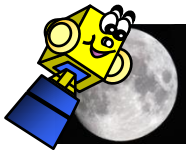
KPLO Program Office
KARI (Korea Aerospace Research Institute)

Agenda

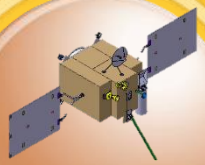


- Korean Lunar Program Overview
- KPLO System & Instruments Overview
- Pre-phase A Study for Lunar Lander
- Project Status & Way Forward

Korean Lunar Program Overview

Phase 1: Domestic Lead / International Collaboration

- Technology demonstration for planetary exploration
- International cooperation
- Establishing deep-space network



Pathfinder Lunar Orbiter (KPLO)

KARI

NASA

Phase 2: Domestic Development

- Science and/or Technology Demonstration ?
- Landing Site Selection ?
- International Collaboration still needed ?
- Energy Source

Lunar Orbiter

Lunar Lander

Payload [1st Phase]

- Lunar science payloads (4)
- International payload (2-3)
- DTN (Delay Tolerant Network)

Deep Space Antenna /Ground Station

- Deep-space antenna
- Science/Imaging data processing
- TM & TC Operation
- PDS compatible archive

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

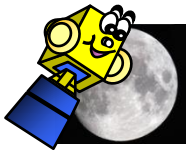
Payload [2nd Phase]

- Space internet
- **Lunar rover**
- Scientific instruments

LV Upper stage

- Trans-lunar injection
- 550kg to trans-lunar orbit

1st Phase Overview



Program 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)

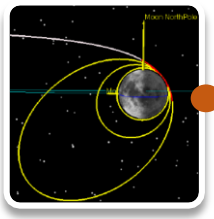
Collaboration with NASA

KARI

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

Hosting Scientific Instruments
Navigation & DSN support
PDS System benchmarking

NASA



Mission Design

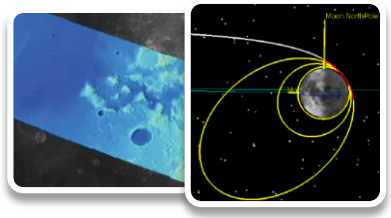
Launch & Tracking

Design, Development & Test

Spacecraft Control

Korean Deep Space Antenna
Space Internet

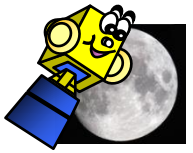
NASA DSN & Operation Support



Navigation Support & Data Archiving

Science Instruments
Space internet (DTN)

