# JAXA's Technology Roadmapping and Development for In-situ Propellant Production on the Moon

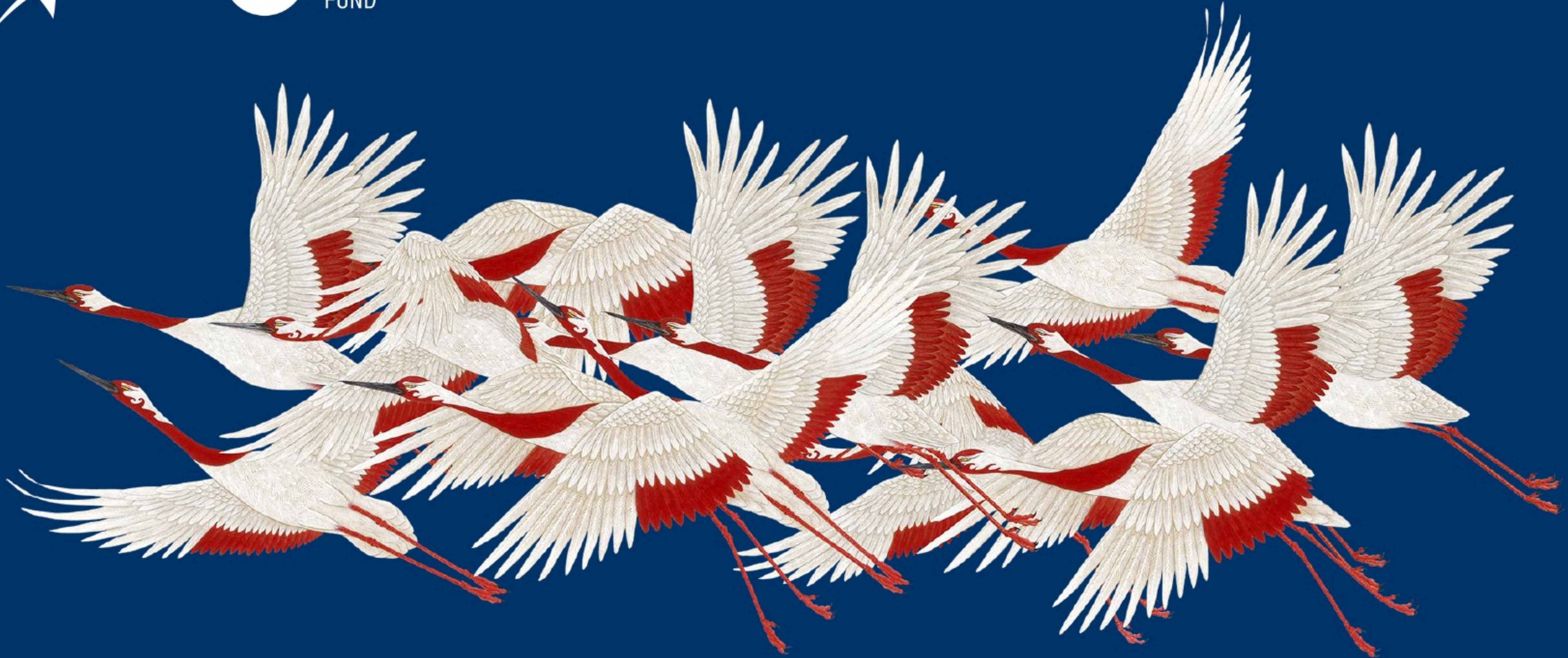
**Lead for ISRU Research**
**JAXA Space Exploration Center (JSEC)**
**Jun SHIMADA**

Latest Updates
- Space Strategy Fund
- JAXA's Lunar Polar Exploration (LUPEX)

ISRU Technology Roadmapping & Development
- Integrated Systems Design
- Core Technology Development

Future Work
- ISRU x ???

SPACE
STRATEGY
FUND



# Space Strategy Fund (SSF)

SPACE STRATEGY FUND

**GOJ**

- **CAO**
- **METI**
- **MEXT**
- **MIC**

Fund Creation →

**Funding Agency**

JAXA

Grant Allocation/ Entrustment (* Not equity) →

Private companies, Startups, Universities, Research Institutions

- Commercialization
- Solving Social Issues
- Frontier Technology Development

## <Fund size and period>

**Aiming at securing 1 trillion yen (approx. 7.0 billion $) in total up to 10 years**

- **1st phase Fund: JPY 300 billion (approx. 2.3 billion $)** by FY2023 Supplementary budget (MEXT: 150 B JPY, METI: 126 B JPY, MIC: 24 B JPY)
- **2nd phase Fund: JPY 300 billion (approx. 2.3 billion $)** by FY2024 Supplementary budget (MEXT: 155 B JPY, METI: 100 B JPY, MIC: 45 B JPY)
- **3rd phase Fund: JPY 200 billion (approx. 1.6 billion $)** by FY2025 Supplementary budget (MEXT: 95 B JPY, METI: 74 B JPY, MIC: 31 B JPY)


3 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 solve global and social issues by utilizing space

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

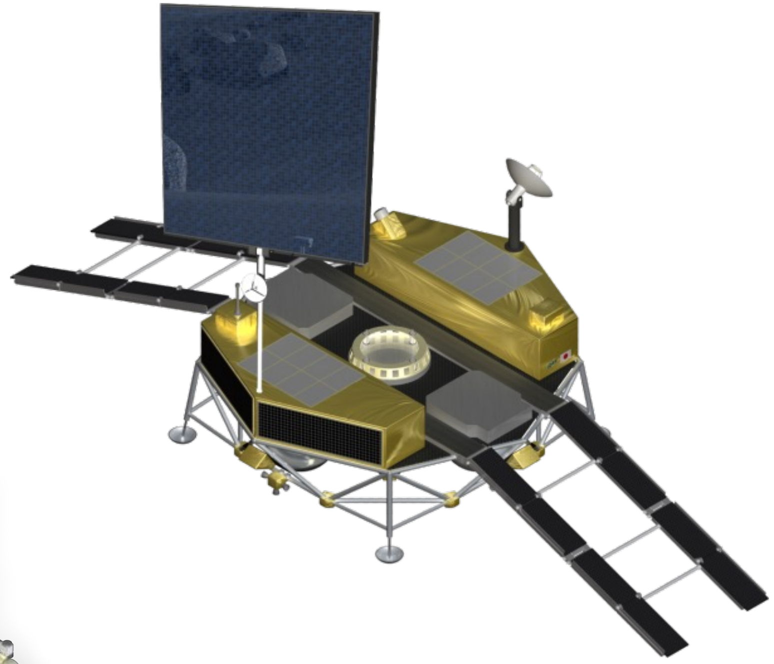
LUPEX

Lunar Polar Exploration

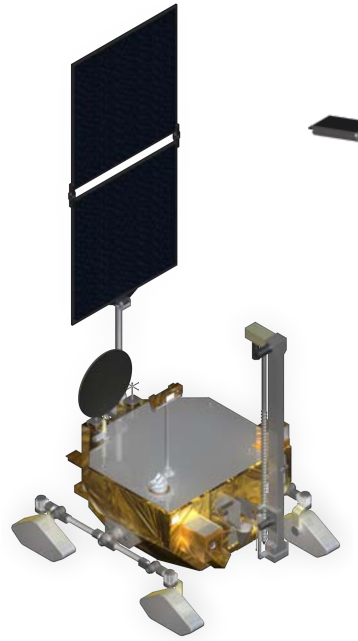
# Lunar Polar Exploration (LUPEX)

- Explore the lunar south pole region by 350kg class rover
- Investigate availability of water-ice resources
- Collaborated w/ Indian Space Research Organisation (ISRO)
- Planned to be launched no earlier than 2028

RECAP



Lander System (ISRO)



Rover System (JAXA)

**System Overview**

| | |
|---|---|
| Rocket | H3 Rocket |
| Total Mass | Approx. 6 mt (incl. lander) |
| Rover | 350kg (incl. mission devices)<br>L1.75m × W1.46m × H1.50m |
| Mission Duration | 3.5 months after lunar landing<br>(extra success: 1 year) |
| Landing Point | Lunar South Pole region |

