National Aeronautics and Space Administration

# CROSS DIRECTORATE SCIENCE UTILIZATION


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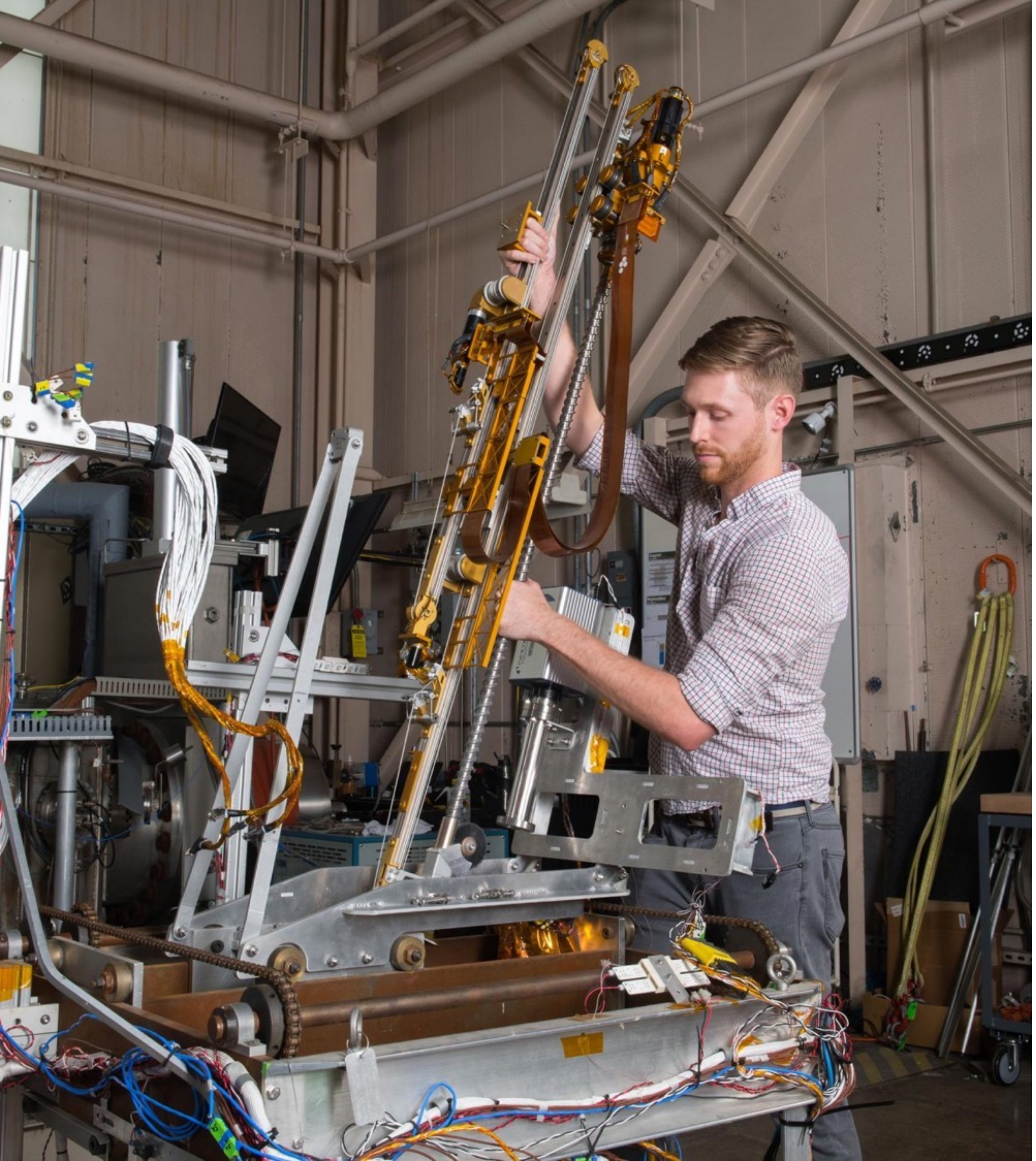
# Artemis Science Objectives

- Understand planetary processes
- Understand the character and origin of lunar polar volatiles
- Interpret impact history of Earth-Moon system
- Reveal the record of the ancient sun and our astronomical environment
- Observe the universe and the local space environment from a unique location
- Conduct experimental science in the lunar environment
- Investigate and mitigate exploration risks

