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

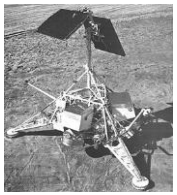
- Introduction to KIGAM
  - National Institute (Geological and Mineral Resources)
  - Established in 1918 (https://www.kigam.re.kr)
- Previous Planetary Research
- Current Building of New Research
- Important in ISRU Work
- International Collaboration

Planetary Surface Investigations

KIGAM

- Moon : Chang'e-3 & 4, Surveyor5-7, *SELENE-R, Chandrayaan-2, KLE*
- *Mars:* Viking, Mars 96, Phobos, Mars Pathfinder, ***Mars Exploration Rover***
- Venus: Ventra
- Asteroids & Comet: ***Rossetta***

Surveyor 5-7



1967, 67,68

Viking1

1975

Viking 2

1975

Ventra 8 (G)

1975

Ventra 9 (G)

1975

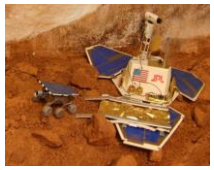
Ventra 10(G)

1975

Ventra 13

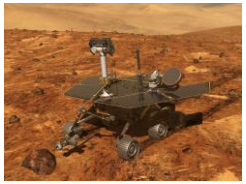
1981

Pathfinder



1997

MER

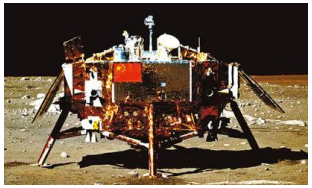


2003

Curiosity (N, X)