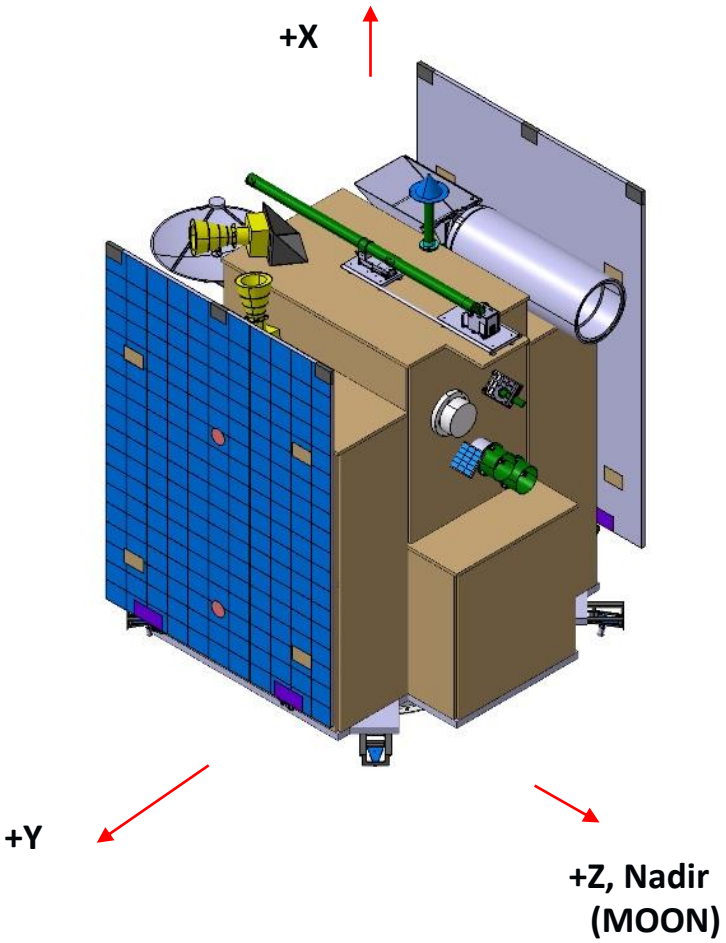
KPLO Baseline of SDR



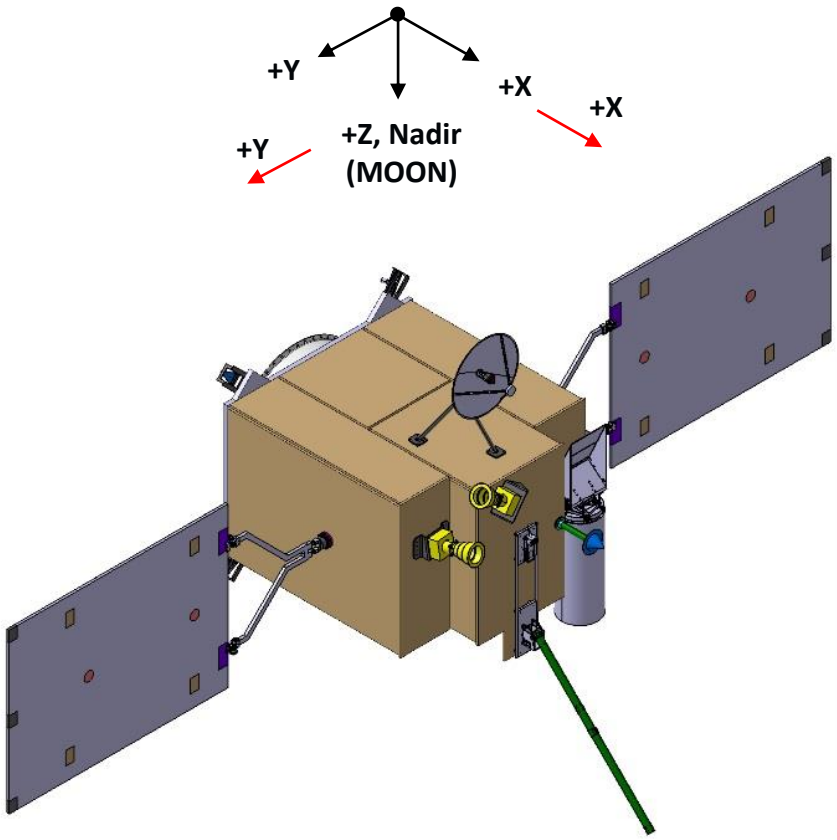
Item	Parameter (Baseline)
Launch Mass	550kg
Power @ EOL	760 Watt, (1-wing, 2-axis gimbal S/A) w/ unregulated 28V
Mission Life	1 Month (Trans-lunar) + 1 Year (on-orbit)
Lunar Transfer Trajectory	Phasing Loop Transfer
Propulsion System	Monopropellant System OMT : 30N x 4 ACT : 5N x 4
Mission Orbit	Lunar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

