# Abstract #1739

## English

### Mining the Moon with ispace, a Lunar Exploration Company

This presentation will introduce ispace, a lunar exploration company headquartered in Tokyo, Japan, with offices at both NASA AMES in California and Luxembourg. Next, it will outline the micro-rover technology that ispace is developing to prospect for resources on the Moon. Finally, it will explain its three-step plan to map, measure, and eventually manage resources on the lunar surface. Included will be an update about the two projects ispace is working on in Luxembourg and NASA AMES as well as a discussion on how the mining community can get involved. ispace is the commercial arm that manages Team Hakuto in the Google Lunar XPRIZE Mission. Founded in 2013, its mission is to find the resources necessary to extend human life into outer space. ispace's primary goal is to locate and utilize water. Observations from the Moon Mineralogy Mapper aboard India's Chandrayaan-1, and measurements from NASA's Lunar Reconnaissance Orbiter, each provide strong evidence for the presence of water ice on the Moon [1]. The water may originate from endogenous sources, delivery by comets or asteroids, or implantation by solar wind. Combining these sources, it is possible that up to ten million tons of water exist on the lunar surface with a further forty trillion tons existing below the surface [2]. While extracting hydrogen and oxygen from lunar regolith will require significant amounts of energy and infrastructure, the higher concentrations of lunar ice recently discovered at the Southern Lunar Pole could offer an energy-efficient alternative. In 2009, LCROSS impacted the permanently shadowed crater Cabeus and measured a water ice concentration of 5.6-2.9 wt% [3]. ispace, partnered with the Space Robotics Laboratory at Tohoku University in Sendai, Japan, has been developing a number of innovative rovers that can not only withstand the harsh environment of space but can also provide mobility options to some of the Moon's most difficult to reach places. ispace has three types of rovers, a 4kg four-wheeled rover, a 2kg, 2-wheeled rover, and tethered system that combines the two. In addition to its rover technology, ispace is now developing its own micro-lander to deliver payloads to every part of the lunar surface. ispace has a three-step plan to map, measure, manage and eventually sell water ice on the lunar surface. First, ispace will demonstrate its rover technology during the GLXP mission. Next ispace will develop its next generation transportation and landing abilities, a tethered-rover crater exploration vehicle, as well as rover with a drilling mechanism which will give the company access to the lunar surface and the resources that lay beneath it. In this phase ispace plans to partner with space agencies and the scientists, and the mining community for sensor and technology development to better detect water ice deposits. Finally, depending on the location, distribution, quality and quantity of the lunar ice, ispace will develop extraction and processing methods with interested industrial partners. An ultimate goal is to convert the ice to fuel and deliver it to private companies such as the United Launch Alliance, who have recently offered to purchase fuel on the lunar surface for $500/kg [4]. References: [1] Delory, T (2010) The LADDE Mission: The Next Step After the Discovery of Water on the Moon. [2] Hauri et al., (2011) High Pre-Eruptive Water Contents Preserved in Lunar Melt Inclusions, Science 333, 213-215 [3] Colaprete et al., (2010) Detection of Water in the LCROSS Ejecta Plume, Science 330, 463-468 [4] David, L (2015) Inside ULA's Plan to have 1,000 People Working in Space by 2045. Space.com

## French

### No abstract title in French

No French resume

## Author(s) and Co-Author(s)

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ispace

# Profile of Mr. Kyle Acierno

## General

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Position:

Preferred Language: [Language not defined]

## Addresses

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**Home**

## Biographies

**Biography submitted with the abstract**

Kyle is the Director of ispace Europe's office in Luxembourg. Previously he served as the Global Business Development Manager and built strategic relations with JAXA, NASA, ESA and universities around the world. Kyle received a BA in International Security from Simon Fraser University in Vancouver, Canada and a M.Sc. in Space Studies from the International Space University. He has previously worked in a Chinese environmental think-tank where he offered policy solutions to the Government of China. He also served as COO of a crypto-currency start-up responsible for providing block-chain solutions to business in Vancouver. Kyle has traveled to over 100 countries and speaks Mandarin.

**Biography in the user profile**

## Collaborators

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[Unknown Title]
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Presenter(s):

Mr. Kyle Acierno
[Unknown Title]
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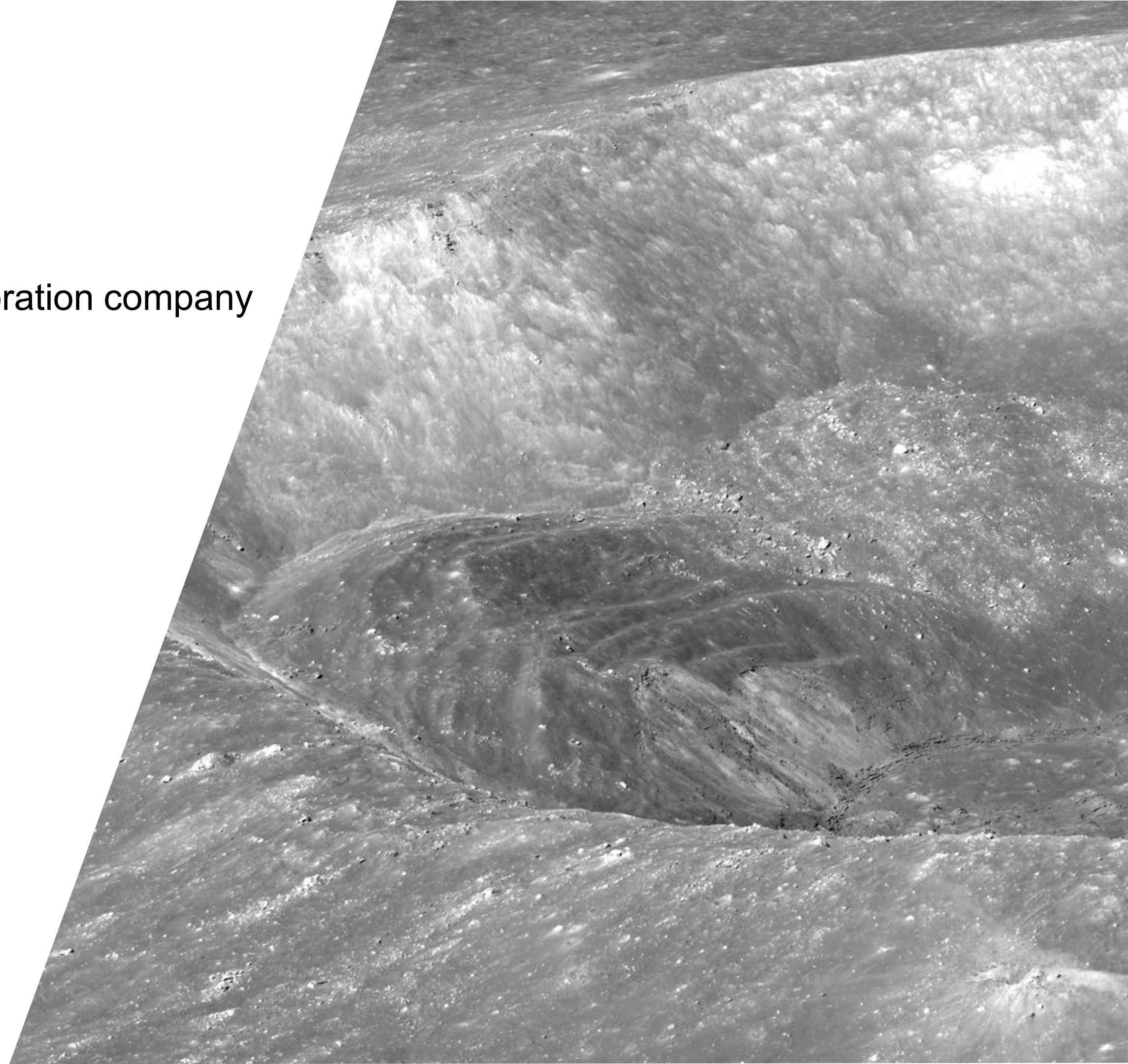
# Mining the Moon with ispace, a Lunar Exploration Company

