# Space Exploration and Innovation 2030

## Strategies for the Moon Base & Space Natural Resources

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**Chair – DLR Executive Board**

**Tokyo, 4 March 2018**

# Rationales for Space Exploration

- Economic benefits
- International Relations
- Scientific discovery
- Education and inspiration

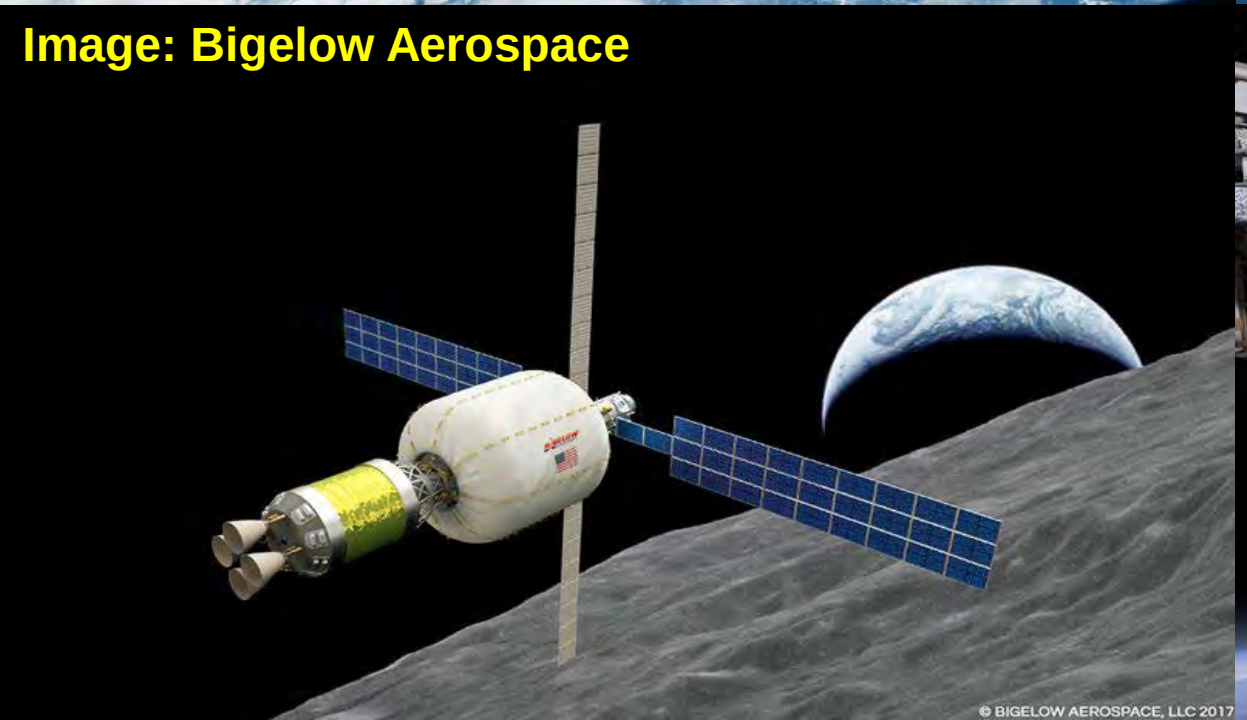
- ...maximize the overall **scientific, cultural, economic, political, and inspirational benefits** of individual milestones at each step along the pathway toward long-term goals

- Vigorously pursue opportunities **for international and commercial collaboration** in order to leverage financial resources and capabilities of other nations and commercial entities

## 2025

# Transition of the domain of lower Earth orbit to the commercial space industry?

Image: Bigelow Aerospace



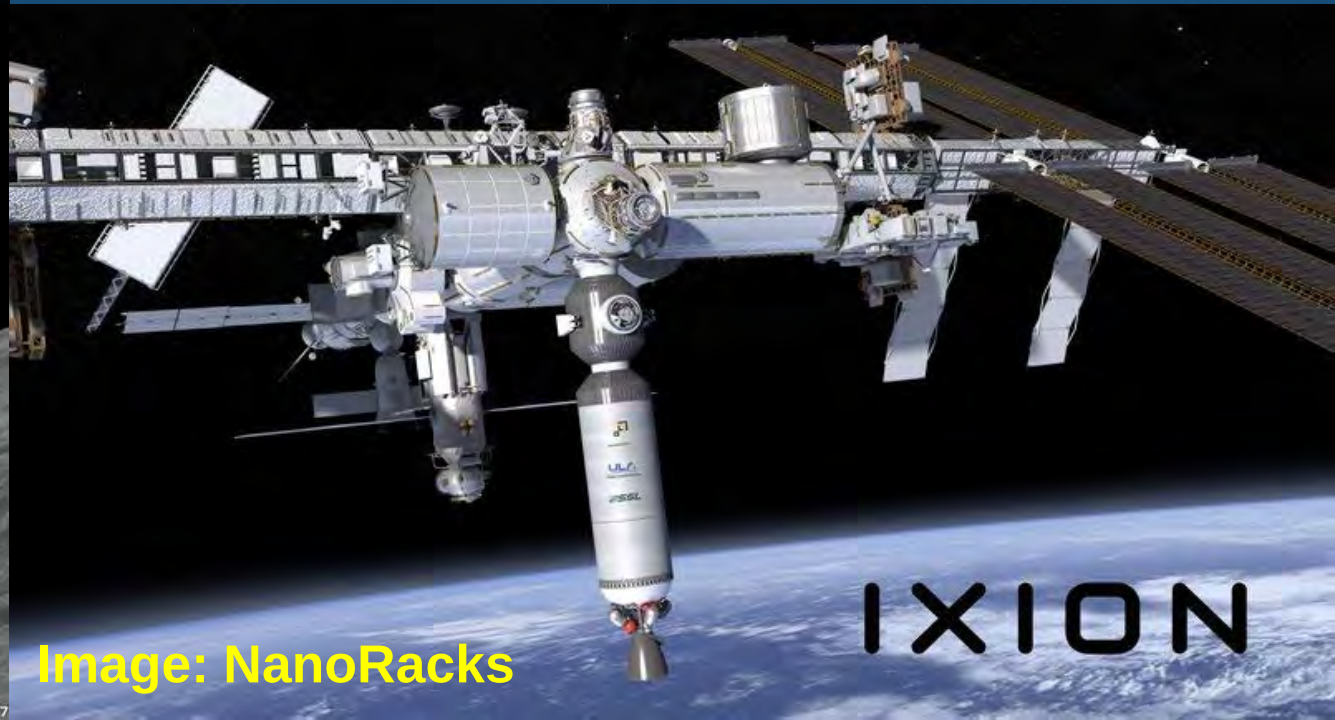
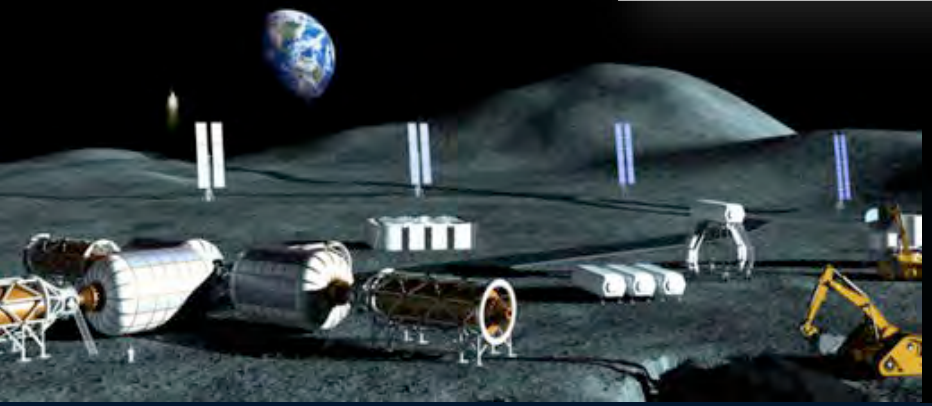



