National Aeronautics and Space Administration

Science & Utilization for Artemis

Renee Weber, Ph.D.
Anne Garber
Logan Kennedy

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We’re going to the Moon

to learn to live on other planets,
for the benefit of all humanity.

With Artemis, NASA will put the first woman and first person of color on the lunar surface, build a long-term presence there and in lunar orbit, and make new scientific discoveries about our solar system.

NASA Astronaut Tracy Caldwell Dyson

Image Credit: Andrew McCarthy

What is Artemis?

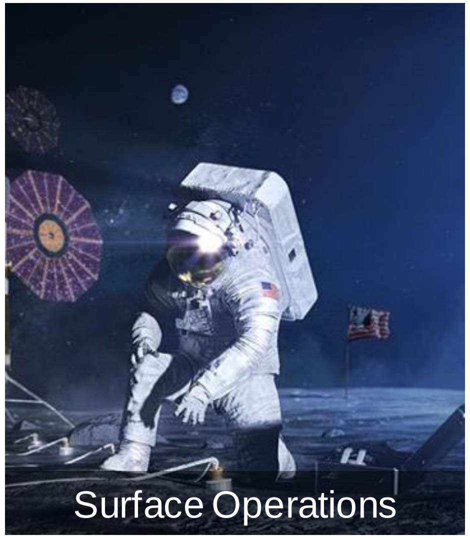
- Global Community on Earth, in Low-Earth Orbit, and in the Lunar Environment
- Space Launch System Rocket
- Orion Crew Spacecraft
- Exploration Ground Systems
- Commercial Lunar Payload Services
- First Woman and First Person of Color on the Lunar Surface
- Gateway in Lunar Orbit
- Artemis Base Camp

Artemis: A Foundation for Deep Space Exploration


Space Launch System


Orion spacecraft


Human Landing System

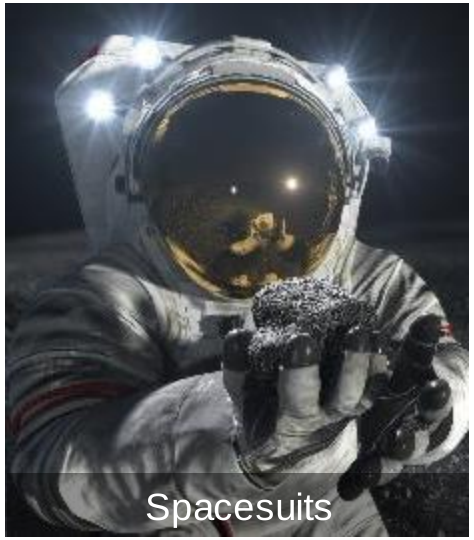

Surface Operations

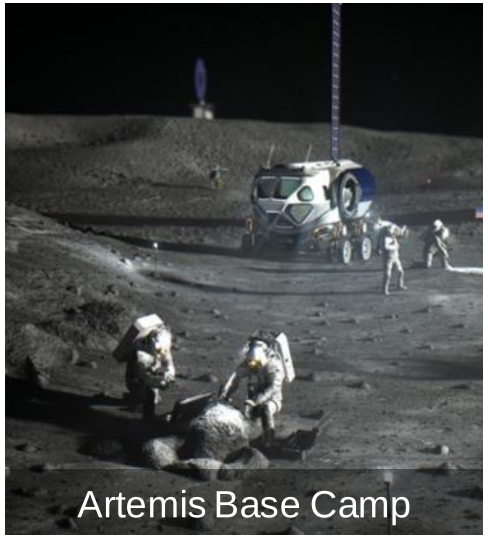

Gateway


Exploration Ground Systems


Space Communications & Navigation


Surface Mobility


Spacesuits


Artemis Base Camp

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

Space Launch System

SLS

Artemis I Mission Highlights:

First flight of SLS and Orion

Uncrewed flight test of the Space Launch System (SLS) rocket, Orion spacecraft, and Exploration Ground Systems (EGS) at Kennedy Space Center

- Operate systems in flight environment
- Demonstrate Orion heatshield at lunar re-entry conditions
- Retrieve spacecraft
- Science

Artemis I Payloads

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

Moonikin Campos

The Moonikin is a male-bodied manikin previously used in Orion vibration tests. Campos will occupy the commander's seat inside and wear an Orion Crew Survival System suit

Radiation Sensors

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

MARE

Radiation shielding Personal Protection Equipment (radiation vest) for astronauts.

