

Off World Living – Challenges & Exploration Roadmaps

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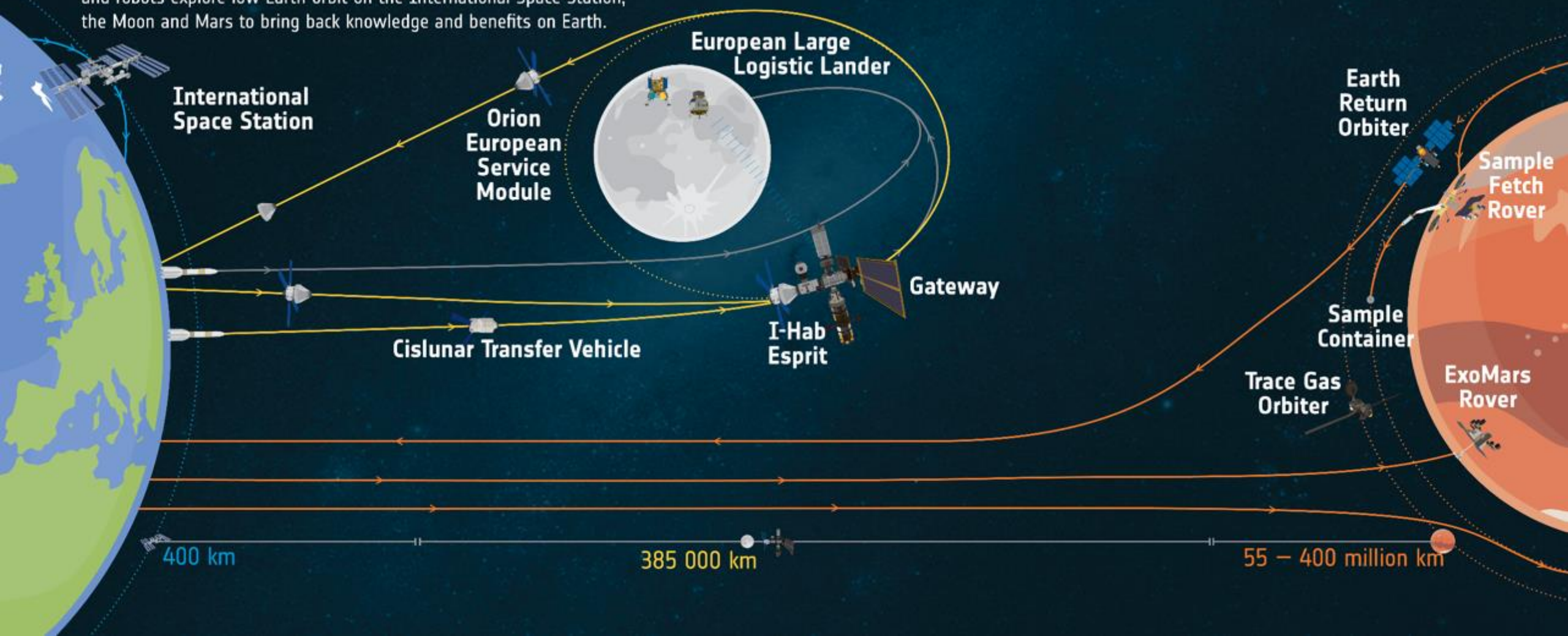
¹ Spaceship EAC, Exploration Preparation Research & Technology Team (ExPeRT), Directorate of Human & Robotic Exploration (HRE), ESA

- Destinations for Exploration
- ExPeRT and how we address (some) challenges of Human Spaceflight & Exploration
- International Agency Exploration Roadmaps



ESA'S HUMAN AND ROBOTIC EXPLORATION DESTINATIONS

ESA's Human and Robotic Exploration programme will see astronauts and robots explore low Earth orbit on the International Space Station, the Moon and Mars to bring back knowledge and benefits on Earth.