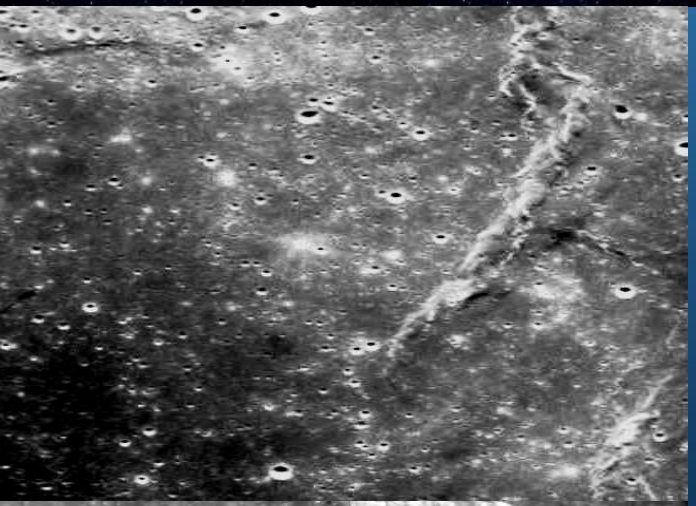

Image: NanoRacks

# Future perspectives of space exploration?

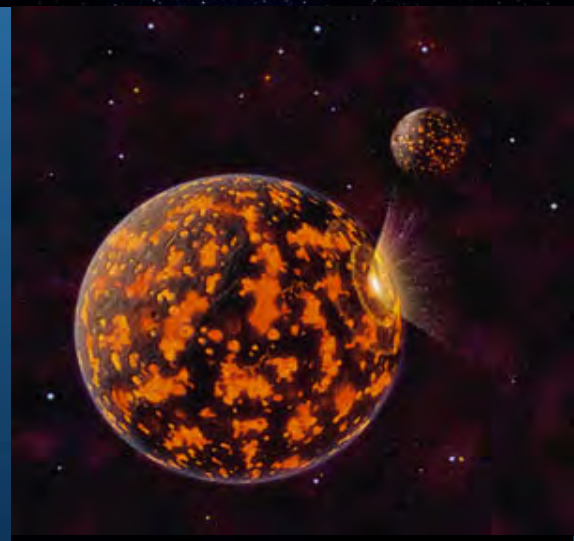

Moon Village



# Destination Moon: a part of Earth.....

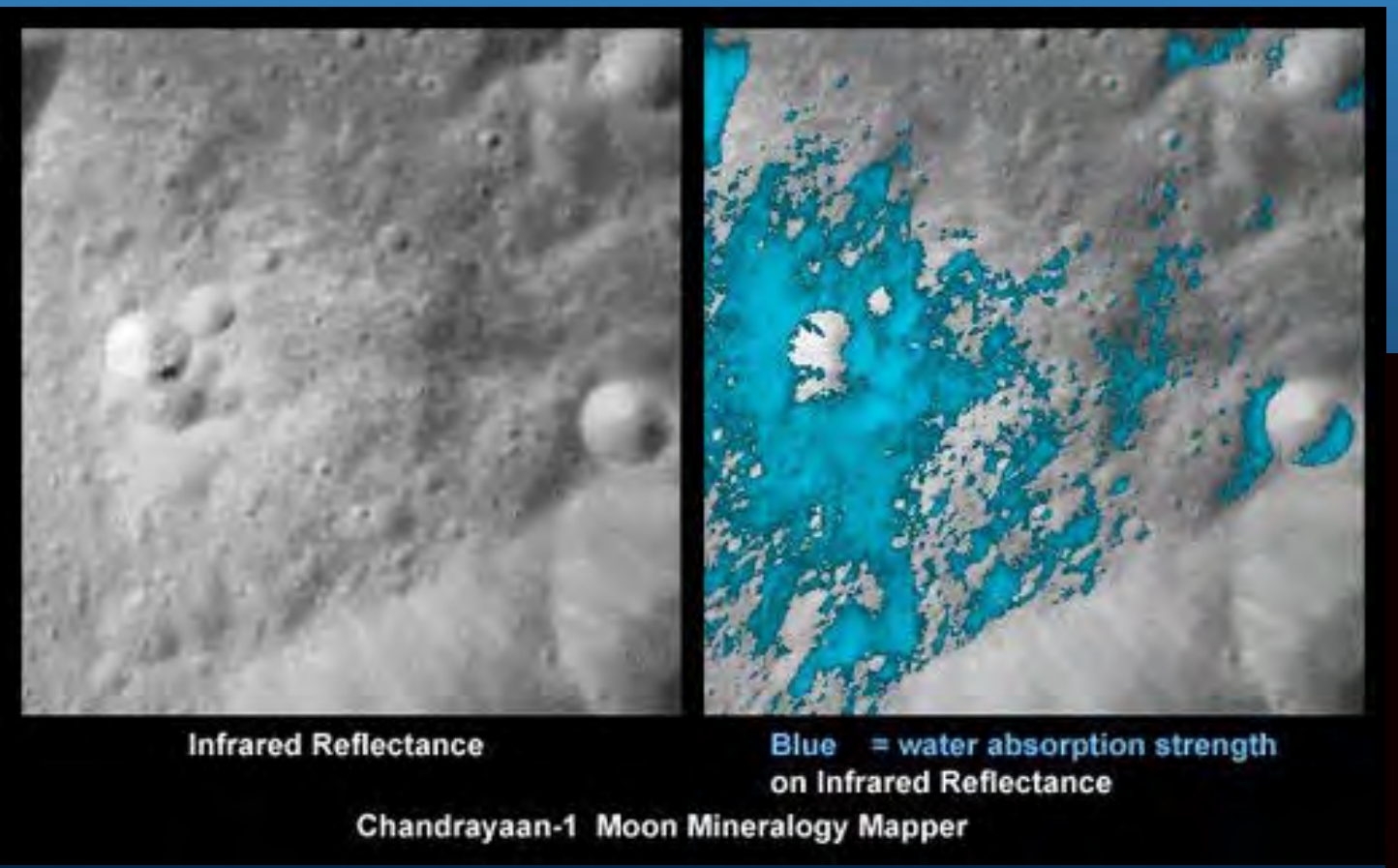


- Early Earth-Moon System