CIM 2017 Convention

Kyle Acierno
Managing Director, ispace Europe

# Contents



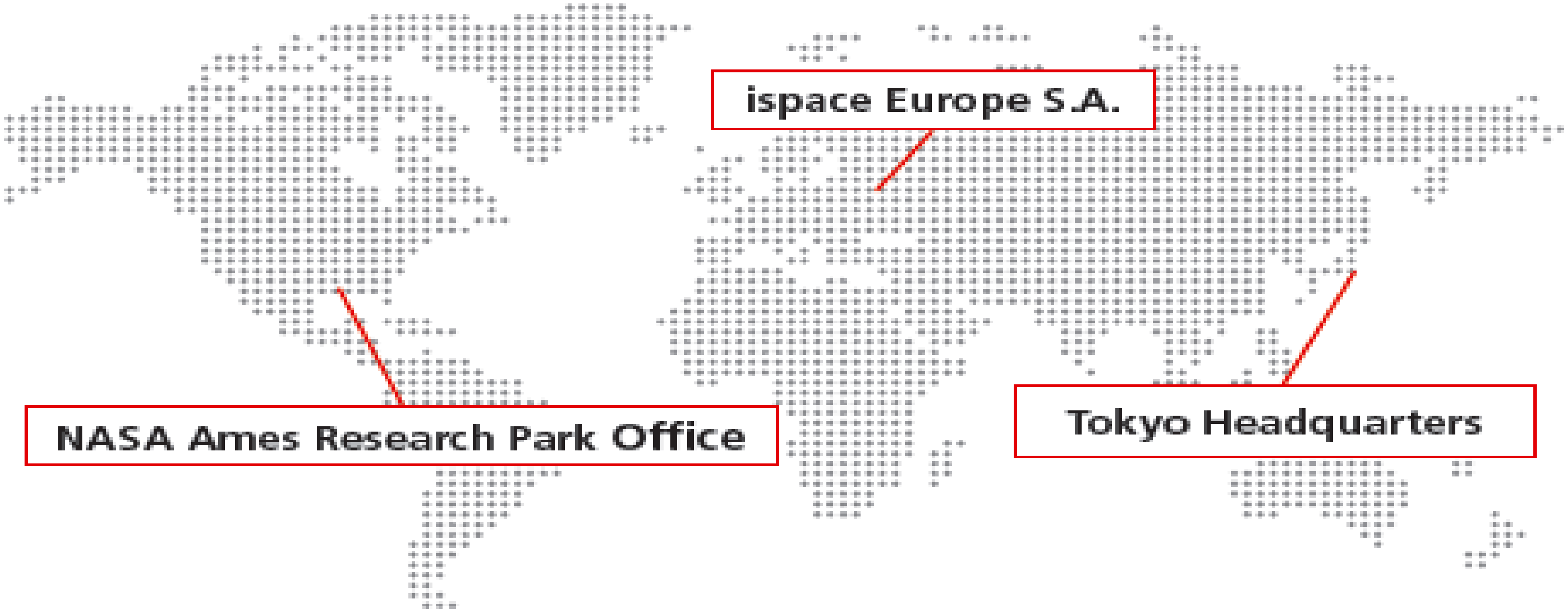


# EXPAND OUR PLANET,
# EXPAND OUR FUTURE

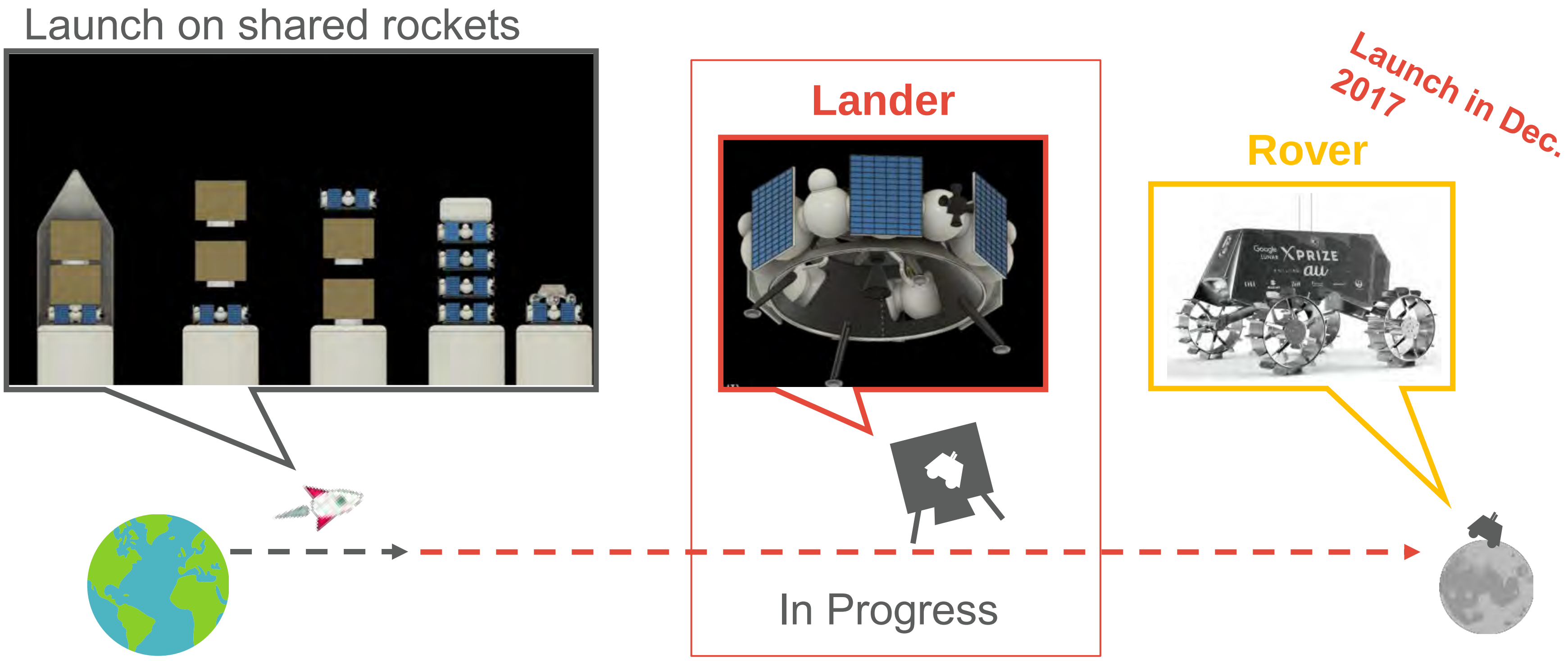
ispace is a junior lunar exploration company with a vision to extend human presence into outer space.

# ispace Global Presence

## 40 Employees in 3 Countries



# ispace is focused on developing micro-robotic technologies to conduct prospecting missions on the Moon



# Why the Moon?

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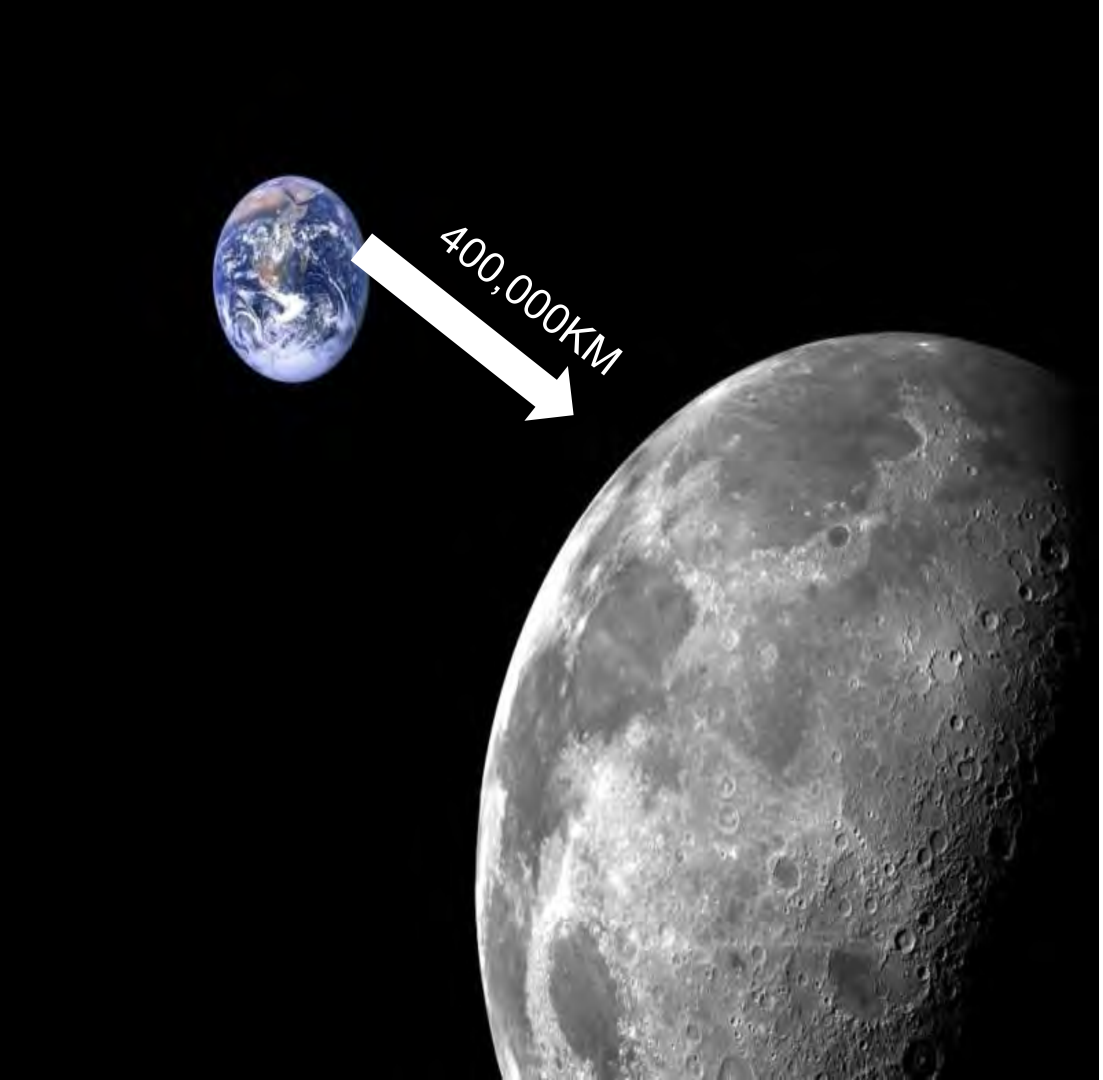



# Why the Moon?

Location

"The Moon is the first milestone on the way to the stars"

Arthur C Clarke

- Short-Time Delay (1.5 Seconds)
- Telerobotic Operation Possible
- 4 day trip for Humans and Equipment

