KIGAM’s new direction for lunar science and exploration in conjunction with lunar and planetary ISRU

Kyeong Ja Kim
Geological Research Division
Korea Institute of Geoscience and Mineral Resources (KIGAM)
KIGAM’s new direction

• Introduction to KIGAM
  – National Institute (Geological and Mineral Resources)
  – Established in 1918 (https://www.kigam.re.kr)

• Previous Planetary Research
• Current Building of New Research
• Important in ISRU Work
• International Collaboration
Planetary Surface Investigations

- **Moon**: Chang’e-3 & 4, Surveyor 5-7, SELENE-R, Chandrayaan-2, KLE
- **Mars**: Viking, Mars 96, Phobos, Mars Pathfinder, Mars Exploration Rover
- **Venus**: Ventra
- **Asteroids & Comet**: Rossetta

Surveyor 5-7  | Viking1 | Viking 2 | Ventra 8 (G) | Ventra 9 (G) | Ventra 10(G) | Ventra 13


Pathfinder  | MER     | Curiosity (N, X) | Chang’e-3 | Rossetta | Chandrayaan-2 | Chang’e-4


*Horizon 2061_2019*
NASA’s Future Plan to visit Mars

Phase 0
Continue research and testing on ISS to solve exploration challenges. Evaluate potential for lunar resources. Develop standards.

Phase 1

Phase 2
Complete Deep Space Transport and conduct yearlong Mars simulation mission.

Phase 3 and 4
Begin sustained crew expeditions to Martian system and surface of Mars.

Now
Using the International Space Station

2020s
Operating in the Lunar Vicinity (proving ground)

After 2030
Leaving the Earth-Moon System and Reaching Mars Orbit
NASA’s Lunar Orbital PlatForm-Gateway

GATEWAY
A spaceport for human and robotic exploration to the Moon and beyond

HUMAN ACCESS TO & FROM LUNAR SURFACE
Astronaut support and teleoperations of surface assets.

U.S. AND INTERNATIONAL CARGO RESUPPLY
Expanding the space economy with supplies delivered aboard partner ships that also provide interim spacecraft volume for additional utilization.

SAMPLE RETURN
Pristine Moon or Mars samples robotically delivered to the Gateway for safe processing and return to Earth.

INTERNATIONAL CREW
International crew expeditions for up to 30 days as early as 2024. Longer expeditions as new elements are delivered to the Gateway.

SCIENCE AND TECH DEMOS
Support payloads inside, affixed outside, free-flying nearby, or on the lunar surface. Experiments and investigations continue operating autonomously when crew is not present.

COMMUNICATIONS RELAY
Data transfer for surface and orbital robotic missions and high-rate communications to and from Earth.

GATEWAY SPECS
- 4 Crew Members
- 30-90 Day Crew Missions
- 125 m² Pressurized Volume
- Up to 75mt with Orion docked
- 384,000 km from Earth

ACCESS
Accessible via NASA’s SLS as well as international and commercial ships.

SIX DAYS TO ORBIT THE MOON
The orbit keeps the crew in constant communication with Earth and out of the Moon’s shadow.

A HUB FOR FARTHER DESTINATIONS
From this orbit, vehicles can embark to multiple destinations: The Moon, Mars and beyond.


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NASA’s Artemis Moon Program

https://www.nasa.gov/sites/default/files/thumbnails/image/human_landing_system_2024_surface_astronauts_0.jpg

Horizon 2061_2019
Artemis Moon Program

Achieving 2024 – A Parallel Path to Success

Artemis will see government and commercial systems moving in parallel to complete the architecture and deliver the Moon landing system.

Artemis 1

First flight test of SLS and Orion as an integrated system.

Artemis 2

First flight of crew to the Moon aboard SLS and Orion.

Artemis 3

First crew to the lunar surface; Logistics delivered for 2024 surface mission.

Between now and 2024, U.S. industry delivers the launches and human landing system necessary for a faster return to the Moon and sustainability through Gateway.

Commercially Provided Elements

PPE

Power Propulsion Element arrives at NRHO via commercial rocket.

Crew Module

Small pressurized crew module launches to Gateway on a commercial rocket.

Human Landing System

Transfer

Transfers lander from Gateway to low lunar orbit.

Descent

Descends from Transfer vehicle to lunar surface.

Ascent

Ascents from lunar surface to Gateway.

Up to three commercial rocket launches, depending on distribution of the Transfer, Descent, and Ascent functions.