KPLO Configuration

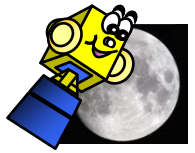
Stowed



Deployed

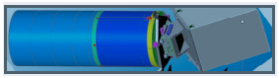


KPLO Instruments Accommodation

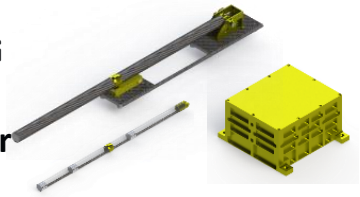


Star Tracker

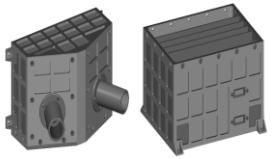
Shadow Cam

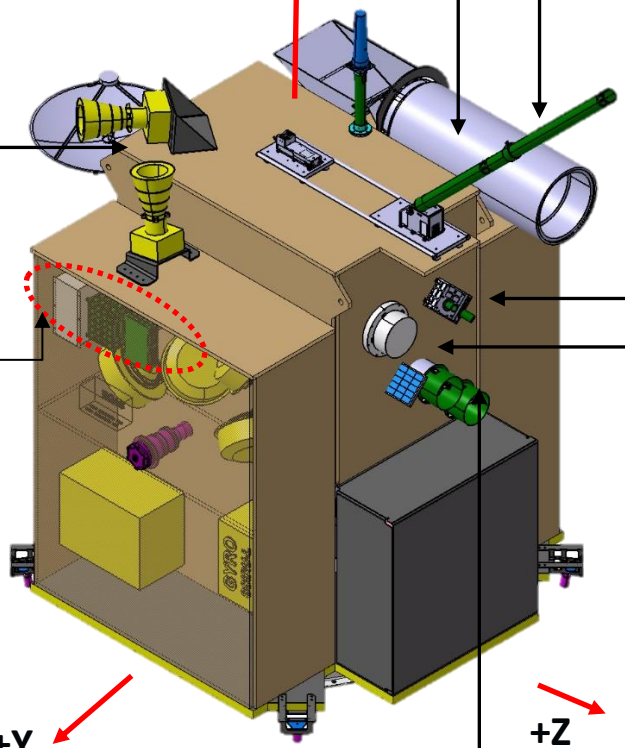


KMAG Boom (Sensor incl.)



+X

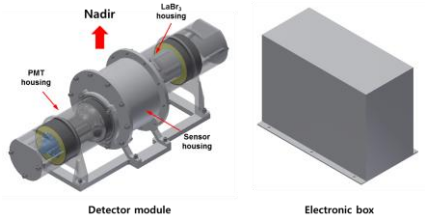




Polcam Assy. (Optical Head)

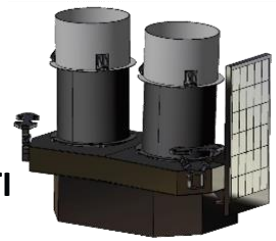
DTNPL /Polcam /KGRS EU-Boxes (Panel inside)

KGRS Assy. (Sensor)



+Y

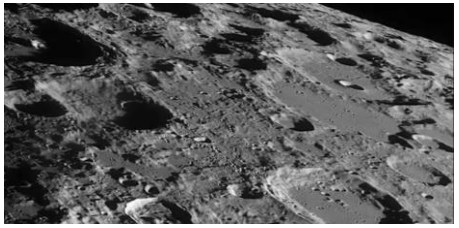
+Z



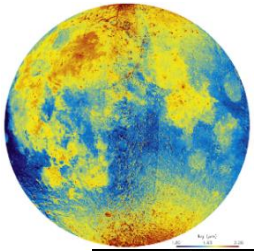
LUTI

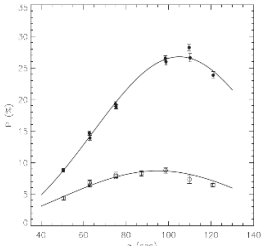
KPLO Scientific Instruments : Scientific Objectives

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

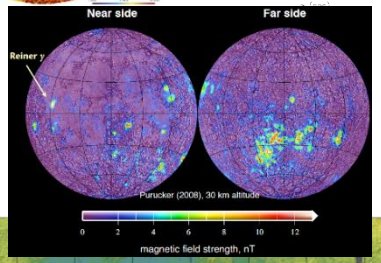


- **PolCam**
  - Polarimetric imaging survey of the entire lunar surface except for the pole regions at various phase angles (0°~120°) and spectral bands (320, 430, 650nm) → First polarimetric map of near-/far-side of the moon
  - Investigate the characteristics of lunar regolith and Ti contents (varying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