- Terrestrial Planet Differentiation and Evolution
- Solar System Impact Record
- Lunar Environment



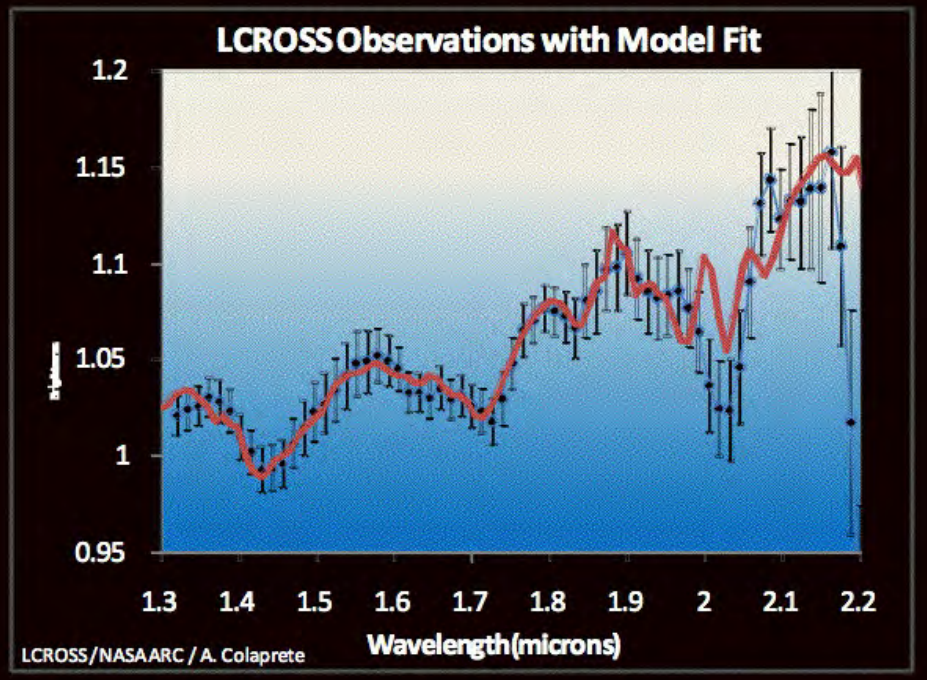
ESA / SPACE-X, Space Exploration Institute

# Water on the Moon .....




Chandrayaan-1
IR spectrometer
hydration signature (OH)