ISRU Work History at KIGAM

- **ISRU Prospecting History**
  - KPLO gamma-ray spectrometer FM development in 2019
  - Lunar gamma-ray spectrometer, neutron spectrometer EM developed 2018
  - PM model of Active X-ray Spectrometer developed in 2012
  - Nuclear science payload development since 2010

- **ISRU Extraction History**
  - Mining, reprocessing & refining materials (Earth surface and sea floor/sea water)
  - Planetary resources research since 2009

- **Participating in Planetary Missions & International Collaborations**
  - Mars Odyssey(GRS), SELENE-1(GRS), SELENE-2 pre-project (AXS), KPLO (GRS)
Payload Development at KIGAM

- Lunar Exploration (2016-2020)
  - KPLO GRS (KGRS)
- Space Core Technology Program (2015-2018)
  - GRS (HPGe)
  - NS
- Internal Program at KIGAM (2012-2014)
  - GRS
  - XRS
- Payload Development for Planetary Exploration (2010-2017)
  - Active X-ray Spectrometer (KARI’s Consigned Project) (2010-2012)
  - EU of XRS by KIGAM’s Internal Project (2017)
Elemental maps for previous lunar orbiters

Apollo 15 & 16

Th

Taylor, G. J., 2009

Apollo Gamma-ray Spectrometer
Thorium Abundance

Apollo Gamma-ray Spectrometer
Iron Abundance

Lawrence et al. 1998

Hasebe et al. 2009

Lunar Prospector

SELENE-1 (Kaguya)

Chang’e-2 Th map

Oriental Basin (K)

Zhu et al. 2013

CE

GRS

CE

GRS
Comparison of lunar GRS Instruments

- **X-ray & Low γ**
  - Chandrayaan-1 (CZT) 0.03
  - Chang’E-2 (LaBr₃)
  - Chang’E-1 (CsI(Tl))
  - SELENE-1 (Ge)
  - Lunar Prospector (BGO)
  - Apollo 15/16 (NaI(Tl))

**Lunar GRS Payloads**

**New**
Future ISRU Investigation on Moon

• **GRS from an Orbit**
  - Apollo 15/16, Lunar Prospector, Kaguya, Chang’e 1 & 2, **KPLO**
  - Global Elemental Mapping
  - Geology & Resources (new discovery desirable)

• **GRS from the Surface (PGNAA)**
  - In-Situ GRS
  - A neutron source and compact GRS required
  - Elemental mapping for a local area
Lunar ISRU & Landing Site, Moon

$^3$He [ppb] from $M^3$ TiO$_2$ and Clementine OMAT

Kim et al. 2019 PSS
Massive underground tunnels on the Moon

The Marius Hills pit, spotted in 2009 by scientists at the Japan Aerospace Exploration Agency (JAXA). The pit stretches 65 meters across and could be a skylight leading down to a lava tube, the scientists say. Credit: NASA/GSFC/Arizona State University

https://www.ancient-code.com/scientists-find-massive-underground-tunnels-on-the-moon/

Comparison of Lunar Pit & Manjang Cave, Jeju

Entrance of Manjang Cave, Jeju

https://images.app.goo.gl/iz1W4WbS3Ydu5dbr8

Image of a possible skylight pit in the Marius Hills, taken by the Lunar Reconnaissance Orbiter Camera. (NASA/Goddard Space Flight Center/Arizona State University)

https://www.newsmax.com/thewire/moon-cave-home-lunar-colonists/2017/10/20/id/820943/

http://findjeju.blogspot.com/2015/12/blog-post_17.html
Proposed Areas of ISRU at KIGAM

- **ISRU Prospecting: Instruments**
  - To detect/identify major & minor elements including water, volatile, REE, gases
    - Gamma-ray spectrometer
    - Neutron spectrometer
    - AXS (AXPS)
    - Mini-LIBS
    - Mass Spectrometer
    - Micro Spectrometer
    - Spectral Imager
    - Surface profiler (GPR)

- **ISRU Resource Extraction**
  - Gas extraction
    - Volatiles
    - Other gases
    - Remaining materials
  - Mineral Extraction
  - Material construction
IBS Underground Facility

예미산 (해발 998m)

인승용케이지 (길이 600m)

지하실험실

진입터널 (길이 782m)

한덕철광

지상연구실

토피고 1100m
Suggested Research Activities

➢ Growing vegetables and grains underground
➢ Check health & behavior of mice underground
➢ Check radiation safety underground from the natural radioactivity
➢ Examine living condition underground
➢ Living in subterranean environment (adaptation)

