JAXA's TECHNOLOGY ROADMAPPING AND DEVELOPMENT FOR IN-SITU PROPELLANT PRODUCTION ON THE MOON. J. Shimada[1] (shimada.jun@jaxa.jp), H. Meguro[1], S. Okamoto[1] and T. Iwaki[1], [1]Japan Aerospace Exploration Agency (JAXA), Tsukuba Space Center, Ibaraki, Japan.

Introduction: This paper summarizes technology roadmapping and development related to in-situ resource utilization (ISRU) led by Japan Aerospace Exploration Agency (JAXA). The present study was undertaken in order to validate technical feasibility of in-situ productions of water, oxygen and cryogenic propellants from local resources on the lunar surface. In-situ productions of consumables such as water, oxygen and propellant are of the essence to establish long-term human presence on space frontiers by drastically reducing launch mass and attendant risks for periodic resupply of these consumables. Figure 1 illustrates a full-scale lunar ISRU plant designed for on-site production of liquid hydrogen (LH2) and liquid oxygen (LOX) from lunar icy regolith. Either lunar regolith excavated in the Permanently Shadowed Regions (PSRs) or extracted water is transferred to a lunar ISRU plant located on illuminated crater rim by transporter(s) as shown in Figure 2. Gaseous hydrogen (GH2) and gaseous oxygen (GOX) produced by electrolysis are transferred to the liquefaction element at a plant. LH2 and LOX are stored in cryogenic storage tanks to be filled into spacecrafts on demand.

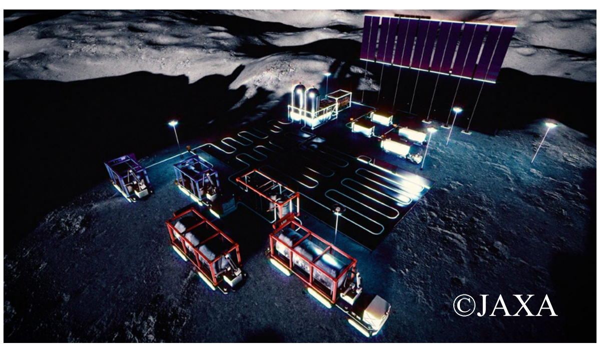

Figure 1. Image of in-situ production of liquid hydrogen (LH2) and liquid oxygen (LOX).

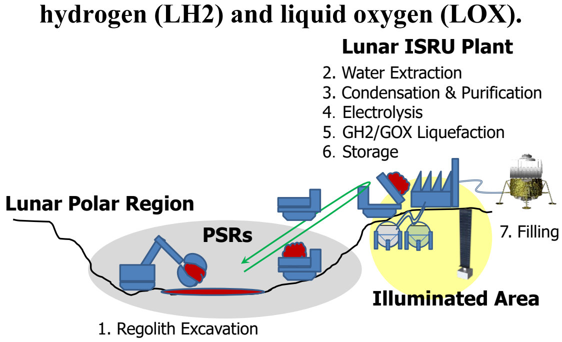

Figure 2. Process flow of full-scale LH2/LOX production from lunar icy regolith.

Technology Roadmapping: The author formulated long-range technological roadmap to strengthen human exploration capabilities through space resource utilization and published Japan's International Space Exploration Scenario [1] in 2022. As illustrated in Figure 3, it is of importance to steadily advance research activities including integrated systems design and core technology development in parallel to keep interdisciplinary projects as one unified set of activities through enhancement of interoperability across systems. Table 1 summarizes the baseline requirements and preconditions of full-scale Lunar ISRU Plant, sub-scale Lunar ISRU Pilot Plant and sub-scale Ground Demonstration Plant.

Integrated Systems Design: System-level feasibility studies of following integrated systems were conducted to investigate technical practicability of in-situ productions of water, oxygen and cryogenic propellant, and identify major technical challenges from a system integration standpoint:

- Feasibility study of full-scale Lunar ISRU Plant (2021-2023)
- Feasibility study of sub-scale Lunar ISRU Pilot Plant and ISRU Ground Demonstration Plant (2023-2024)
- Conceptual and preliminary design of sub-scale ISRU Ground Demonstration Plant (2024-2026)

Core Technology Development: Technical studies on core elements were conducted to strategize long-term R&D strategies and increase the technology readiness levels (TRLs) through breadboard model (BBM) development and testing if required.