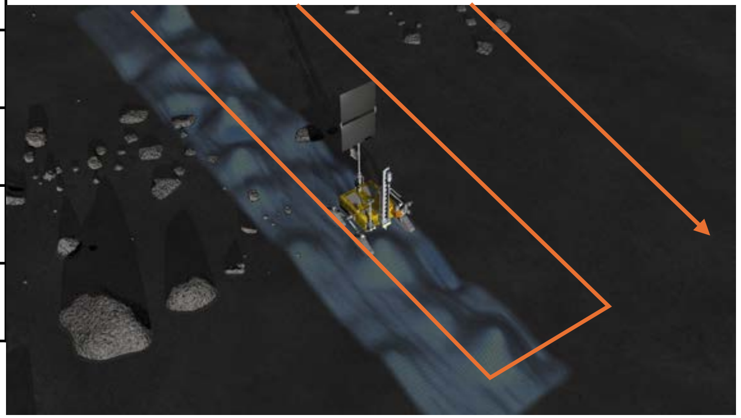
R E C A P

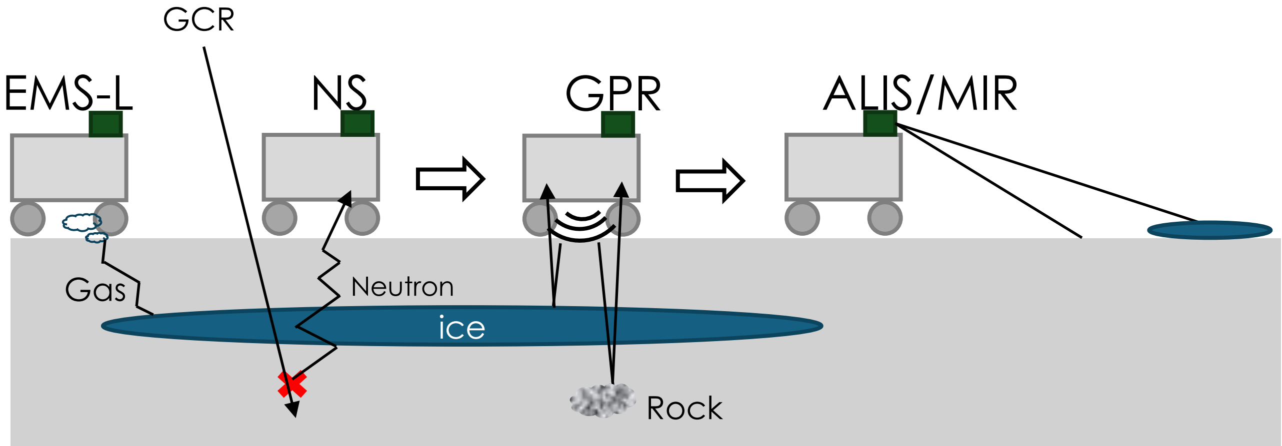
# LUPEX Mission Instruments

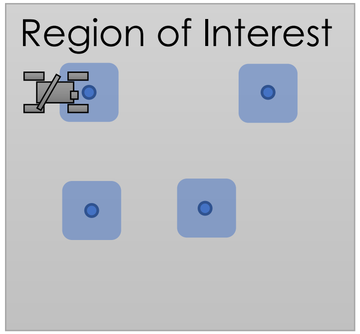
LUPEX
Lunar Polar Exploration

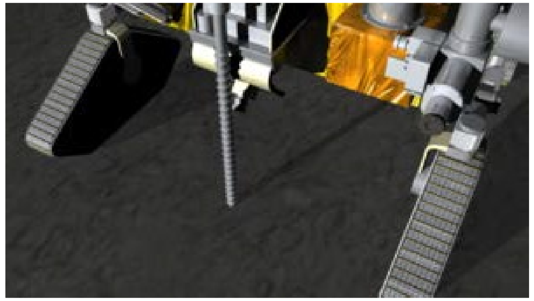
| Mission Instruments | Developer |
|---|---|
| Resource Investigation Water Analyzer: REIWA<br>LTGA (*1) / TRITON (*2) / ADORE (*3)<br>ISAP (*4) | JAXA<br>・JAXA<br>・ISRO |
| Advanced Lunar Imaging Spectrometer: ALIS | JAXA |
| Neutron Spectrometer: NS | NASA |
| Ground Penetrating Rader: GPR | ISRO |
| Exospheric Mass Spectrometer for LUPEX: EMS-L | ESA |
| Mid-Infrared Imaging Spectrometer; MIR | ISRO |

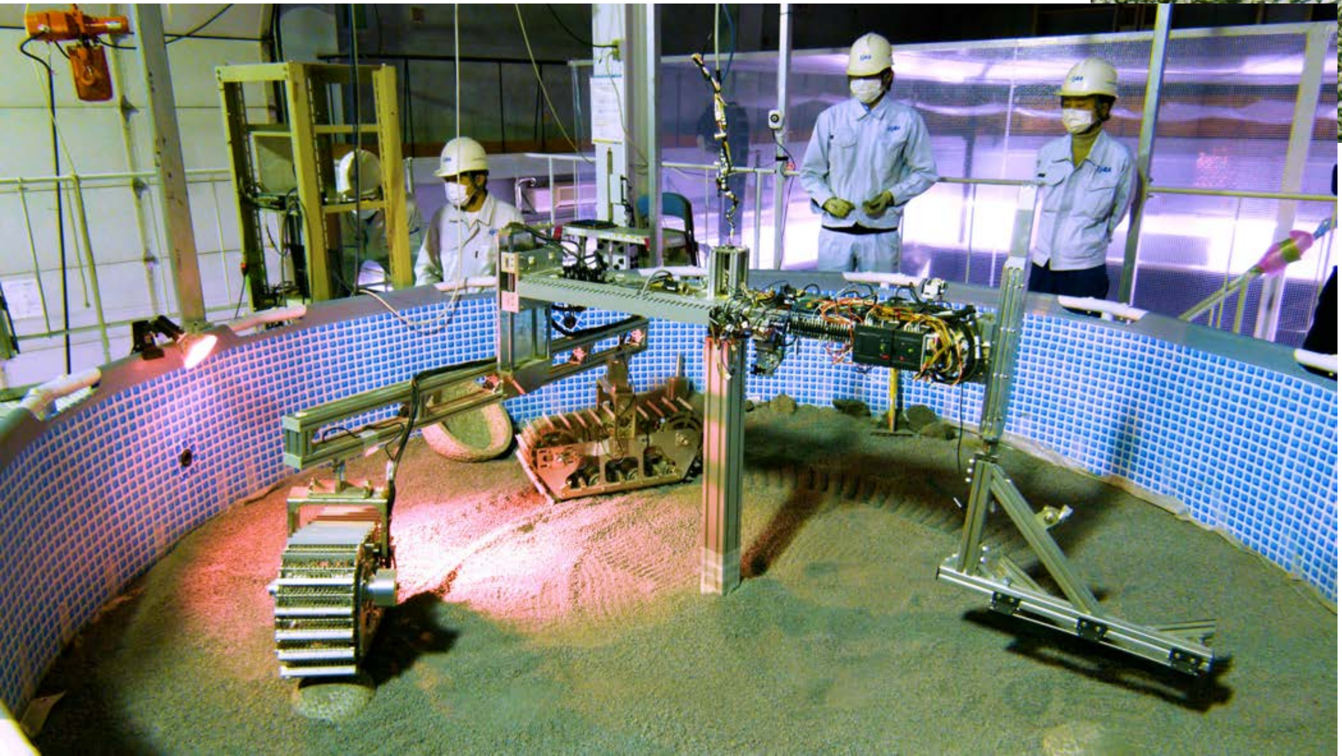
(*1) Lunar ThermoGravimetric Analyzer
(*2) TRipLe reflection reflecTrON
(*3) Aquatic Detector using Optical Resonance
(*4) ISRO Sample Analysis Package





