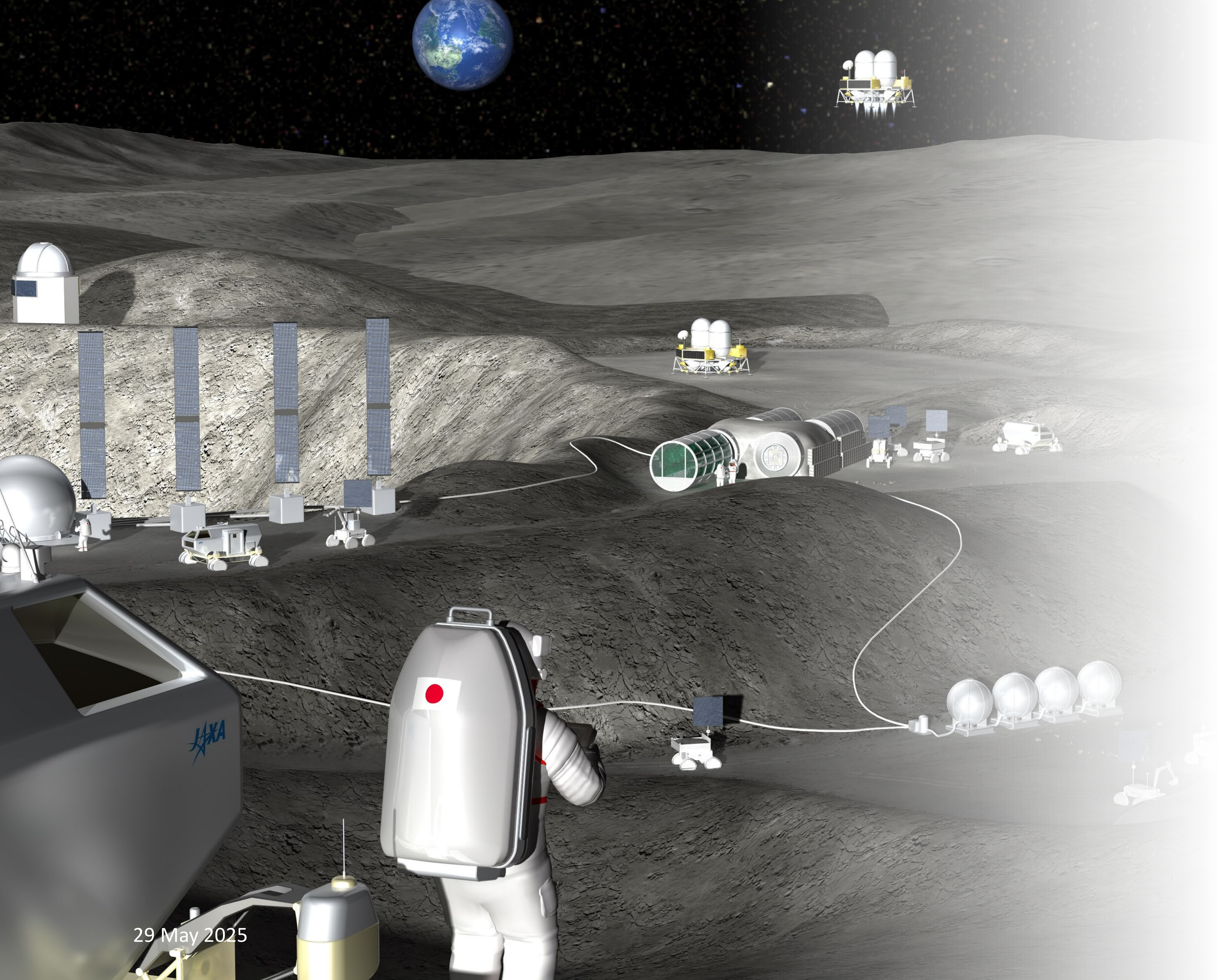
ISRU Mission Objectives and Technology Development at JAXA

Lead for ISRU Research
JAXA Space Exploration Center (JSEC)
Jun SHIMADA



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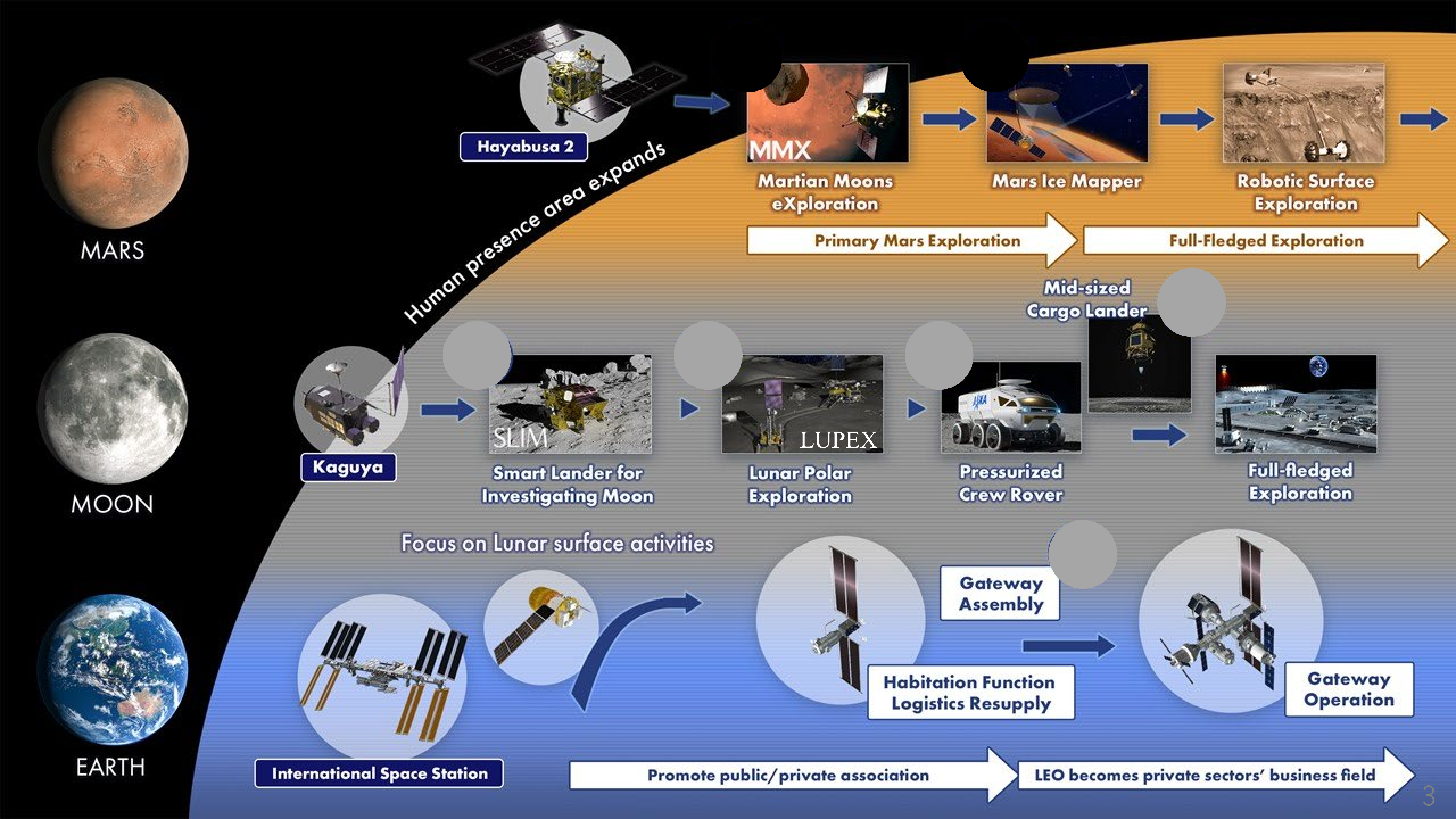