**Pictured left:** NASA astronaut candidates and field instructors hike during geology training in Arizona



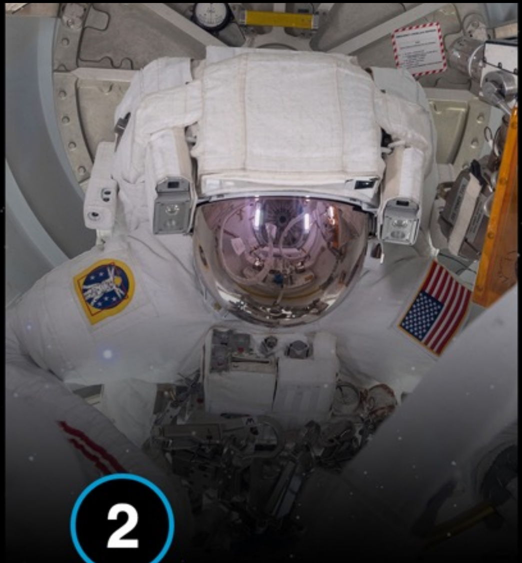
# Artemis Technology Objectives

The **Lunar Surface Innovation Initiative (LSII)** works across industry, academia and government through in-house efforts and public-private partnerships to develop transformative capabilities like:

- In-situ resource utilization (ISRU)
- Surface power
- Dust mitigation
- Extreme environment
- Extreme access
- Excavation and construction

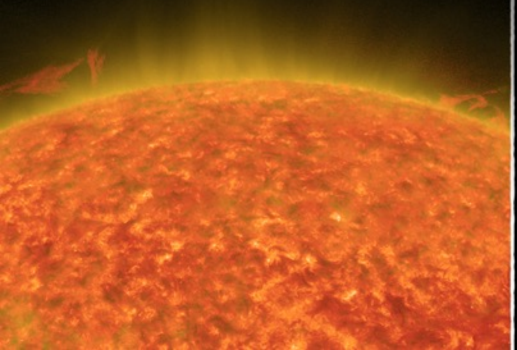
**Pictured left:** A Honeybee Robotics systems engineer installs The Regolith and Ice Drill for Exploring New Terrain (TRIDENT) on a trolley for thermal vacuum chamber testing. TRIDENT will drill up to three feet deep, extracting lunar soil and demonstrating a critical capability for future ISRU.

# Hazards of Human Spaceflight



## 1 Space Radiation

Invisible to the human eye, radiation increases cancer risk, damages the central nervous system, and can alter cognitive function, reduce motor function and prompt behavioral changes.



## 2 Isolation and Confinement

Sleep loss, circadian desynchronization, and work overload may lead to performance reductions, adverse health outcomes, and compromised mission objectives.

## 3 Distance from Earth

Planning and self-sufficiency are essential keys to a successful mission. Communication delays, the possibility of equipment failures and medical emergencies are some situations the astronauts must be capable of confronting.

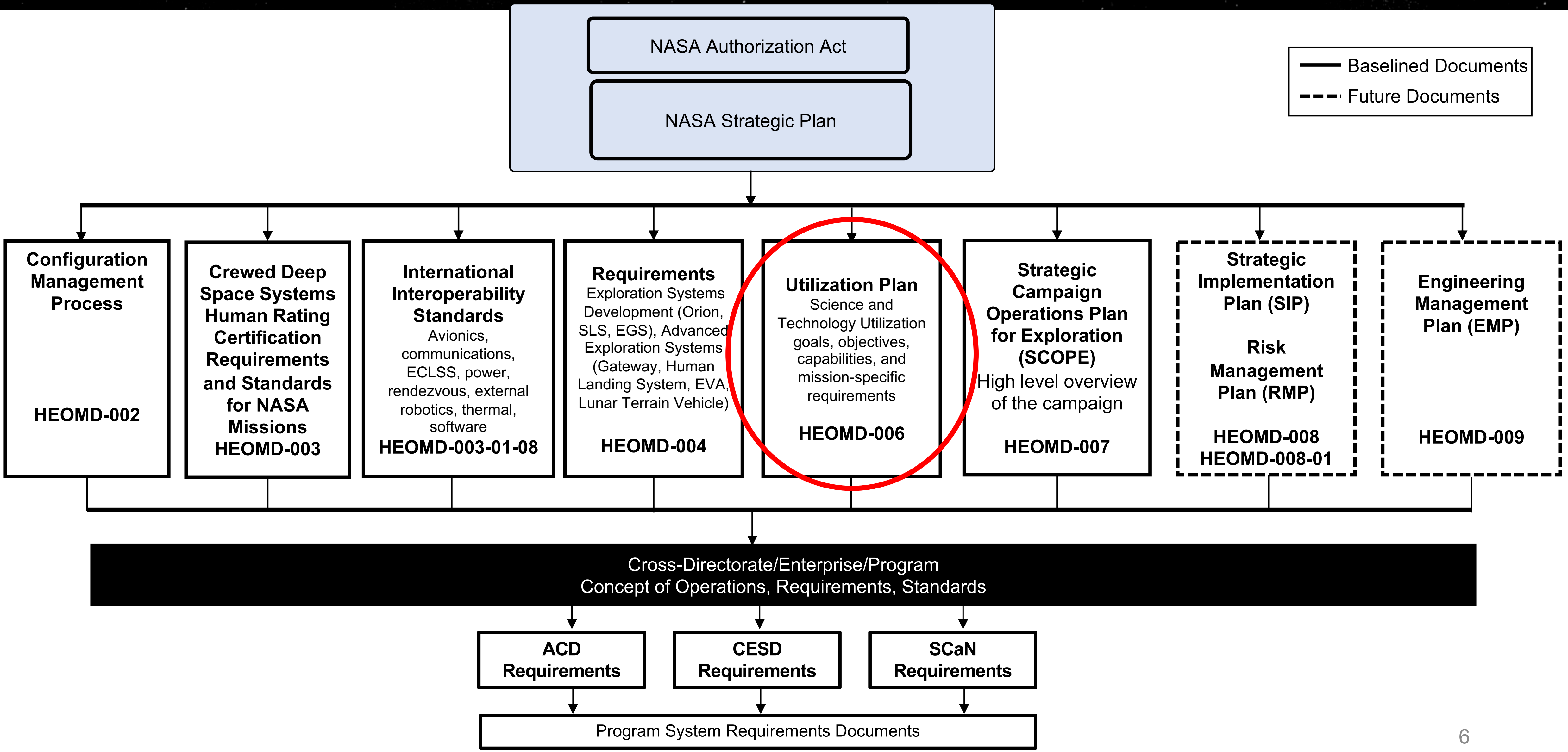
## 4 Gravity (or lack thereof)