& Moon Impact Probe



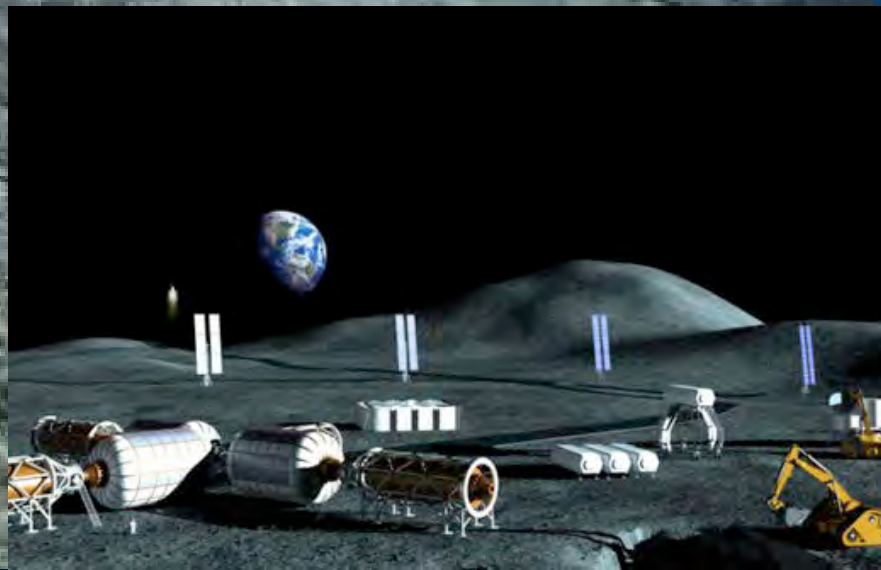

LCROSS impact
Water detection from shepherd
NIR spectrometer

# Global exploration strategy of the Moon

- Characterize lunar environment
- Use the Moon as stepping stone for Mars exploration
- Study resource potential of the Moon
- Prepare for future human presence
- Construct Habitation modules

**Expanding life beyond Earth…**

# Return to the Moon



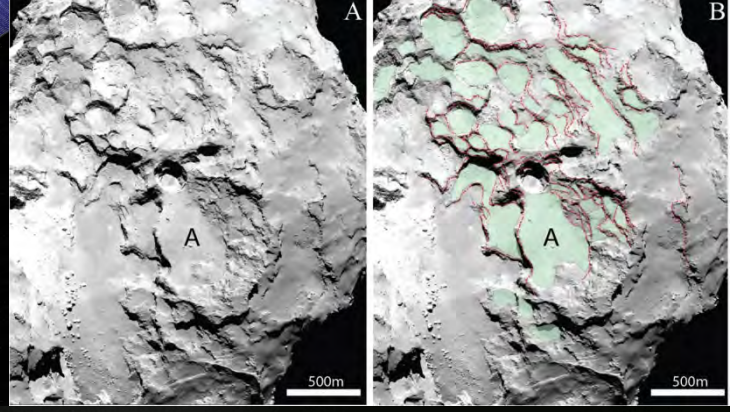
Credit: ESA/Foster + Partners

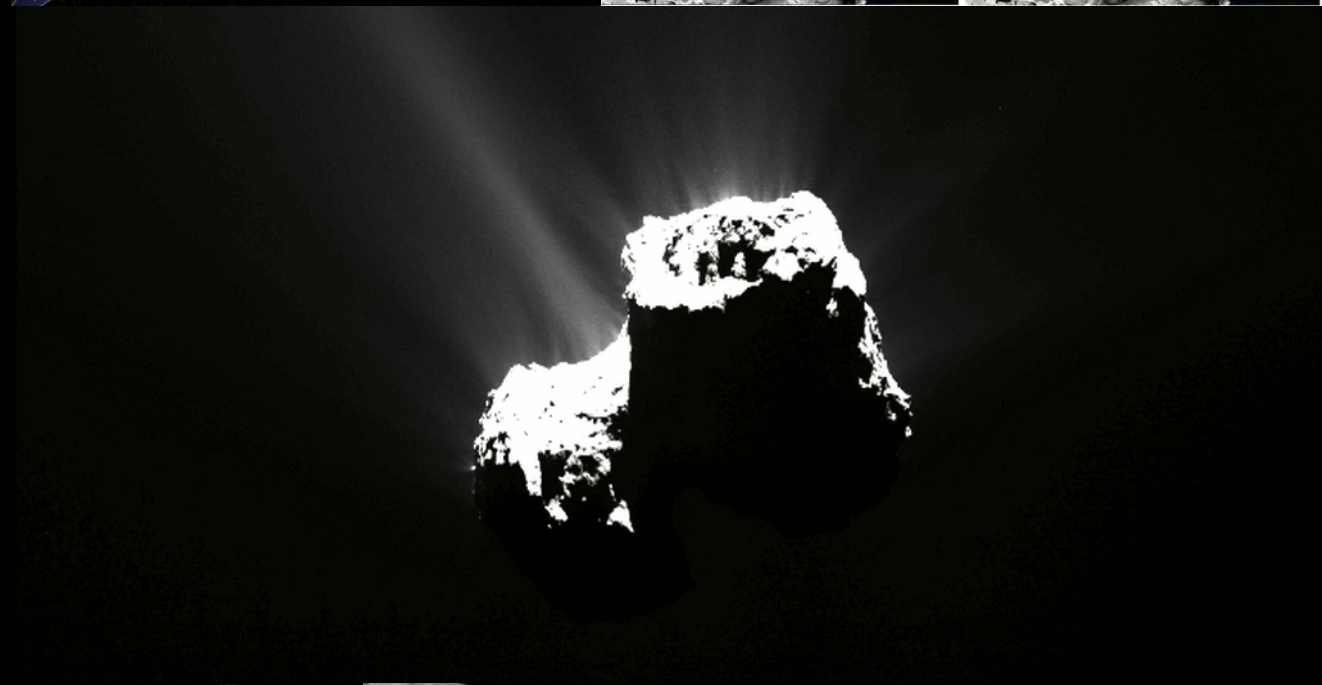
# Success Story Rosetta

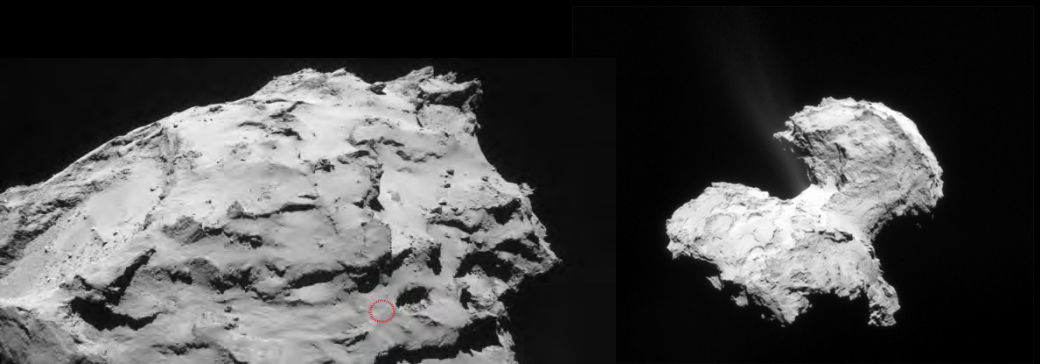
Rosetta ESA cornerstone mission to Churyumov Gerasimenko 67/P