- Exploration Preparation, Research and Technology (ExPeRT)
- Technology themes fundamental for Exploration:
 1. Propulsion
 2. Novel Energy Systems
 3. Robotics and Mechanisms
 4. Artificial Intelligence
 5. Advanced Life Support Systems
 6. In-Situ Manufacturing
 7. Crew Health Management
 8. Space Resources

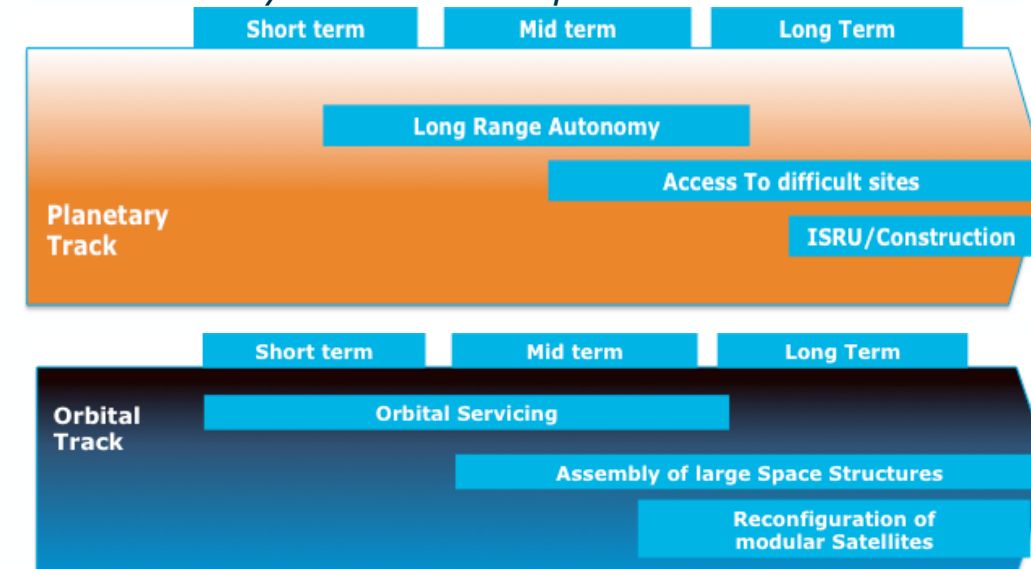


Challenges for Exploration – Prospecting & Robotics

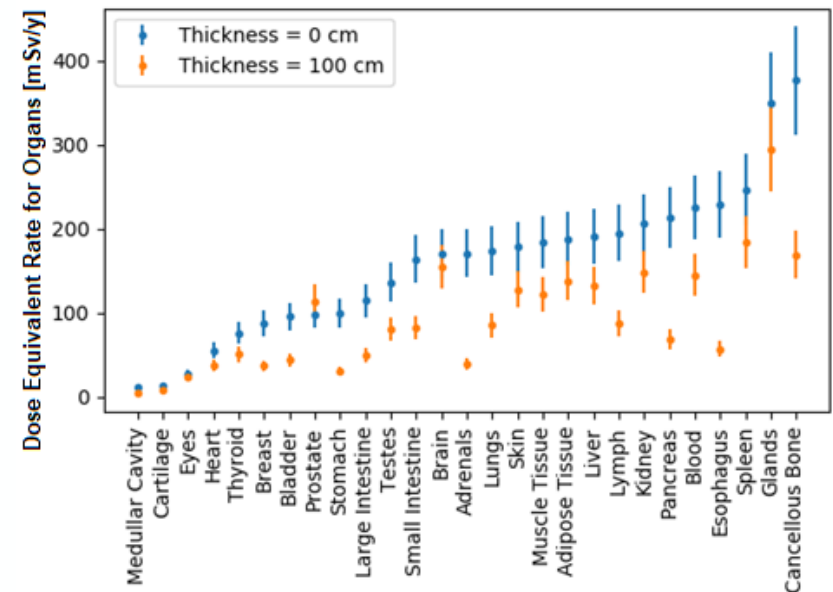
- Deployment of advanced robotic systems interacting with humans, ranging from tele-operated systems from Earth and the Gateway to human-robot and robot-robot collaboration (cobotics)
- Advanced systems that provide autonomy in decision-making and action taking
- High mobility rovers with scientific capability to scout regions of interest on the Moon and on Mars are considered valuable for the initial stage of the ISRU value chain (**please check out recent ESA-ESRIC competition on ISRU prospecting!**)
- In space manufacturing and on orbit assembly are also challenges that need to be addressed