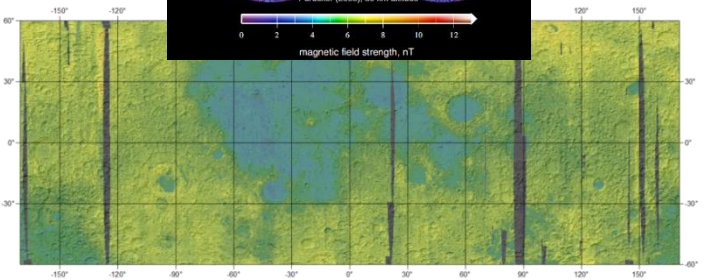




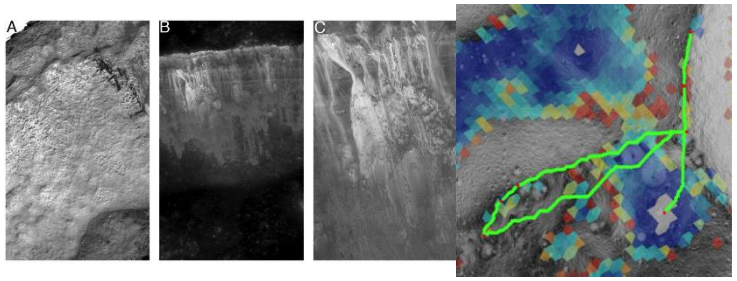
- **KMAG**
  - Investigate the origin of the crustal magnetism of the Moon (Impact/Dynamo etc)
  - Characteristics of the lunar magnetic anomalies



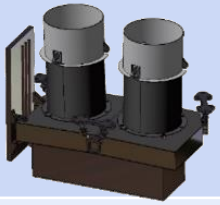
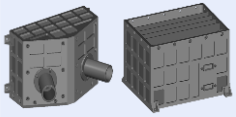
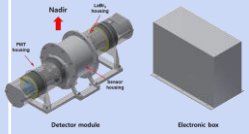
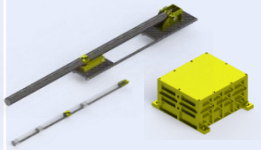
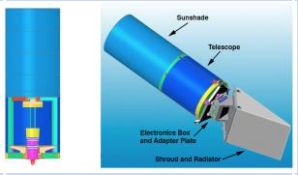
- **KGRS**
  - Map the distribution of major elements (Mg, Ni, Cr, Ca, Al, Ti, Fe, Si, O, U, He-3, Water) on the lunar surface and the beneath of the surface (up to 50cm)
  - Geological and geochemical activities of the Moon
  - Obtain radiation map of lunar environment



- **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



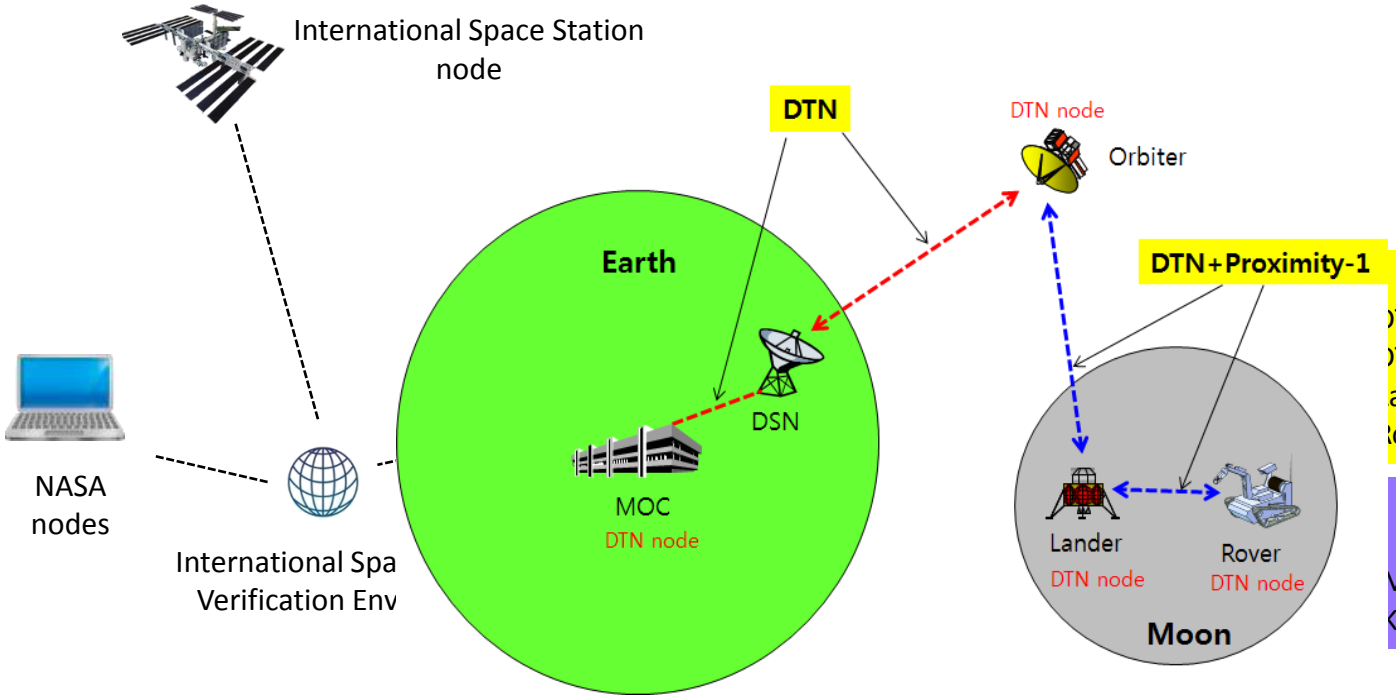
KPLO Scientific Instruments : Features & Specifications