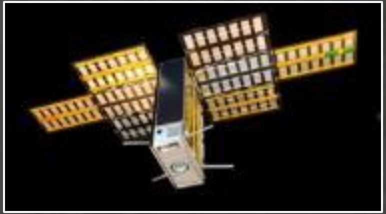
Crew Interface Technology Payload (CITP)

Creates an interactive experience between Orion and the public during the mission

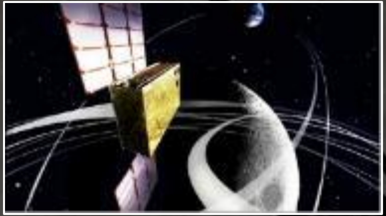
Bio-Experiment-1

Battery-powered life sciences payload for biology research beyond low-Earth orbit (LEO)

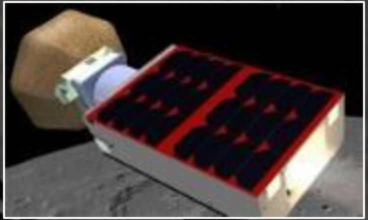
ArgoMoon



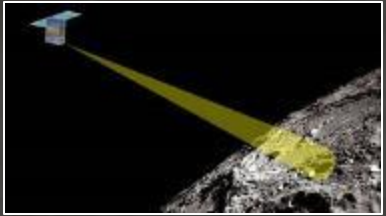
LunaH-Map



EQUULEUS

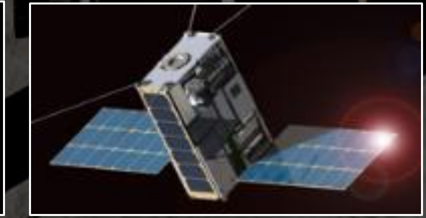


OMOTENASHI

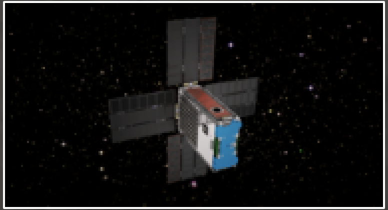


LunIR

Near-Earth Asteroid Scout (NEA Scout)



Lunar IceCube



BioSentinel

Team Miles

CuSP

Artemis I Pressurized Payloads

Payloads that will fly inside of the Orion crew module, returning data during and after the mission

ESA Active Dosimeters *

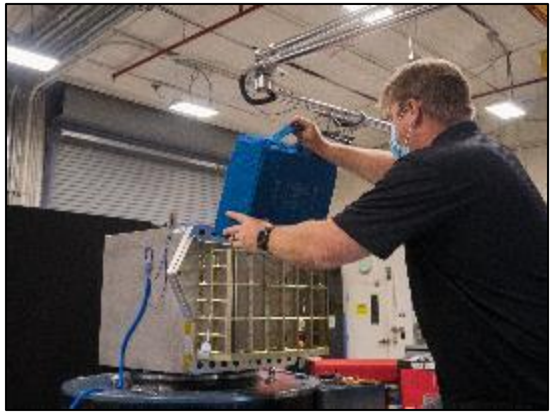
Radiation monitoring system that will fly up to 5 monitoring units

Crew Interface Technology Payload (CITP)

Creates an interactive experience between Orion and the public during the mission

Matroshka AstroRad Radiation Experiment (MARE) *

Radiation shielding Personal Protection Equipment (radiation vest) for astronauts



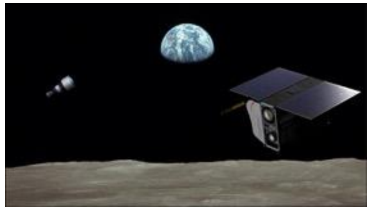
Bio-Experiment-1

Battery-powered life sciences payload for biology research beyond low-Earth orbit (LEO)

*International Collaboration

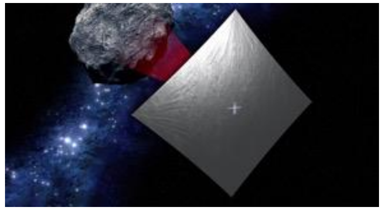
Artemis I Secondary Payloads

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



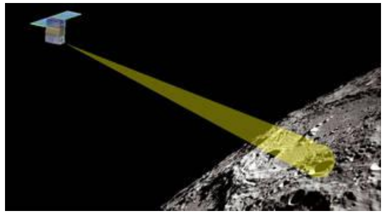
ArgoMoon *

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



Near-Earth Asteroid Scout (NEA Scout)

Detect target NEA, perform reconnaissance and close proximity imaging.

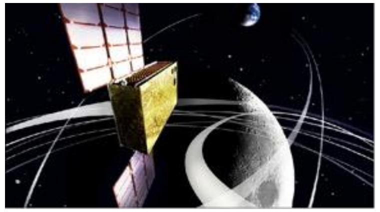


LunIR

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.