Astronauts encounter a variance of gravity during missions. On Mars, astronauts would need to live and work in three-eighths of Earth's gravitational pull for up to two years.

## 5 Hostile/Closed Environments

The ecosystem inside a vehicle plays a big role in everyday astronaut life. Important habitability factors include temperature, pressure, lighting, noise, and quantity of space. It's essential that astronauts stay healthy and happy in such an environment.

# ESDMD/SOMD Directorate-level Technical Documentation – Current and Planned



# SCIENCE & TECHNOLOGY UTILIZATION

## INTEGRATING ACROSS MISSION DIRECTORATES

Integrate science and technology goals from mission directorates and international partners to develop HEO utilization goals, objectives and requirements for Artemis missions, and the cross-platform research strategy to prepare for human missions to Mars

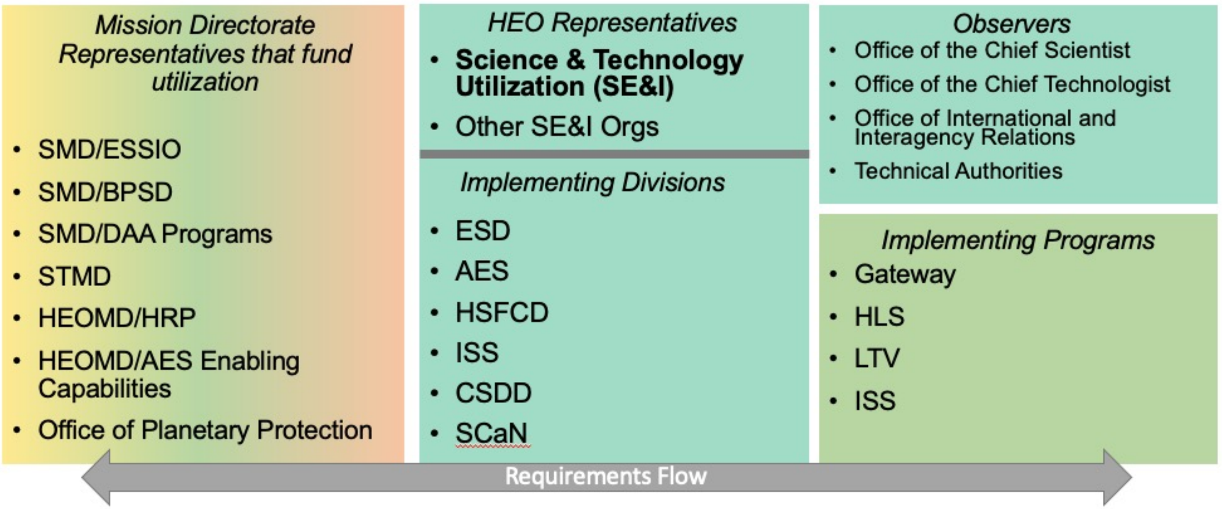
## EXAMPLES:

- HEO-006 Utilization Plan joint with SMD and STMD - High level utilization goals, objectives and requirements
    - Utilization capabilities and their phasing over time
    - Mission-specific annexes with mission directorate requirements to enable research solicitations
    - Includes ISS, Commercial LEO, Artemis and Mars
- Co-chair the Utilization Coordination and Integration Working Group (UCIG) with SMD & STMD
- Coordinating HEO process for using our CLPS mass allocations and representative to SMD CLPS manifest selection board

## INTEGRATING WITH HEO DIVISIONS

- Work with divisions and users on high-level goals, objectives, and strategic plans
- Interface with AES and ESD on approach to implementation and payload manifest for Artemis
- Ensure science and technology inputs are integrated into Exploration formulation activities

**UTILIZATION COORDINATION AND INTEGRATION WORKING GROUP (UCIG) REQUIREMENTS FLOW**



# Human Spaceflight Utilization Plan (HEOMD-006)

Identifies and describes NASA's science and technology utilization goals and objectives that will be enabled by human missions.