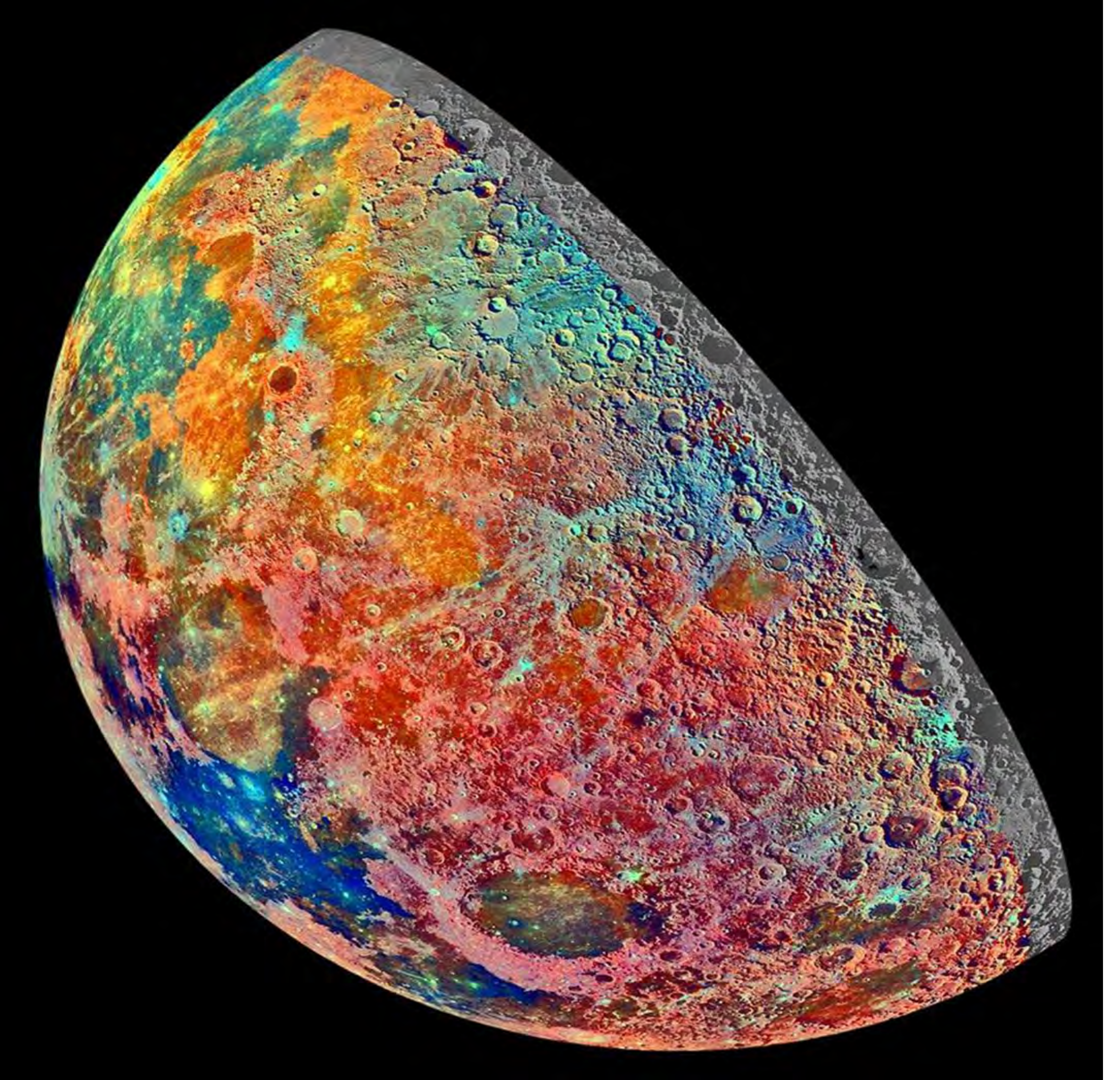
# Why the Moon?

Environment

"If God wanted man to become a spacefaring species, He would have given man a moon."

Krafft Eriche

- Unique Environment for experiments
- 1/6 Gravity of Earth
- Test Bed for future exploration



# Why the Moon?

Resources

- Metals (Fe, Ti, Al, Si)
- Rare Earth Elements and Platinum Group Metals
- Volatiles (H, N, Cl,)
- $H_2O$
- Moon Treasure

# Rover Technology

# Over 20 Years of R&D Efforts by Space Robotics Lab.

TOHOKU UNIVERSITY

The SPACE ROBOTICS Lab.


Hayabusa 1&2


Planetary Rovers


Micro-Satellites

CTO, ispace

**Dr. Kazuya Yoshida**

Professor at Tohoku University

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# Rover Designs

Two-Wheeled

- Swarm
- Terrain
- Mapping

Four-Wheeled

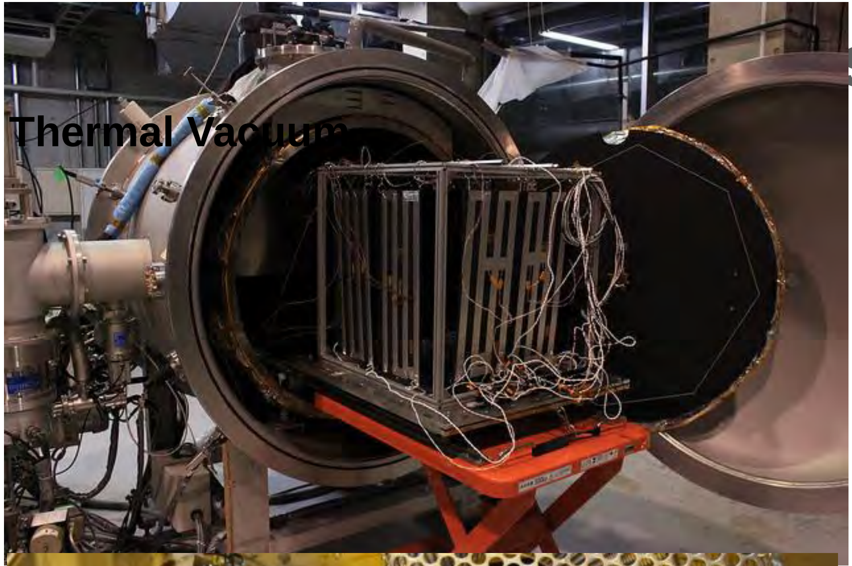
- Prospecting
- Larger Payloads
- GLXP

Tethered Approach

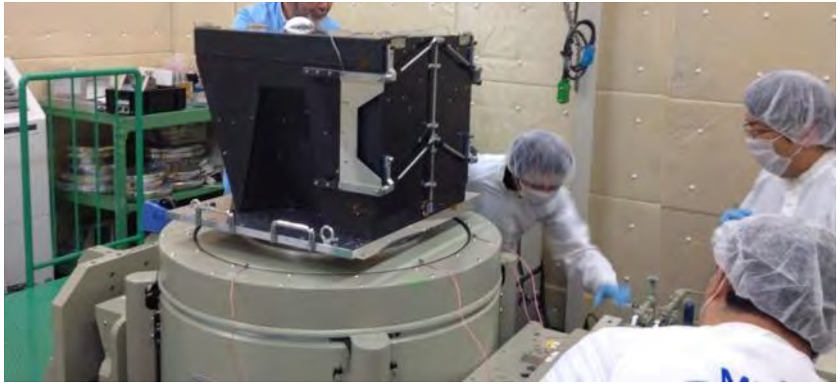
- Caves
- Steep Craters

# s, Proven Mobility

**Thermal Vacuum**



**Vibration**



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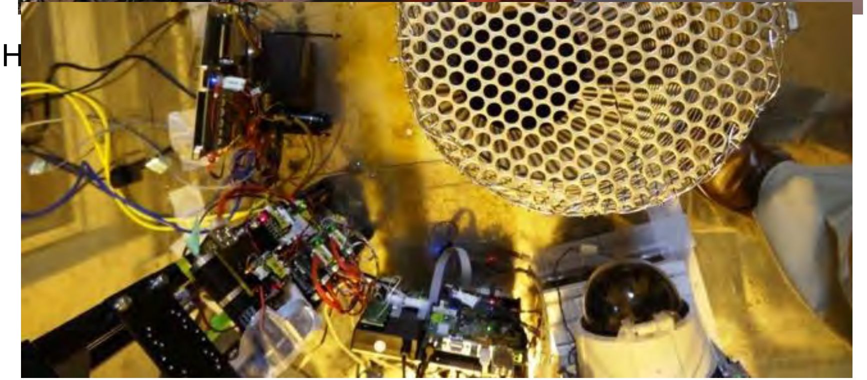