2011

Chang'e-3



2013

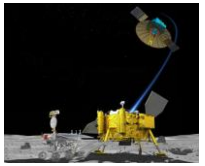
Rossetta

2014

Chandrayaan-2

2018

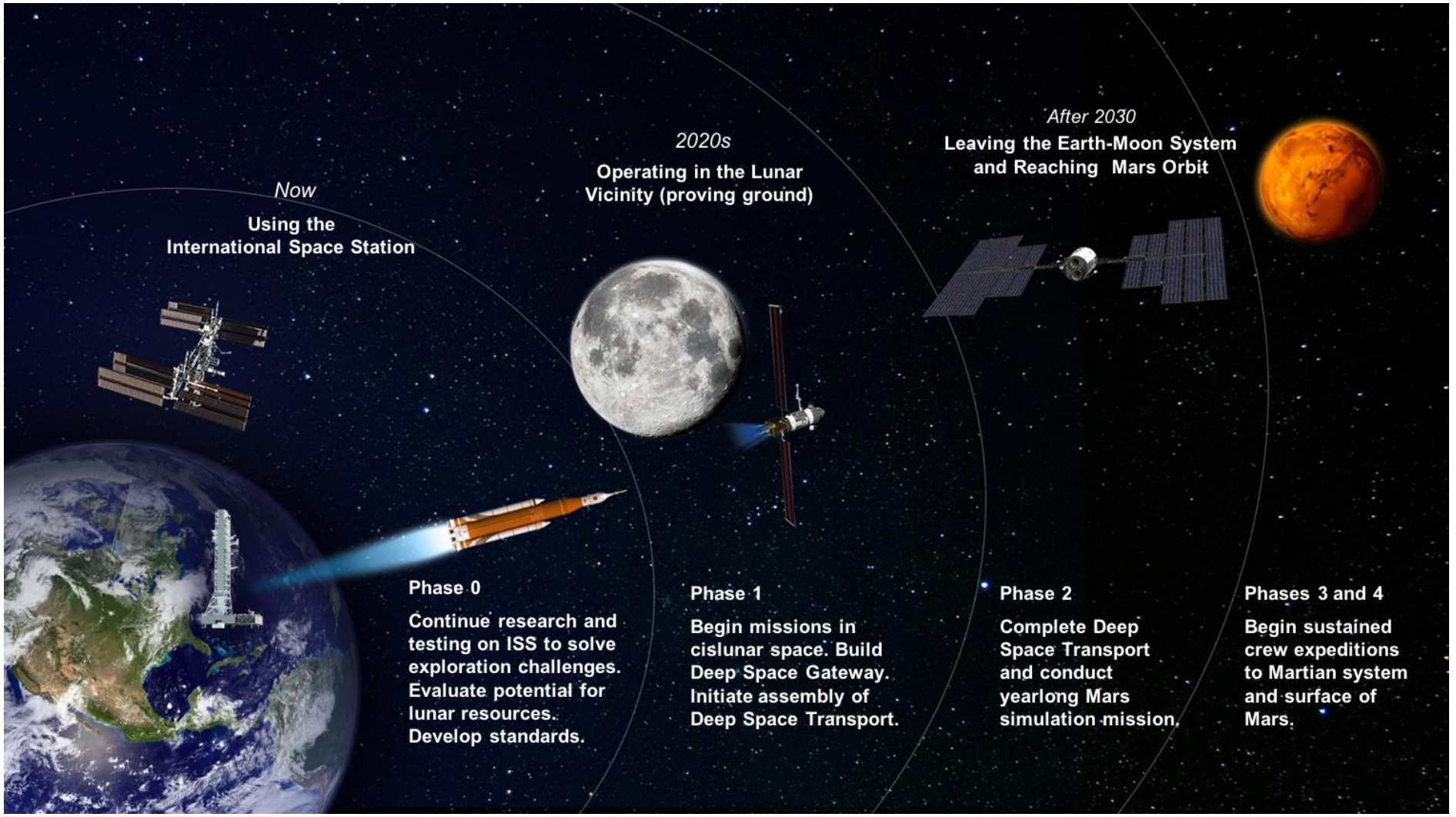
Chang'e-4



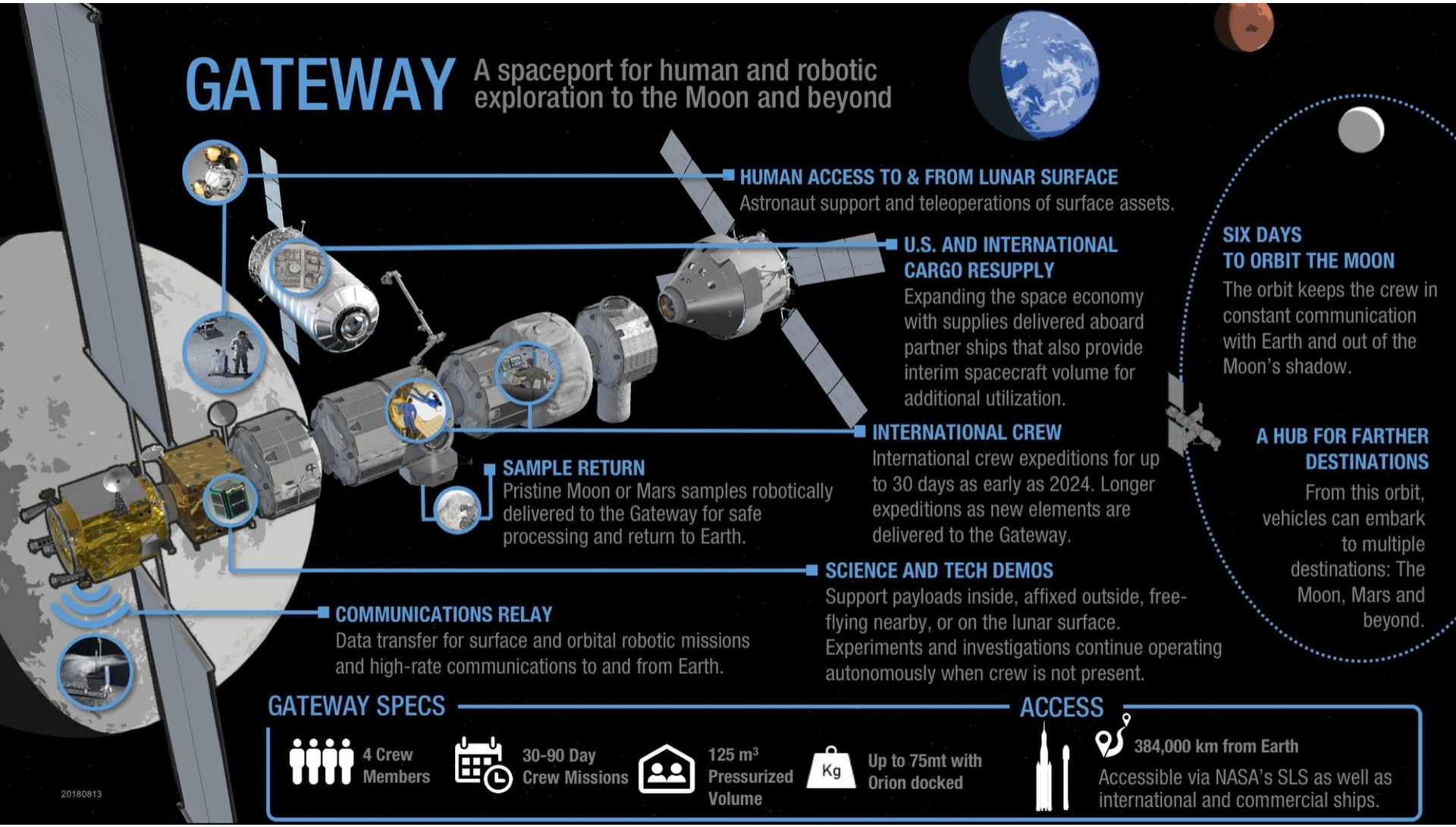
2018

NASA's Future Plan to visit Mars

KIGAM



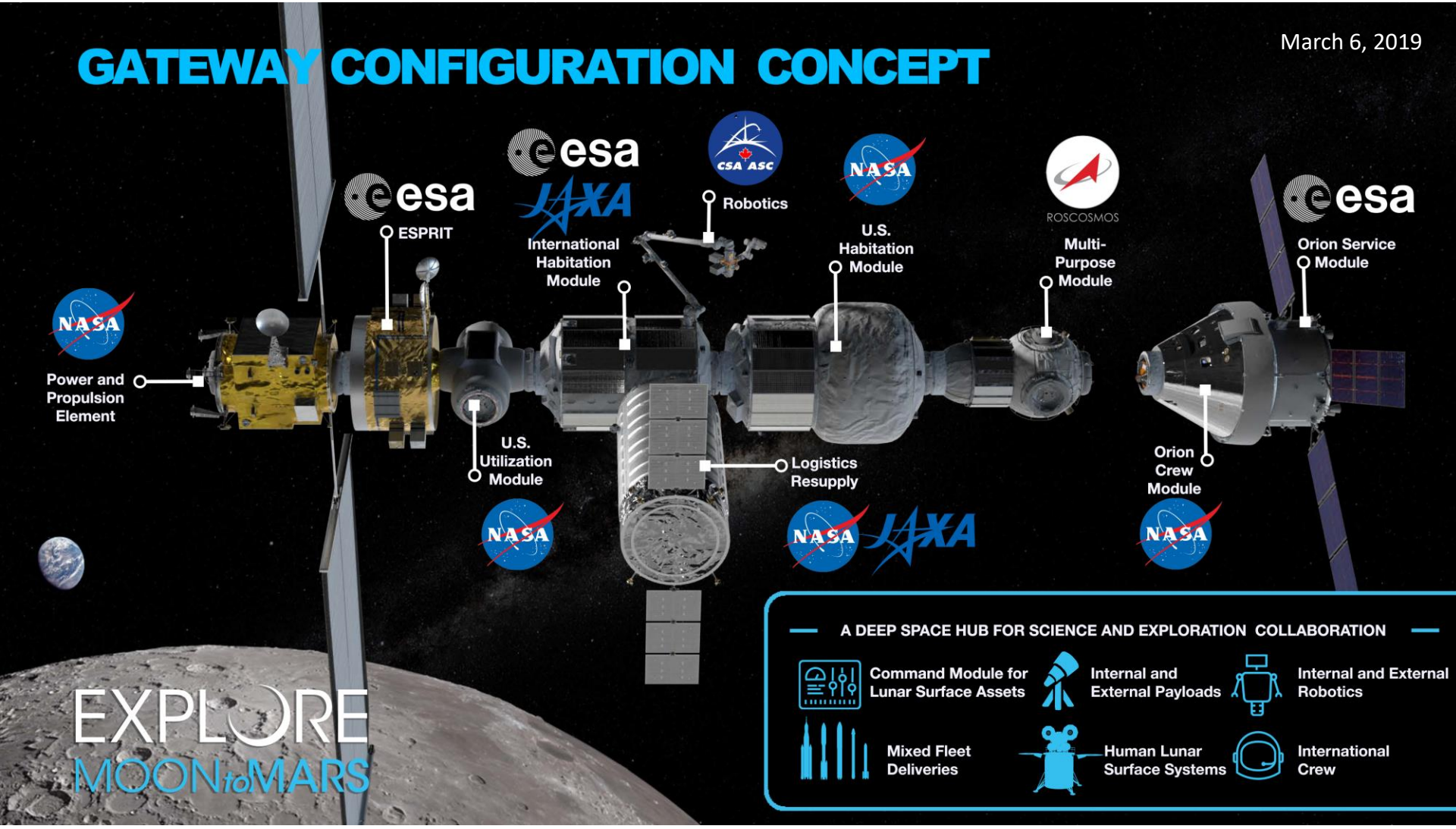
NASA's Lunar Orbital PlatForm-Gateway KIGAM



http://www.leonarddavid.com/wp-content/uploads/2018/08/GATEWAY-8.jpg

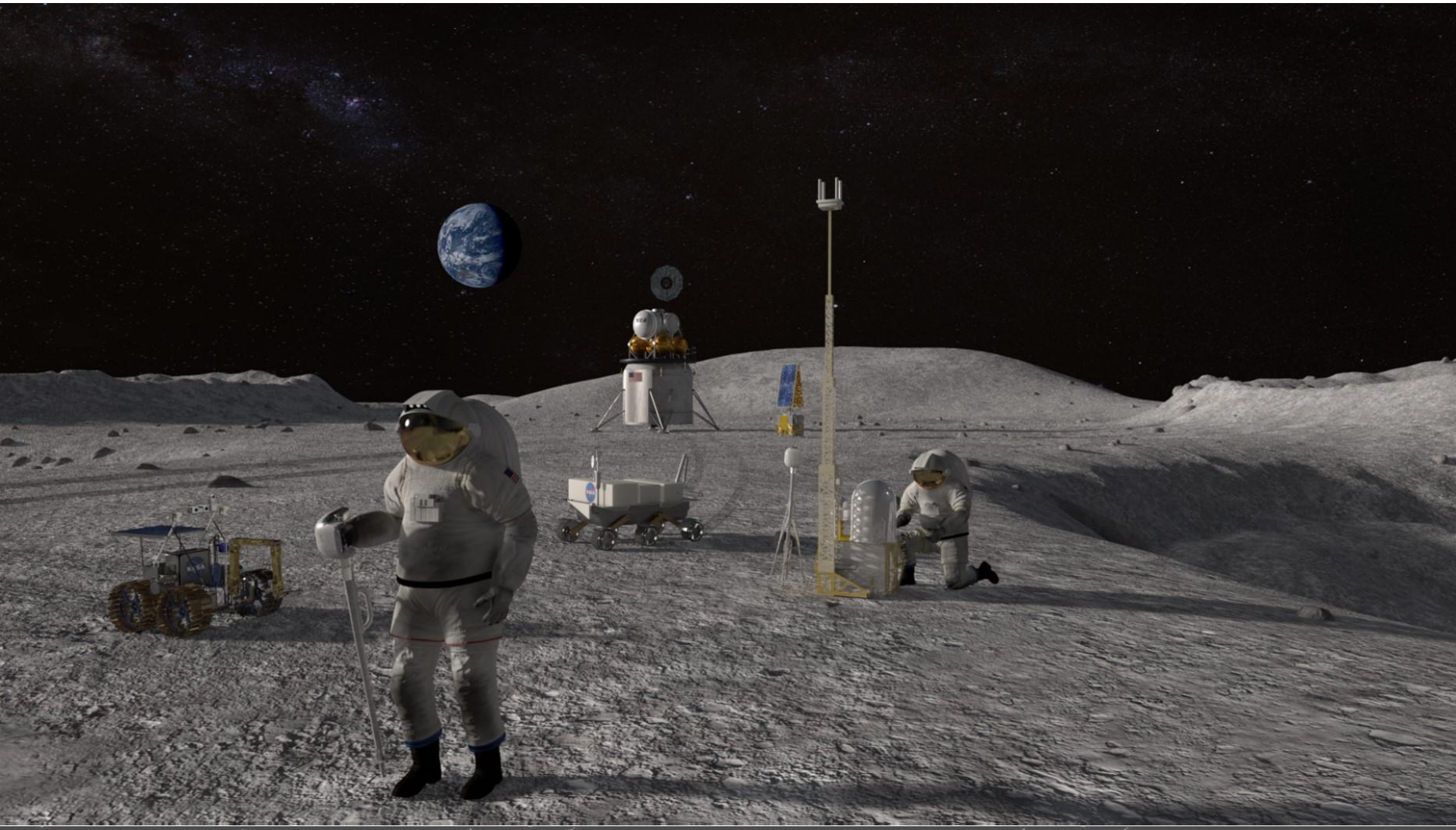
Horizon 2061_2019

Multilateral Coordination Board Joint



https://www.nasa.gov/sites/default/files/thumbnails/image/gateway_configuration_concept_5march2019_final.jpg

NASA’s Artemis Moon Program



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

Artemis Moon Program

KIGAM

Achieving 2024 – A Parallel Path to Success

Artemis will see government and commercial systems moving in parallel to complete the architecture and deliv