Authority Quad-Directorate:
- Science Mission Directorate (SMD),
- Space Technology Mission Directorate (STMD),
- Space Operations Mission Directorate (SOMD)
- Exploration Systems Development Mission Directorate (ESDMD)

Purpose:
Identify how human missions will support the science and technology communities to conduct fundamental research about our universe and solve the scientific and technological challenges for sustaining and expanding human exploration

Scope: Utilization of ISS/LEO, Artemis, Mars

https://ntrs.nasa.gov/citations/20220005087


National Aeronautics and Space Administration

Exploration Systems Development Mission Directorate (ESDMD)
HEOMD-006
REVISION A
RELEASE DATE: 03/30/2022

EXPLORATION SYSTEMS DEVELOPMENT MISSION DIRECTORATE
UTILIZATION PLAN

*This document has been reviewed for Proprietary, CUI, and Export Control (ITAR/EAR) and has been determined to be non-sensitive. It has been released to the public via the NASA Scientific and Technical Information (STI) Process DAA #20220005087*

*This document was approved by NASA's Exploration Systems Development Mission Directorate (ESDMD), Space Operations Mission Directorate (SOMD), Science Mission Directorate (SMD), Space Technology Mission Directorate (STMD)*

March 2022

# Utilization Plan
# Main Body Goals By NASA Directorate

Goals and Objectives are owned by each mission directorate and updated as needed (e.g., Decadal Survey inputs, Agency Strategic Planning, etc.)

| Mission Directorate | | Utilization Goals |
|---|---|---|
| **3.1 SMD** | SMD Utilization Goal 1 | Enable scientific investigations from the lunar surface, including field relationships, in-situ observations, and sample return, to address the multidisciplinary objectives of the Science Mission Directorate |
| | SMD Utilization Goal 2 | Enable scientific investigations from human spaceflight platforms to address the multidisciplinary objectives of the Science Mission Directorate |
| | SMD Utilization Goal 3 | Enable science investigations on the surface of Mars, in Mars orbit, and in Mars transit |
| **3.2 STMD** | STMD Utilization Goal 1 | Enable sustainable living and working farther from Earth ("Live") |
| | STMD Utilization Goal 2 | Enable transformative missions and discoveries ("Explore") |
| **3.3 ESDMD / SOMD** | ESDMD/SOMD Utilization Goal 1 | Advance knowledge to support safe, productive human space travel, and enable systems development and testing to reduce health and performance risks for future human exploration |
| | ESDMD/SOMD Utilization Goal 2 | Advance the operational capabilities required for sustainable lunar operations and the first human missions to Mars *including demonstrating approaches to planetary protection.* |
| **3.4 NASA Multi-directorate** | Multi-directorate Utilization Goal 1 | Enable commercial, interagency, and international partnerships to make space exploration more affordable and sustainable, grow new markets, and increase capabilities |

# HEOMD-006 Utilization Plan
# Annex 1: Cornerstone Capabilities that Enable Multiple Objectives

1.1 MODEL TRAVERSE APPROACHES

1.2 END-TO-END SAMPLE RETURN

1.3 INTEGRATED PLANETARY PROTECTION STRATEGY

1.4 EXTENDED MISSIONS

1.5 INTEGRATED CREW RESEARCH

1.6 ROBOTIC UTILIZATION FOR HEO ASSETS

1.7 INTEGRATED INSTRUMENT STRATEGY

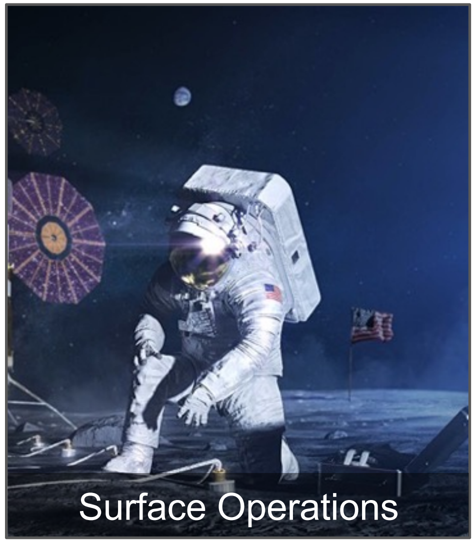
1.8 OPERATIONS IN COLD & SHADOWED REGIONS