Instrument	Layout	Features	Specifications
LUTI **(KARI+)** **PI : Haeng Huh**		High dynamic range EO Cassegrain type telescope Push broom camera w/ linear CCD (450-850nm)	Mass : <15kg GSD : 5m at 100km Swath : 8km MTF : 10%
PolCam **(KASI+)** **PI : Young Choi**		Push broom scanning Polarimetric & photometric measurement	Mass : 3kg. FOV : 10deg Polar : 430, 650nm Photo : 320nm Data : ~8Gbits/day
KGRS **(KIGAM+)** **PI : Kyeong KIm**		Gamma-ray detector LaBr3 main detector BGO/PS shielding detector	Mass : 5kg Energy range : 0.03-10MeV Energy res : < 4% @ 661 keV Data : 25.Gbits/day
KMAG **(KHU+)** **PI : Ho JIn**		Boom/Hinge/Actuator Flux Gate Magnetometer sensor Measuring the magnetic field closer to lunar surface (<70 km)	Mass : 3.5kg, Length : 1550mm Measure range : ± 1000 nT Resolution : < 0.05 nT at 10 Hz Data : < 291Mbit/day
NASA **ShadowCam** **(ASU)** **PI : Mark Robinson**		LRO NAC heritage w/ Ti adapter TDI detector(~3000 pixels with 128 TDI lines) 800x sensitivity	Mass : <15kg Resolution : 1.7m@100km SNR : >100

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



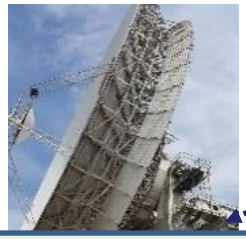
DTN nodes

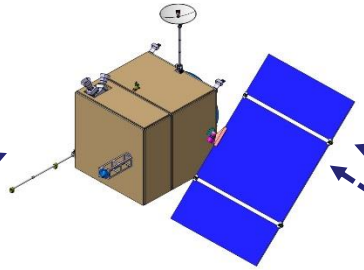
- DTN Control Center (DCC)
- DTN Payload (DTNPL)
- Lander Communication Model (LCM)
- Rover Communication Model (RCM)

Non DTN nodes

- Mission Operation Center (MOC)
- Korea Deep Space Antenna (KDSA)

Ground Segment





KARI Ground System

KDSA

Comm. & Operation Element (COE)

- TT&C
- Real Time Operation Subsystem (ROS)

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)