NASA Programs SLS and Orion

Artemis 1

First flight test of SLS and Orion as an integrated system

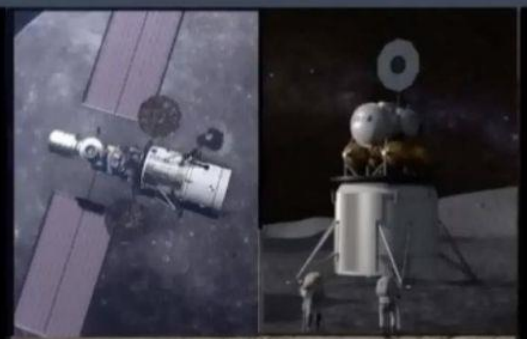
Artemis 2

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

Ascends from lunar surface to Gateway

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

current draft as of 5/21/2019

https://www.spaceflightinsider.com/wp-content/uploads/2019/05/D7RRRzUW4AERn20.jpg

ISRU Work History at KIGAM

➢ ISRU Prospecting History

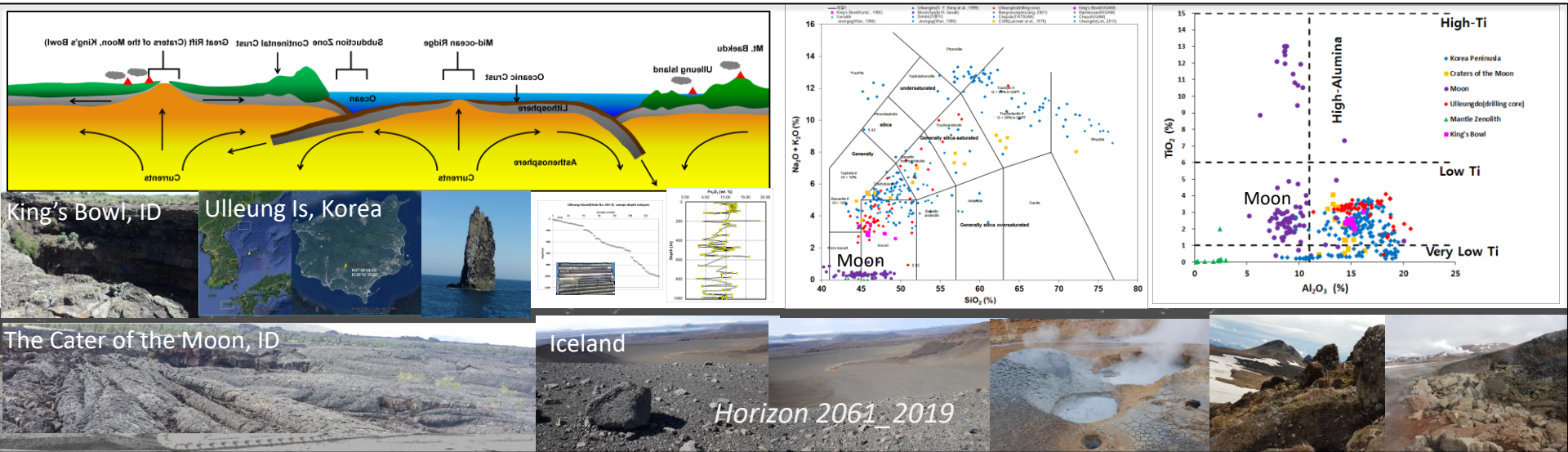
- ✓ KPLO gamma-ray spectrometer FM development in 2019
- ✓ Lunar gamma-ray spectrometer, neutron spectrometer EM developed 2018
- ✓ PM model of Active X-ray Spectrometer developed in 2012
- ✓ Nuclear science payload development since 2010

➢ ISRU Extraction History

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

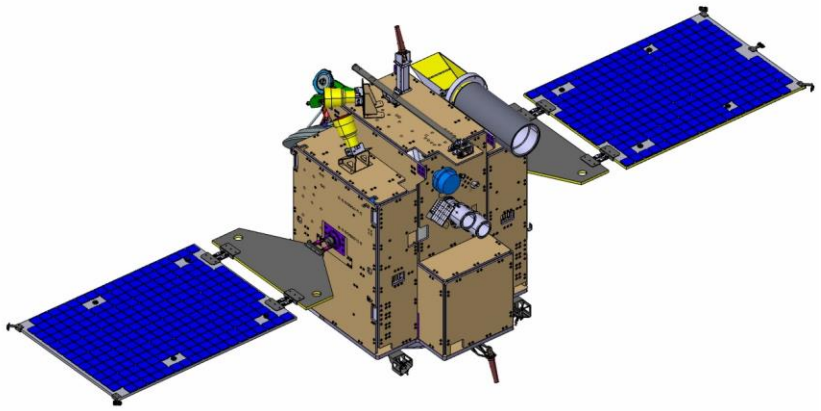
➢ Participating in Planetary Missions & International Collaborations

- ✓ Mars Odyssey(GRS), SELENE-1(GRS), SELENE-2 pre-project (AXS), KPLO (GRS)
- ✓ **NASA SSERVI (FINESSE, RESOURCE) 2013-2025, NASA MDAP 2018-2022**

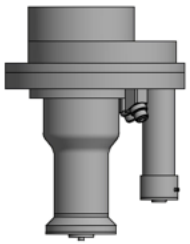


Payload Development at KIGAM

Korea Lunar Pathfinder Orbiter GRS



2018

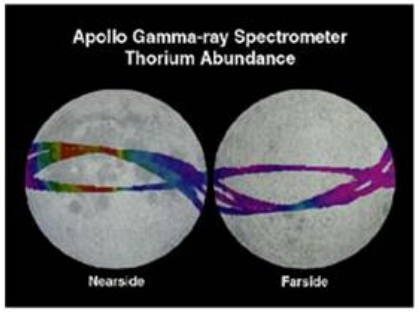


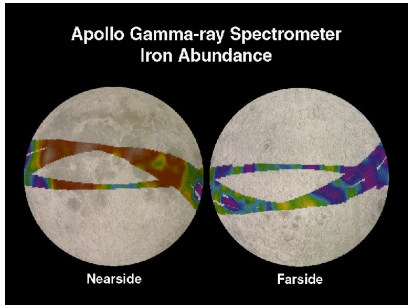
- Lunar Exploration (2016-2020)
  - ✓ KPLO GRS (KGRS)
- Space Core Technology Program (2015-2018)
  - ✓ GRS (HPGe)
  - ✓ NS
- Internal Program at KIGAM (2012-2014)
  - ✓ GRS
  - ✓ XRS
- Payload Development for Planetary Exploration (2010-2017)
  - ✓ Active X-ray Spectrometer (KARI's Consigned Project)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

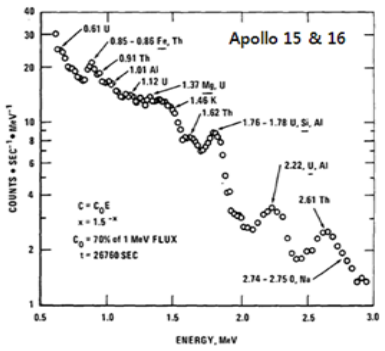
Elemental maps for previous lunar orbiters

KIGAM

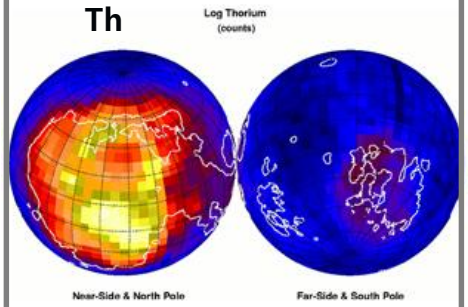
Apollo 15 & 16

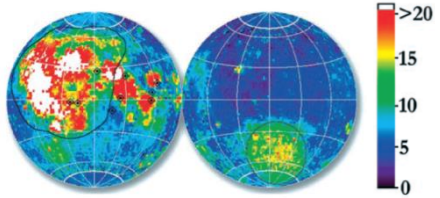




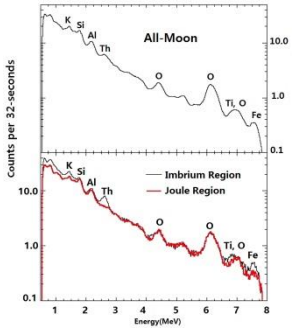


Lunar Prospector



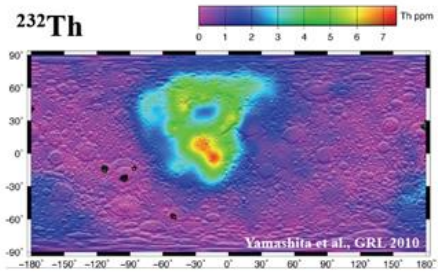


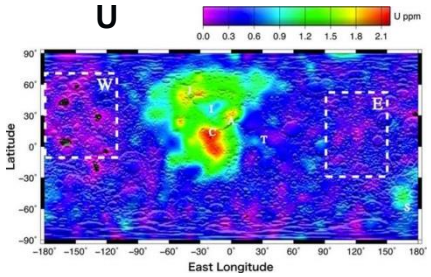
Taylor, G. J., 2009



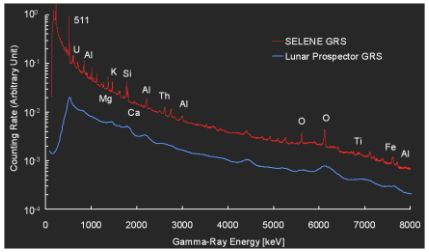
Lawrence et al. 1998

SELENE-1 (Kaguya)