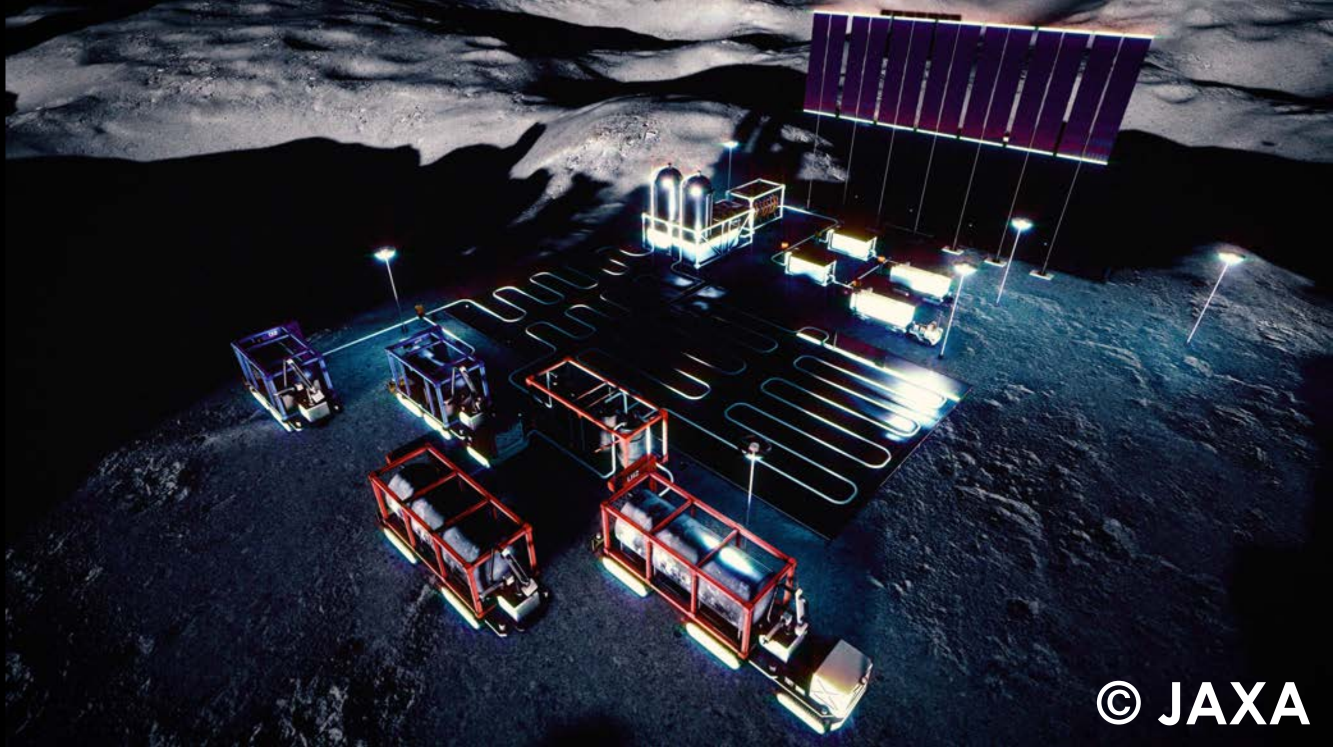



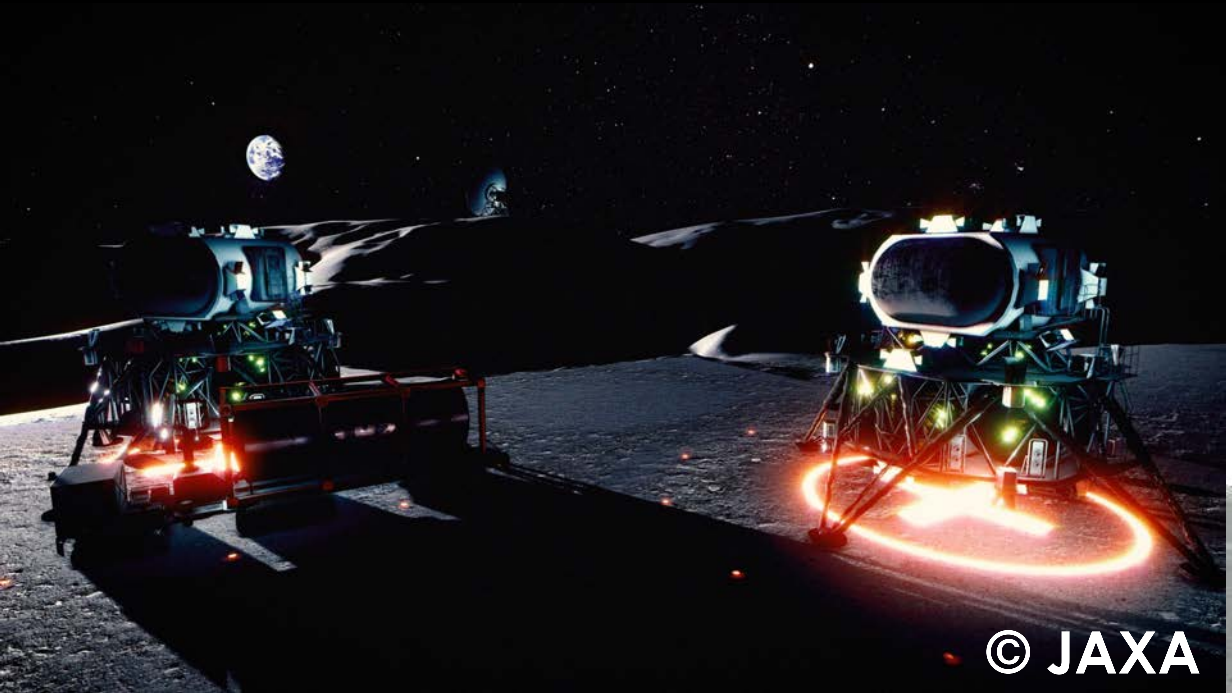



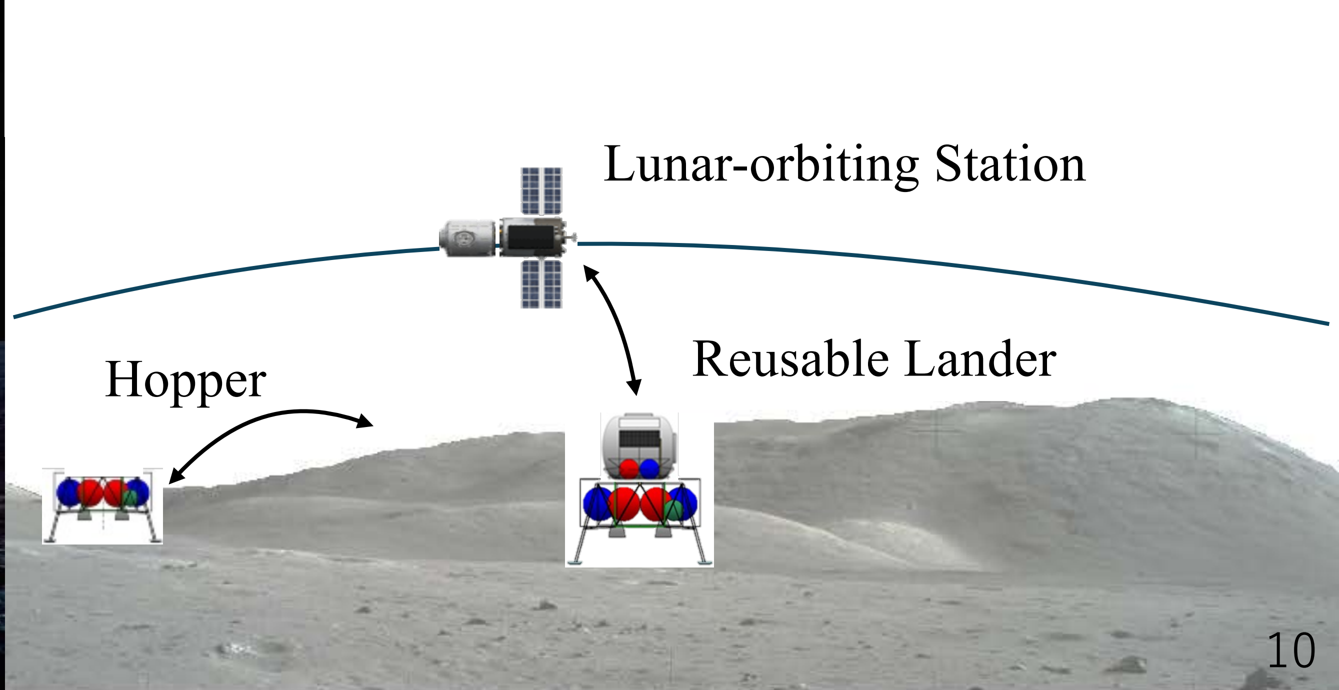


# ISRU Mission Objective

**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.**



# ISRU Technology Roadmapping and Development

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

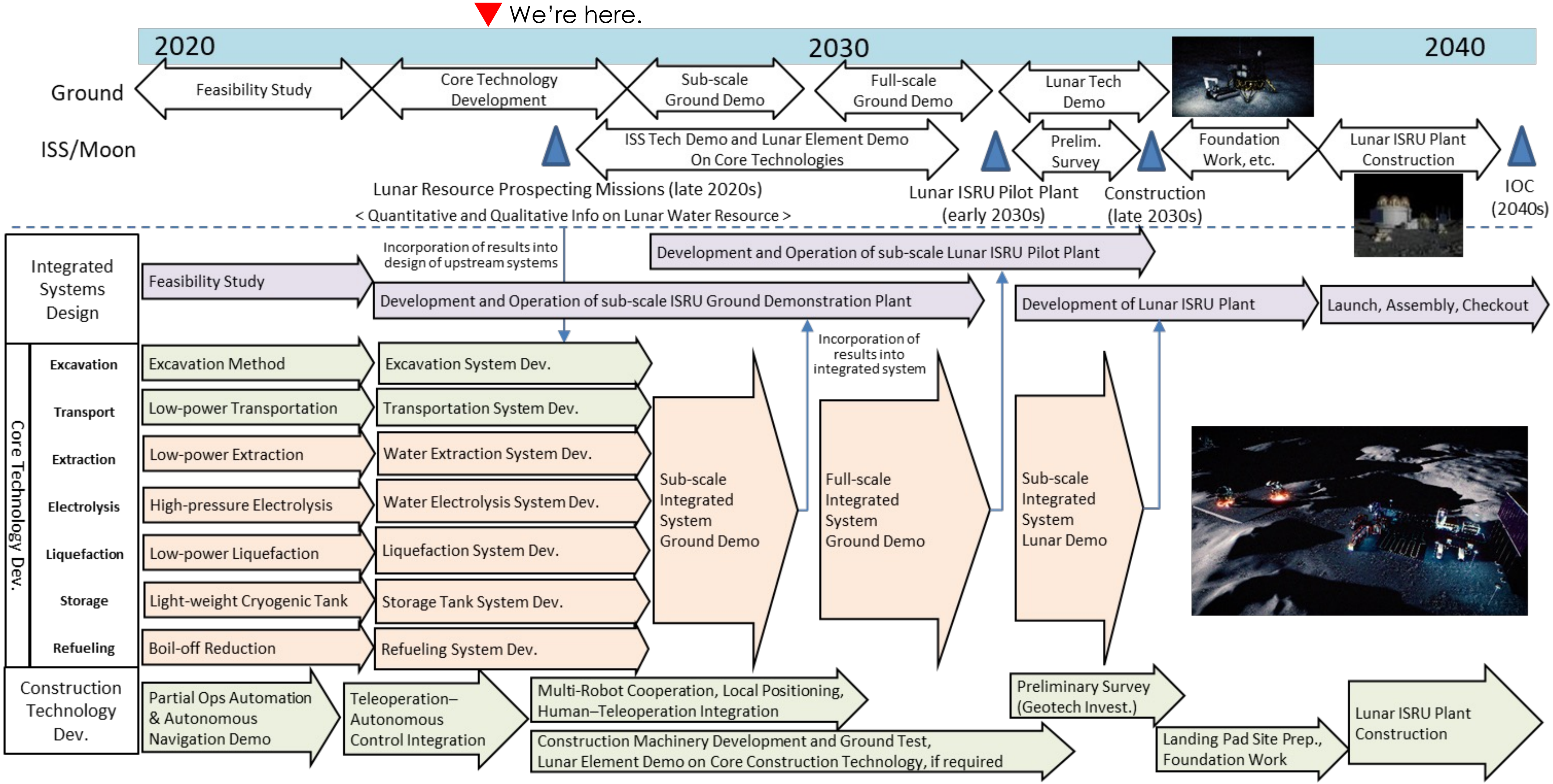
- JAXA's ISRU Research Team formulated and published long-range technological roadmap and R&D strategy toward future lunar ISRU.
- JAXA focuses on integrated systems design of:

  ① **Lunar ISRU Plant [Full-scale]**

  ② **Lunar ISRU Pilot Plant [Sub-scale]**

  ③ **ISRU Ground Demonstration Plant [Sub-scale]**

- Performed fundamental research and experiments on core technologies to produce water, gaseous oxygen and cryogenic propellent (LOX/LH2).


We're here.
2020
2030
2040
Ground
Feasibility Study
Core Technology Development
Sub-scale Ground Demo
Full-scale Ground Demo
Lunar Tech Demo
ISS/Moon
ISS Tech Demo and Lunar Element Demo On Core Technologies
Prelim. Survey
Foundation Work, etc.
Lunar ISRU Plant Construction
Lunar Resource Prospecting Missions (late 2020s)
< Quantitative and Qualitative Info on Lunar Water Resource >
Lunar ISRU Pilot Plant (early 2030s)
Construction (late 2030s)
IOC (2040s)
Integrated Systems Design
Feasibility Study
Incorporation of results into design of upstream systems
Development and Operation of sub-scale Lunar ISRU Pilot Plant
Development and Operation of sub-scale ISRU Ground Demonstration Plant
Development of Lunar ISRU Plant
Launch, Assembly, Checkout
Incorporation of results into integrated system
Core Technology Dev.
Excavation
Excavation Method
Excavation System Dev.
Transport
Low-power Transportation
Transportation System Dev.
Extraction
Low-power Extraction
Water Extraction System Dev.
Electrolysis
High-pressure Electrolysis
Water Electrolysis System Dev.
Liquefaction
Low-power Liquefaction
Liquefaction System Dev.
Storage
Light-weight Cryogenic Tank
Storage Tank System Dev.
Refueling
Boil-off Reduction
Refueling System Dev.
Sub-scale Integrated System Ground Demo
Full-scale Integrated System Ground Demo
Sub-scale Integrated System Lunar Demo
Construction Technology Dev.
Partial Ops Automation & Autonomous Navigation Demo
Teleoperation–Autonomous Control Integration
Multi-Robot Cooperation, Local Positioning, Human–Teleoperation Integration
Construction Machinery Development and Ground Test, Lunar Element Demo on Core Construction Technology, if required
Preliminary Survey (Geotech Invest.)
Landing Pad Site Prep., Foundation Work
Lunar ISRU Plant Construction

RECAP

JGC

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

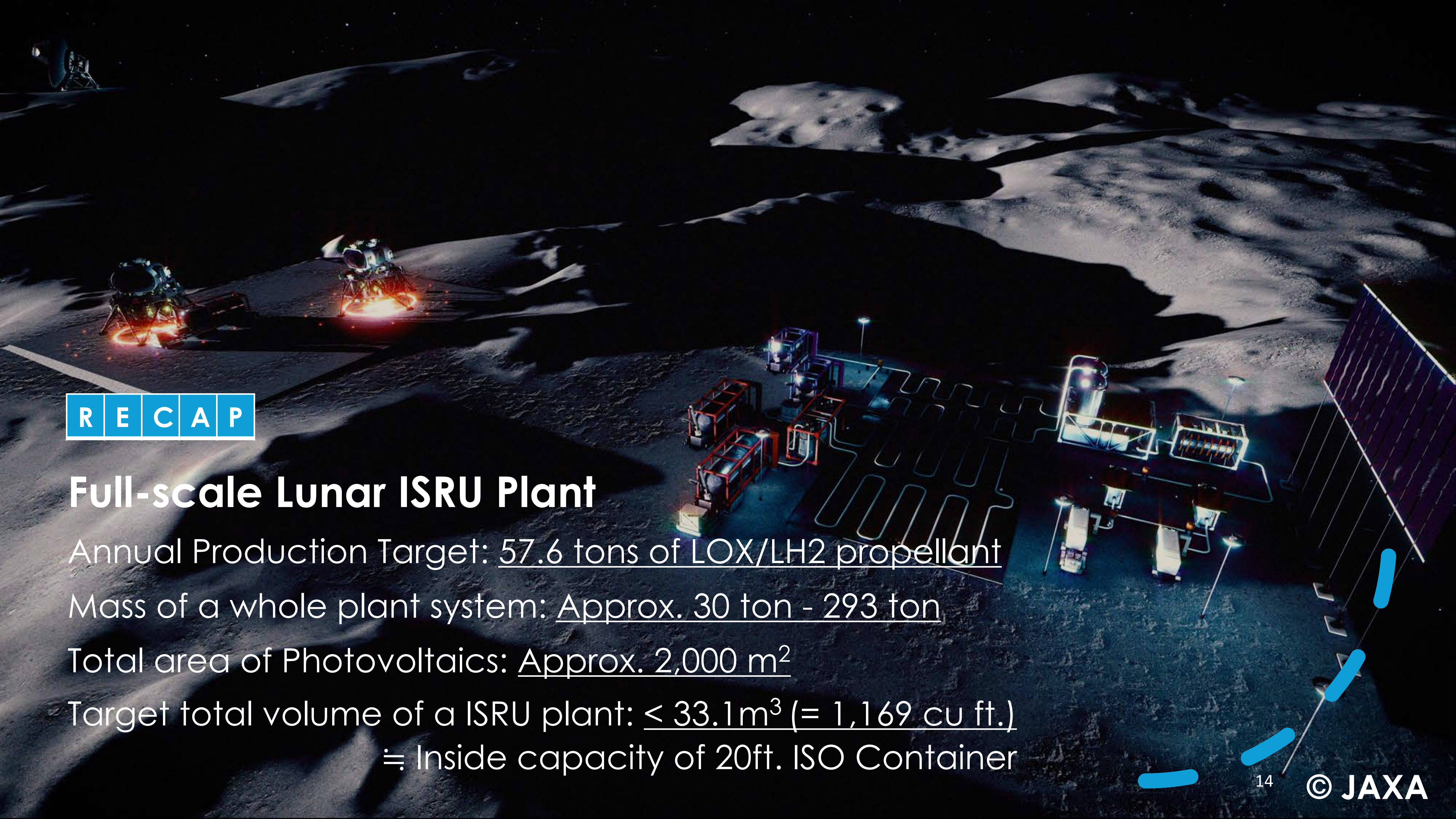
JAXA

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



RECAP

## Full-scale Lunar ISRU Plant

Annual Production Target: 57.6 tons of LOX/LH2 propellant

Mass of a whole plant system: Approx. 30 ton - 293 ton

Total area of Photovoltaics: Approx. 2,000 $m^2$

Target total volume of a ISRU plant: $< 33.1 m^3$ (= 1,169 cu ft.)