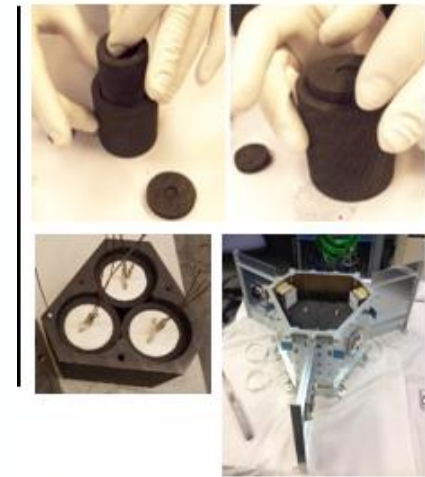
Robotics systems roadmap



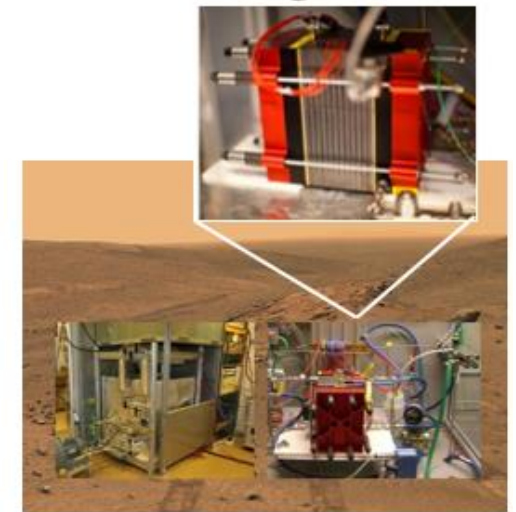
- A round-trip to Mars will require much longer duration stays than any previous missions in a significantly different environment, different from LEO
- Innovative technologies will have to be an order of magnitude more sophisticated than the ones in LEO or for the Gateway even, namely in terms of
 - Autonomy
 - Life support systems
 - Waste management
 - Inflight training & operational concepts
 - Medical support
 - Repair capability (additive manufacturing)
 - Crew psychology
- Radiation Protection is a critical technology
 - Radiation shielding by ISRU (regolith) and/or innovative materials (lightweight materials)



- Energy is a critical component for supporting human spaceflight exploration
- Nuclear Power
 - Radioisotope Heater Units (via Americium 241 pellets) and Radioisotope Thermoelectric Generators
 - Sterling engine technology
 - Nuclear fission reactors
- Electrochemical Systems
 - Advanced batteries
 - Fuel Cell systems
 - closed loop Regenerative Fuel Cells System (RFCS) using Earth-based resources (H₂O) is already under development
- Novel energy solutions (e.g hybrid systems with ISRU products)



Credit: University of Leicester (UK)



Credit: Prototech (NO)