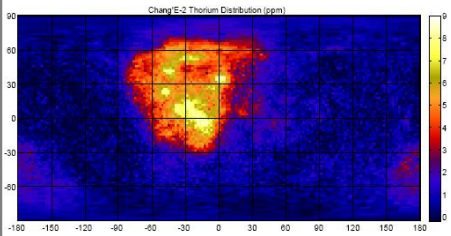


Yamashita et al. 2012

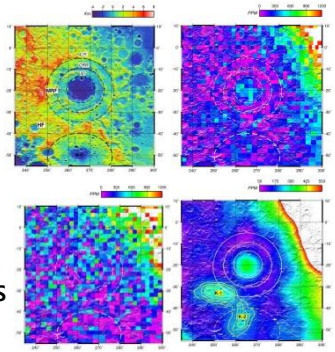


Hasebe et al. 2009

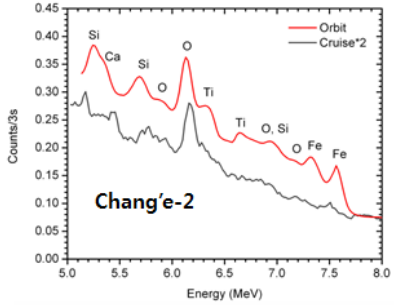
Chang'e-2 Th map



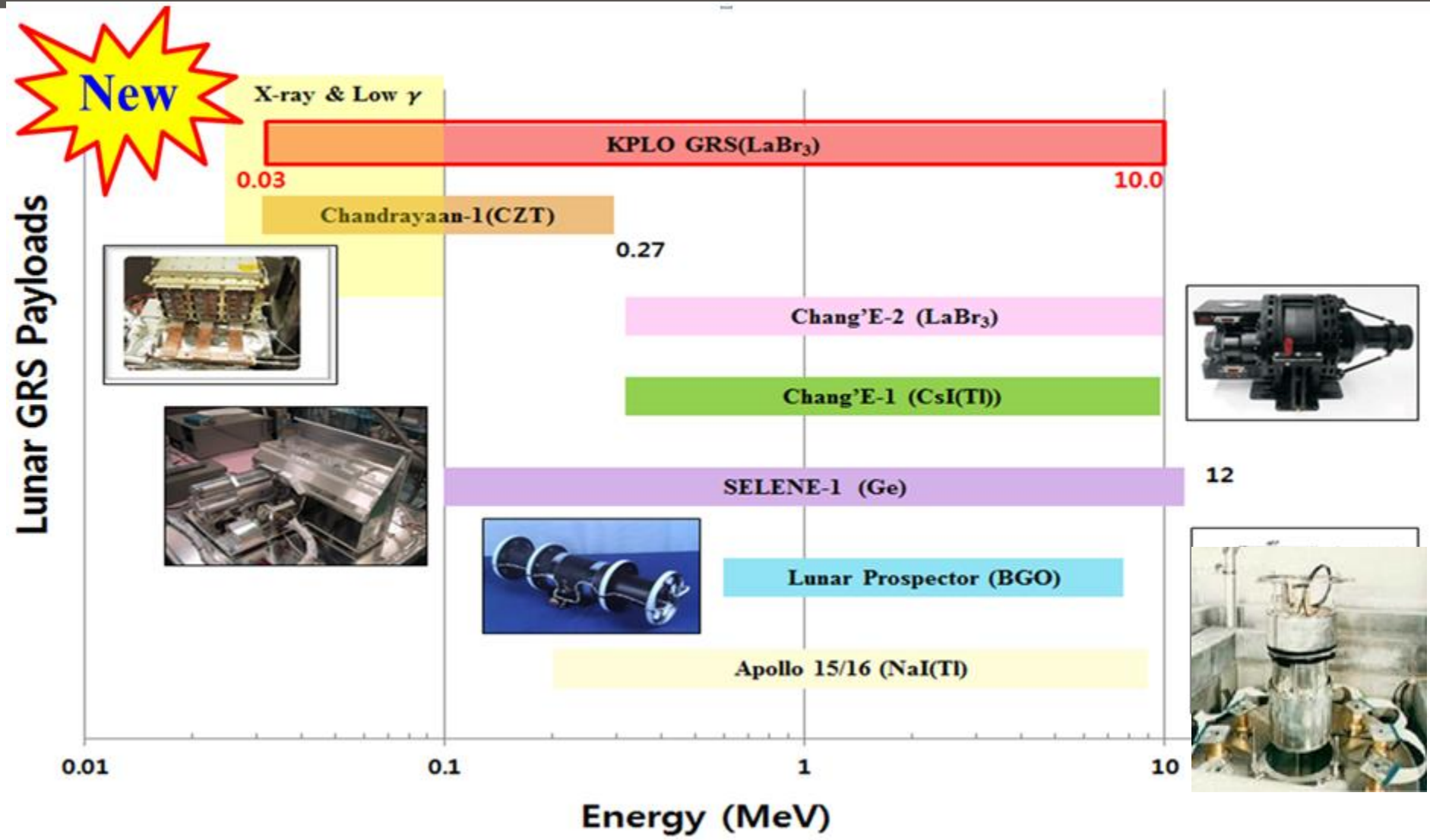
Oriental Basin (K)