20,000 people lived, 250 feet, 15th BCE

Derinkuyu

https://mymodernmet.com/derinkuyu-underground-city/


EARTH–MOON–MARS ECONOMY

- SETTLERS, HEAVY EQUIPMENT
  - C, H, N (ammonia, methane)
  - Volatiles needed by Moon

- BUILDING MATERIALS
  - HELIUM–3 SOLAR ENERGY
    - OXYGEN, WATER, FOOD, FURNISHINGS

- SETTLERS, LIGHT EQUIPMENT AND SEEDS
  - Volatiles lacking on Moon

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<우주탐사 추진 로드맵>

1단계
- 시험용 달 궤도선
  - 해외발사체 이용
  - 국제협력 기반 행성탐사 기술 도입

2단계
- 달 착륙선 자력 발사
  - 한국발사체 이용
  - 독자적 행성탐사 기술기반

3단계
- 소행성 샘플 귀환선 자력 발사
  - 한국발사체 이용
  - 도킹, 지구재진입 등 행성탐사 전략기술 검증

- 제안된 응용 연구

전략기술 조기확보 추진
- 도킹, 지구재진입 등 고난도도 전략기술의 조기 개발 착수
- 1, 2단계 사업을 통한 정밀자세 및 심우주 항법 등 전략기술 확보

보고자료: 과학기술정보통신부

Horizon 2061_2019
Korea’s Plans & Prospective Lunar and Planetary Explorations

- **Korea Pathfinder lunar Orbiter (July, 2022)**
  - KARI

- **Korean Lunar Exploration, Lander (Before 2030)**
  - KARI

- **Asteroid Mission (2035)**
  - KARI

- **CLPS (Commercial Lander Payload Service) (2024), SMD & KASI collaboration**
  - KASI/NASA

- **Moon Race (~2024)**
  - Airbus/ KARI, KICT

- **Lunar Orbital Platform-Gateway, ISRU**
  - NASA LaRC/JSC ISRU
    - International Collaboration
    - NASA ARC
KIGAM’s Research Areas in Planetary Geology and Resources

- **KIGAM Internal**
  - Planet Geo
  - Planet. Geo Basic Study
  - Remote Sensing

- **External**
  - R & D Planning
  - Tech. Development Planning
  - National R & D

- **Geology and Resources Core Tech & Science Development**
  - Korean Moon/Asteroid Exploration
  - NASA LOP-G, ISRU Collaboration
  - CLPS
  - ESA/Europe Lunar Cooperative Program

- **KIGAM’s Planetary Geology and Resources**

- **Geology and Resources Outcome**

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**Planetary Geology and Resources Utilization**

- **KPLO (orbiter)**
- **Lunar Lander**
- **Asteroid Mission**
- **CLPS**
- **Moon Race**
- **NASA (LOP-G) and ISRU**
- **Lunar Base Construction**
### Researchers for ISRU Team at KIGAM

<table>
<thead>
<tr>
<th>Research Field</th>
<th>Name</th>
<th>Major</th>
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<tr>
<td>Planetary Geology</td>
<td>Seok-Gi Kwon</td>
<td>Mineralogy</td>
<td>Senior Researcher</td>
<td>Planetary resources, Analog Study, Planetary Material, Soil Study</td>
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<td>Takao Kobayashi</td>
<td>Geophysics</td>
<td>Senior Researcher</td>
<td>Cave study for Moon and Mars</td>
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<td>Hyncheol Kim</td>
<td>Petrology</td>
<td>Principal Researcher</td>
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<td>GIS Mapping</td>
<td>Young-Kwang Yeong</td>
<td>Computer engineering</td>
<td>Principal Researcher</td>
<td>Planetary Geoinformatics and DATA Base</td>
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<td>Payload Development</td>
<td>Kyeong Ja Kim</td>
<td>Cosmo-Geology</td>
<td>Principal Researcher</td>
<td>Planetary Remote Sensing, Payload Development, Cosmochemistry</td>
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<td>Yire Choi</td>
<td>Geophysical Exploration</td>
<td>Senior Researcher</td>
<td>Planetary Remote Sensing, Payload Development, Cosmochemistry</td>
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<td>Jung-Hun Park</td>
<td>Nuclear Experiment</td>
<td>Principal Researcher</td>
<td>Planetary Remote Sensing, Payload Development, Simulation</td>
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<td>Gil-Jae Lee</td>
<td>Mine</td>
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Thank you for your attention!