**Radiation**


**Lunar analog field**

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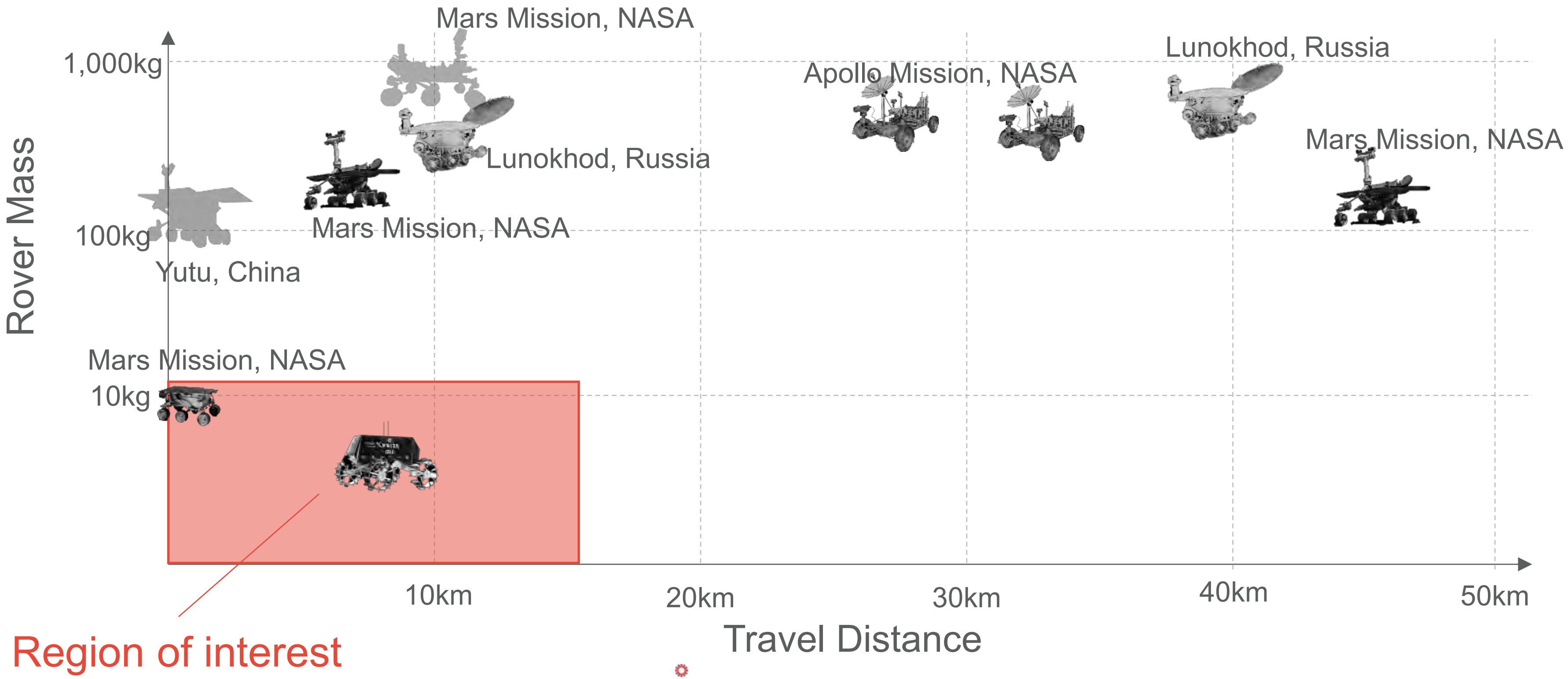
# Faster, Cheaper, Good Enough

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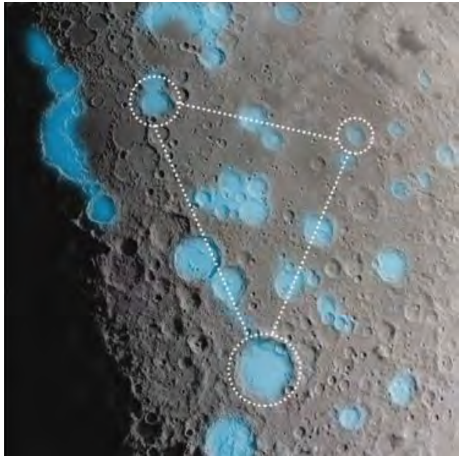
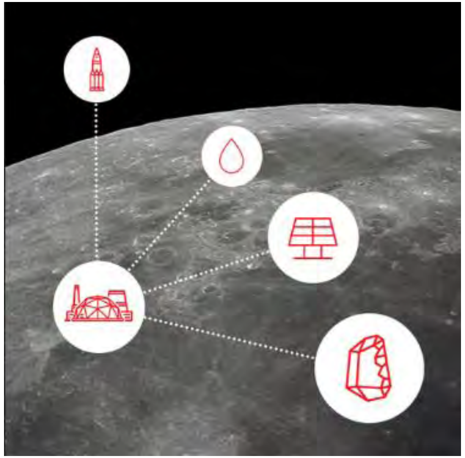
# ispace prospecting plan

# Phased Approach

| 2017 | 2018-2024 | 2025- |
|---|---|---|
| **Phase1** | **Phase2** | **Phase3** |



## Google Lunar XPRIZE

- ✓ Validate micro robot technology

## Prospecting & Exploration

- ✓ Obtain technology to access the Moon
- ✓ Provide a frequent delivery service
- ✓ Map resources with swarm systems
- ✓ Develop ISRU systems

## Extract, Process Deliver

- ✓ Provide essential products for customers on the Moon and in CIS-Lunar Space

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Phase1
HAKUTO
Google LUNAR XPRIZE
au
IHI
Zoff
Google LUNAR XPRIZE
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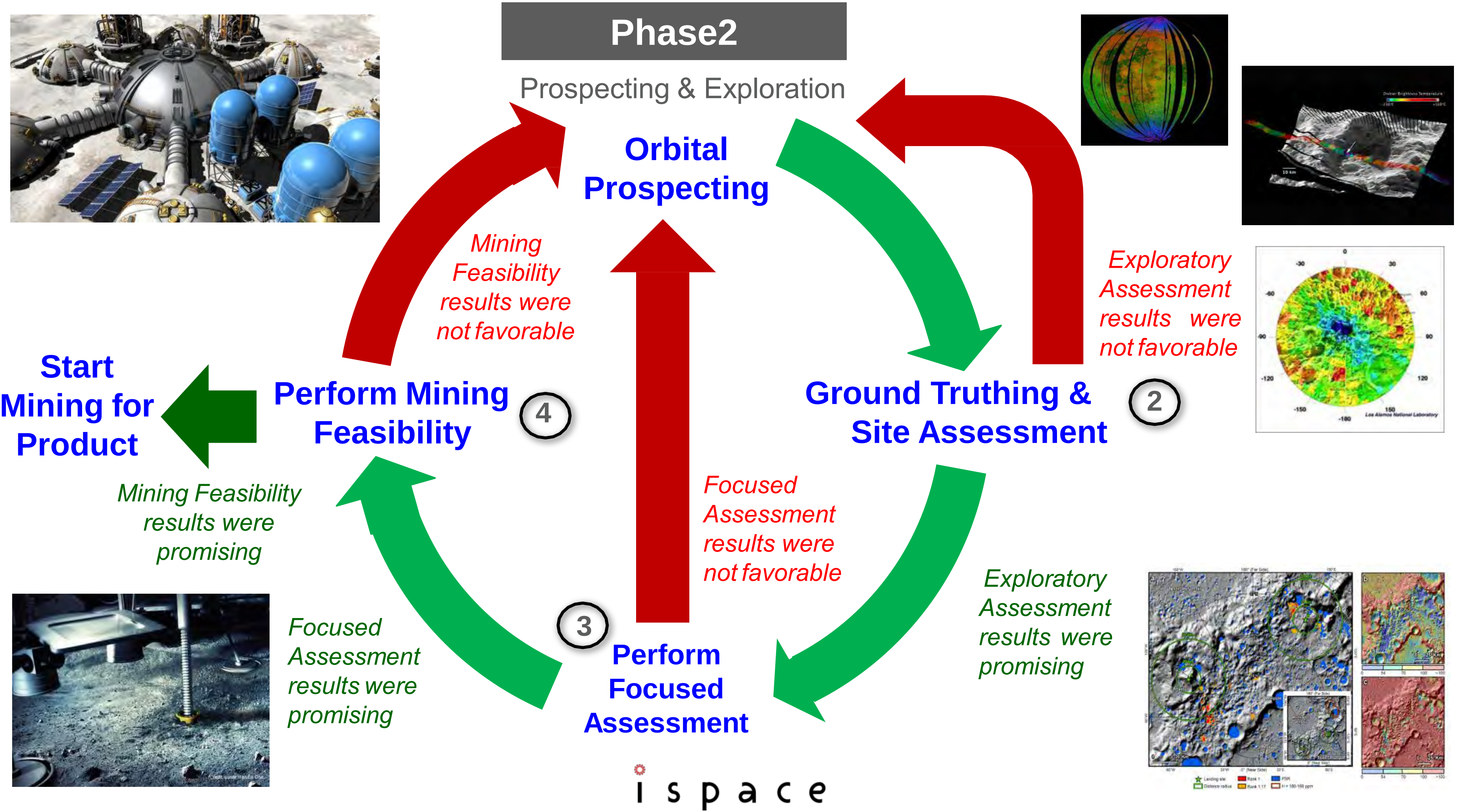
Phase2
Prospecting & Exploration
Orbital Prospecting
Exploratory Assessment results were not favorable
Ground Truthing & Site Assessment
2
Exploratory Assessment results were promising
Perform Focused Assessment
3
Focused Assessment results were not favorable
Focused Assessment results were promising
Perform Mining Feasibility
4
Mining Feasibility results were not favorable
Mining Feasibility results were promising
Start Mining for Product
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# Phase3

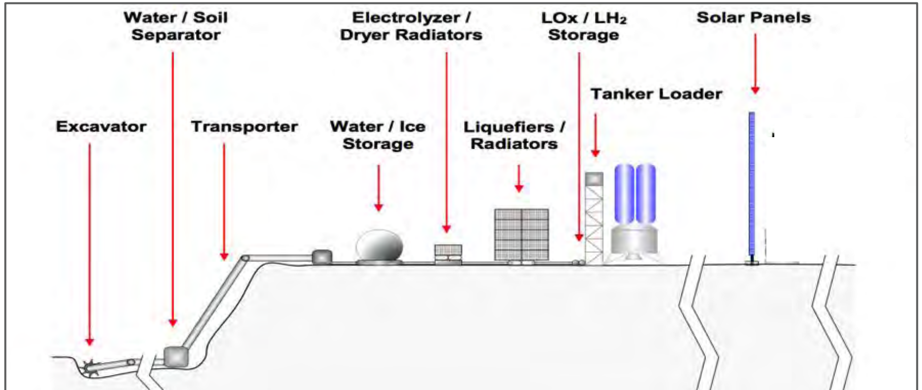
Cis-Lunar Econosphere

## Extract, Process Deliver

Resource mining on the Moon

Transport from the Earth to the Moon

| Exploration | Extraction | Production & Storage | Transport | Others |
| --- | --- | --- | --- | --- |