MARS
MOON
EARTH
Hayabusa 2
Human presence area expands
MMX
Martian Moons eXploration
Mars Ice Mapper
Robotic Surface Exploration
Primary Mars Exploration
Full-Fledged Exploration
Mid-sized Cargo Lander
Kaguya
SLIM
Smart Lander for Investigating Moon
LUPEX
Lunar Polar Exploration
Pressurized Crew Rover
Full-fledged Exploration
Focus on Lunar surface activities
Gateway Assembly
Habitation Function Logistics Resupply
Gateway Operation
International Space Station
Promote public/private association
LEO becomes private sectors' business field

JAXA's New Role: The Space Strategy Fund (SSF)

"Basic Plan on Space Policy" – Cabinet decision on June 13, 2023

"**Strengthen JAXA's strategic and flexible funding function. By doing so, JAXA will be utilized as a hub** for technology development and demonstration, human resources, and technical information among industry, academia, and government, both domestically and internationally"

"Comprehensive Economic Measures" – Cabinet decision on November 2, 2023

"**Establish a 10-year "Space Strategy Fund**" at the Japan Aerospace Exploration Agency (JAXA) ··· with the aim of providing support of **1 trillion yen (approx. 6 billion $) in total as soon as possible**."

FY2023 Supplementary budget for the Fund: JPY 300 billion
(MEXT: JPY 150 billion, METI: JPY 126 billion, MIC: JPY 24 billion)

JAXA Missions

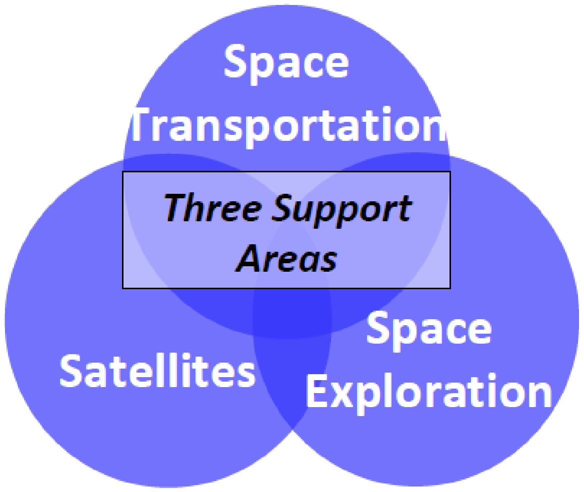
Space Strategy Fund

NEW! Since 2024

SSF Objectives/ Scheme

- The fund aims to accelerate and strengthen the achievements of the below three goals.

  *Caution: This fund is for entrustment and grant allocation, not for equity investment.



Three goals

- Expanding the space market

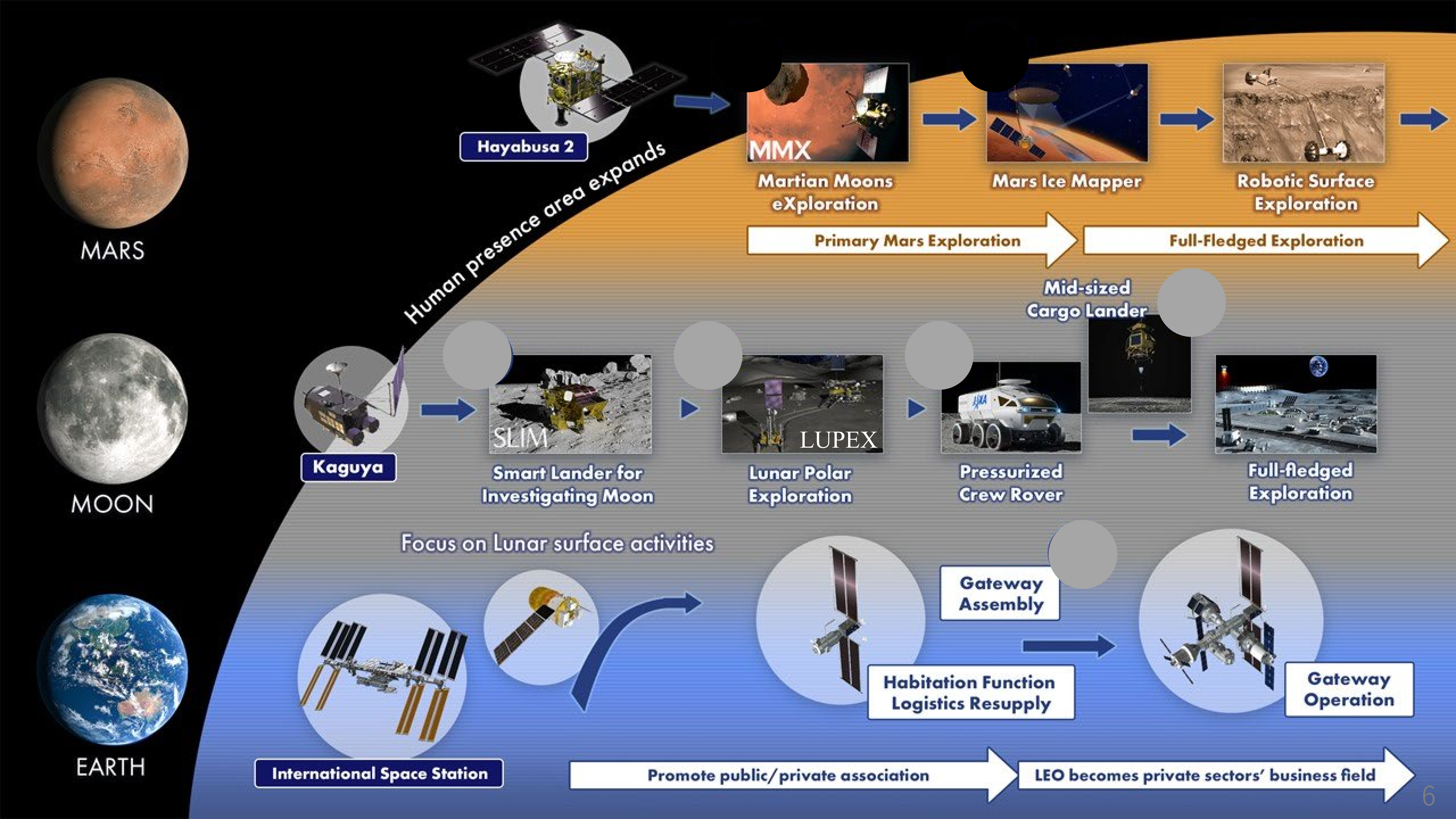
Double the size of Japanese domestic space market (4T JPY→8T JPY (approx. 60B USD) in the early 2030s)

- Solving global and social issues

Contribute to solving global and social issues by utilizing space

- Pioneering frontier

Deeper exploration of knowledge in the universe, and stronger basic and fundamental technologies