Zhu et al. 2013

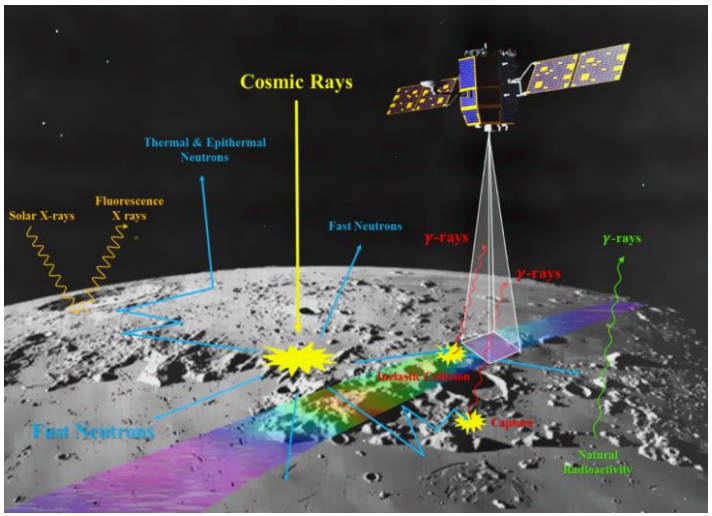


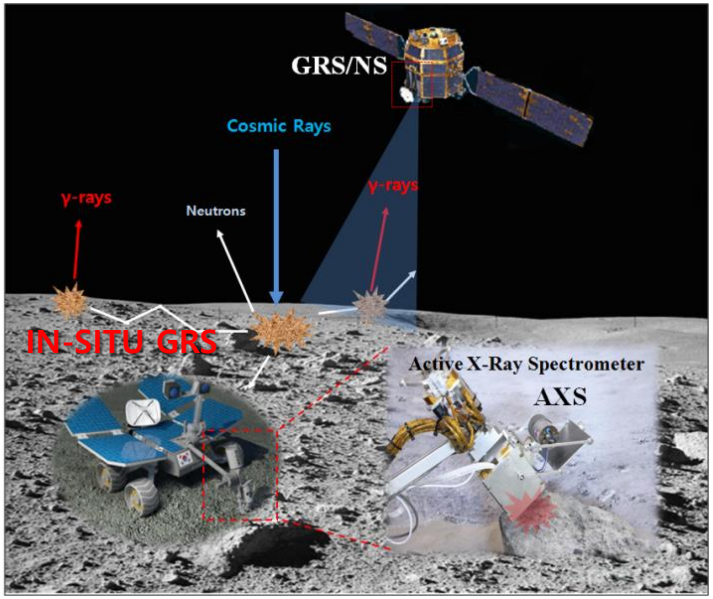
Comparison of lunar GRS Instruments



Future ISRU Investigation on

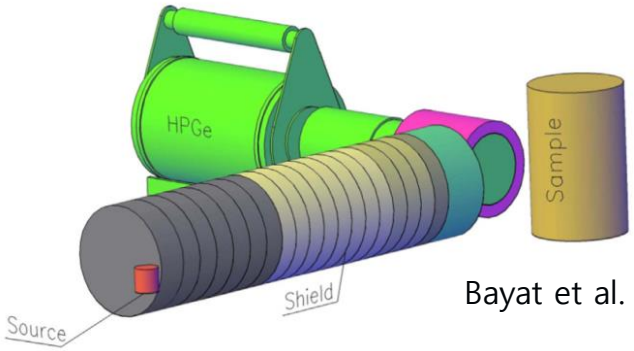
KIGAM





- **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

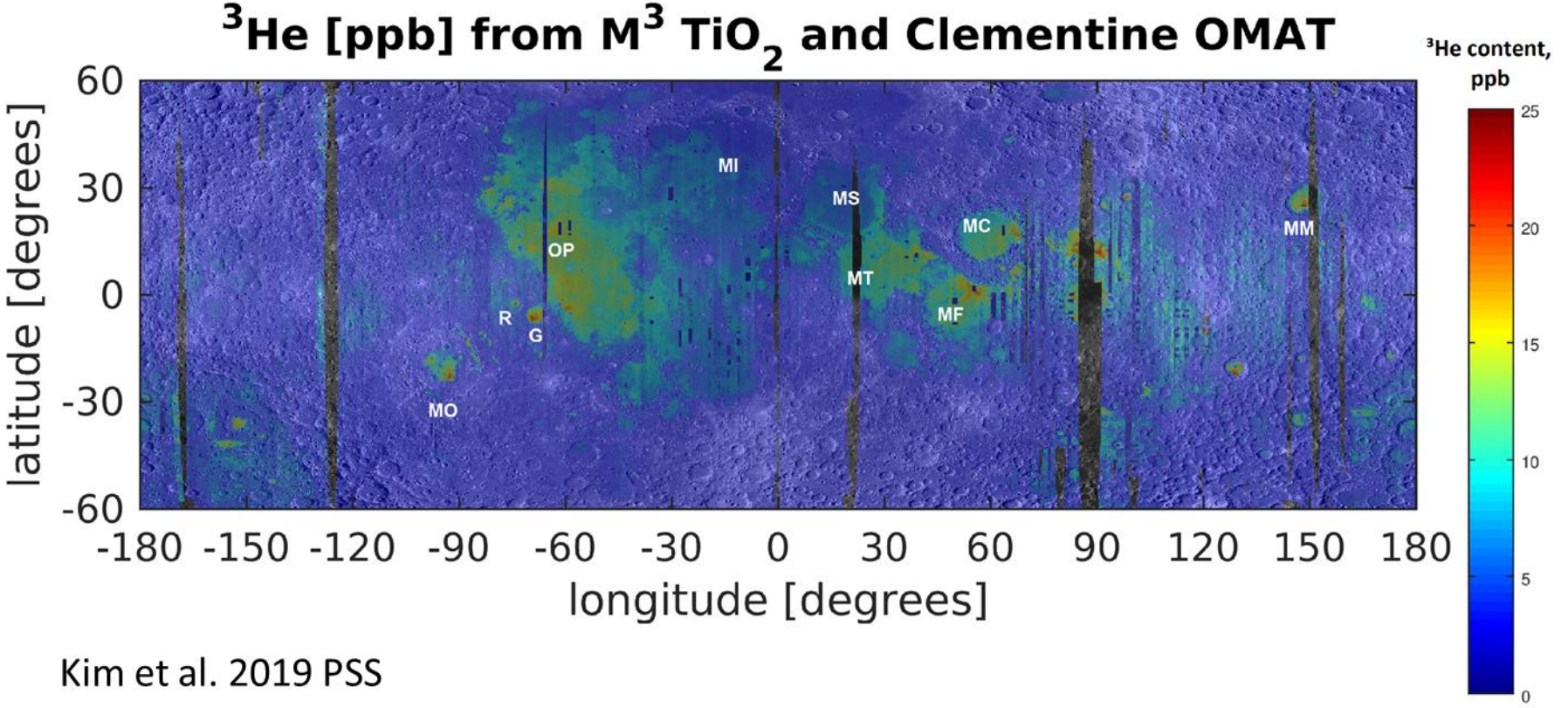
Current various applications



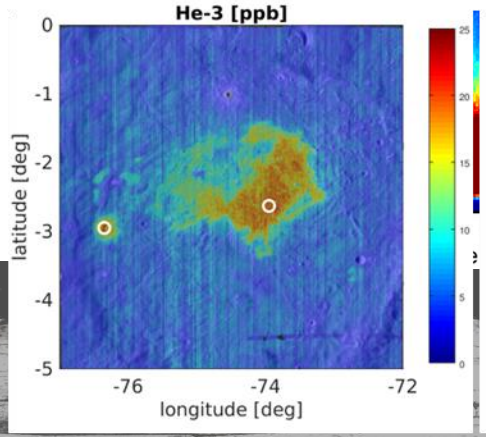
Bayat et al. 2015

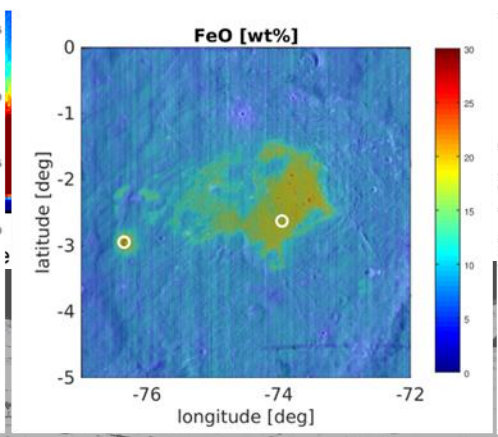
Lunar ISRU & Landing Site, Moon

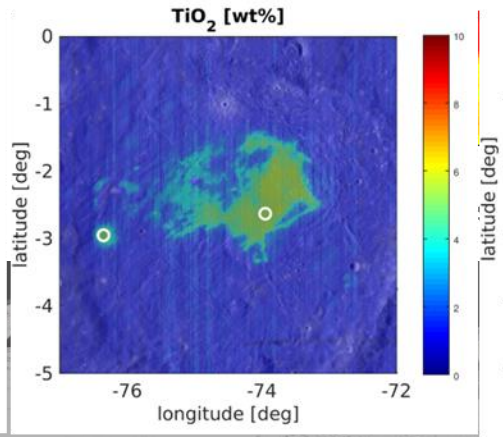
KIGAM

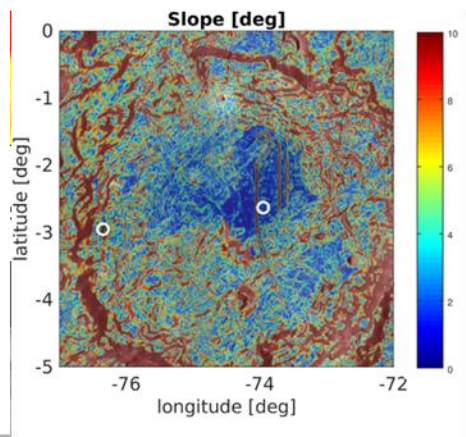