出典　清水建設

BIGELOW
SHIMIZU CORPORATION SHIMZ
ULA United Launch Alliance
BLUE ORIGIN
bhpbilliton resourcing the future
KUMBA IRON ORE
AngloAmerican
RioTinto
AngloGold Ashanti
BARRICK
ARM African Rainbow Minerals
NORILSK NICKEL
VALE
AfriSam
BANNERMAN
Stefanutti Stocks
Universiteit van Pretoria University of Pretoria Yunibesithi ya Pretoria
METOREX LIMITED
MINERSA
Platmin
NKOMATI
TRAFIGURA
ASHANTE
IAMGOLD
DMC ENERGY
RECLAM
Teal Exploration & Mining
HMM Hotazel Manganese Mines

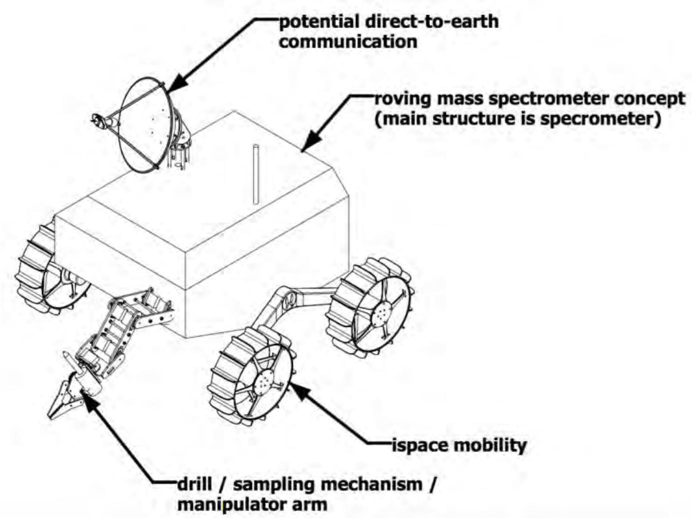
# Luxembourg Prospecting Mission

# Luxembourg – ispace MOU

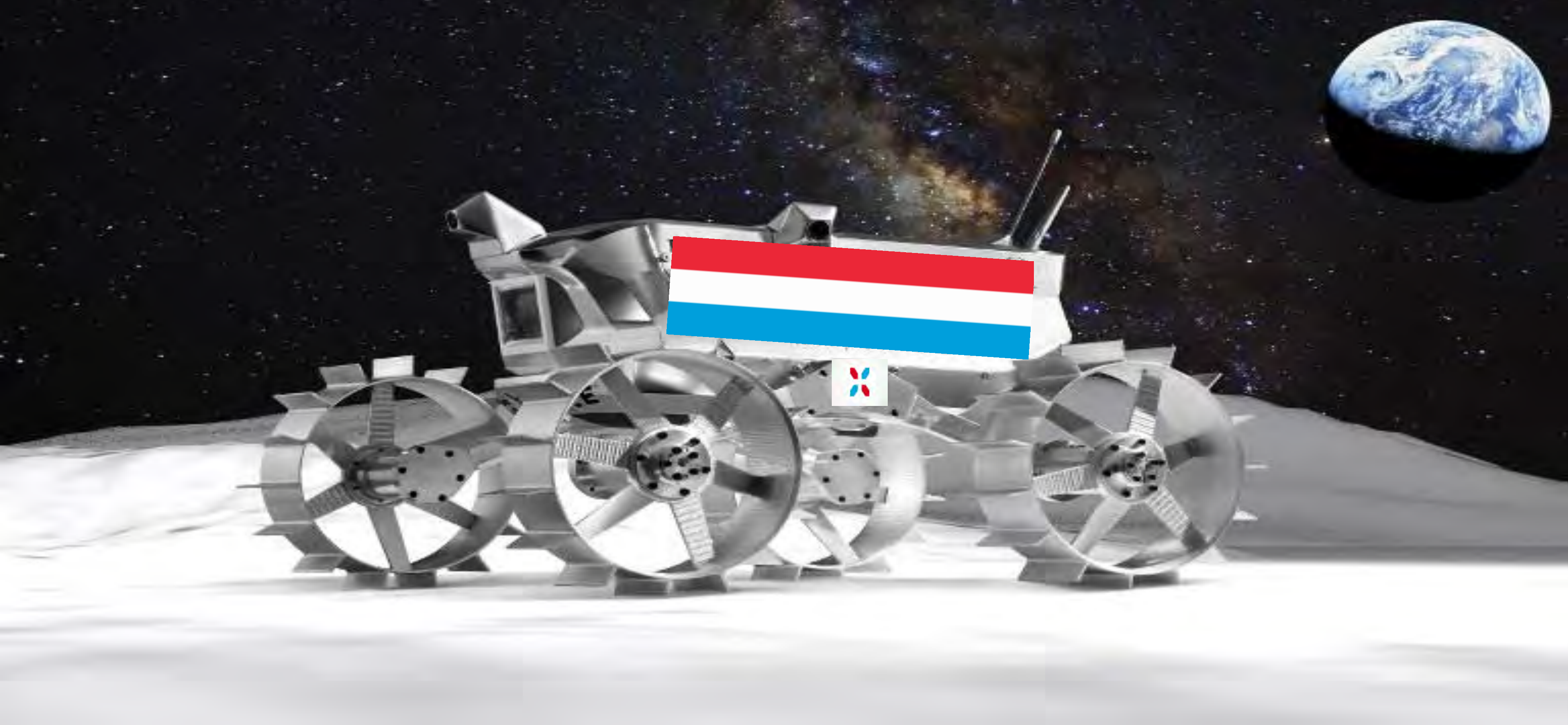
March 02, 2017


LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY

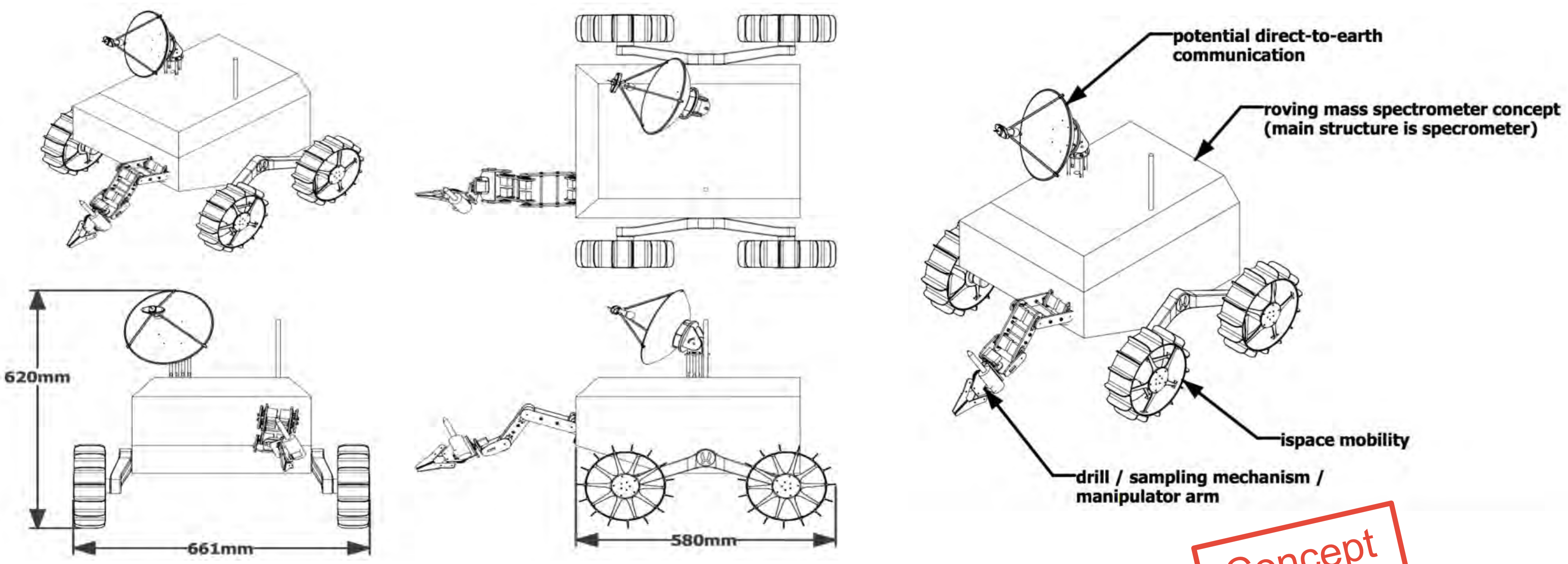
LIST



# Roving Spectrometer Mission



# Roving Spectrometer Concept




Concept

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# Mass Spectrometer

- Characterize the distribution of water and other volatiles at the lunar poles
  - Map the surface and subsurface distribution of hydrogen rich materials
  - Determine the constituents and quantities of the volatiles extracted
    - Quantify important volatiles: $H_2$, He, CO, $CO_2$, $CH_4$, $H_2O$, $N_2$, $NH_3$, $H_2S$, $SO_2$