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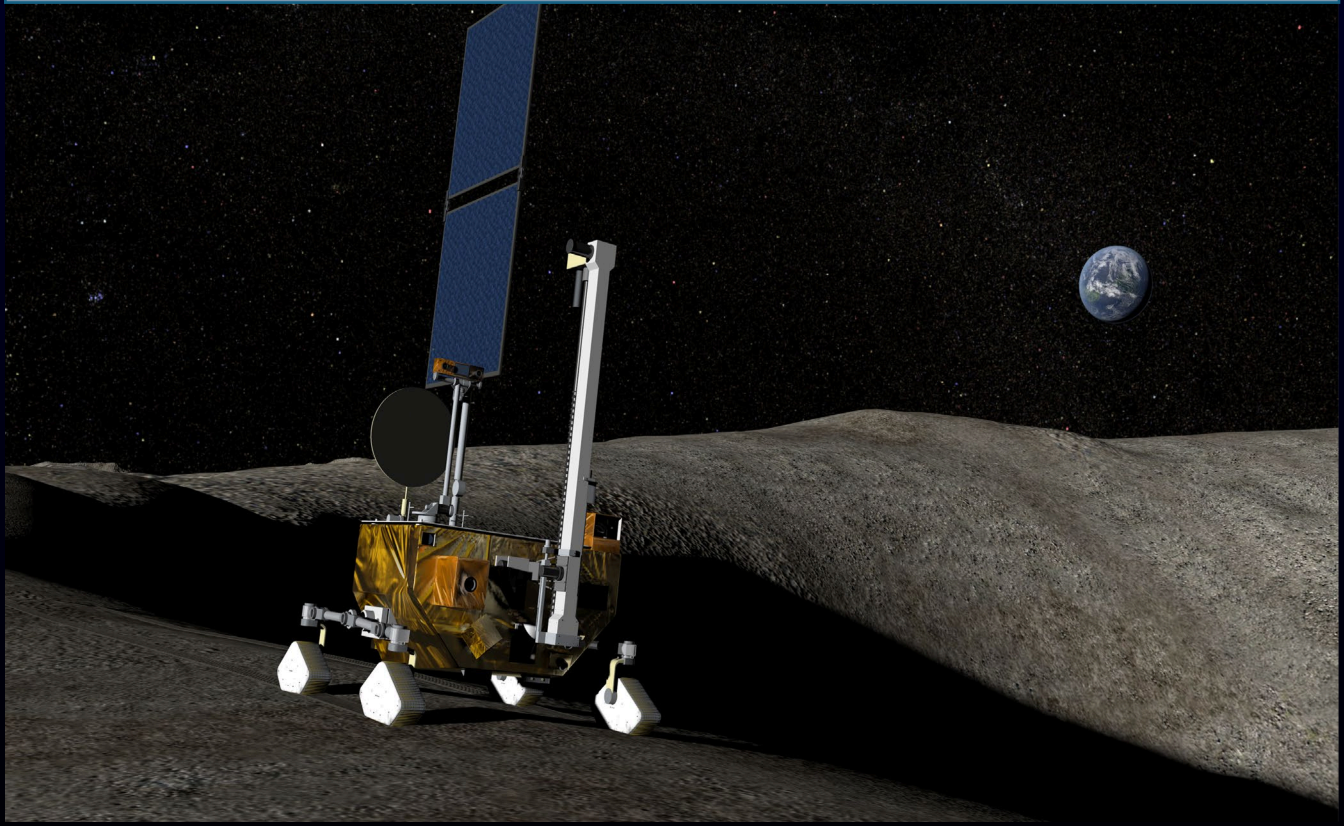
- Latest Updates -

Smart Lander for Investigating Moon (SLIM)

- 100m precision landing tech demo
- Mass: 200kg (Dry) Size: 2.4m x 1.7m x 2.7m
- Landed on the Moon on Jan 20, 2024.
- Landing Site: Vicinity of "Sea of Nectar"

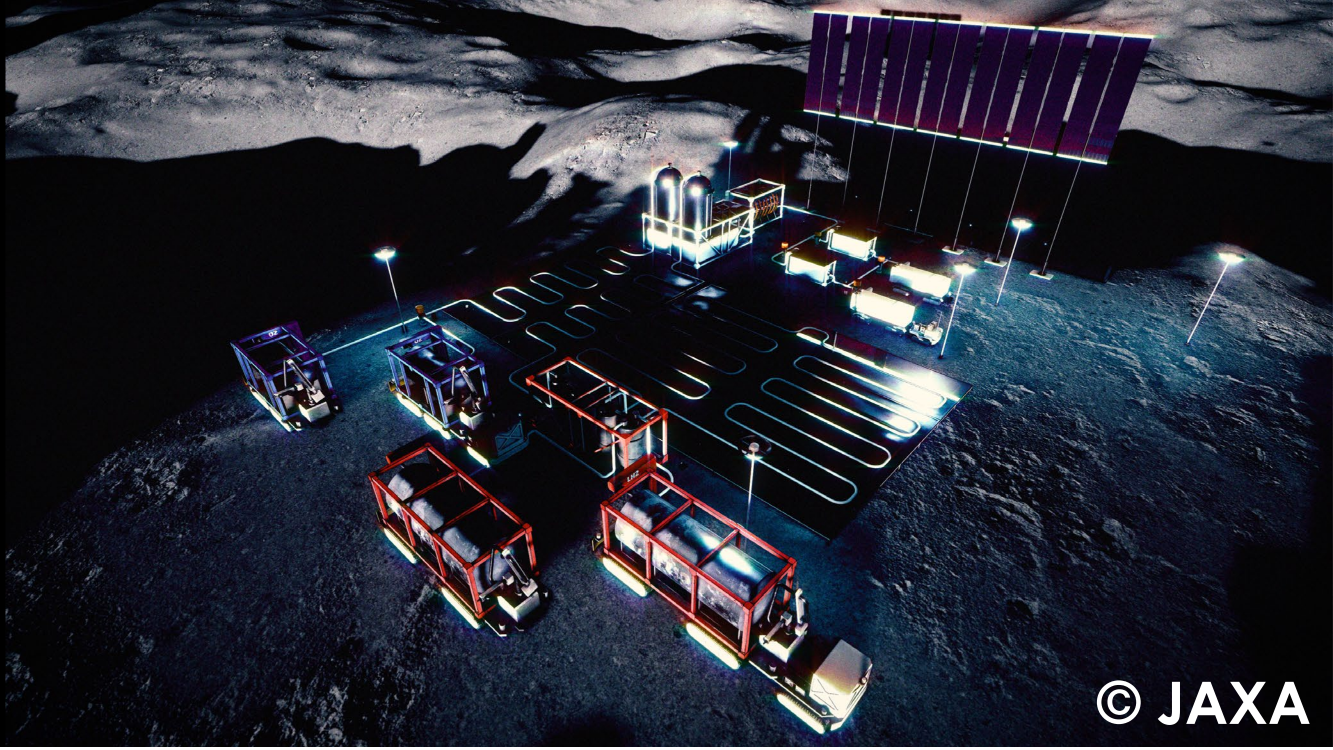
Lunar Polar Exploration (LUPEX)