Example – Lunar Exploration Reference Scenario

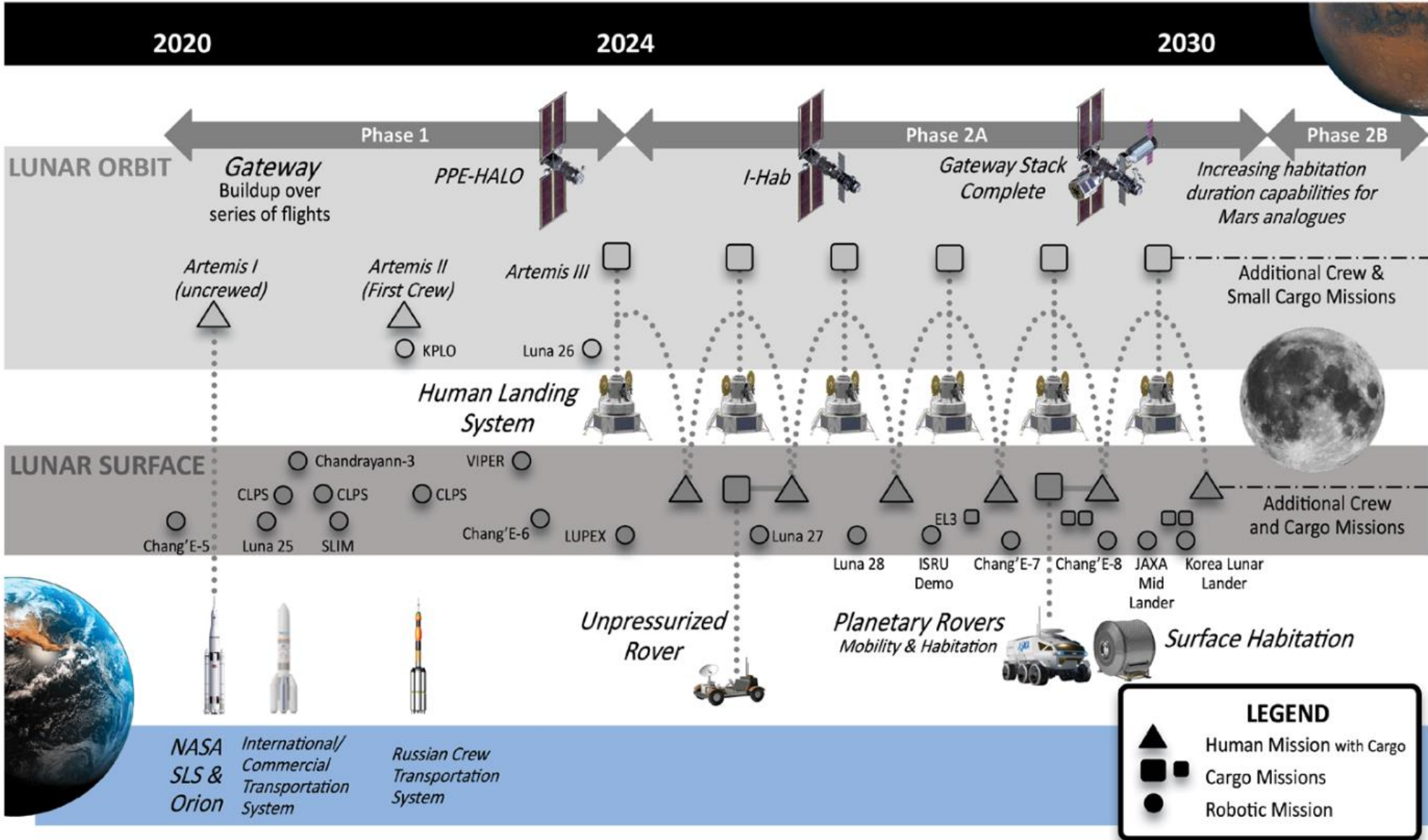
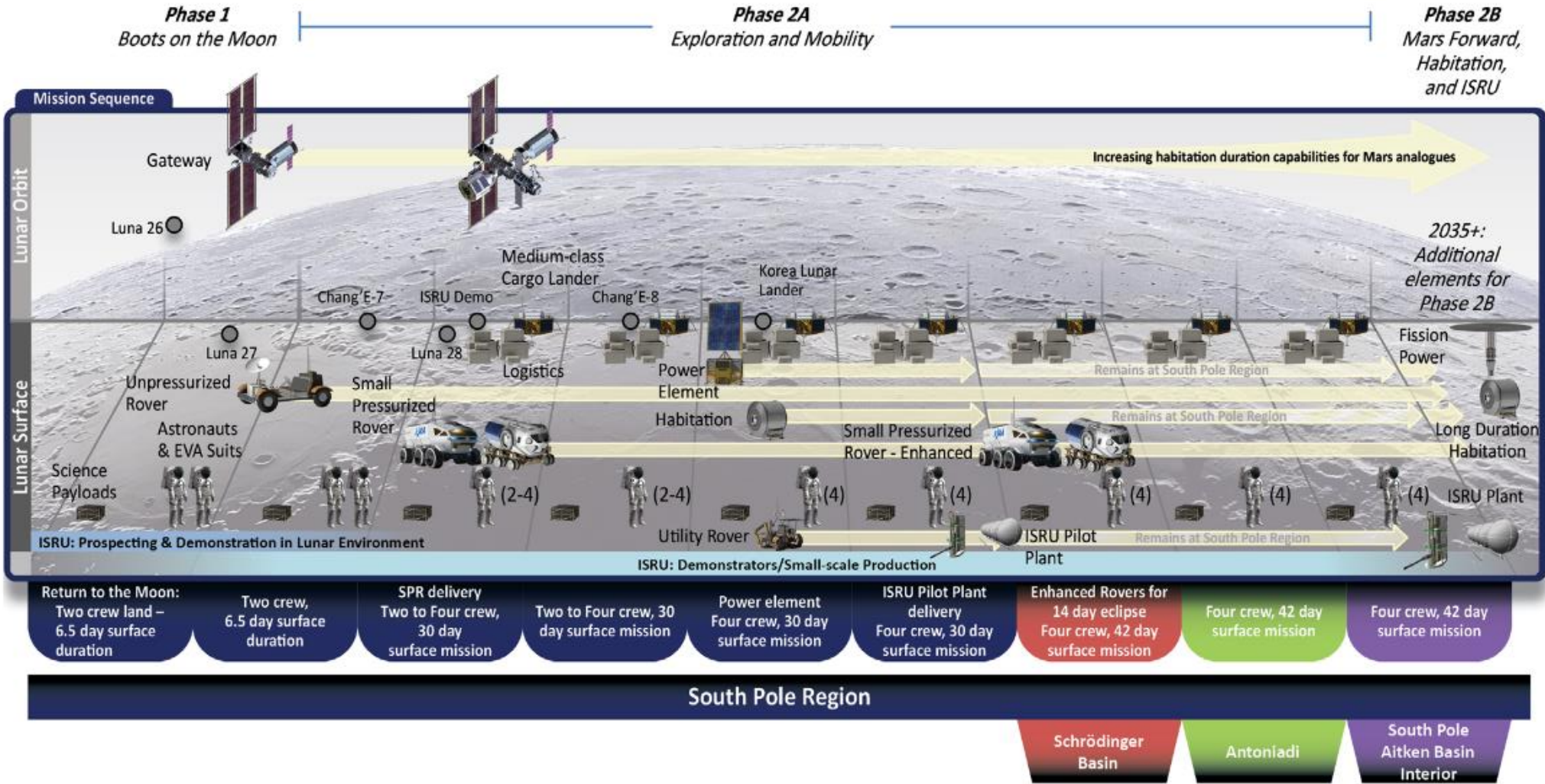