Kim et al. 2019 PSS

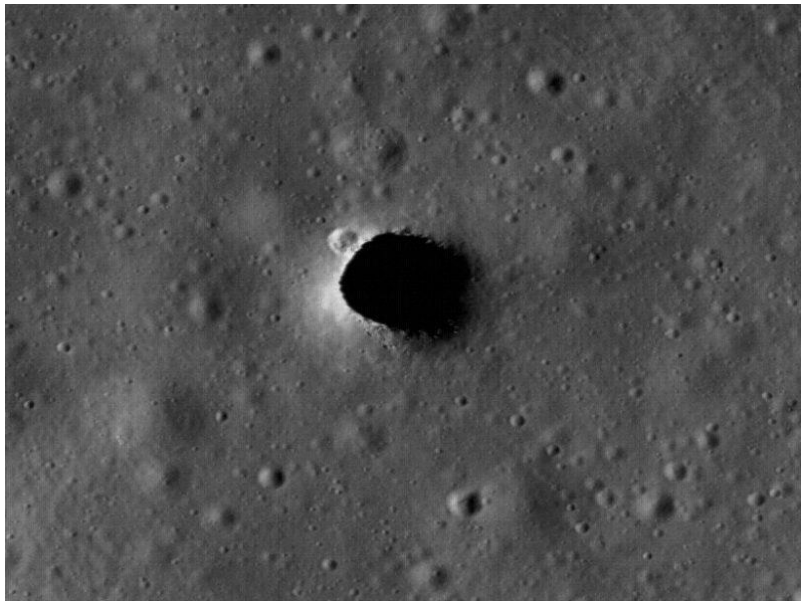


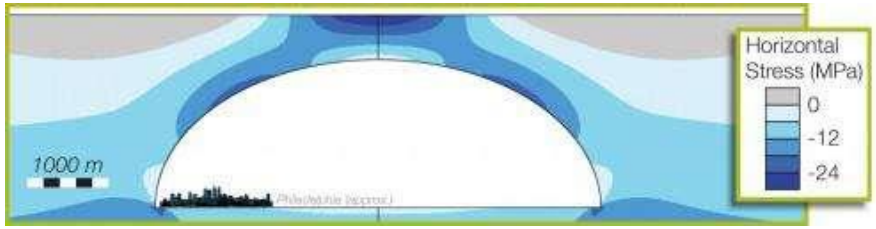




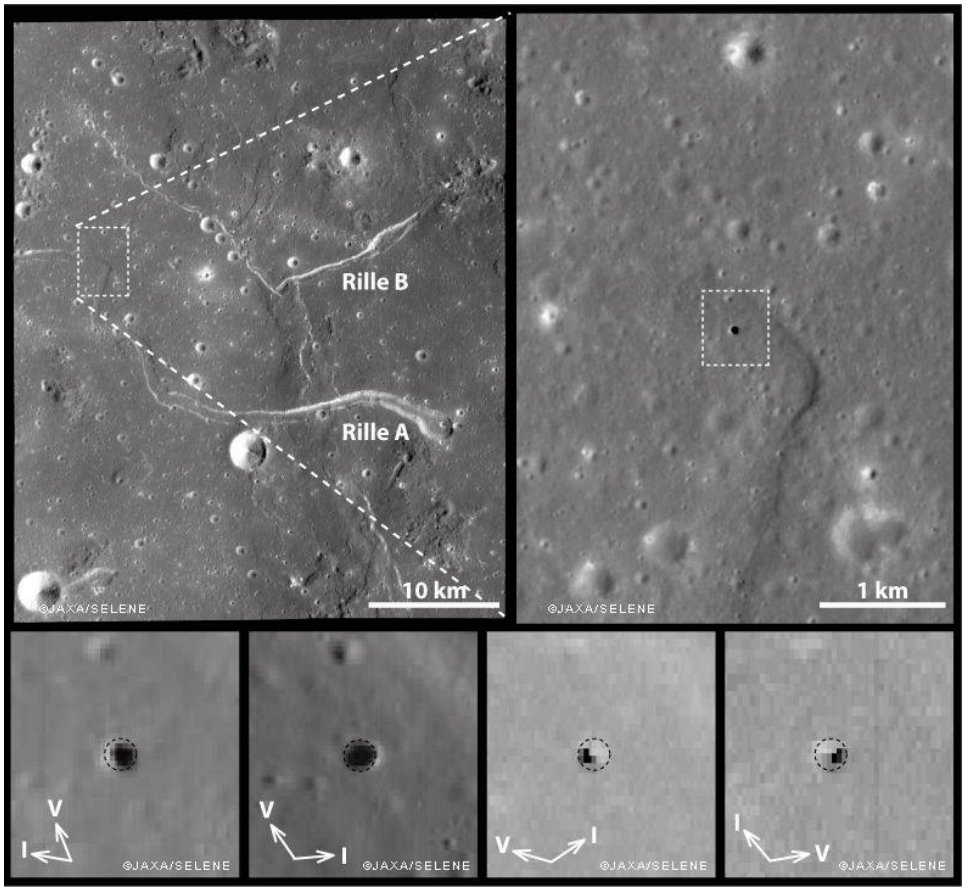


Massive underground tunnels on the Moon





https://phys.org/news/2015-03-theoretical-huge-lava-tubes-moon.html



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

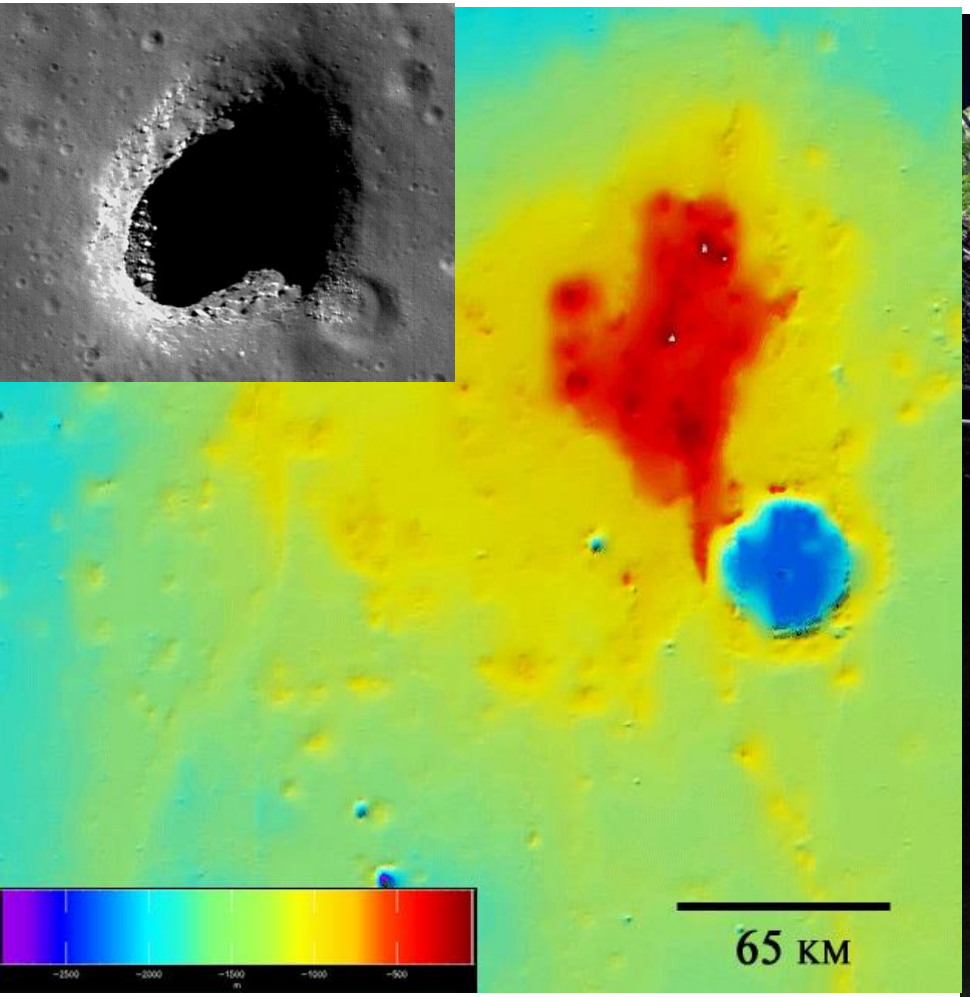
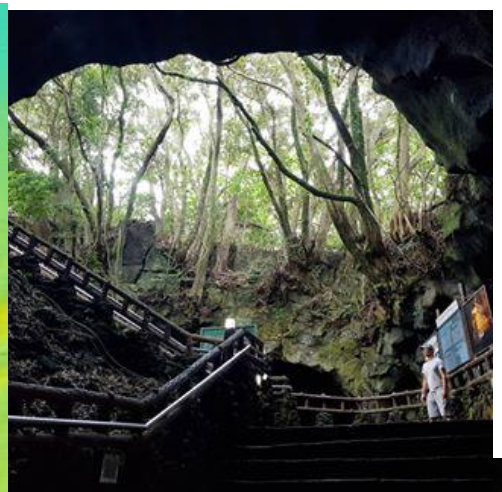


Image of a possible skylight pit in the Marius Hills, taken by the Lunar Reconnaissance Orbiter Camera. (NASA/Goddard Space Flight Center/Arizona State University)