≒ Inside capacity of 20ft. ISO Container

RECAP

# Sub-scale ISRU Pilot Plant

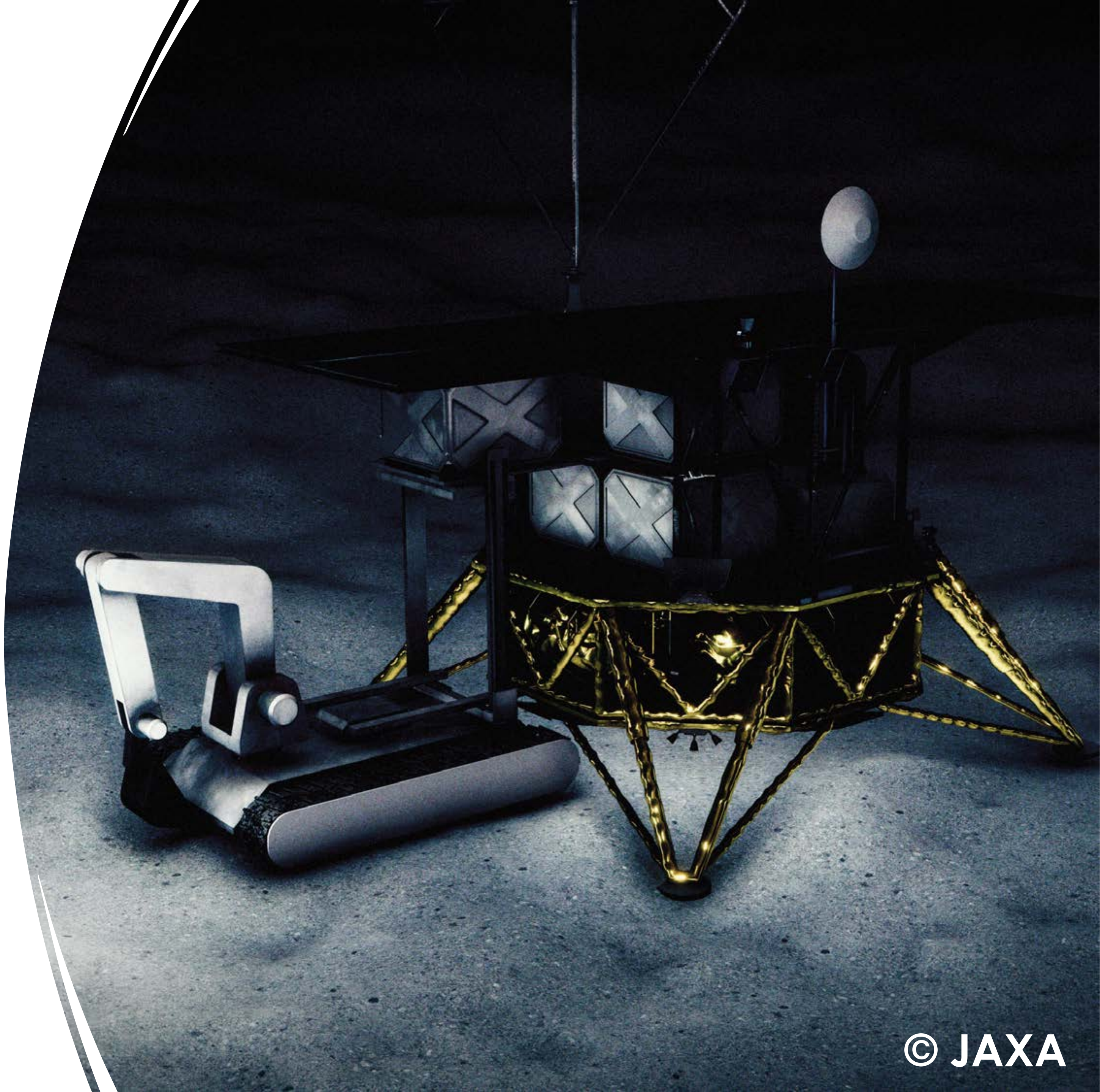
Annual Production Target:

Water (340 kg) & Oxygen (150 kg)

Resource Estimation:

- Mass: < 250 kg

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

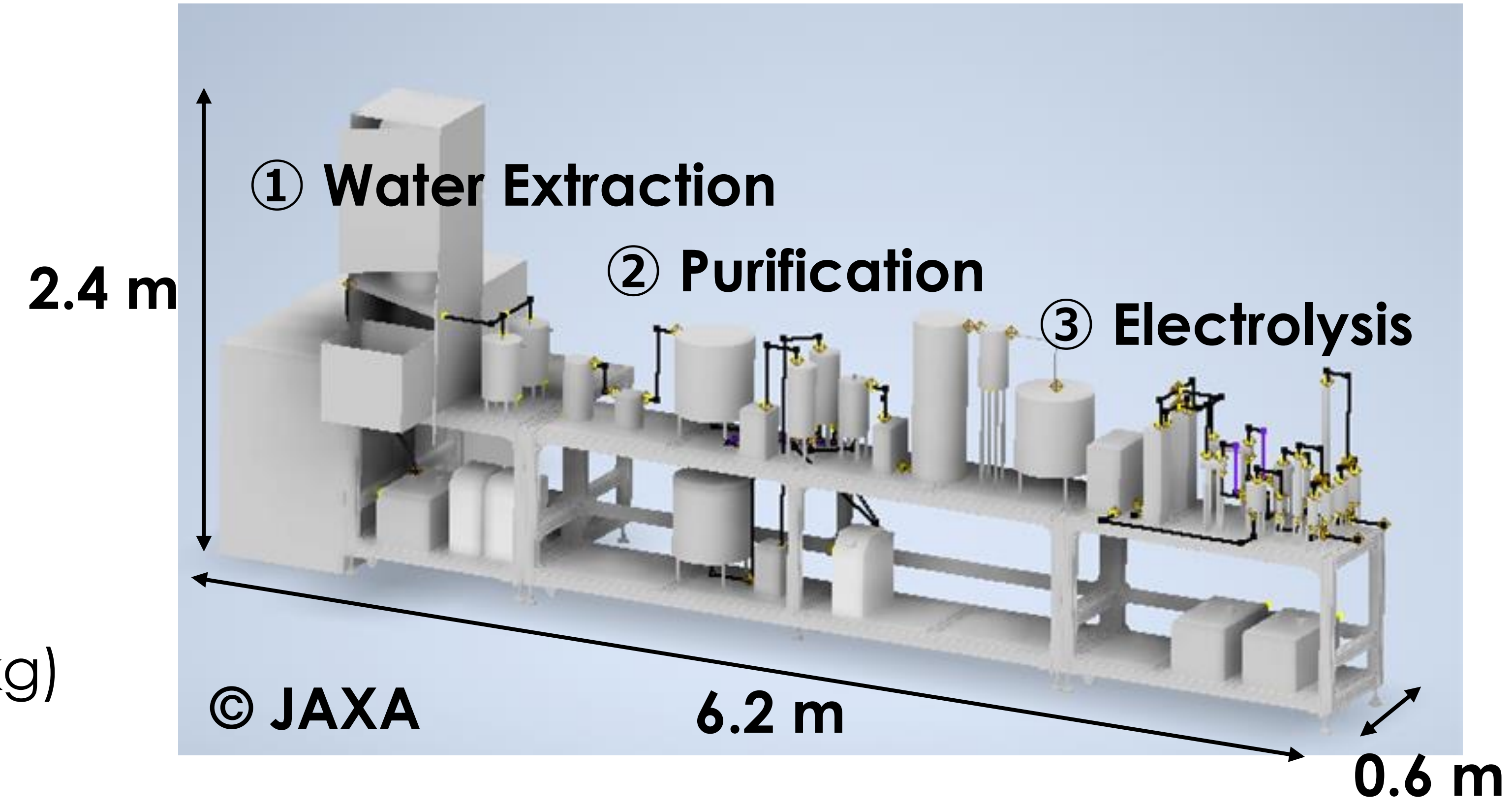


NEW!

# Sub-scale ISRU Ground Demonstration Plant

Annual Production Target:

Water (340 kg) & Oxygen (150 kg)




## Objective

- Design validation of end-to-end integrated ISRU system

## Scope

① Water extraction from lunar regolith with contaminants (e.g. $CH_4$, $NH_3$)

② Purification of extracted water with contaminants

③ PEM water electrolysis to produce $O_2$ & $H_2$

NEW!