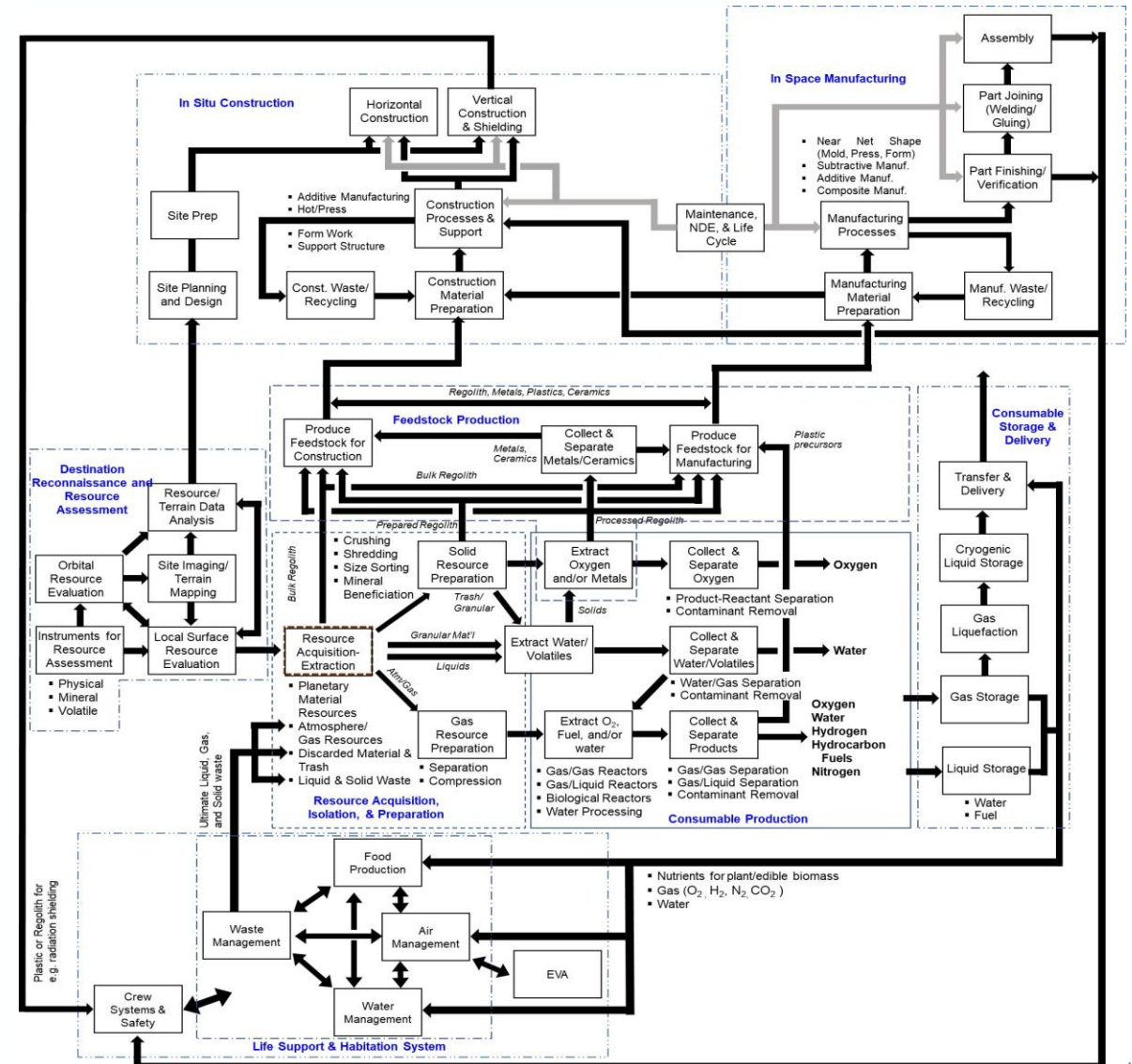
Figure 1. Updated ISECG Lunar Surface Exploration Scenario.

Expanded Phase 2 of Lunar Exploration



ISECG Gap Assessment Reports

- **LOx/Methane propulsion**
[LOx/Methane Propulsion Gap Assessment Report](#)
 [Issue date: 25 January 2016]
- **Dust mitigation**
[Dust Mitigation Gap Assessment Report](#)
 [Issue date: 06 February 2016]
- **Telerobotics**
[Telerobotic Control of Systems with Time Delay Gap Assessment Report](#)
 [Issue date: 01 July 2018]
- **Autonomy**
[Autonomy Gap Assessment Report](#)
 [Issue date: 15 May 2020]
- **In-Situ Resource Utilisation**
[In-Situ Resource Utilisation Gap Assessment Report](#)
 [Issue date: 21 April 2021]



ESA has a defined strategy document for Exploration, freely available for the wider community

- **ESA Exploration Strategy**

'Google ESA Exploration Strategy'

- **ESA Space Resources Strategy**

'Google ESA Space Resources Strategy'





Low
Earth
Orbit

Moon

Mars

we explore. you benefit.

Human Spaceflight and Robotic Exploration