External Ground Station

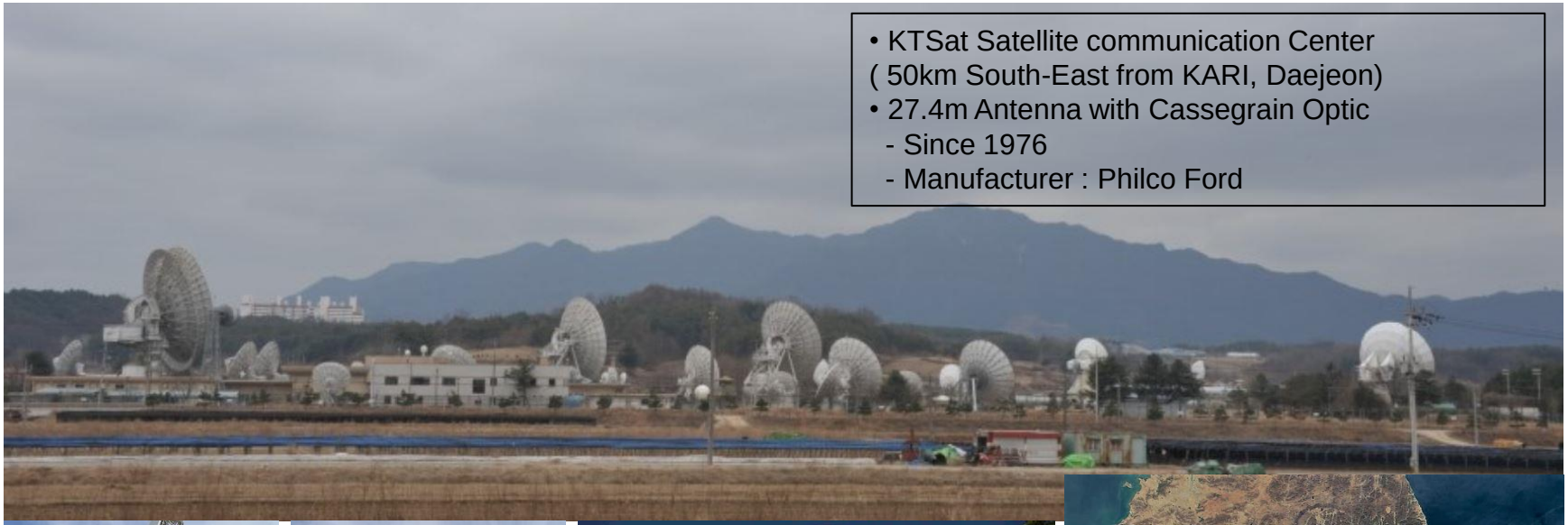
- DSN
- NEN
- USN

ETRI

- DTN Node(s)

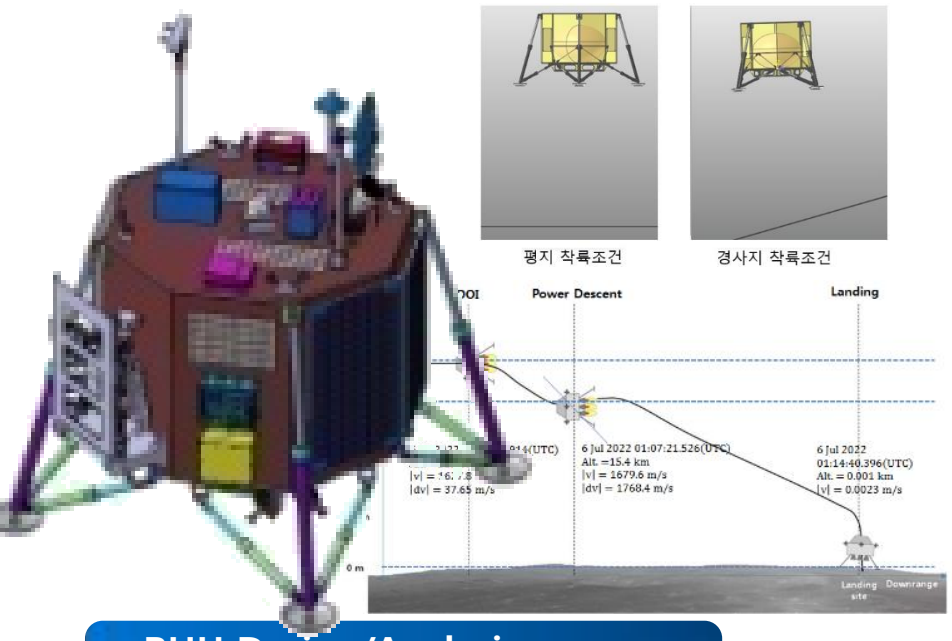
USERs

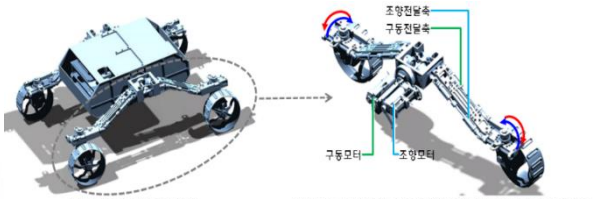
Keumsan Satellite Communication Center



- 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

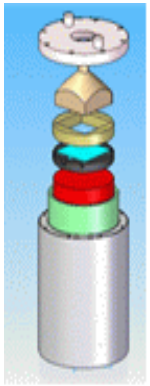




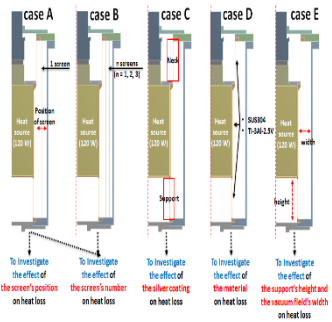
〈로버DM 기본설계 형상〉
〈이중축 동력전달 구조 전/후축 연동조향/동력전달 구조〉