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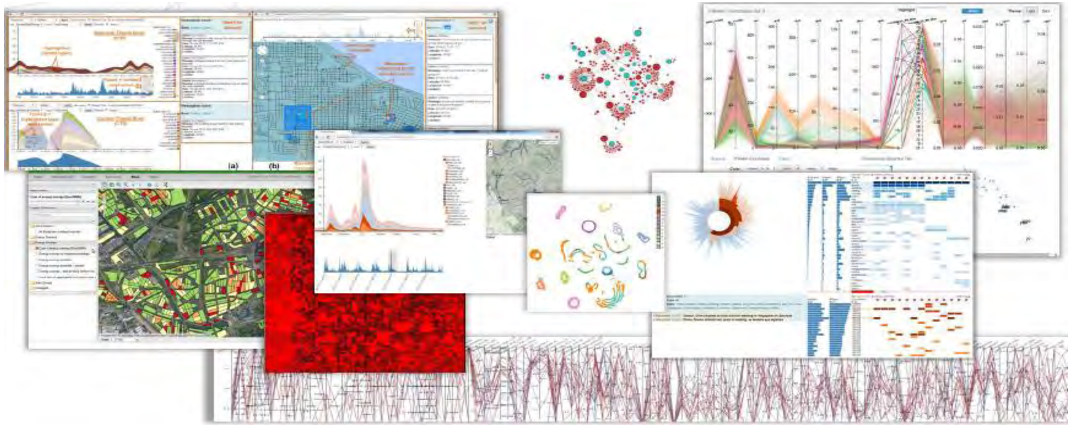

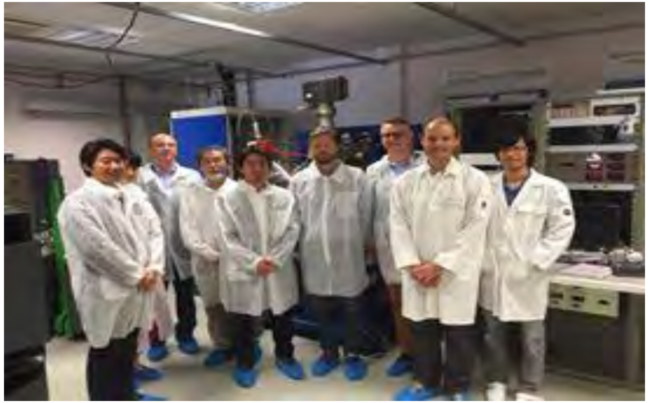

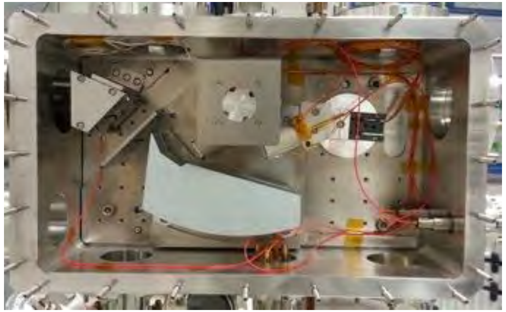

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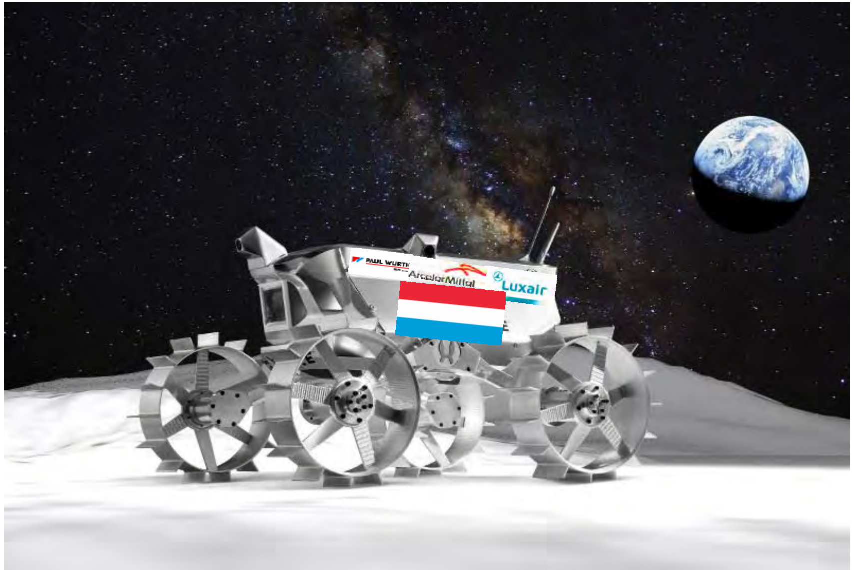
# Roving Spectrometer Main Objectives




- Develop a light weight, mobile, and cost effective roving mass spectrometer
- The 'Roving Spectrometer' will traverse several kilometers and drill for ice in a permanently shadowed region of the lunar poles in order to accomplish goals such as:
  - Quantify and qualify lunar ice and other resources
  - Defining the composition, form, and extent of the water ice;
  - Characterizing the environment in which the ice is found;
  - Defining the accessibility/extractability of the resources;
  - Quantifying the geotechnical properties of the lunar regolith in the areas where resources are found
  - Identify sites for targeting future missions

# Short Term Commercialization

# Advertising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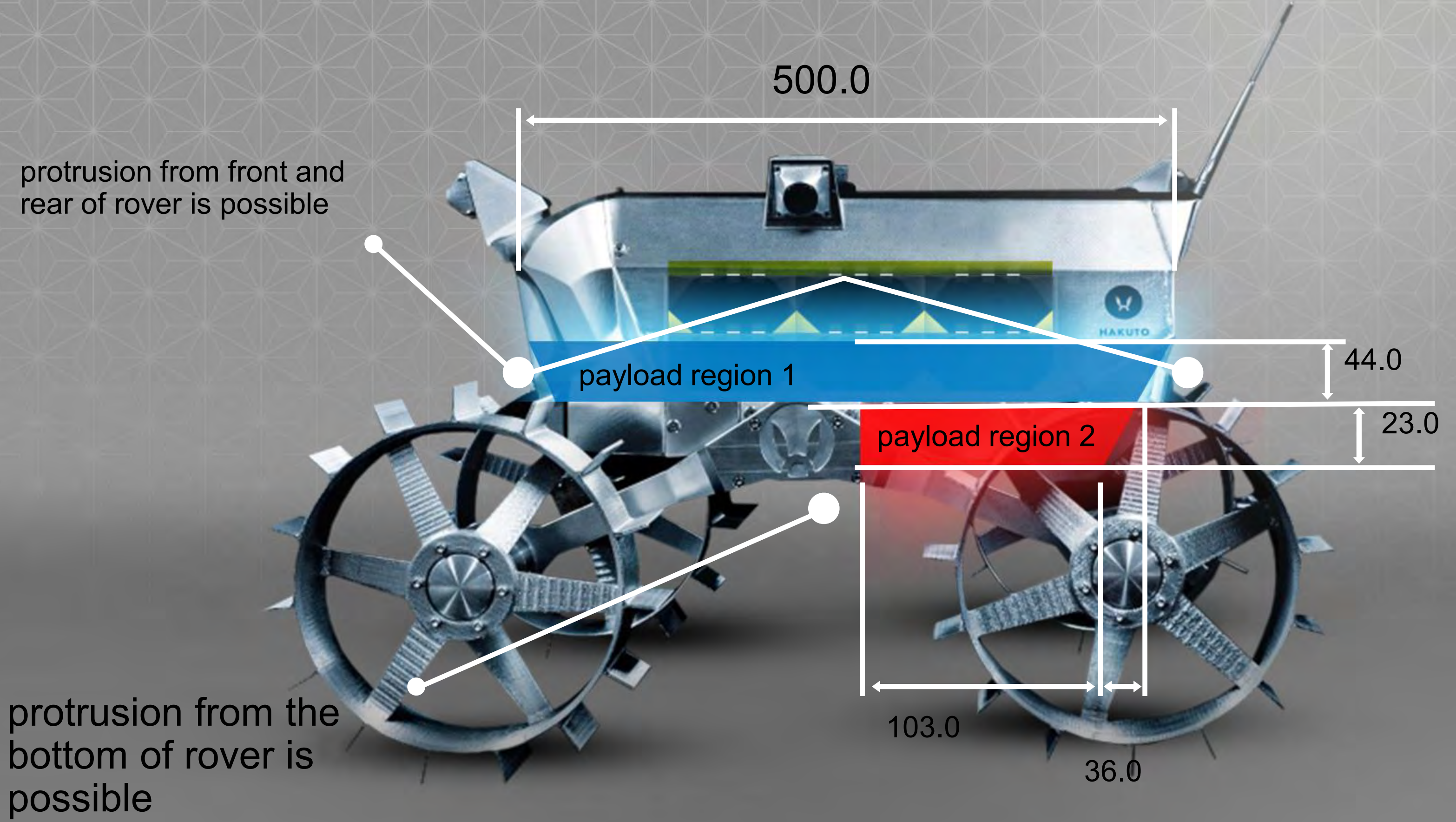
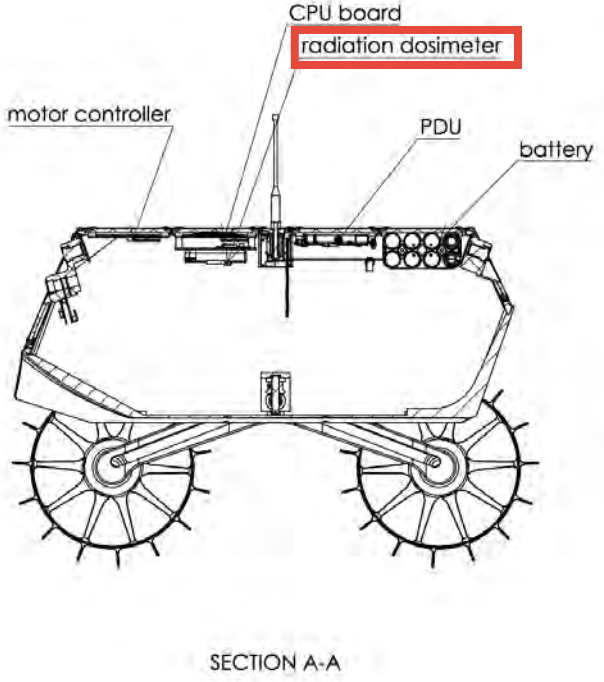
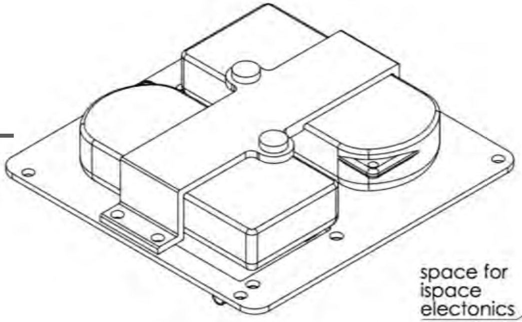
# HOSTED PAYLOAD