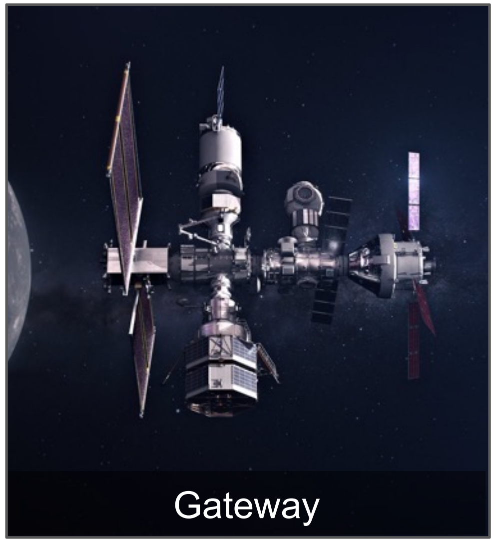
# Artemis: A Foundation for Deep Space Exploration


Space Launch System


Orion spacecraft


Human Landing System


Surface Operations

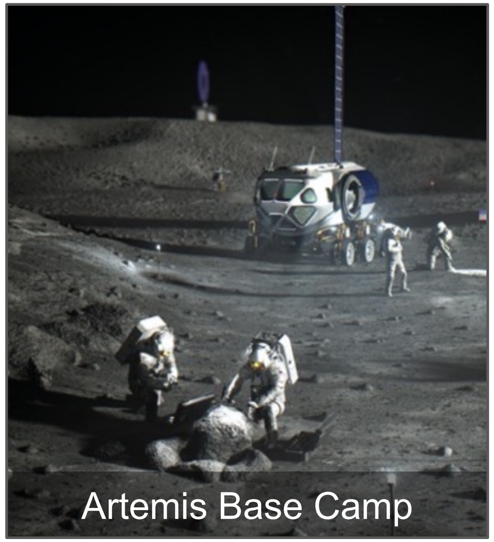

Gateway

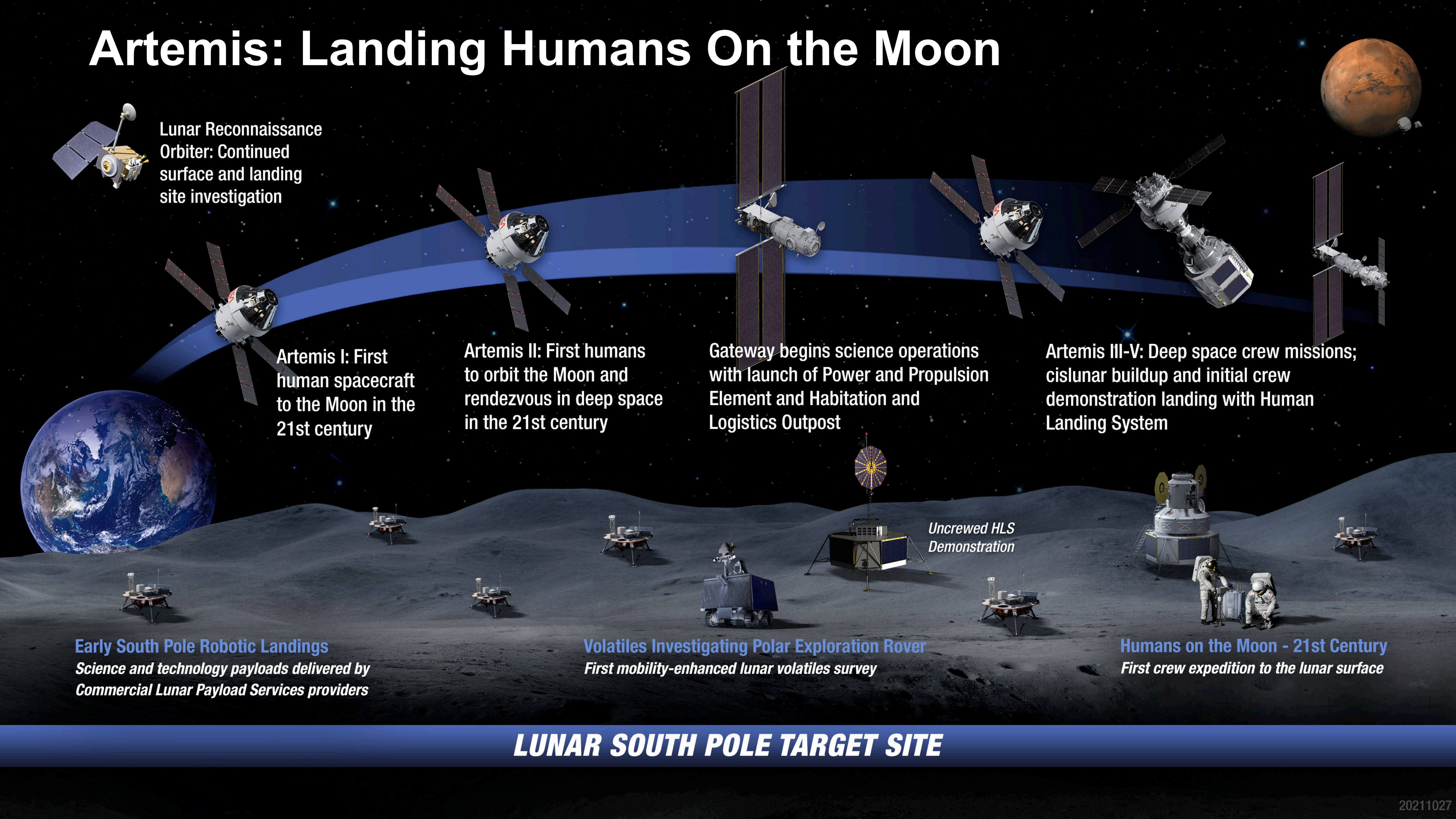
Exploration Ground Systems


Space Communications & Navigation


Surface Mobility


Space Suits


Artemis Base Camp

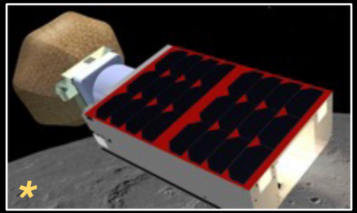

Artemis: Landing Humans On the Moon
Lunar Reconnaissance Orbiter: Continued surface and landing site investigation
Artemis I: First human spacecraft to the Moon in the 21st century
Artemis II: First humans to orbit the Moon and rendezvous in deep space in the 21st century
Gateway begins science operations with launch of Power and Propulsion Element and Habitation and Logistics Outpost
Artemis III-V: Deep space crew missions; cislunar buildup and initial crew demonstration landing with Human Landing System
Uncrewed HLS Demonstration
Early South Pole Robotic Landings
Science and technology payloads delivered by Commercial Lunar Payload Services providers
Volatiles Investigating Polar Exploration Rover
First mobility-enhanced lunar volatiles survey
Humans on the Moon - 21st Century
First crew expedition to the lunar surface
LUNAR SOUTH POLE TARGET SITE
20211027

# Artemis I CubeSat Payloads

*Science and technology investigations and demonstrations paving the way for future, deep space human exploration*