Rosetta/Philae instruments from DLR **Philae Lander**

Philae landing - 12. Nov. 2014 first successful **landing(s)** on a comet





# Near-Earth Asteroids: tracing origins...

- Knowledge of formation, properties, distribution and evolution of NEOs
- Record: solar system and planet formation



**First sample return - Future missions**

NEAs < 1.3 AU

JAXA Hayabusa-2 on the way…

Launched 09/2016

NASA's Osiris-Rex 2016

# Explosions in der Atmosphere ……

Tunguska, 1908 (~50 m object)

Explosion over Chelyabinsk
15 Feb. 2013 (17 m object)

# Mission Hayabusa-2

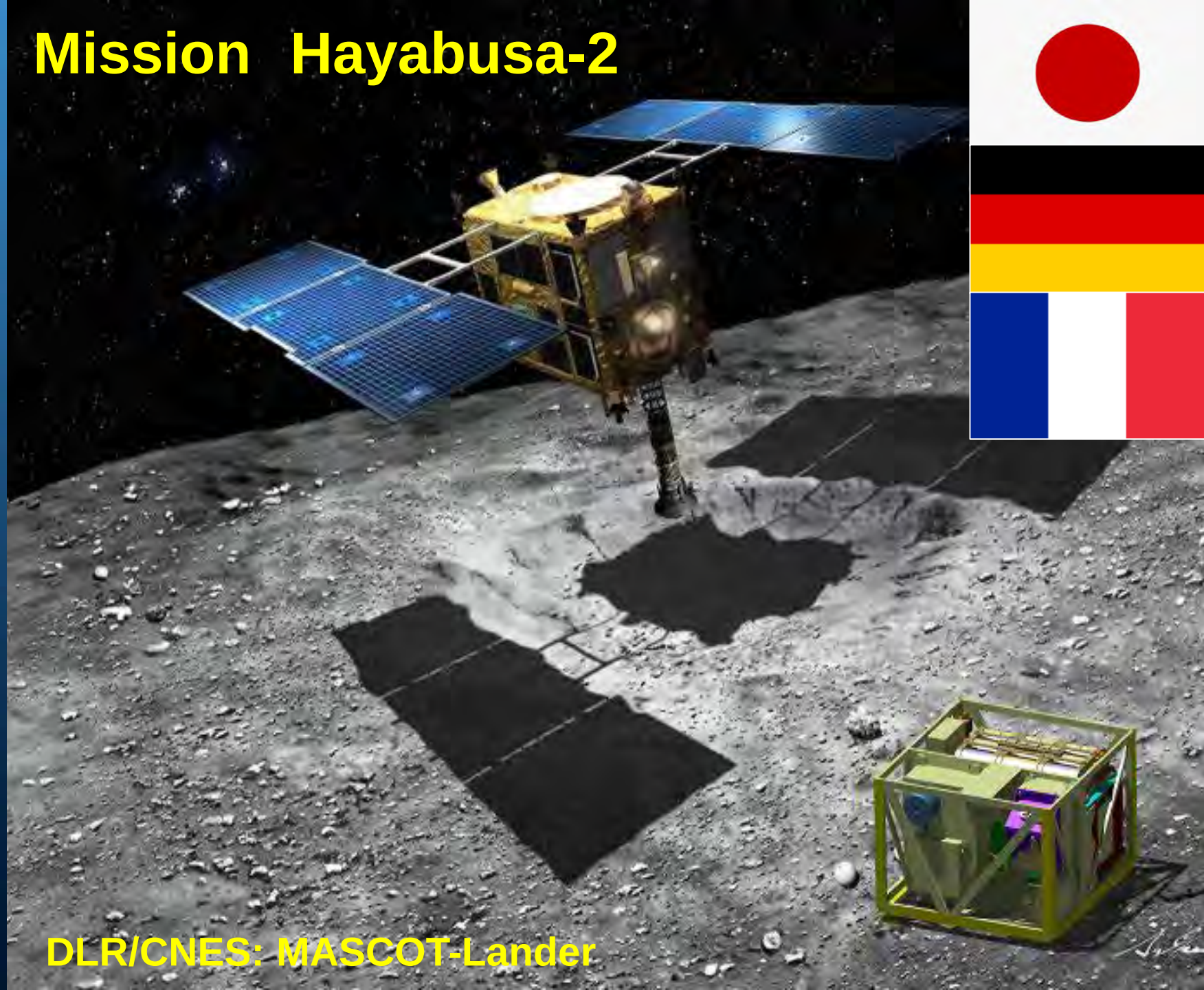
JAXA mission
Follow-on Mission to
C-type Asteroid
Launch: 2014
Target: 1999 JU3 „Ryugu“