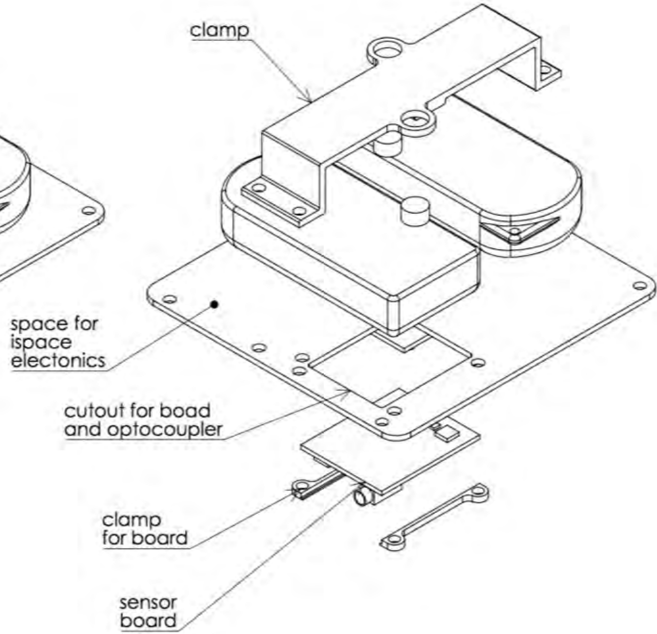


# Prospecting with ispace

## Payload delivery for JAXA

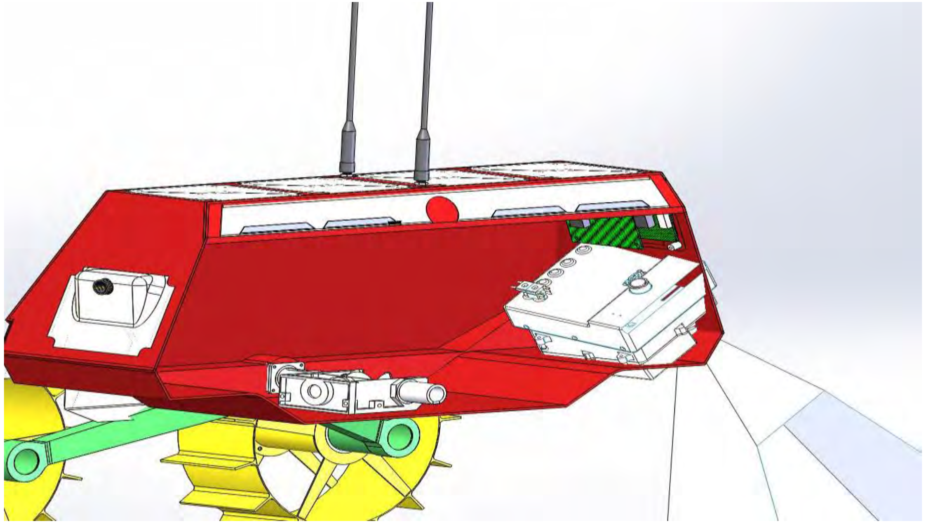


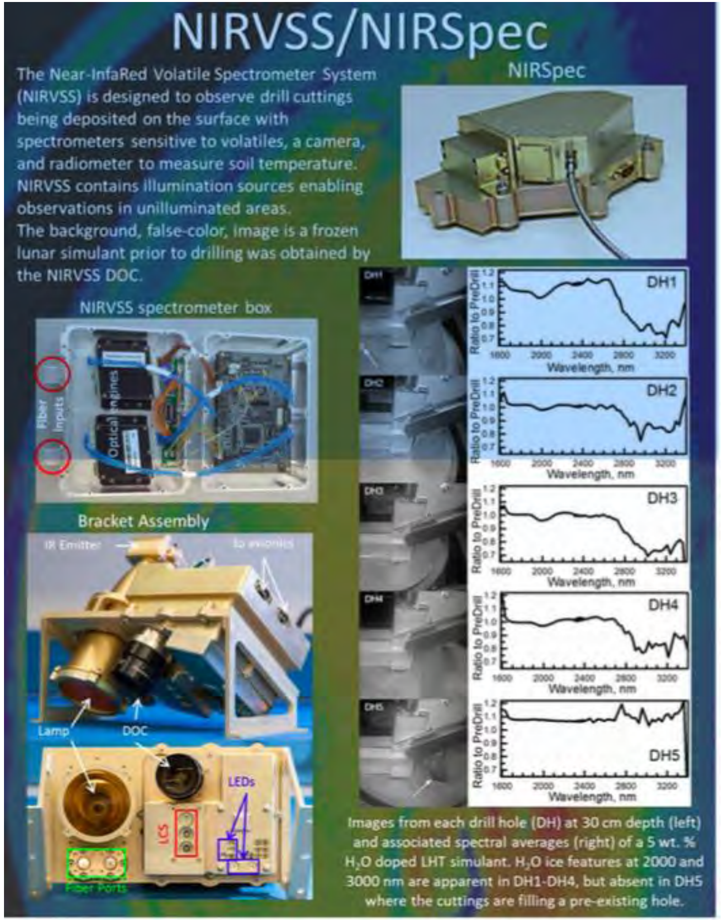






# Prospecting with ispace

## Payload delivery for NASA






No ITAR/EAR export materials herein

# Prospecting with ispace

## Payload delivery in Luxembourg

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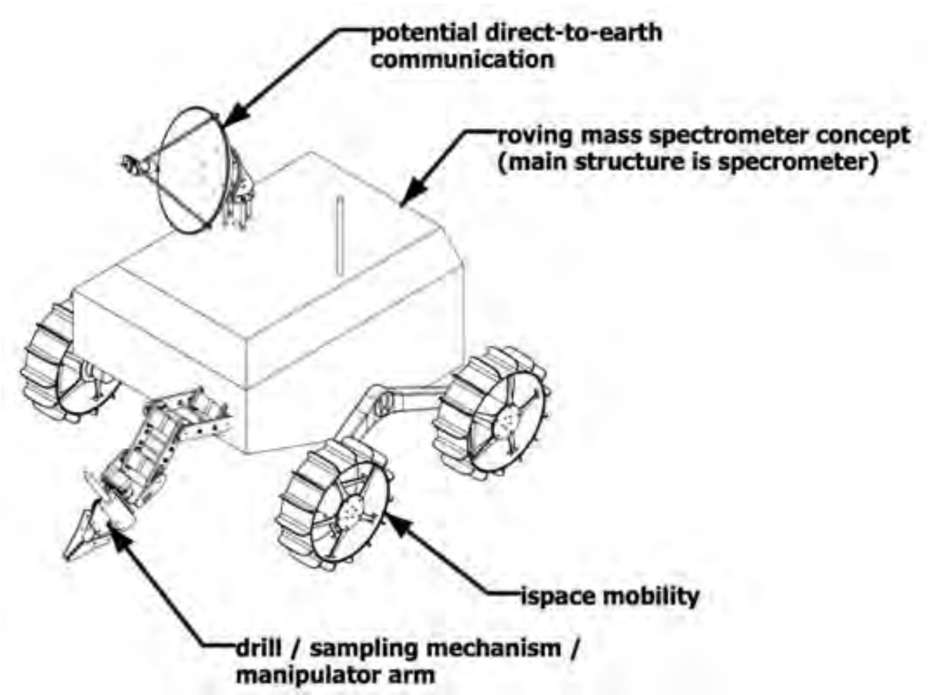