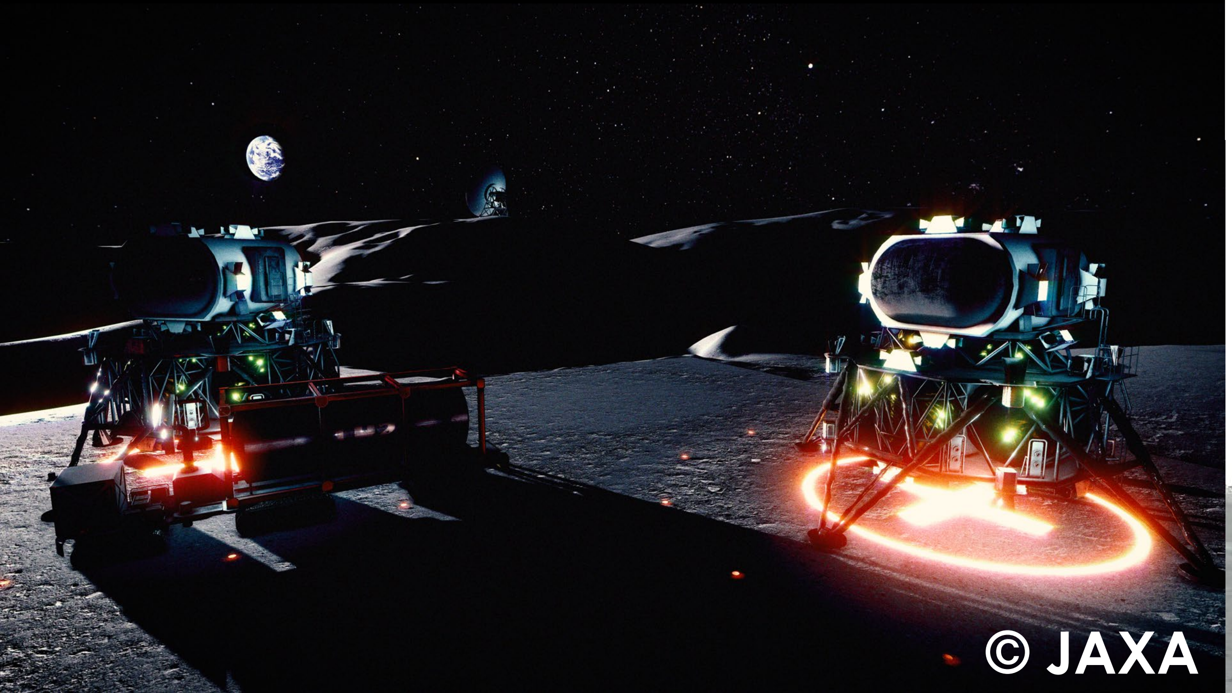
- Explore the south pole region by 350kg class rover
- Investigate availability of water-ice resources
- Planned to be launched in JFY2026
- Collaborated w/ Indian Space Research Organisation