Arrival: 2018 and stay for up to 18 months

Surface and sub-surface sampling

Connect cross-scale info between the mothership and sample analyses

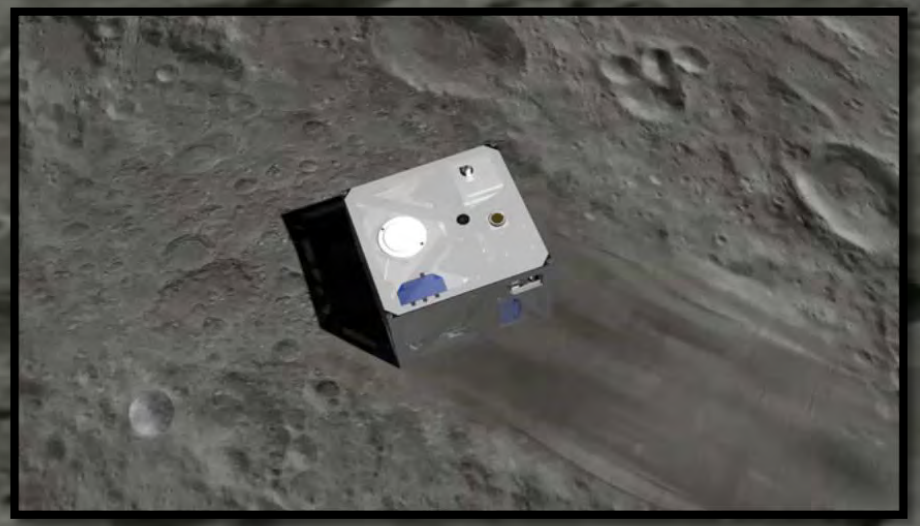
Return to Earth in 2020



# Hayabusa 2 – JAXA - Asteroid Ryugu

**MASCOT will free fall from a height of 100 m, landing on Ryugu**

**Mascot Lander (10kg): hopping 70 m**



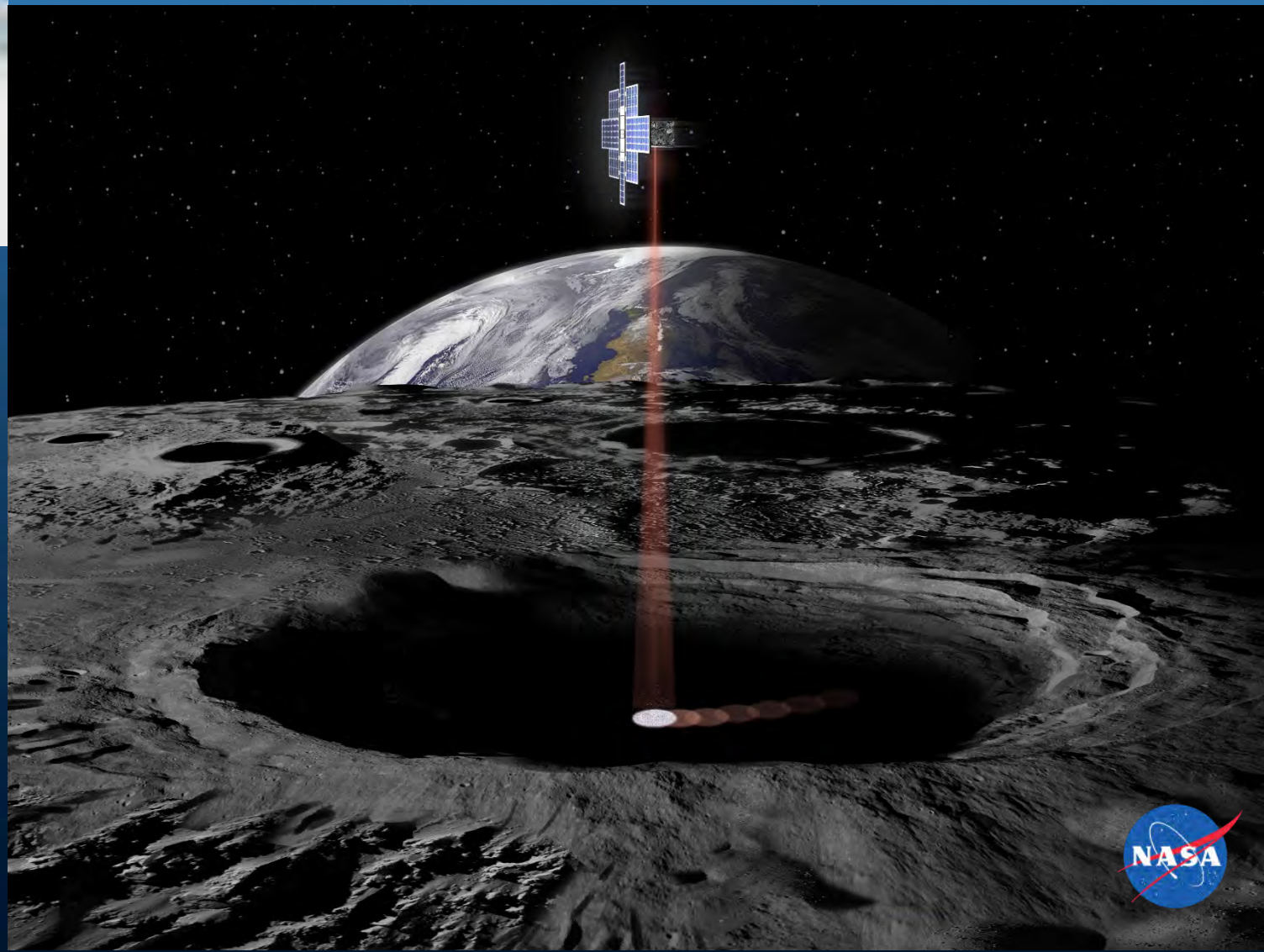
**4 instruments:**

- **Radiometer: surface temperature**
- **Wide-angle camera**
- **IR spectrometer: compositon**
- **Magnetometer: magnetic field**