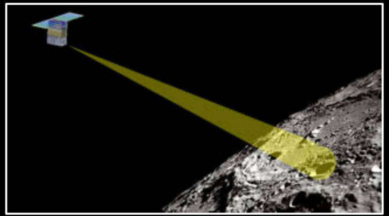
### ArgoMoon

Photograph the Interim Cryogenic Propulsion Stage (ICPS) CubeSat deployment, the Earth and Moon using HD cameras and advanced imaging software.



### OMOTENASHI

Develop world's smallest lunar lander and observe lunar radiation environment.

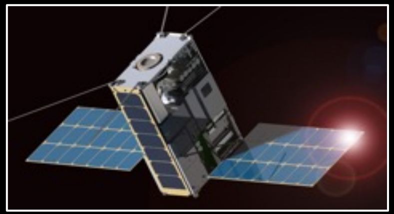


### LunIR

Use a miniature high-temperature Mid-Wave Infrared (MWIR) sensor to characterize the lunar surface.

### LunaH-Map

Perform neutron spectroscopy to characterize abundance of hydrogen in permanently shaded craters.

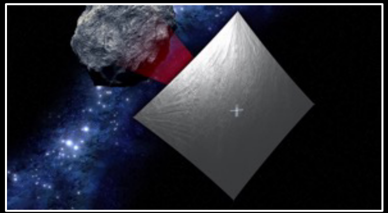


### Lunar IceCube

Search for water (and other volatiles) in ice, liquid and vapor states using infrared spectrometer.

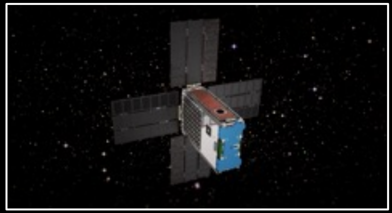
### Team Miles

Demonstrate propulsion using plasma thrusters; compete in NASA's Deep Space Derby.



### Near-Earth Asteroid Scout (NEA Scout)

Detect target NEA, perform reconnaissance and close proximity imaging.

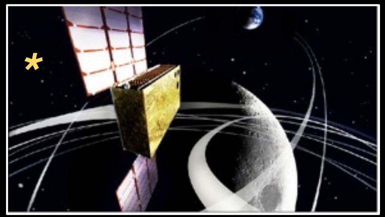


### BioSentinel

Use yeast as a biosensor to evaluate the effects of ambient space radiation on DNA.

### CubeSat to Study Solar Particles (CuSP)

Measure incoming radiation that can create a wide variety of effects on Earth.



### EQUULEUS

Demonstrate trajectory control techniques within the Sun-Earth-Moon region and image Earth's plasmasphere.