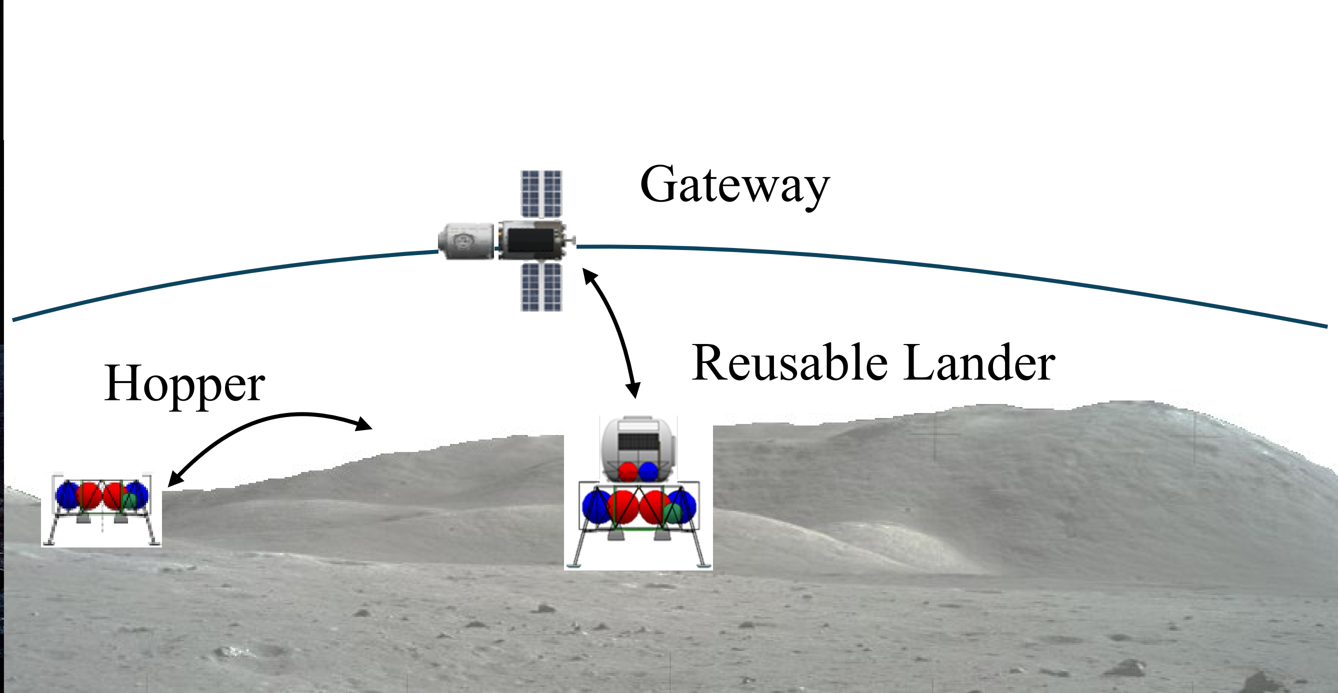


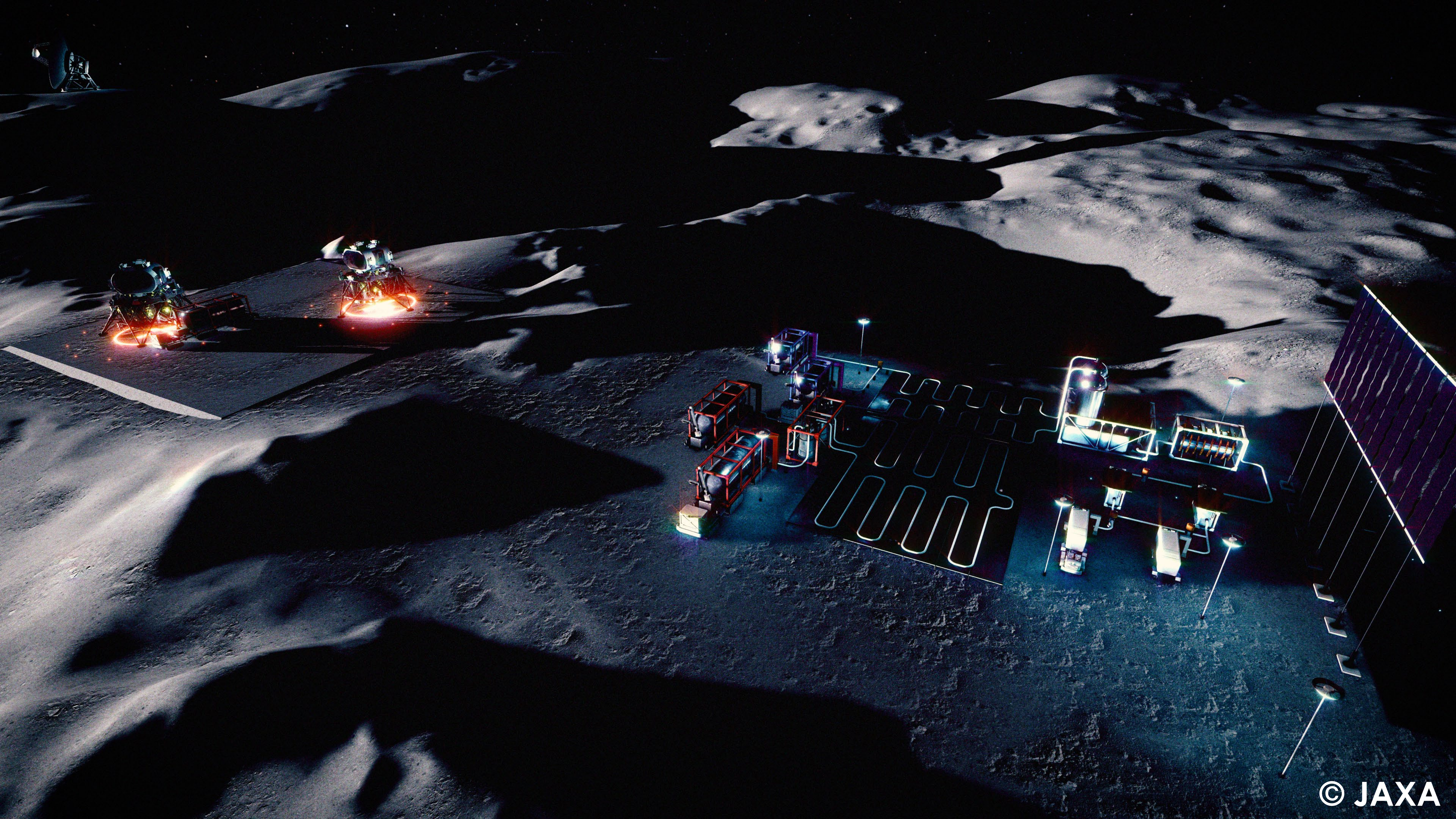
ISRU Mission Objective

Ensure long-term sustainability of lunar surface exploration by in-situ production of O2 and H2 from icy regolith to refill reusable landers and hoppers.