# In-Situ Resource Utilization
# Using Space-Based Resources for Human Missions in Deep Space

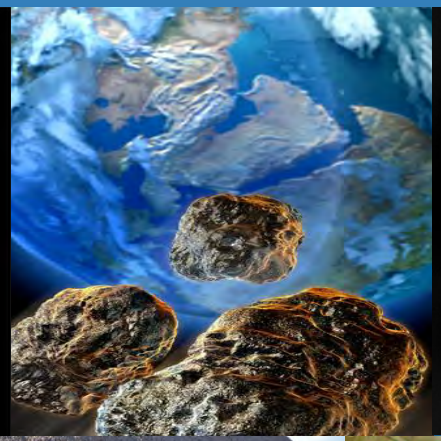
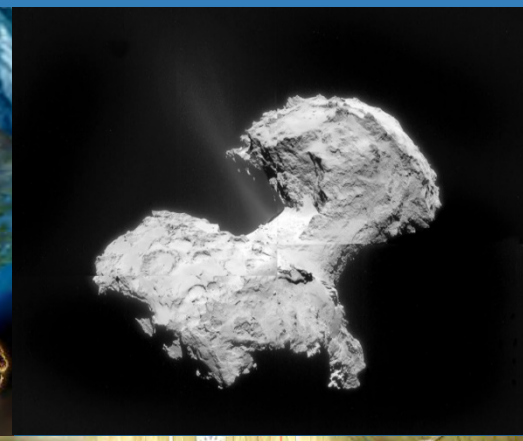

Planetary Resources

**Arkyd-6** spacecraft
is a technology demonstration
It will test systems for the
**Arkyd-100 satellites**, especially
core technology to measure
resources on water-rich
asteroids.



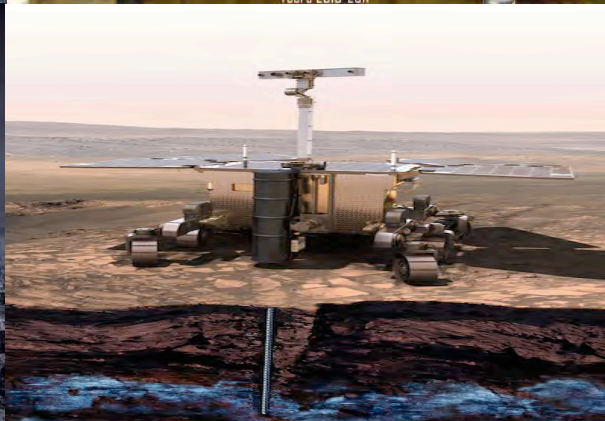
# Exploring the Earth-Moon-Mars Space





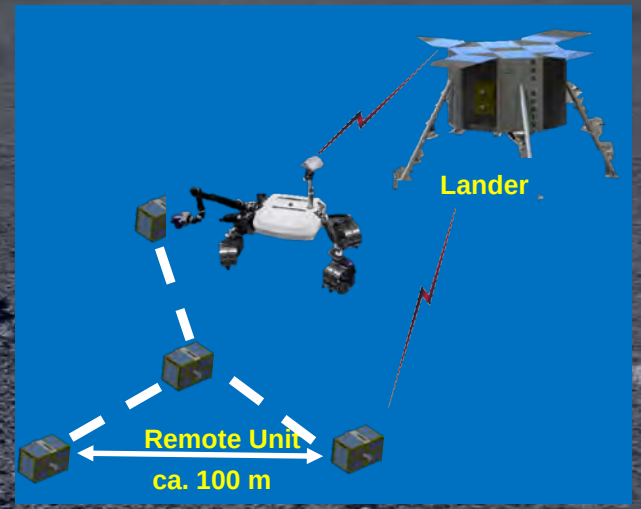
Science
Technology Development
Benefits for Society
International cooperation
Inspiration

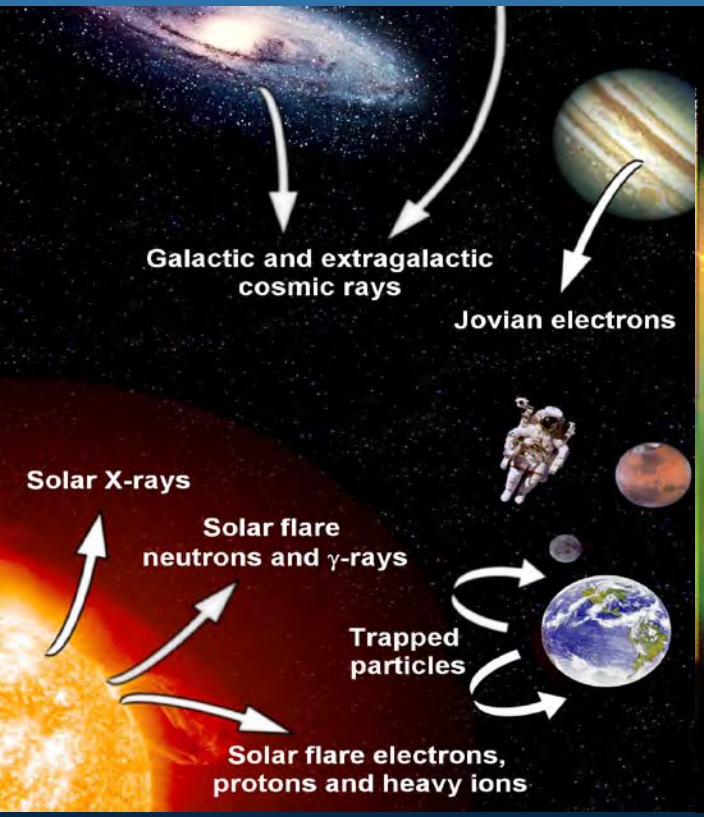
# ROBEX – Robot for Extreme Environments