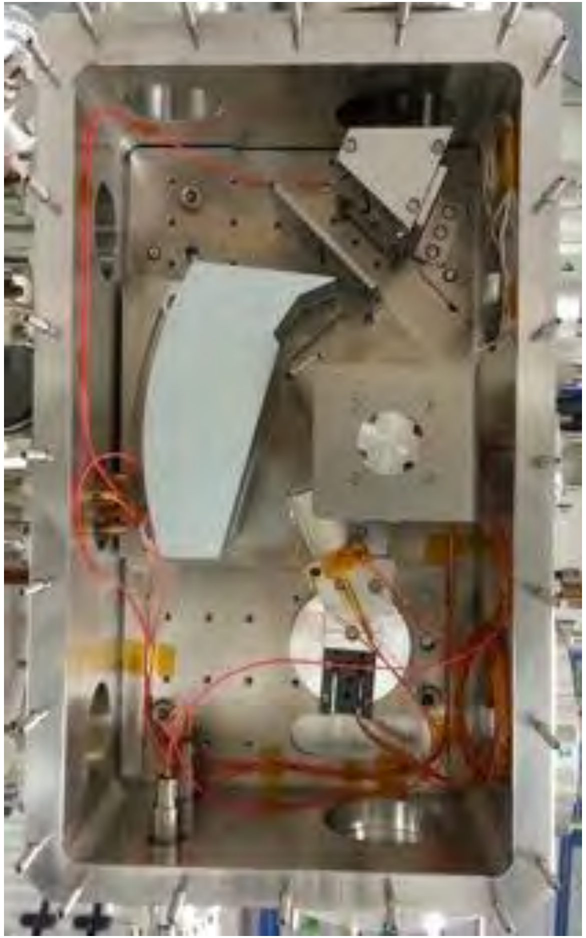

# Next Steps

- Community input Needed
- Drill and Ionizer Needed
- Great people Needed

## TOKYO, JAPAN

Software Engineer

Spacecraft Harness Engineer

Spacecraft Propulsion Development Engineer

Spacecraft Structural Analysis Engineer

Spacecraft Communications Engineer

Software (GUI) Engineer

Spacecraft Software Lead Engineer

Spacecraft Systems Engineering and Integration Lead Engineer

Lunar Lander Guidance, Navigation and Control Lead Engineer

Spacecraft Propulsion Analysis Engineer

# Thank you

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# The legislation of commercial space mining is speeding up globally.

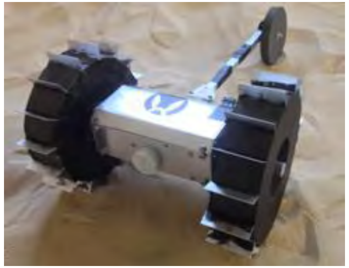
# The Government of Japan also declared support for space mining

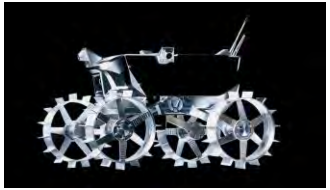
| U.S. | Luxembourg | Japan |
|---|---|---|
|  |  |  |
| • Passed a law that allows private companies to mine and sell space resources | • Announced the draft of space resource utilization (to be approved in 2017) | • Space mining is added to the schedule of Japanese space policy (2016)<br>• The Diet passed a collateral resolution about space mining (2016) |

# Rover History

| | | |
|---|---|---|
| 2010.9 | | Started as White Label Space Japan |
| 2011.8 | **PM1** | Completion of Prototype 1 |
| 2013.12 | **EM** | Completion of Engineering Model |
| 2014.8 | **PFM1** | Completion of Pre-Flight Model 1 |
| 2015.10 | **PFM3** | Completion of Pre-Flight Model 3 |
| 2016.8 | **FM** | Flight Model Design Announcement |



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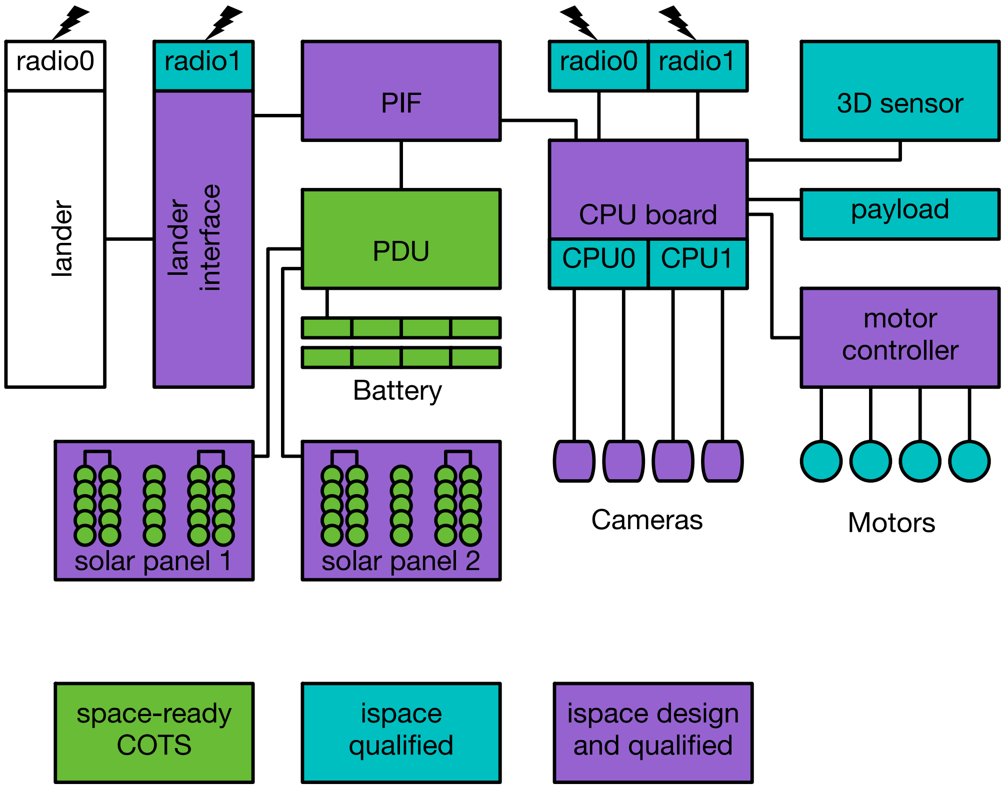
# Design of the Flight Model 4 Wheel Rover

- **4 kg** Mass
- **2kg** payload capacity
- **15 W** power consumption
- **15 km** Mission distance capability
- **2** redundant radios
- **2** redundant CPUs
- **4** cameras
- **360º** imaging
- **1280x720p** video
- **1000** m Radio connectivity

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# HAKUTO Rover Flight Model

## 360º VISIBILITY

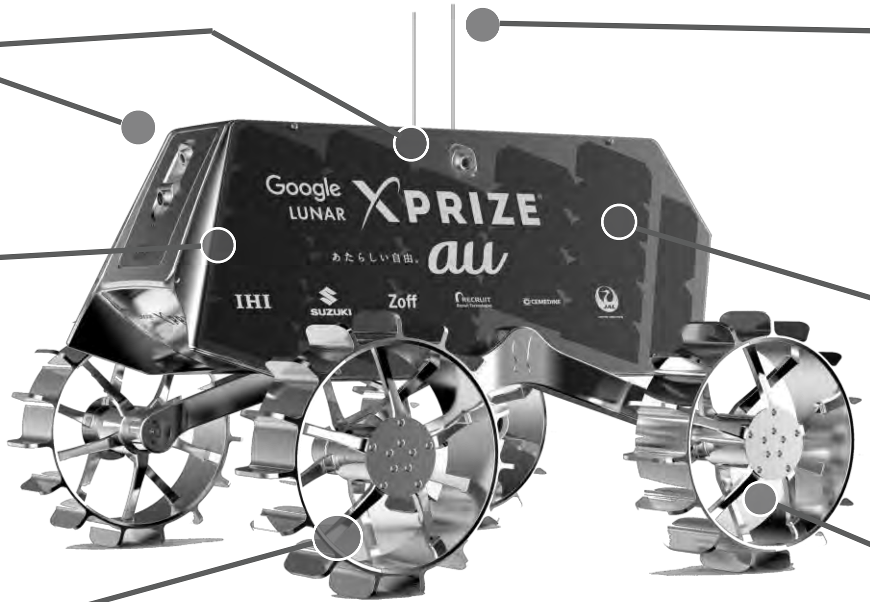
The rover's camera system uses four cameras that capture images from 360º for both research and maneuvering.

## CARBON-FIBER ENFORCED PLASTIC

Carbon-fiber enforced plastic (CFRP), makes up the rover's body. It offers unparalleled weight savings and strength.

## ULTEM RESIN

We've 3D printed the rover's wheels from ULTEM, which can handle extreme heat and offers strength and rigidity.




## HYBRID COMMUNICATION

The hybrid communication architecture combines the 900MHz and 2.4 GHz frequencies for connectivity and speed.

## SOLAR PANELS

Lightweight solar panels positioned on either side of the rover offer more exposure to sunlight.

## WHEELS

The powder-like sand of the Moon presents new challenges for mobility, so we developed wheels with grouser tracks.

Penetrators

Initial traverse path based on pre-mission orbital data

- Hypothesize location of volatiles based global data, terrain, and geological context
- Plan surface exploration before landing/impact based on landing/impact error and/or rover capabilities
- For rover missions:
  - Re-plan traverse based on accumulations of results and new hypotheses

## *Driving Questions*

*Where are polar volatiles located?*

*What is the form, concentration and distribution of polar resources?*

*Are long term operations at the lunar poles feasible'?*

- Utilize non-invasive surface and subsurface instruments to guide selection of sample sites; Instrument suite may be limited
- Perform coring and volatile analysis at selected location

➢ Characterize the distribution of water and other volatiles at the lunar poles

- Map the surface and subsurface distribution of hydrogen rich materials
- Determine the constituents and quantities of the volatiles extracted

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