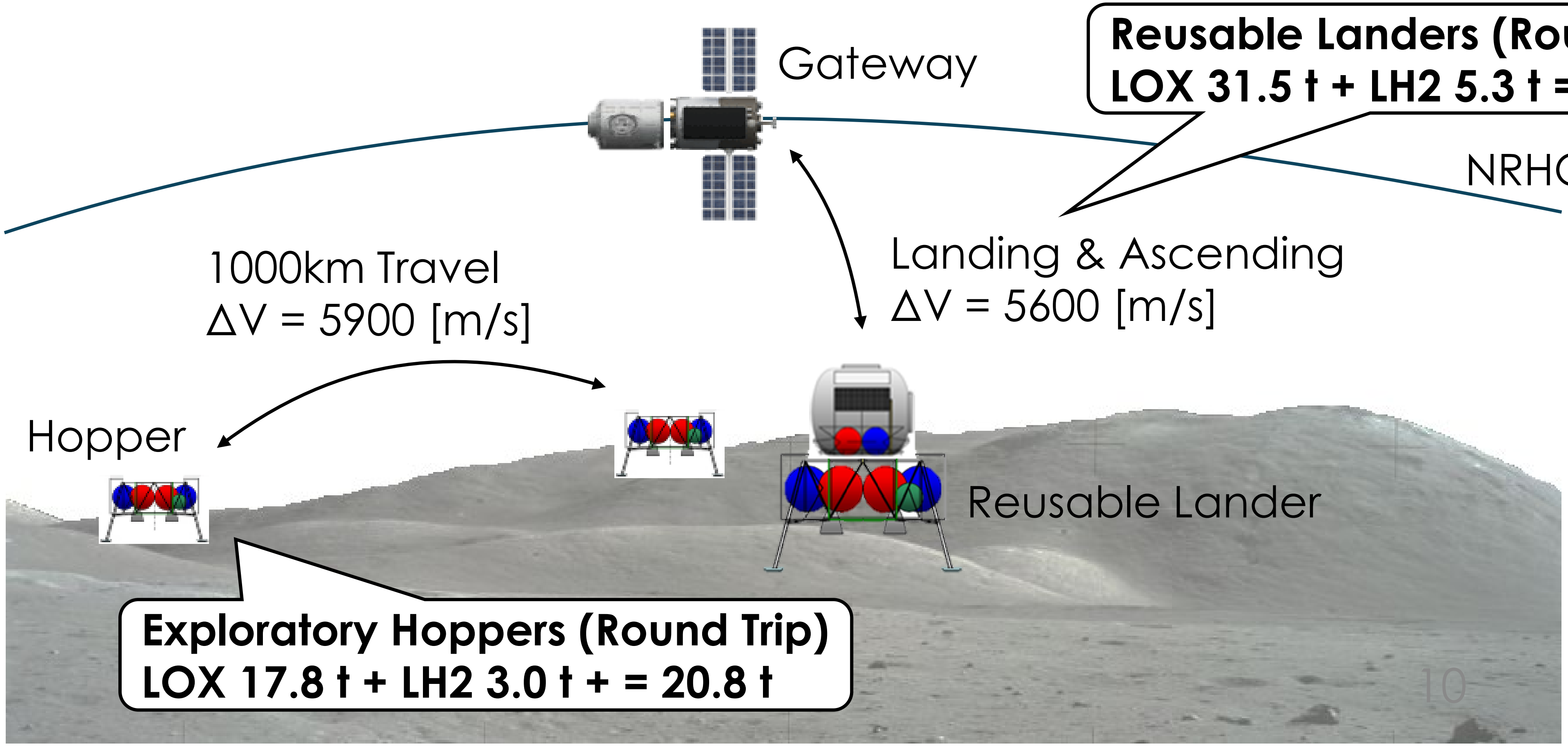


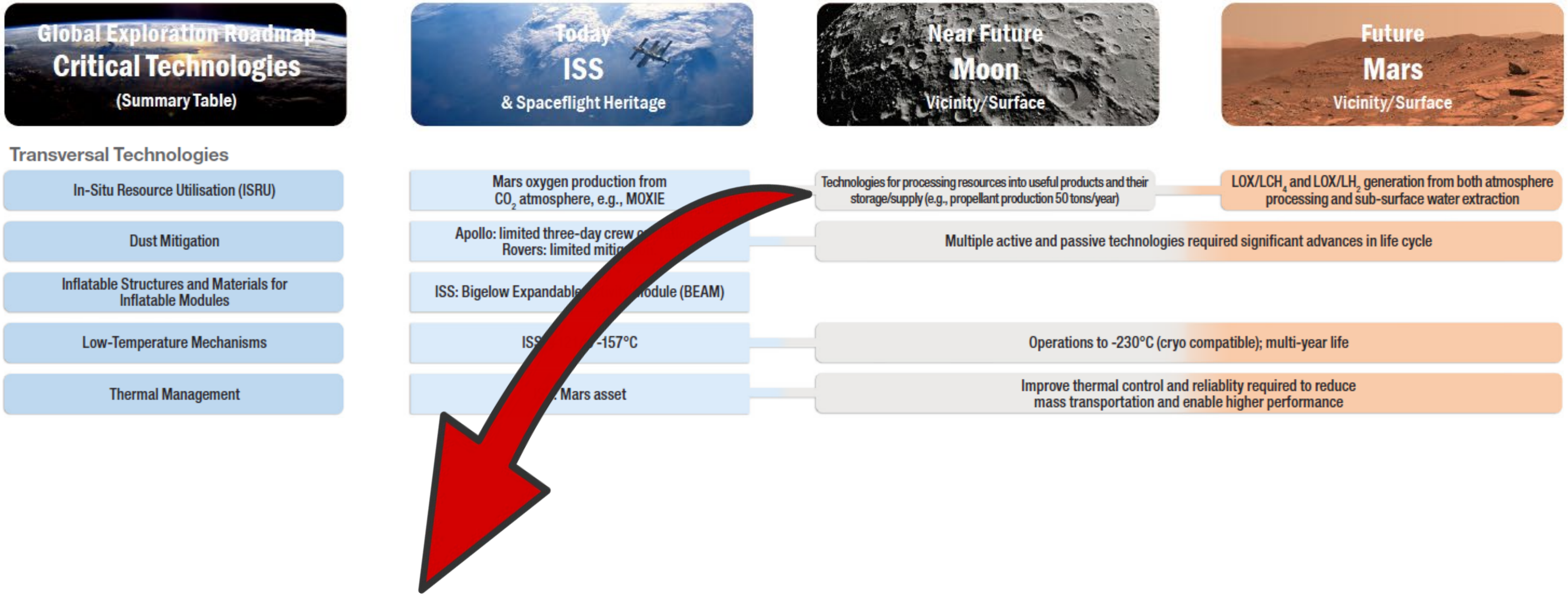


Baseline Requirements

Production Rate

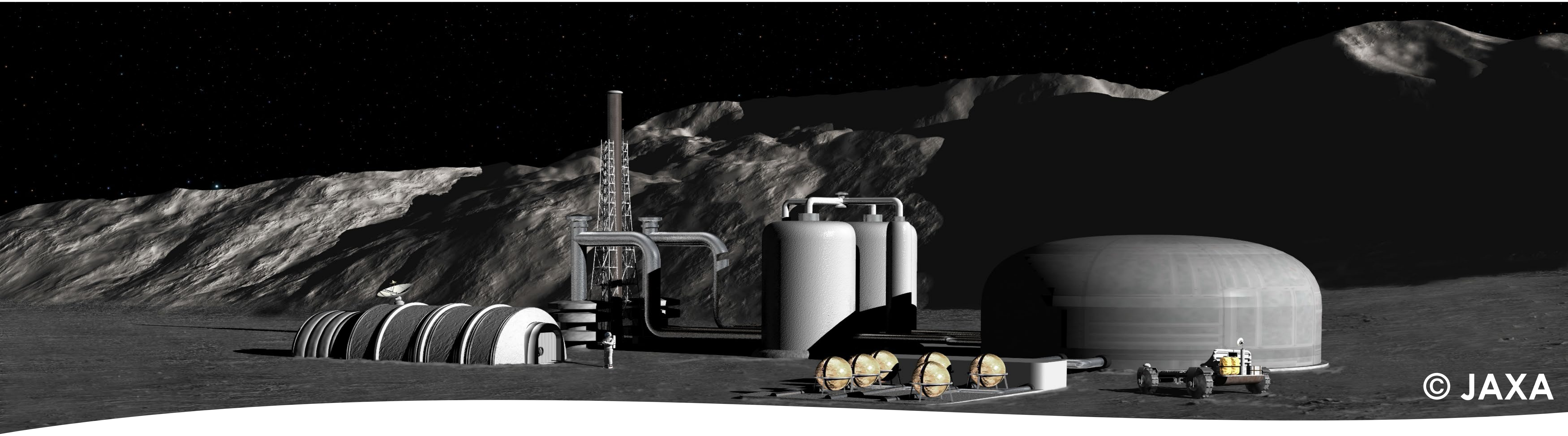
Propellant Production: 57.6 ton/year
(LOX 49.3 ton/year + LH2 8.3 ton/year)





Technologies for processing resources into useful products and their storage/supply (e.g., propellant production 50 tons/year)

Milestones



Ground Tech Demo & Lunar ISRU Pilot Plant

- Perform a sub-scale tech demo on the Ground in 2020s and on the Moon in 2030s.
- Produce water (340 kg/year) and Oxygen (150 kg/year) from icy regolith as intermediates.

Large-scale ISRU Plant

- Commence to build a large-scale lunar ISRU plant.
- Produce LOX (>49.3 ton/year) and LH2 (>8.3 ton/year) from regolith to refill spacecrafts.

NOTICE: Above-mentioned plans and requirements are defined based on the conceptual study of a lunar ISRU plant. Target production rate may change. Not budgeted by the Government of Japan at this moment.

Technology Development on ISRU Research

- In-situ Production of Oxygen & Hydrogen from Icy Regolith -

- In 2023 JAXA carried out conceptual study of a lunar full-scale plant and sub-scale pilot plant in cooperation with Japanese private total engineering companies: JGC Corp. and Chiyoda Corp.
- JAXA's ISRU Team currently focuses on technology demonstration on the ground ranging from integrated system design to experiments on key elements (esp. water extraction, purification and electrolysis).

JGC

Total Engineering Company
- **Conceptual study on ISRU Plant in 2021-2023**
- **Integrated system design for ground demo in 2024**
- **Experiments on water extraction in 2024**

JAXA

Kurita

Water Solutions Provider
- **Experiments on water purification in 2024**
- Past involvement: Development of JWRS (JEM Water Recycling System) onboard ISS

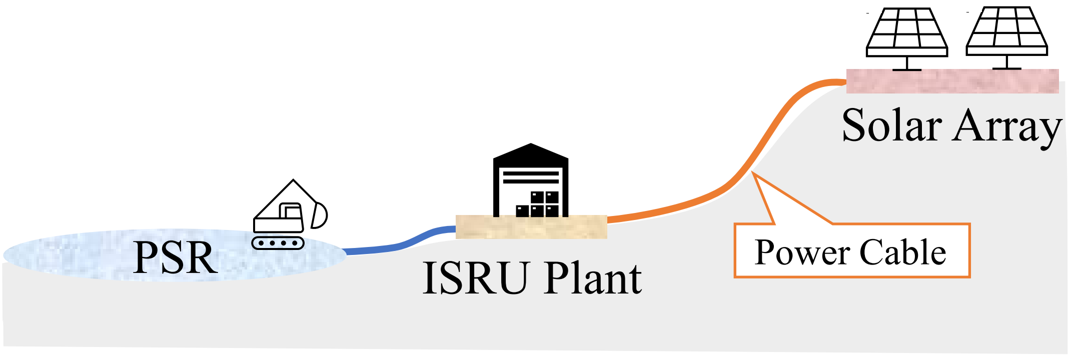
CHIYODA CORPORATION

Total Engineering Company
- **Conceptual study on ISRU plant in 2023**
- Past involvement: Development of experimental devices onboard ISS/JEM