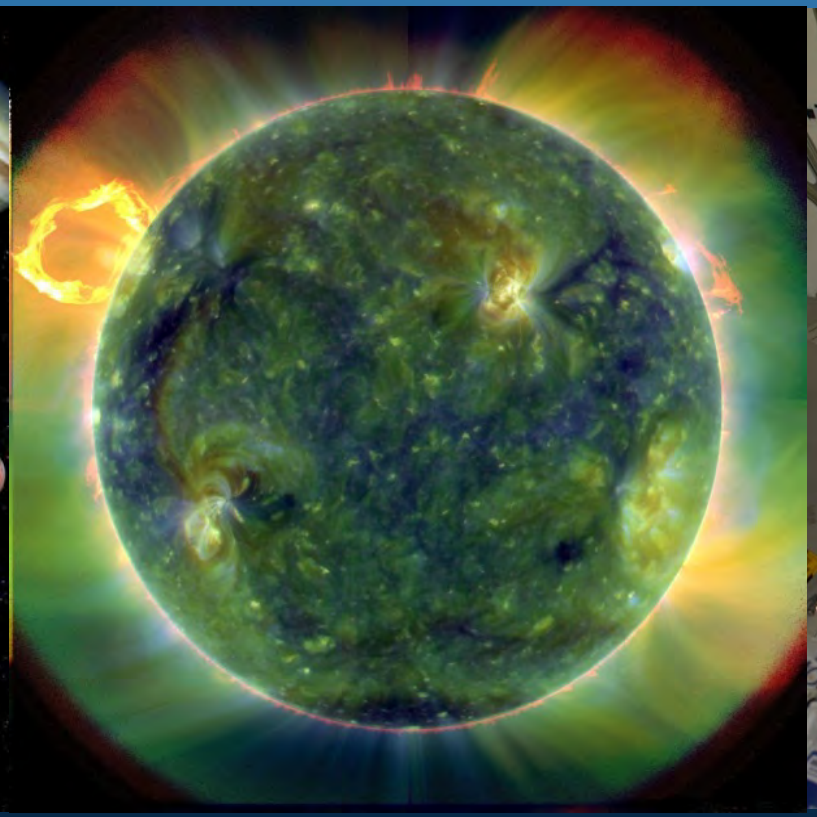
- Preparation of technology for a lunar mission
- Scientific goal: placement of an array of seismometers for study of moon geological properties
- Demonstration in analog environment

Rover uses its camera eyes to scan the environment and to plan its route autonomously x3



# Spaceflight – Creating a Unique Working Environment with Specific Health Effects



Alexander Gerst on the ISS

## Space Radiation
Monitoring
Risk assessment
Countermeasures

## Weightlessness

## Closed Habitat
Microbial burden
Limited resources


DEEP SPACE GATEWAY
NASA


BLUE ORIGIN


SPACEX

# International Agreements on Planetary Protection

**The United Nations Outer Space Treaty (OST) of 1967:**

- Proposed to the UN in 1966
- Signed by the US, UK and Soviet Union in January 1967
- Ratified by the US Senate on April 25th, 1967

**OST Article IX:**

"...parties to the Treaty shall pursue studies of outer space including the Moon and other celestial bodies, and conduct exploration of them *so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter* and, where necessary, shall adopt appropriate measures for this purpose..."

# The COSPAR Planetary Protection Policy

- Describes requirements for different planetary protection categories depending on the
  - type of mission
  - the target body and
  - the type of scientific investigations

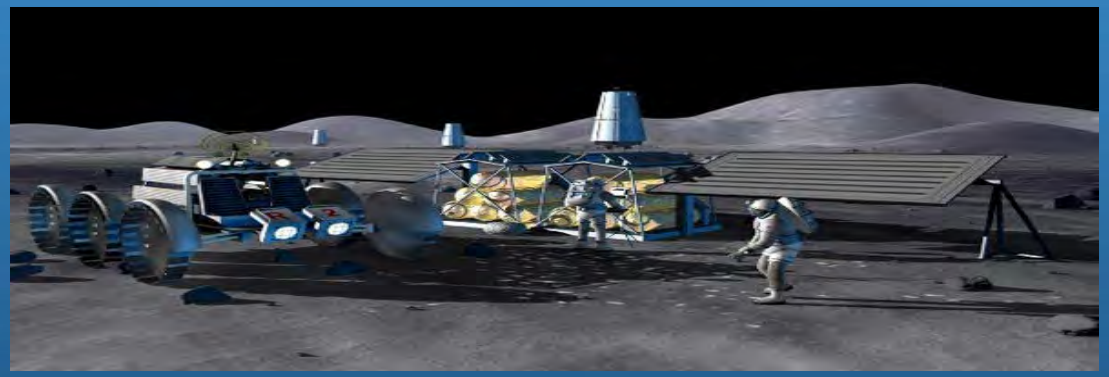
- Updating the COSPAR Planetary Protection Policy is an iterative process that is based on new scientific discoveries, new understanding of scientific observations, or, responds to needs identified to prepare future space missions

# The space exploration arena is changing

- **Increase in numbers of nations, partnerships, commercial and private ventures planning exploration missions**
- **There is a growing need to establish more comprehensive regulations governing diverse activities on the Moon and celestial bodies**
- **Pathway towards an international environmental regime for space exploratio → STEPWISE**

**….. must borrow from past experiences**

# Concrete steps to environmental stewardship



- A Lunar Environmental Protocol should be developed to guide the combined activities of science and non-science ventures to the Moon in the coming years (e.g. GLXP guidelines)

- Mars and outer solar system targets: measures should be reinforced and refined in the face of increasing numbers of proposed non-science ventures

- COSPAR, IAA, UN and other international organizations should continue to articulate detailed operational guidelines for mission planners for future Solar System missions

DLR

# Space Exploration

... is very cost-intensiv
... is not going to be funded without political support
... drives technology development
... drives innovation
... drives key technologies and services for tomorrow
... drives technology start-ups and businesses

**... drives humankind further: scientifically, economically and politically!**


German Aerospace Center
Thank you!
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