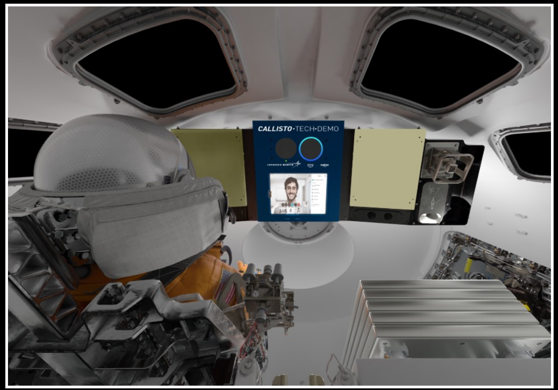
* INTERNATIONAL COLLABORATION

# Artemis I Pressurized Payloads

*Payloads that will fly inside of the Orion crew module*

**Radiation Sensors***

There will be three types of sensors, including the ESA Active Dosimeters, Hybrid Electronic Radiation Assessor (HERA), and the Radiation Area Monitor (RAM).

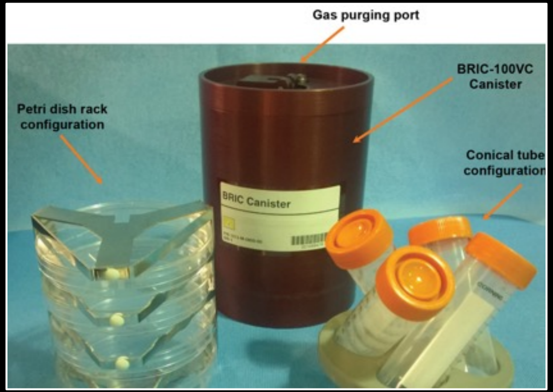



**Callisto**

Demonstrate voice activated virtual assistant which enables hands free crew interface. Evaluate effectiveness of on board vs. ground supported crew assisted capabilities.

**Matroshka AstroRad Radiation Experiment (MARE)***

Investigation with DLR and ISA for to evaluation radiation protection vest for astronauts.




**Bio-Experiment-1**

A battery-powered life sciences payload for biology research beyond low-Earth orbit (LEO). May be as many as four investigations.

* INTERNATIONAL COLLABORATION

# SSERVI Overview

## SSERVI at a Glance:

Jointly funded by NASA HEOMD and SMD, SSERVI is focused on ***science enabling human exploration and science enabled by human exploration.***

Currently **12 Overlapping U.S. Teams** funded in 2017 and 2019, each with 5-year cooperative agreements.

**1000+ publications** since SSERVI started in 2013. Many additional conference publications and other scientific products.

Management of the **Solar System Treks Project (SSTP)**, a visualization tool originally created during Constellation program, at request of NASA HQ.

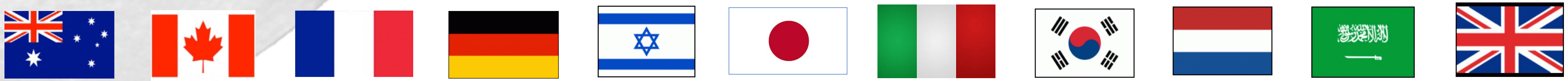
**11 Int'l partners** with a focus on lunar science and missions:

**The Solar System Exploration Research Virtual Institute (SSERVI)** supports human exploration and scientific discovery by integrating interdisciplinary research to prioritize and resolve key knowledge gaps.

**Key Exploration Science Events:**

- **NASA Exploration Science Forum (NESF):** Virtual/In-person conference featuring scientific discussions about the Moon and other exploration targets of interest. All past Forum recordings and archives available at sservi.nasa.gov
- **European Lunar Symposium (ELS):** Annual meeting that brings together the U.S. and European lunar science, exploration, and launch communities. ELS documents and video archives: https://els2020.arc.nasa.gov/
- **Solar System Treks Project (SSTP):** A free, web-based application that provides high-resolution images and visualizations of planetary bodies using real spacecraft data. Provides mission planning data analyses to domestic and international lunar missions. New portals and updates released in support of upcoming missions. Access all Trek portals at https://trek.nasa.gov