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



Entrance of Manjang Cave, Jeju

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

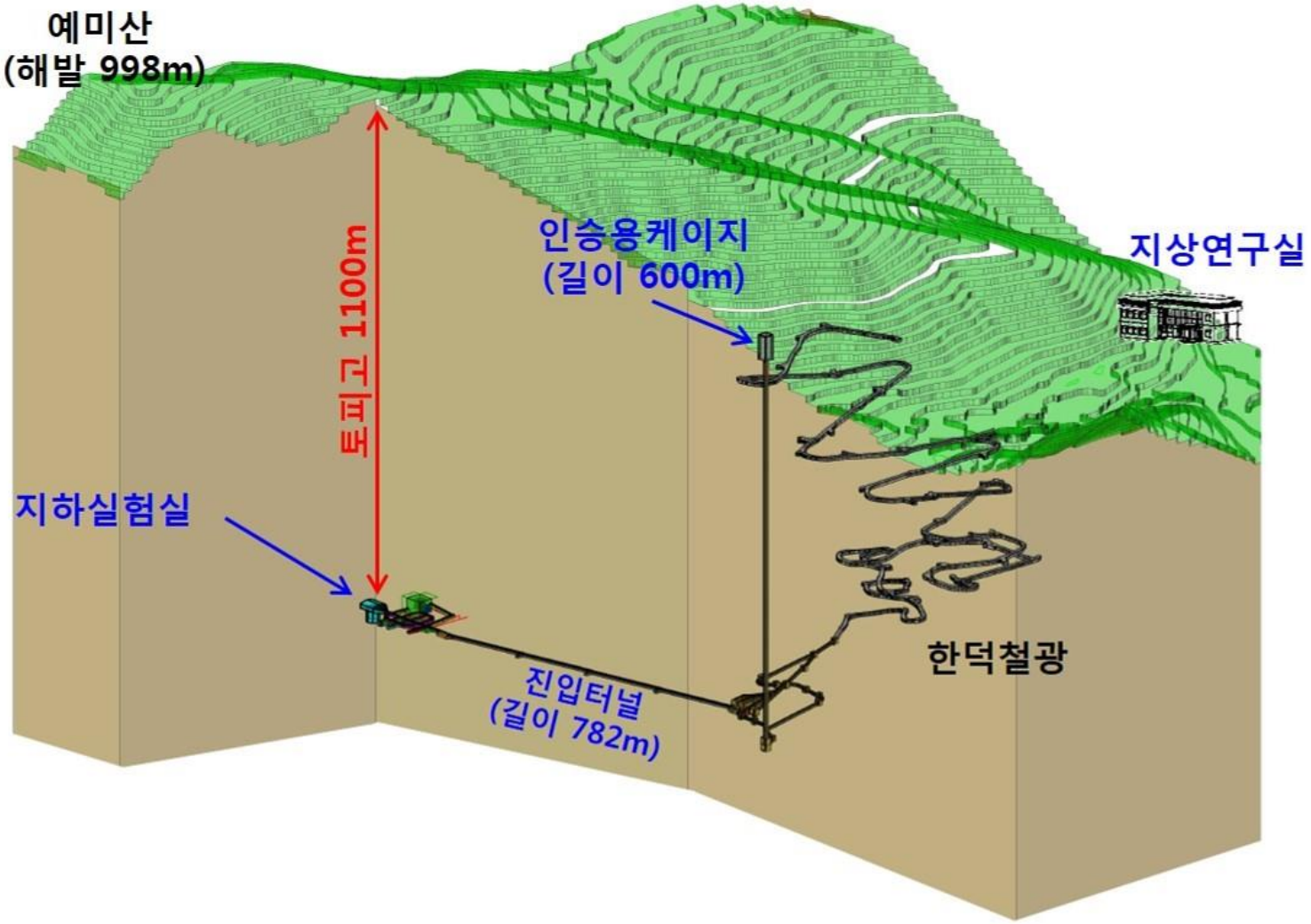
Manjang Cave

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



https://www.ibs.re.kr/cop/bbs/BBSMSTR_000000000511/selectBoardArticle.do?nttId=16992&kind=&mno=sitemap_02&pageIndex=1&searchCnd=&searchWrd=

Suggested Research Activities

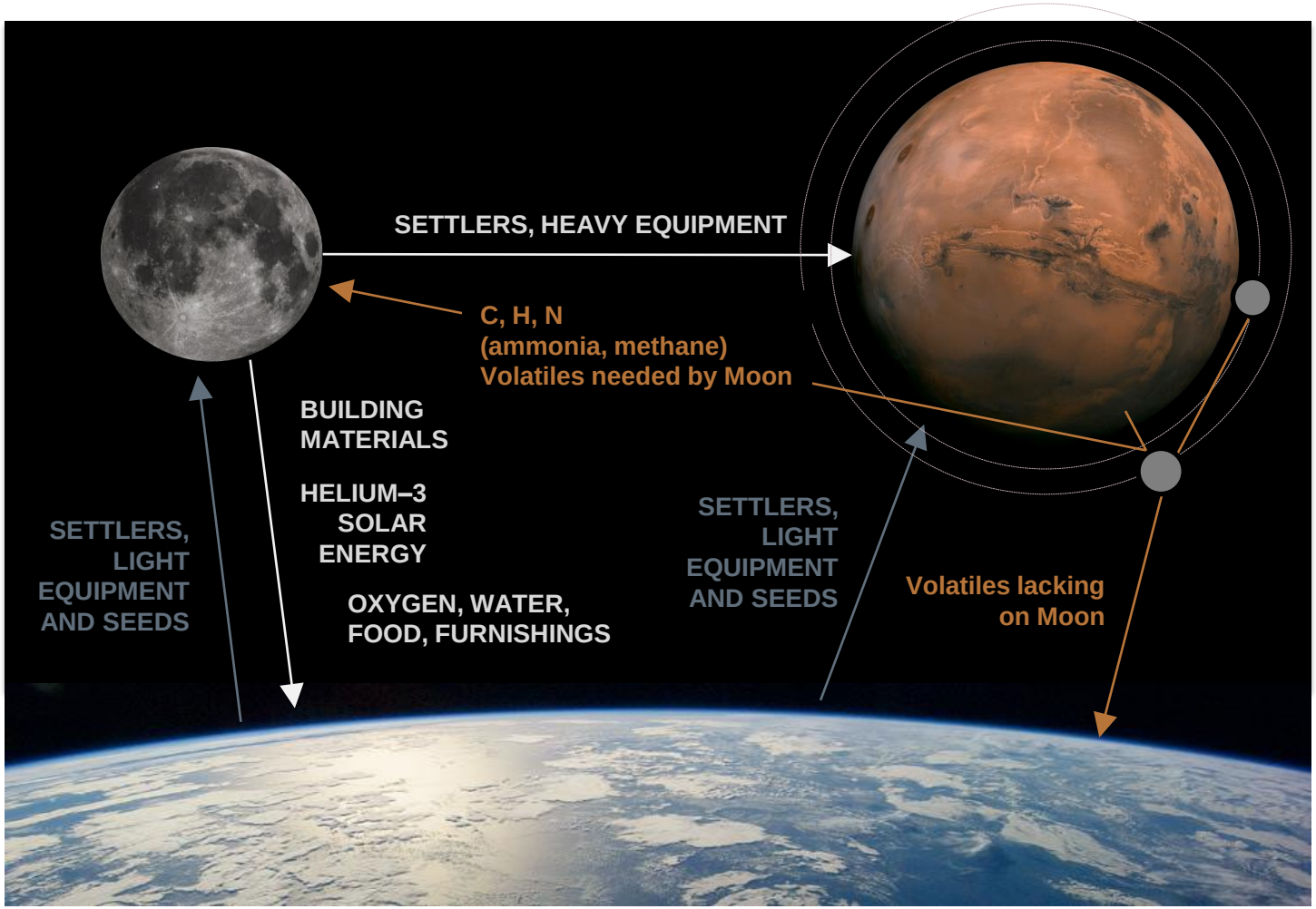
- Growing vegetables and grains underground
- Check health & behavior of mice underground
- Check radiation safety underground from the natural radioactivity
- Examine living condition underground
- Living in subterranean environment (adaptation)