Conceptual Study of Lunar Full-scale ISRU Plant

◆ Mass & Size Estimation

- Mass of a whole plant system to produce 57.6 tons of LOX/LH2 propellant:
  Approx. 30 ton - 293 ton
- Total area of Photovoltaics:
  Approx. 2,000 m^2
- Target total volume of a ISRU plant:
  < 33.1m^3 (= 1,169 cu ft.)
  ≒ Inside capacity of 20ft. ISO Container



Configuration of a lunar ISRU Plant

20ft. ISO Container

Conceptual Study of Lunar Full-scale ISRU Plant

◆ Construction

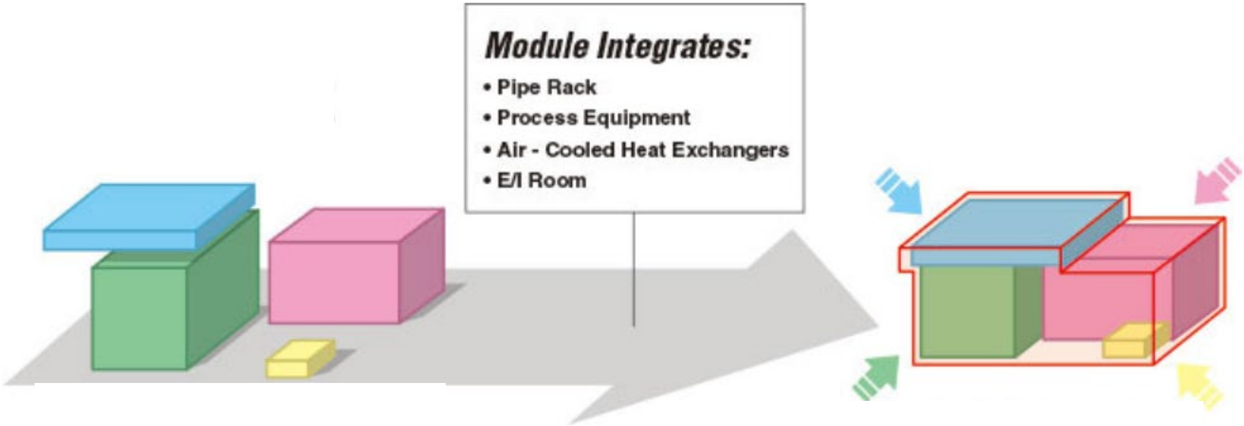
- "Modular construction method" developed method of LNG plant construction on the ground could be applied to a lunar ISRU plant with the aim of speedy construction.

Module Rifting

Maritime Transportation

Delivery to Construction Site

Land Transportation



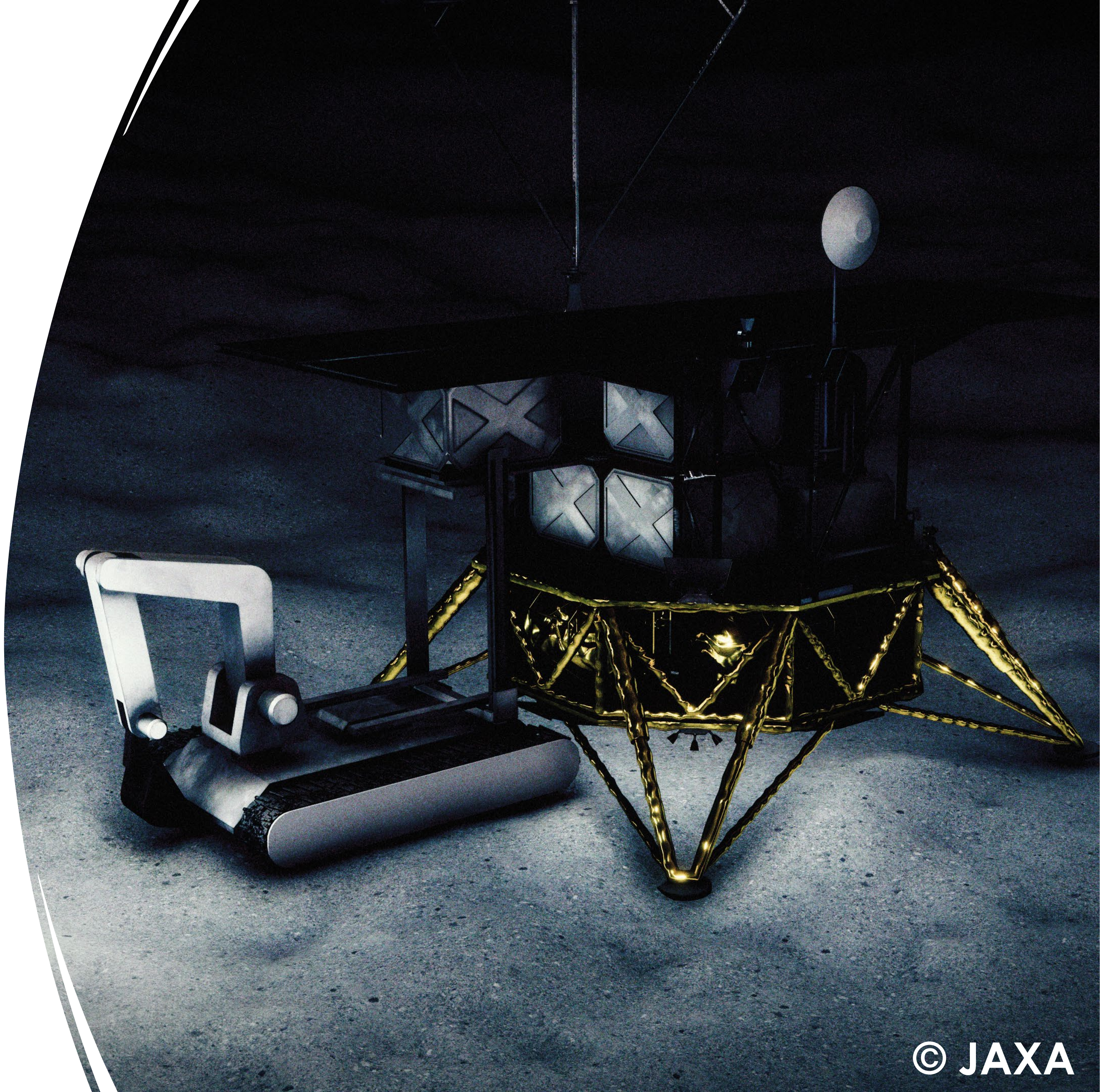
SPMT (Self-Propelled Modular Transporter) / Mammoet

Sub-scale ISRU Pilot Plant

Annual Production Target:
Water (340 kg) & Oxygen (150 kg)

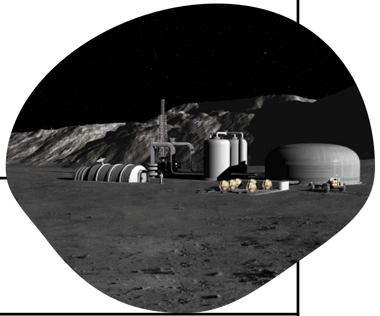
Resource Estimation:

- Mass: < 250 kg
  (except lander and regolith excavator)
- Size: < 2 m^3
- Power: < 2 kW (peak)