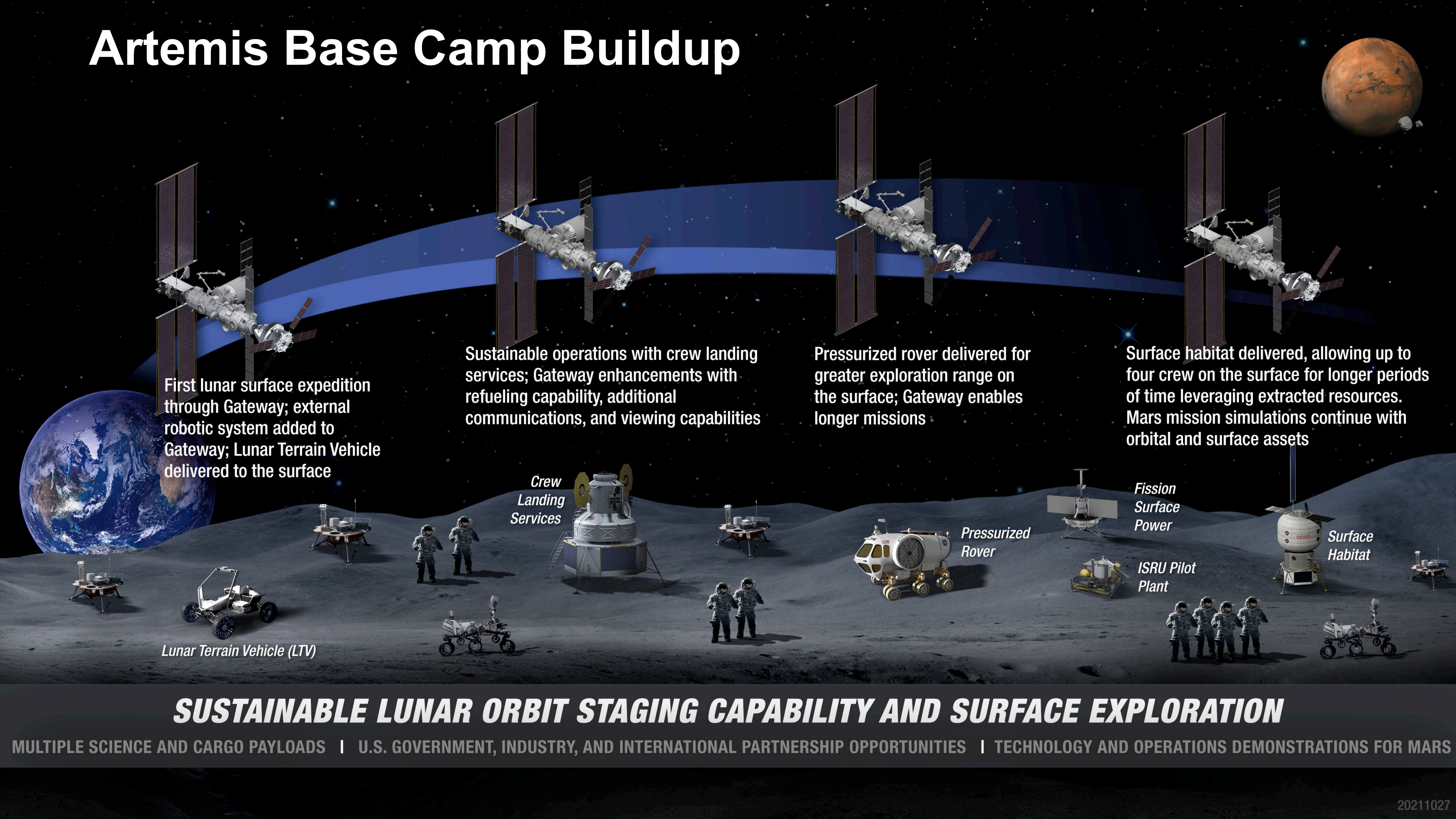

Australia, Canada, France, Germany, Israel, Italy, Japan, Korea, the Netherlands, Saudi Arabia, United Kingdom



# Early Gateway Science Payloads

## Launched with PPE and HALO

- **ERSA:** The European Space Agency's (ESA) radiation instrument package will help provide an understanding of how to keep astronauts safe by monitoring the radiation exposure in Gateway's unique orbit.
- **HERMES:** NASA's space weather instrument suite will observe solar particles and solar wind created by the Sun.
- ESA **Internal Dosimeter Array**, including instruments provided by the Japan Aerospace Exploration Agency. Data provided will allow for the study of radiation shielding effects and improve radiation physics models for cancer, cardiovascular, and central nervous system effects, helping assess crew risk on exploration missions.


Artemis Base Camp Buildup
First lunar surface expedition through Gateway; external robotic system added to Gateway; Lunar Terrain Vehicle delivered to the surface
Sustainable operations with crew landing services; Gateway enhancements with refueling capability, additional communications, and viewing capabilities
Pressurized rover delivered for greater exploration range on the surface; Gateway enables longer missions
Surface habitat delivered, allowing up to four crew on the surface for longer periods of time leveraging extracted resources. Mars mission simulations continue with orbital and surface assets
Lunar Terrain Vehicle (LTV)
Crew Landing Services
Pressurized Rover
Fission Surface Power
ISRU Pilot Plant
Surface Habitat
SUSTAINABLE LUNAR ORBIT STAGING CAPABILITY AND SURFACE EXPLORATION
MULTIPLE SCIENCE AND CARGO PAYLOADS | U.S. GOVERNMENT, INDUSTRY, AND INTERNATIONAL PARTNERSHIP OPPORTUNITIES | TECHNOLOGY AND OPERATIONS DEMONSTRATIONS FOR MARS
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