Water Extraction. Extraction from lunar regolith simulant which contains a certain amount of water and predefined chemical species in the vacuum environment.

Purification of extracted water. Purification of extracted water to satisfy the water quality requirement to be properly processed by downstream subsystems without causing efficiency degradation and malfunctions due to residual impurities trapped in extracted water.

Water Electrolysis. Production of gaseous hydrogen and oxygen by electrolysis.

References: [1] JAXA (2025) Japanese International Space Exploration Scenario 2025. [2] NASA (2020) Cross-Program Design Specification for Natural Environments (DSNE).

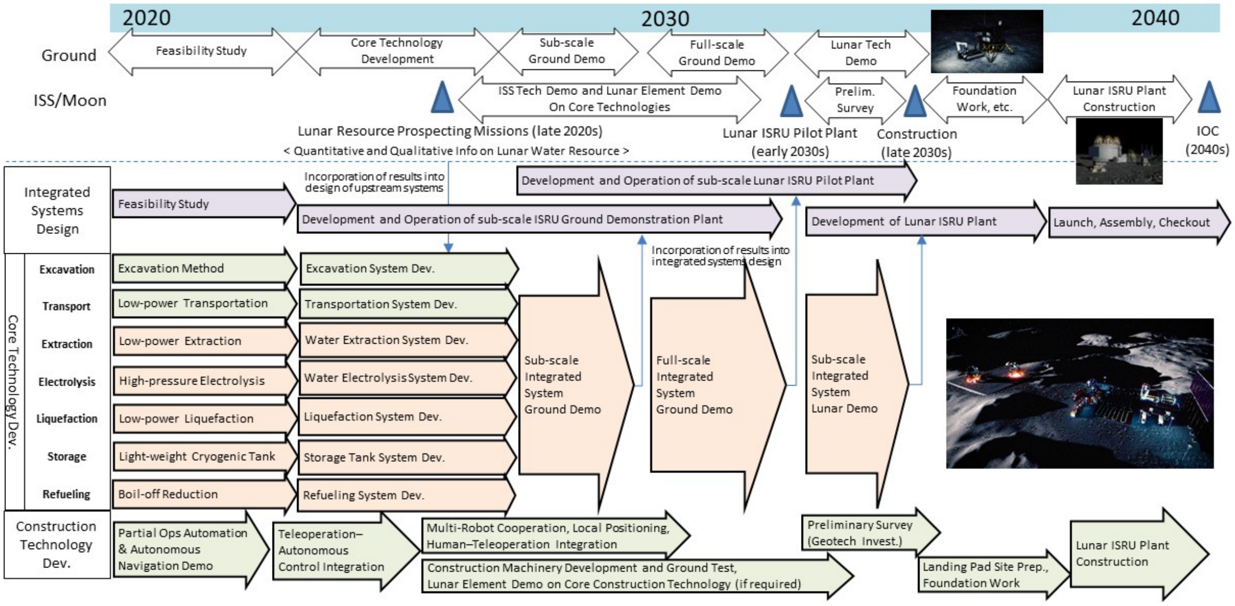

Figure 3. JAXA's lunar ISRU technology roadmap. *Development of sub-scale ISRU Ground Demonstration Plant was initiated in the early 2020s. Sub-scale lunar demonstration is planned in early 2030s. Achievement of initial operation capability (IOC) of full-scale Lunar ISRU Plant is targeted in 2040s* [1].

Table 1. Baseline requirements and preconditions

Symbol	Description	Unit	Lunar ISRU Plant (Full-scale)	Lunar ISRU Pilot Plant (Sub-scale)	ISRU Ground Demonstration Plant (Sub-scale)
$\dot{P}_{LOX}$	Mass production rate of LOX	t/yr	49.3	-	-
$\dot{P}_{LH_2}$	Mass production rate of LH_2	t/yr	8.3	-	-
$\dot{P}_{water}$	Mass production rate of water	kg/yr	-	340	340
$\dot{P}_{GOX}$	Mass production rate of GOX	kg/yr	-	150	150
w_r	Water content of regolith	wt%	5	5	1 (min) 5 (max)
t_d	Design lifetime	yr	20	1	3
-	Feedstock	-	Icy Regolith	Icy Regolith	Regolith Simulant
-	Location	-	Lunar South Pole Region		JAXA Tsukuba Space Center
-	Environmental condition	-	NASA SLS-SPEC-159 [2]		Ambient