RHU Design/Analysis

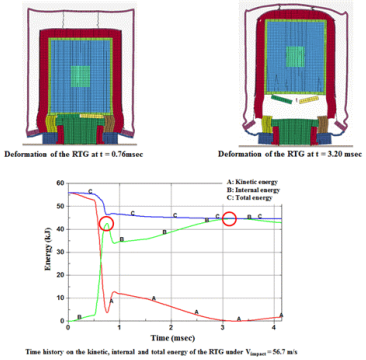
Preliminary Design



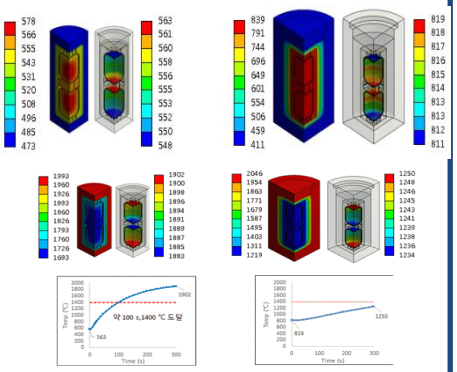
Structural Optimization



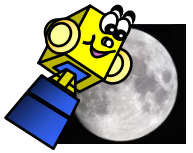
Impact Analysis



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

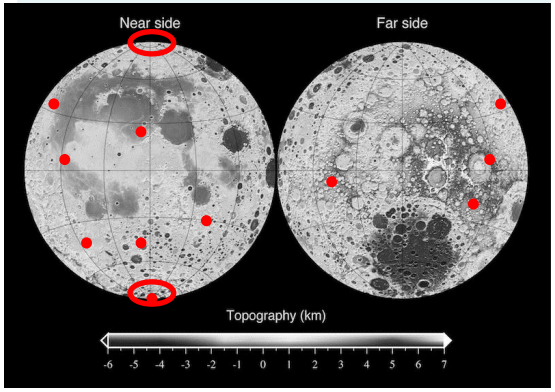
Evaluation Platform

- 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 Candidate

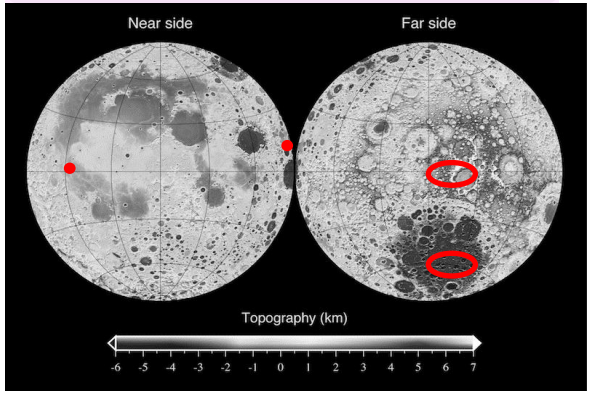
Lunar Characterization & History

- **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)



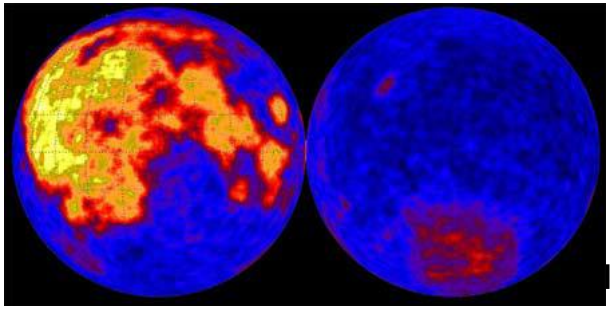
Lunar Science & Environments

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

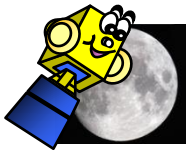


Investigation on Lunar Mineral Resources

- **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



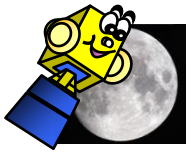
Milestone

- 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-NASA Robotic Lunar Feasibility Study Agreement (July 2014) & Study Report (Apr 2015)
- 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