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

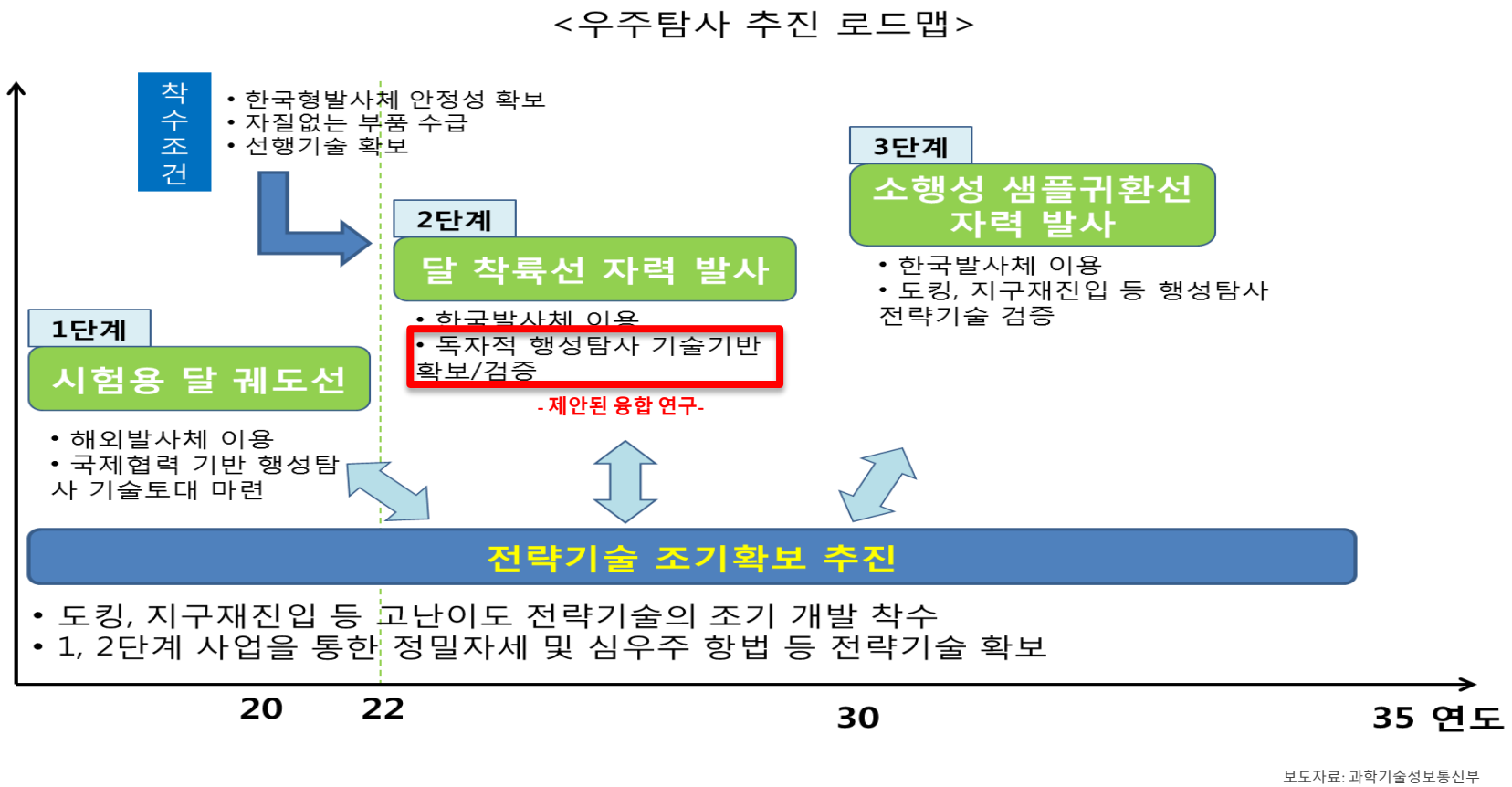

http://www.bbc.com/future/story/20151218-how-to-survive-the-freezing-lunar-night


https://www.engadget.com/2017/04/28/nasas-inflatable-greenhouse-mars-moon/

EARTH–MOON–MARS ECONOMY



Korea Space Development Roadmap



보도자료: 과학기술정보통신부

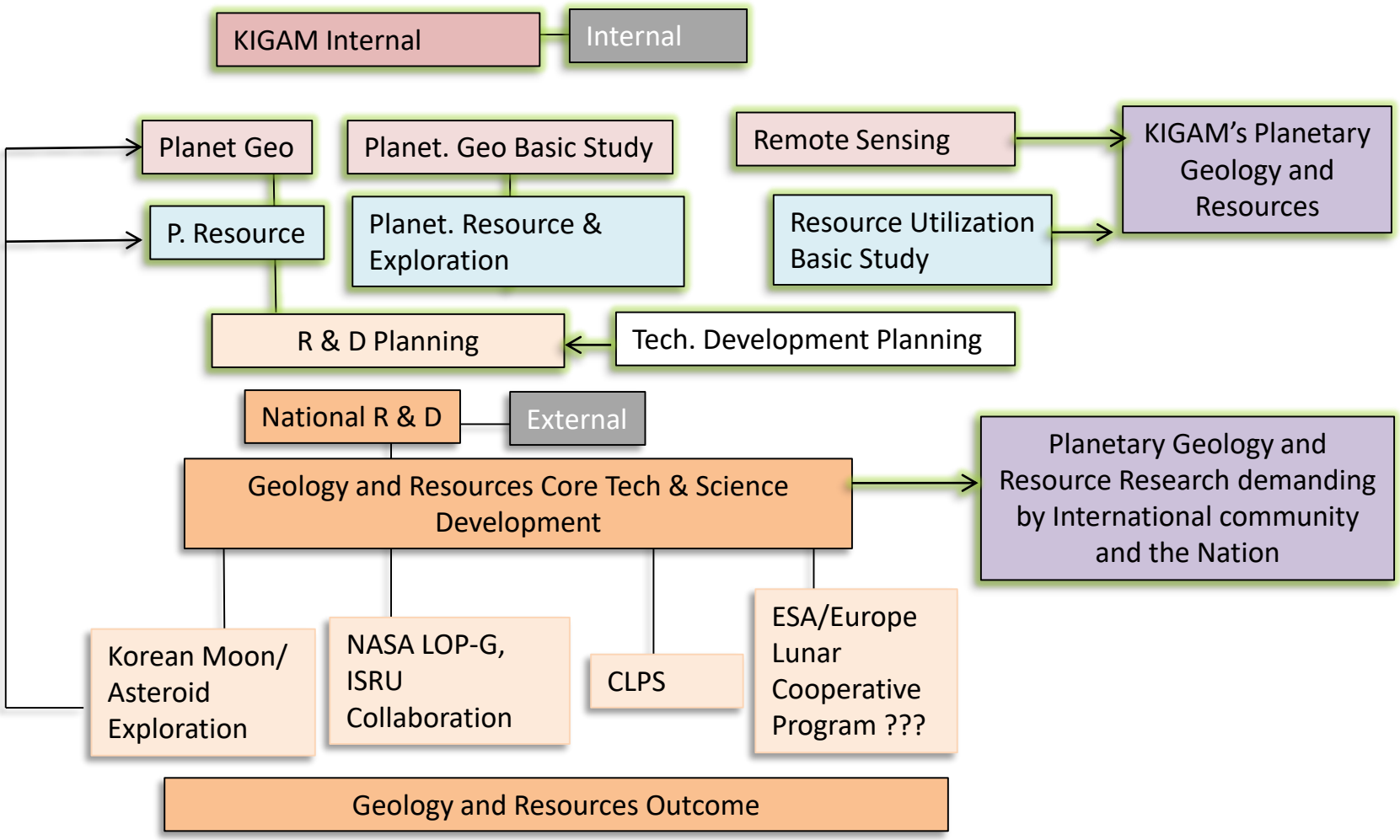
Korea's Plans & Prospective Lunar and Planetary Explorations

KIGAM

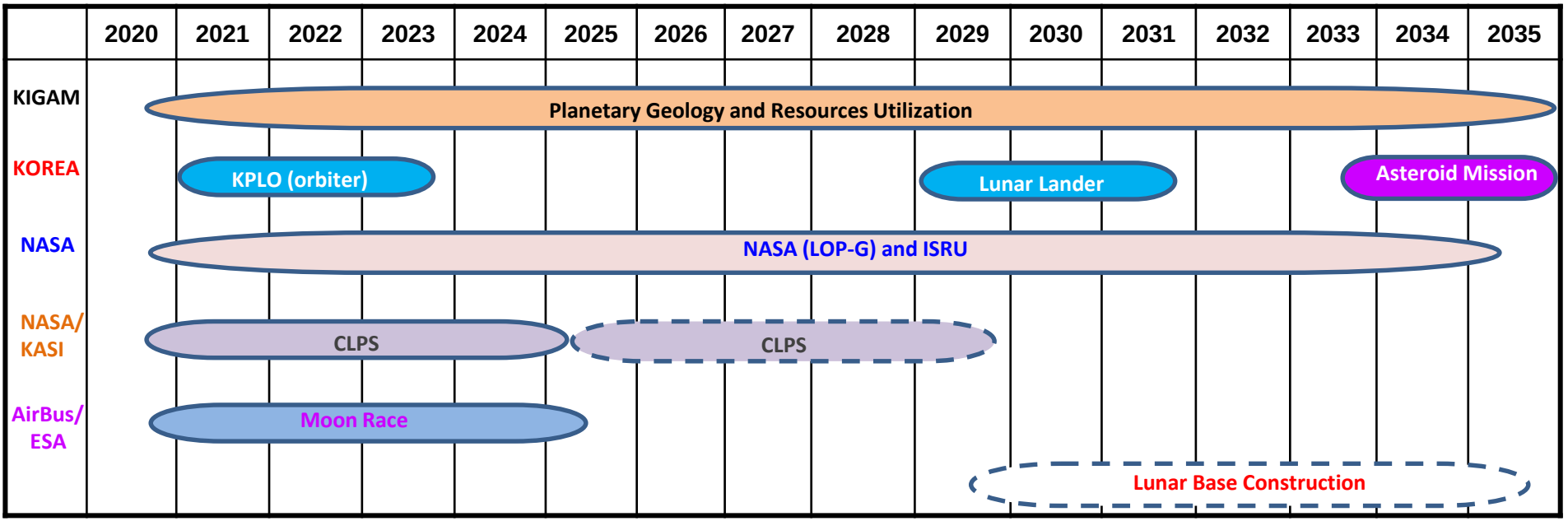
Ministry of S & T, ICT of Korea

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



Korea's Potential International Collaboration in Planetary Exploration



Researchers for ISRU Team at KIGAM

Research Field	Name	Major	Position	Research Areas
Planetary Geology	Seok-Gi Kwon	Mineralogy	Senior Researcher	Planetary resources, Analog Study, Planetary Material , Soil Study
	Takao Kobayashi	Geophysics	Senior Researcher	Cave study for Moon and Mars
	Hyncheol Kim	Petrology	Principal Researcher	Planetary resources, Analog Study, Planetary Material , Soil Study
	Sung-soon Lee	Remote Sensing	Principal Researcher	GIS based Planetary Mapping System, Remote Sensing Data Processing
GIS Mapping	Young-Kwang Yeong	Computer engineering	Principal Researcher	Planetary Geoinformatics and DATA Base
Payload Development	Kyeong Ja Kim	Cosmo-Geology	Principal Researcher	Planetary Remote Sensing, Payload Development, Cosomochemistry
	Yire Choi	Geophysical Exploration	Senior Researcher	Planetary Remote Sensing, Payload Development, Cosomochemistry
	Jung-Hun Park	Nuclear Experiment	Principal Researcher	Planetary Remote Sensing, Payload Development, Simulation
Geophysical Exploration	Gil-Jae Lee	Mine	Senior Researcher	Planetary Mineralogy,Terrestrial Resource Exploration
Electronics	Woong Kang	Electronics	Senior Researcher	Planetary Exploration, Payload Development
Resource Extraction	Sujeong Lee	Mineral processing	Principal Researcher	Resource Recovery and Reprocessing, Material Development
Resource Utilization	Jihyeok Choi	Metal Engineering	Senior Researcher	Resource Utilization and Material Development


Thank you for your attention!