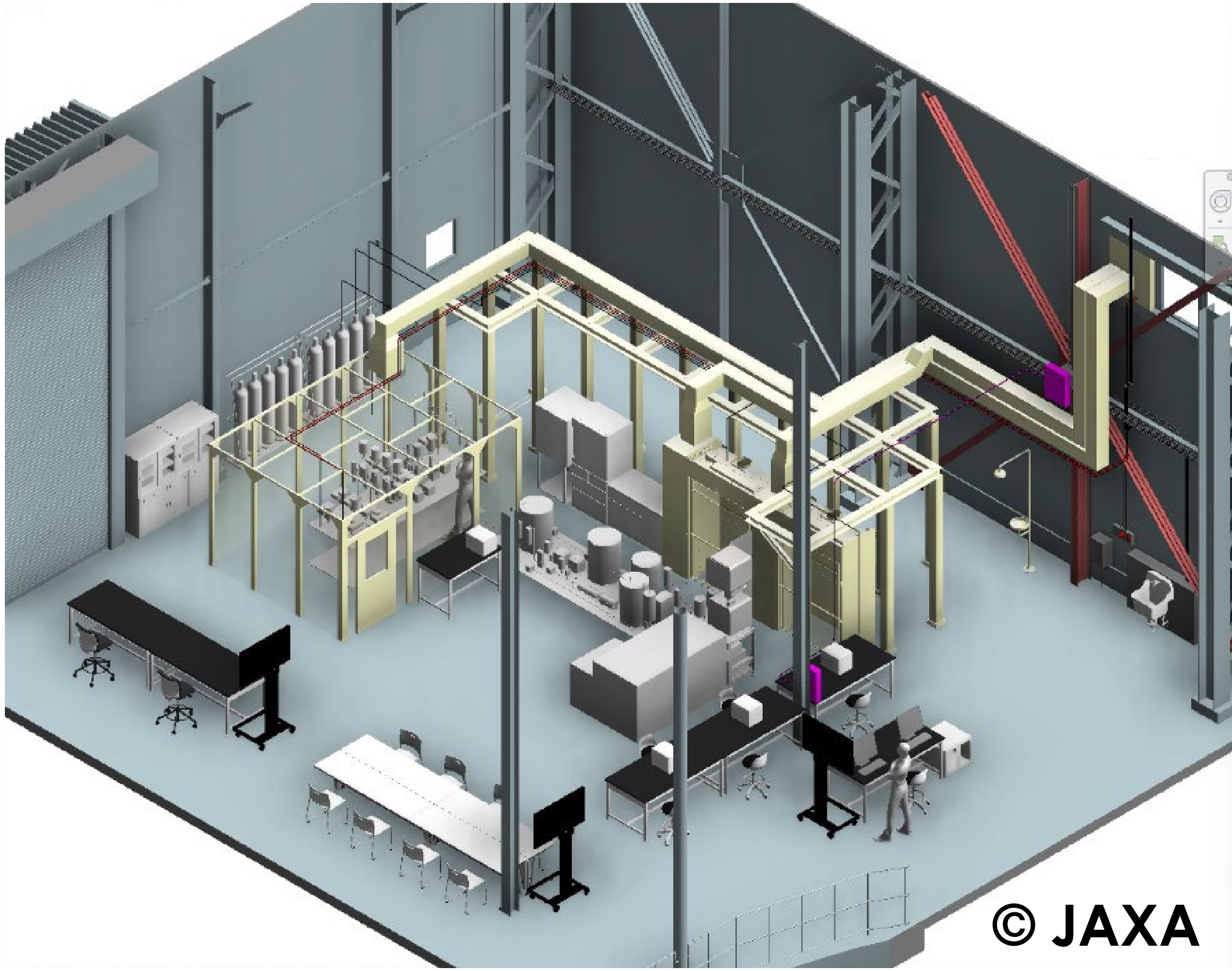
# Sub-scale ISRU Ground Demonstration Plant

## Status

- JAXA completed preliminary design of ISRU Ground Demonstration Plant in March 2026 in cooperation with Japanese private companies.

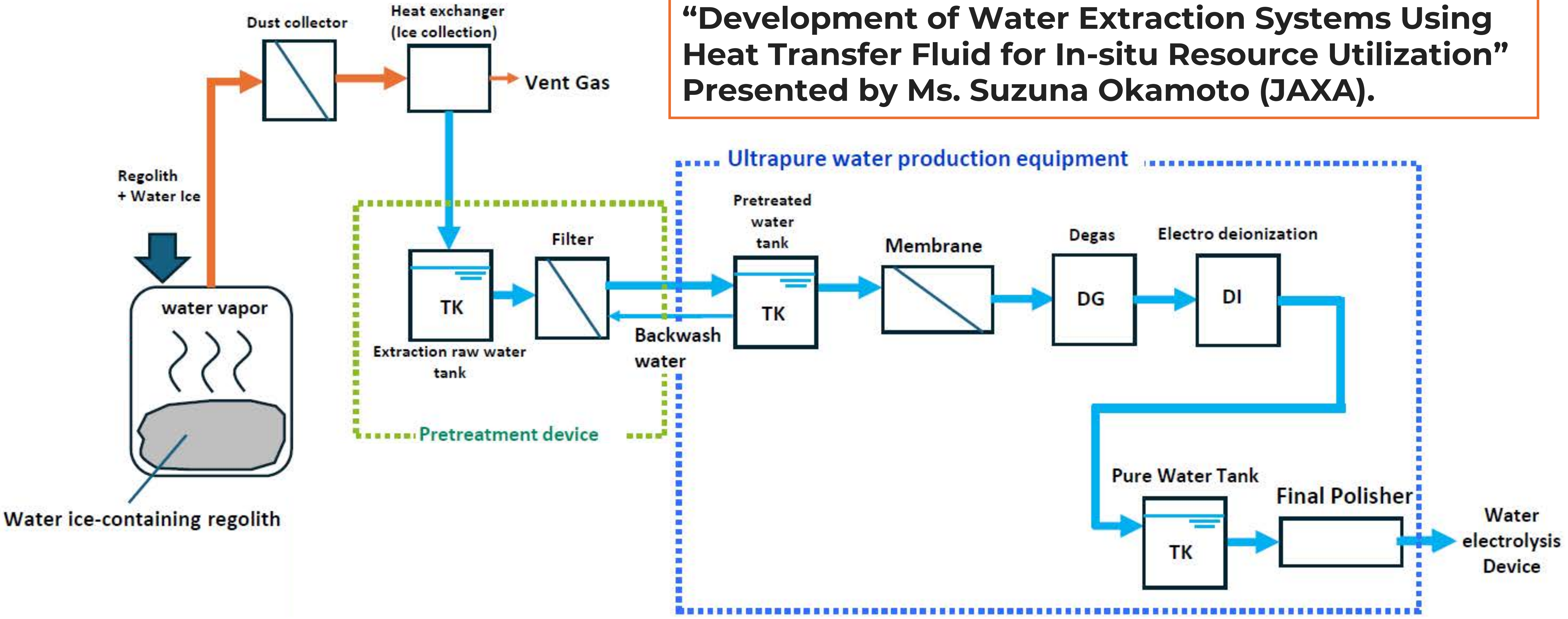
## Publishment

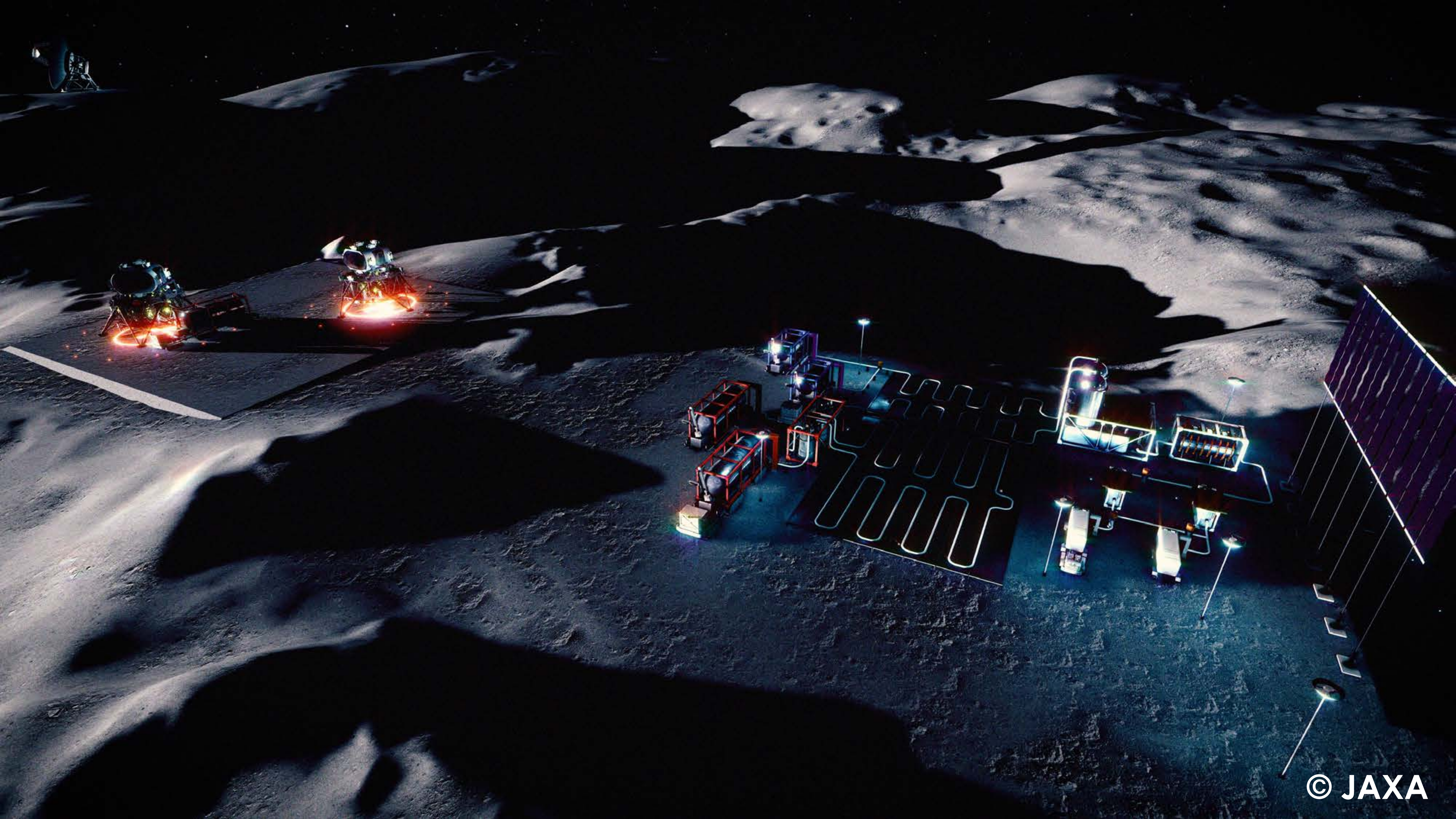
- Results of fundamental research and experiments would be published at the International Conference on Environmental Systems (ICES) 2026.