R&D Priority

Process	Key Technical Elements (Examples)
Regolith Excavation	・Low-power regolith excavation ・Remote control and automatic operations of construction machinery ・Decentralized control of multiple construction machinery
Water Extraction	・Efficient heating (microwave, resistance heating, solar power) ・Reduction of volatile impurities in extracted water ・Dust mitigation & Effect analysis of regolith contamination ・Efficient condensation after water extraction
Water Purification	・Design of water tank in consideration of 1/6G ・Purification to minimize performance degradation of electrolytic cells
Electrolysis	・Efficient electrolyzing methods in 1/6 gravity ・Reduction in weight of electrolysis ・Dehumidification of GOX/GH2 prior to liquefaction
Liquefaction	・Energy-efficient cooling mechanism (vapor-compression, magnetic refrigeration)
Storage	・Lightweight cryogenic storage tanks with material compatibility ・Boil-off reduction ・Energy-efficient recondensation method



Water Extraction & Purification

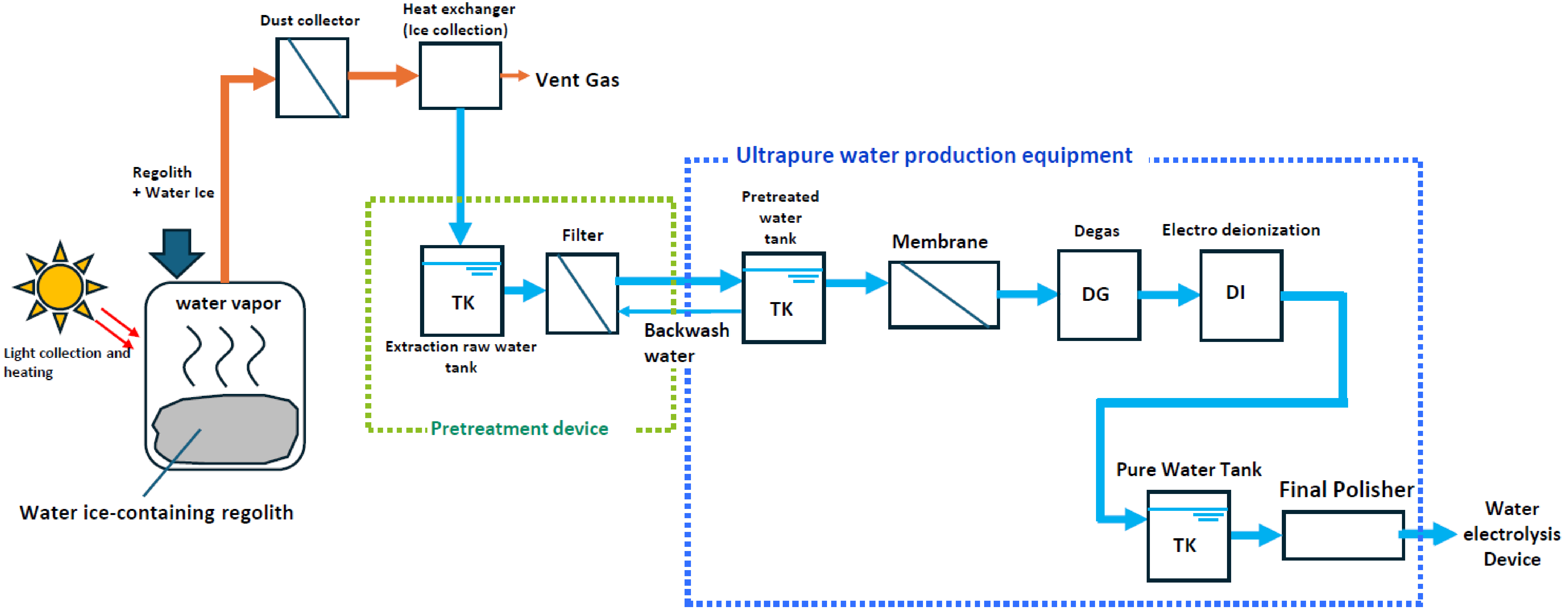


Table. Assumptions on Concentrations of Impurities Trapped in Regolith Simulant for Ground Demo

Substance	Concentration of Impurities [mol% of H2O]	
	Limited Case*1	Worst Case*2
H_2S	0.13	16.75
NH_3	0.05	6.03
SO_2	N/A	3.19
C_2H_4	N/A	3.12
CO_2	0.02	2.17
CH_3OH	0.03	1.55
CH_4	0.01	0.65

*1 Originally defined by JAXA's ISRU Research Team in consideration with the limitation of water treatment technology on Earth.

*2 Defined based on remote sensing data acquired by NASA's Lunar Crater Observation and Sensing Satellite (LCROSS) mission.

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Future Work

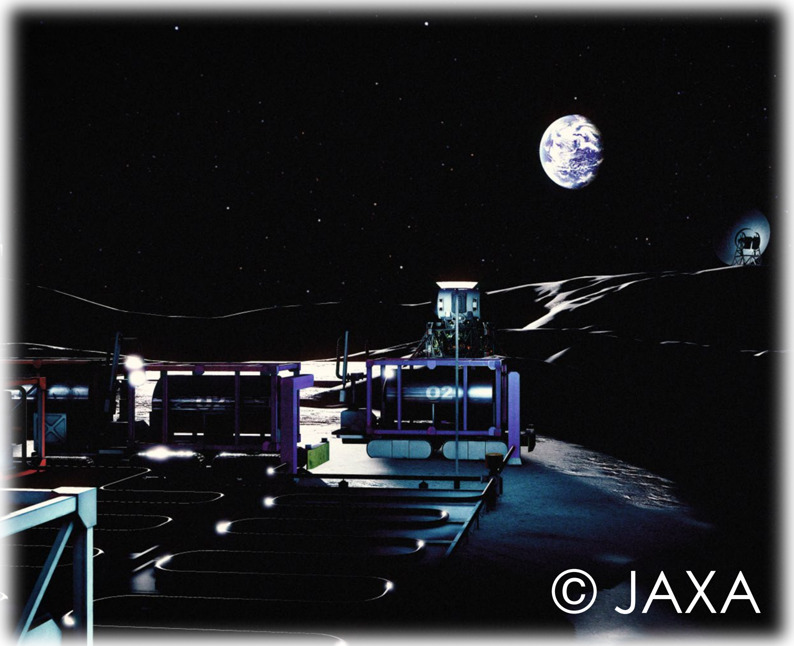
1. Define System Requirements

- Define system requirements for in-situ production, taking account of stakeholders' expectations and constraints.
- Flow down system requirements to subsystem/component level to formulate long-term R&D strategies.
- Define architecture-level system requirements such as power and CPNT (communication, positioning, navigation and timing) to strategize architecture development which enables ISRU.

Future Work

2. Accelerate ISRU Technology Demonstration

- Deepen fundamental research on key technical elements in cooperation with industrial partners and academia.
- Demonstrate water & oxygen production from regolith simulant through integrated ISRU system development in 2020s.



Future Work

3. ISRU Community Expansion

- Stir imagination of present and future generations through continuous discussions towards sustainable and responsible space exploration.
- Provide opportunities to consider what could be done to expand space frontiers using their expertise in the realm of ISRU.

VALUE OF RESOURCES: RECIPE FOR IN-SITU RESOURCE UTILIZATION ON SPACE FRONTIERS

PLENARY PROGRAMME PP

MILAN 2024 iac 75th INTERNATIONAL ASTRONAUTICAL CONGRESS

14 – 18 OCTOBER 2024 MILAN – ITALY

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