# Water Extraction & Purification

**Wed, 6 May, 11:00-11:30 @ Sigma Room**
**"Development of Water Extraction Systems Using Heat Transfer Fluid for In-situ Resource Utilization"**
**Presented by Ms. Suzuna Okamoto (JAXA).**

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**Andrew Dempster**

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Professor

**Mark Sonter**

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ROCK and ROLL: Striking a Chord Between Terrestrial Mining Innovation and Space Resource Utilization Opportunities
MODERATOR
SPEAKERS


Tanegashima Space Center

# ISRU x ???

# ISRU x Plant Engineering



- JAXA and JGC Corporation co-investigated application of HAZOP (Hazard and Operability Study), process-oriented risk analysis method which has been applied in plant engineering to design LNG plants.

- HAZOP x FMEA (Failure Mode and Effects Analysis) / FTA (Fault Tree Analysis)
= new risk analysis method for lunar ISRU integrated systems

# ISRU x Quantum Computing

# “Quantum Resource Utilization”..?

# ISRU x Content Creation


ENERGY
FACTORY OPERATION
メインエンジンスタート、リフトオフ
Three, two, one. Main engines start. Liftoff!
© JAXA


ENERGY
FACTORY OPERATION
メインエンジンスタート、リフトオフ
Three, two, one. Main engines start. Liftoff!


# Jun SHIMADA

Lead for ISRU Research at Space Exploration Center

Japan Aerospace Exploration Agency (JAXA)
Representative for ISECG's Technology Working Group

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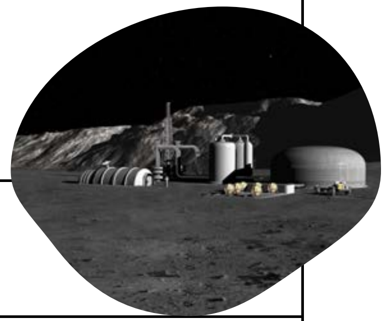
[JAXA HP] https://global.jaxa.jp/

# Backup

# R&D Priority

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

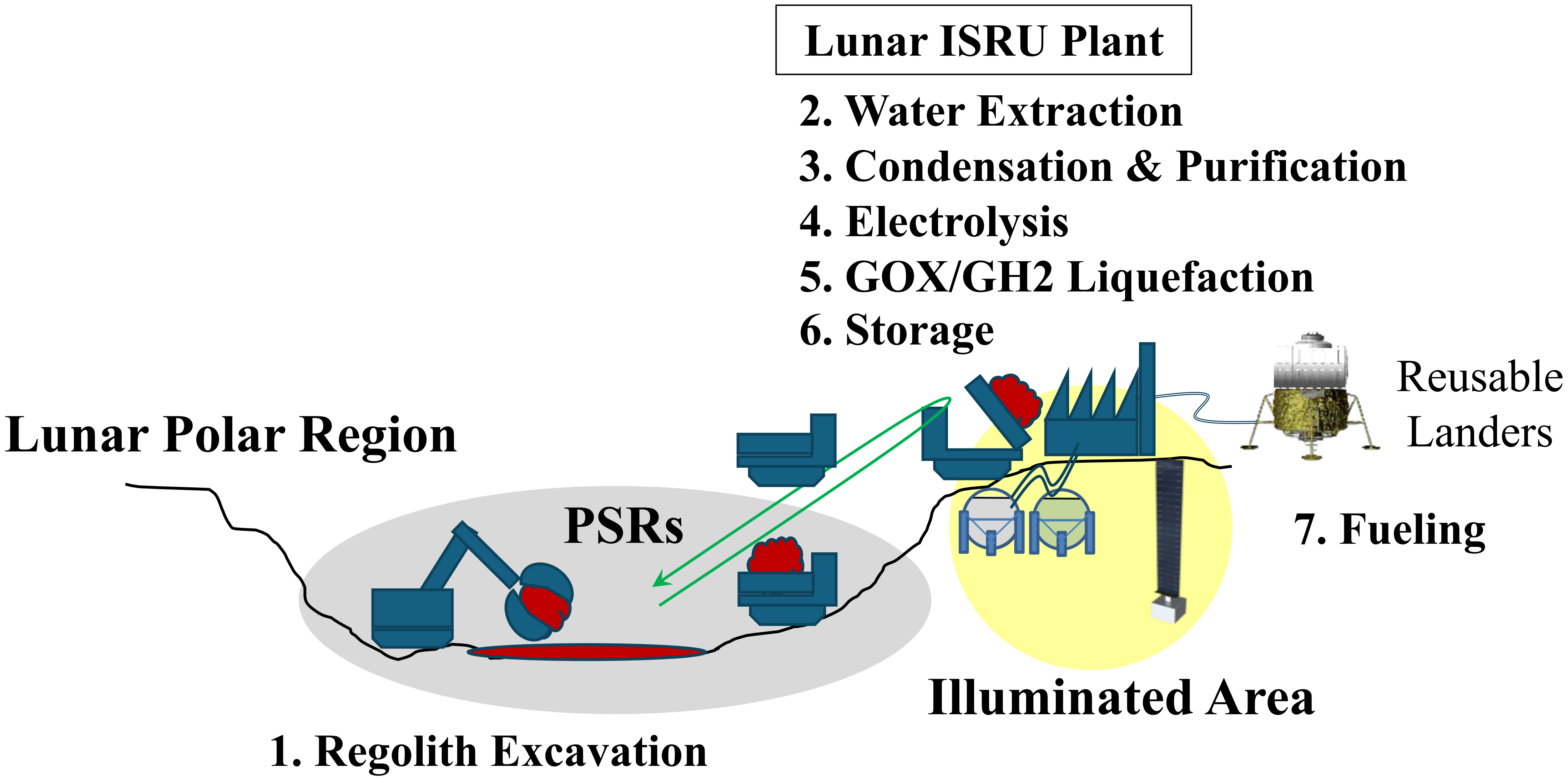


# Overview of SSF Phase 1-3

SPACE STRATEGY FUND

| | 1st Phase (FY2024-) | 2nd Phase (FY2025-) | 3rd Phase (FY2026-) |
|---|---|---|---|
| **Size** | **300 B JPY** | **300 B JPY** | **200 B JPY** |
| Transportation<br>Satellites etc.<br>Exploration etc.<br>Cross-Cutting Areas | Approx. 36 B JPY<br>Approx. 165 B JPY<br>Approx. 74 B JPY<br>Approx. 16 B JPY | Approx. 63 B JPY<br>Approx. 134 B JPY<br>Approx. 50 B JPY<br>Approx. 44 B JPY | Approx. 48 B JPY<br>Approx. 96 B JPY<br>Approx. 32 B JPY<br>Approx. 24 B JPY |
| Number of Themes | 22 themes | 24 themes | 19 themes |
| Number of Funded Projects | Approx. 50 projects | Approx. 140 projects (Scheduled) | Approx. 80 projects (Scheduled) |
| Approach | Themes are formulated for technology development projects for which plans and funding needs have already been clearly identified and which should be initiated promptly. | New themes are formulated that are expected to particularly contribute to expanding involvement in the space sector and broadening its base. | Themes are formulated to promote the acceleration of demonstration, social implementation, and commercialization of space technologies by leveraging collaboration and integration with technologies from other fields. |
| Key Features | ・Accelerating Private-Sector Initiatives<br>・Accelerating the Transfer of Technologies to the Private Sector Across Various Fields<br>・Enhancing Japan's "Strength" technologies | ・Creation of New Services<br>・Promotion of Entry from Non-Space Sectors and Expansion of the Industry Base<br>・Acceleration of Initiatives Toward High Frequency Launches | ・Demonstration in the Space Domain through Collaboration and Integration with Technologies from Other Fields<br>・Acceleration of Demonstration through the Integration of Space Technologies<br>・Acceleration of Transportation Technology Demonstration and Support for Commercialization |

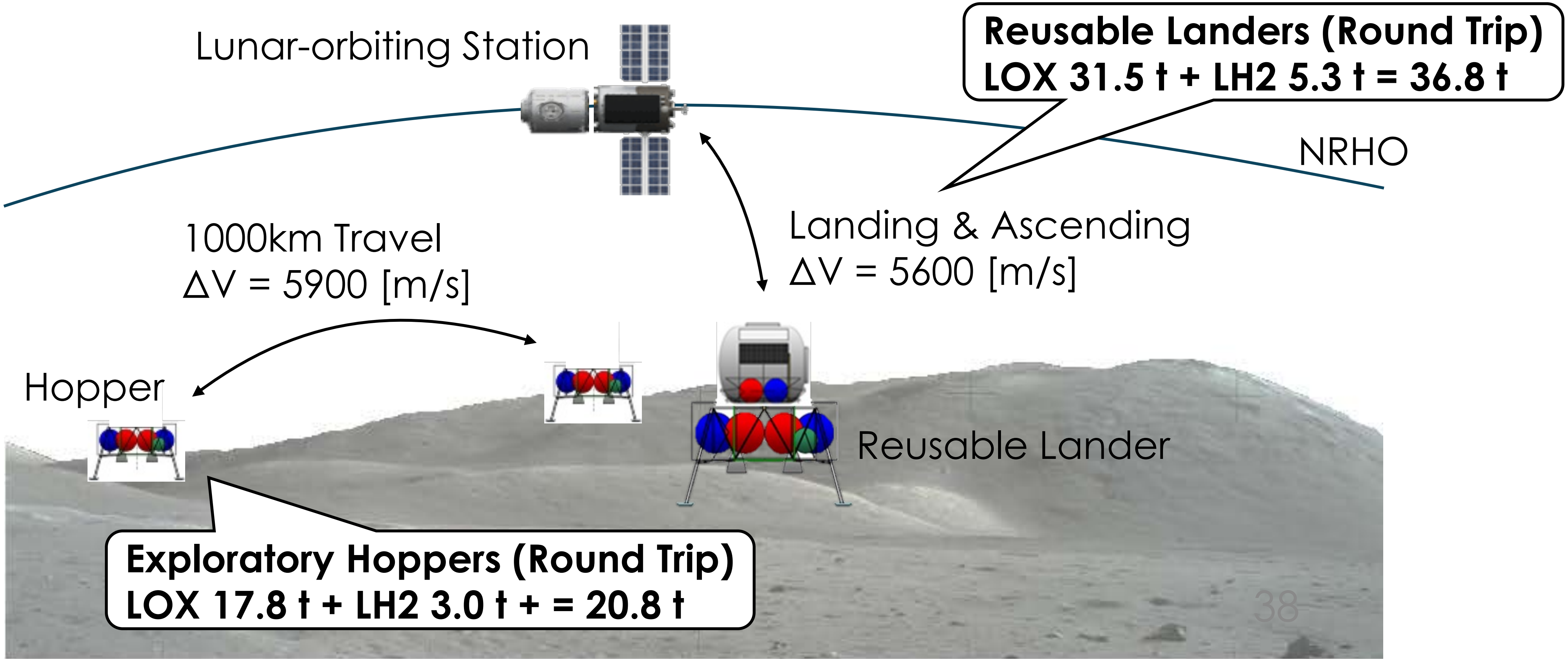
# Concept of a Lunar ISRU Plant



# Baseline Requirements

## Production Rate

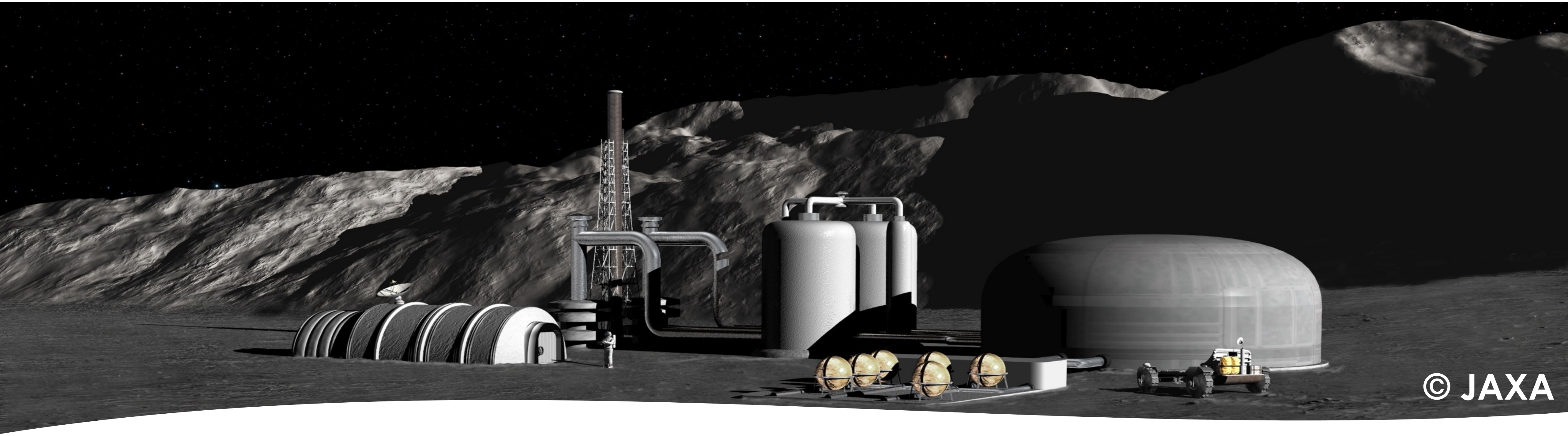
**Propellant Production: 57.6 ton/year**
**(LOX 49.3 ton/year + LH2 8.3 ton/year)**




| Global Exploration Roadmap Critical Technologies (Summary Table) | Today ISS & Spaceflight Heritage | Near Future Moon Vicinity/Surface | Future Mars Vicinity/Surface |
|---|---|---|---|
| **Transversal Technologies** | | | |
| In-Situ Resource Utilisation (ISRU) | Mars oxygen production from $CO_2$ atmosphere, e.g., MOXIE | Technologies for processing resources into useful products and their storage/supply (e.g., propellant production 50 tons/year) | $LOX/LCH_4$ and $LOX/LH_2$ generation from both atmosphere processing and sub-surface water extraction |
| Dust Mitigation | Apollo: limited three-day crew ... Rovers: limited miti... | Multiple active and passive technologies required significant advances in life cycle | |
| Inflatable Structures and Materials for Inflatable Modules | ISS: Bigelow Expandable ... Module (BEAM) | | |
| Low-Temperature Mechanisms | ISS ... -157°C | Operations to -230°C (cryo compatible); multi-year life | |
| Thermal Management | ... Mars asset | Improve thermal control and reliablity required to reduce mass transportation and enable higher performance | |

**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.

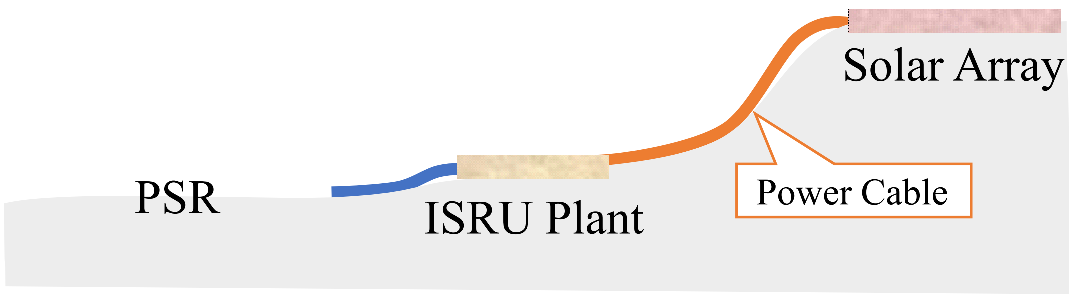
# Conceptual Study of Lunar Full-scale ISRU Plant

## ◆ 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:
  
  < 33.1$m^3$ (= 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

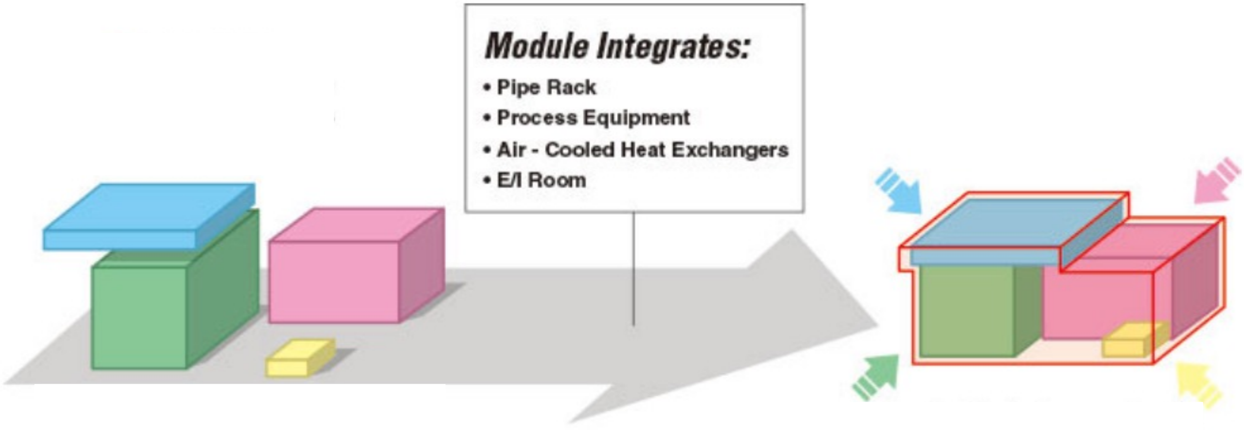
☐ "Modular construction method" developed method of LNG plant construction on the ground could be applied to a lunar ISRU plant with the aim of speedy construction.

Module Rifting

Maritime Transportation


Delivery to Construction Site

Land Transportation





SPMT (Self-Propelled Modular Transporter) / Mammoet