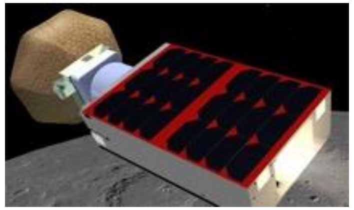


EQUULEUS *

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

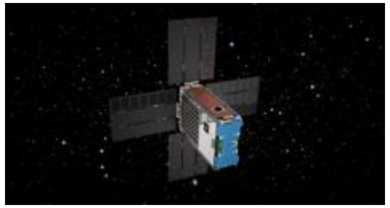
Team Miles

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



OMOTENASHI *

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

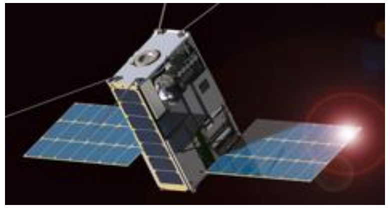


BioSentinel

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.



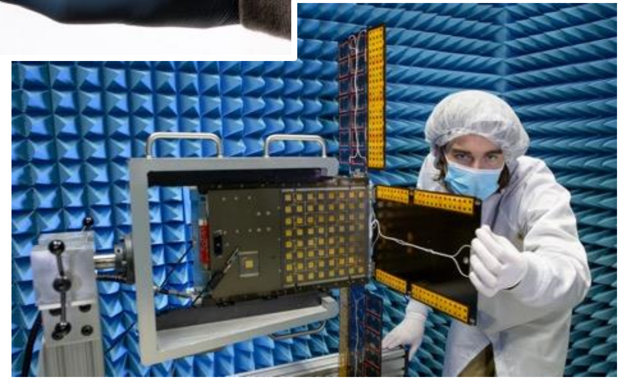
Lunar IceCube

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

*International Collaboration

ESDMD Artemis I CubeSats

BioSentinel



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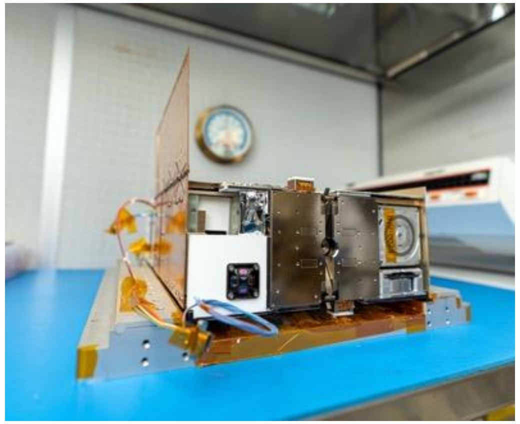

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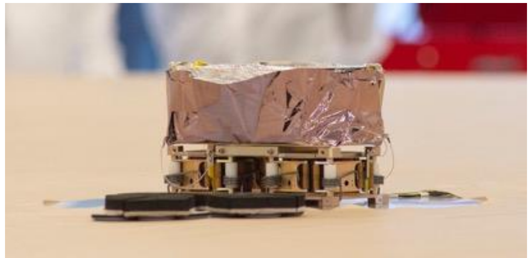
Near-Earth Asteroid (NEA) Scout



Detect target NEA, perform reconnaissance and close proximity imaging.

Initial Human Landing System

HLS

NASA has awarded SpaceX a contract to develop its HLS Starship for use on Artemis III, the mission that will put the next two Americans on the surface of the Moon.

The contract includes two surface missions:

- SpaceX Uncrewed Lunar Demo-A
- SpaceX Crewed Lunar Demo-A

Image Credit: SpaceX

Initial HLS Starship Progress

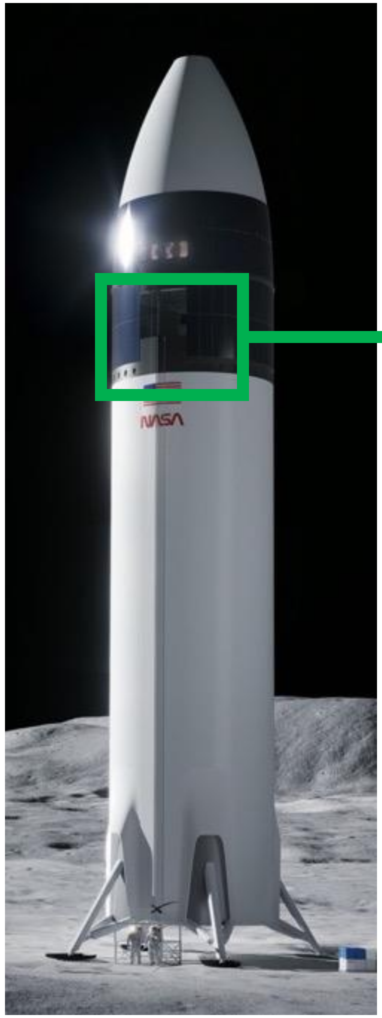


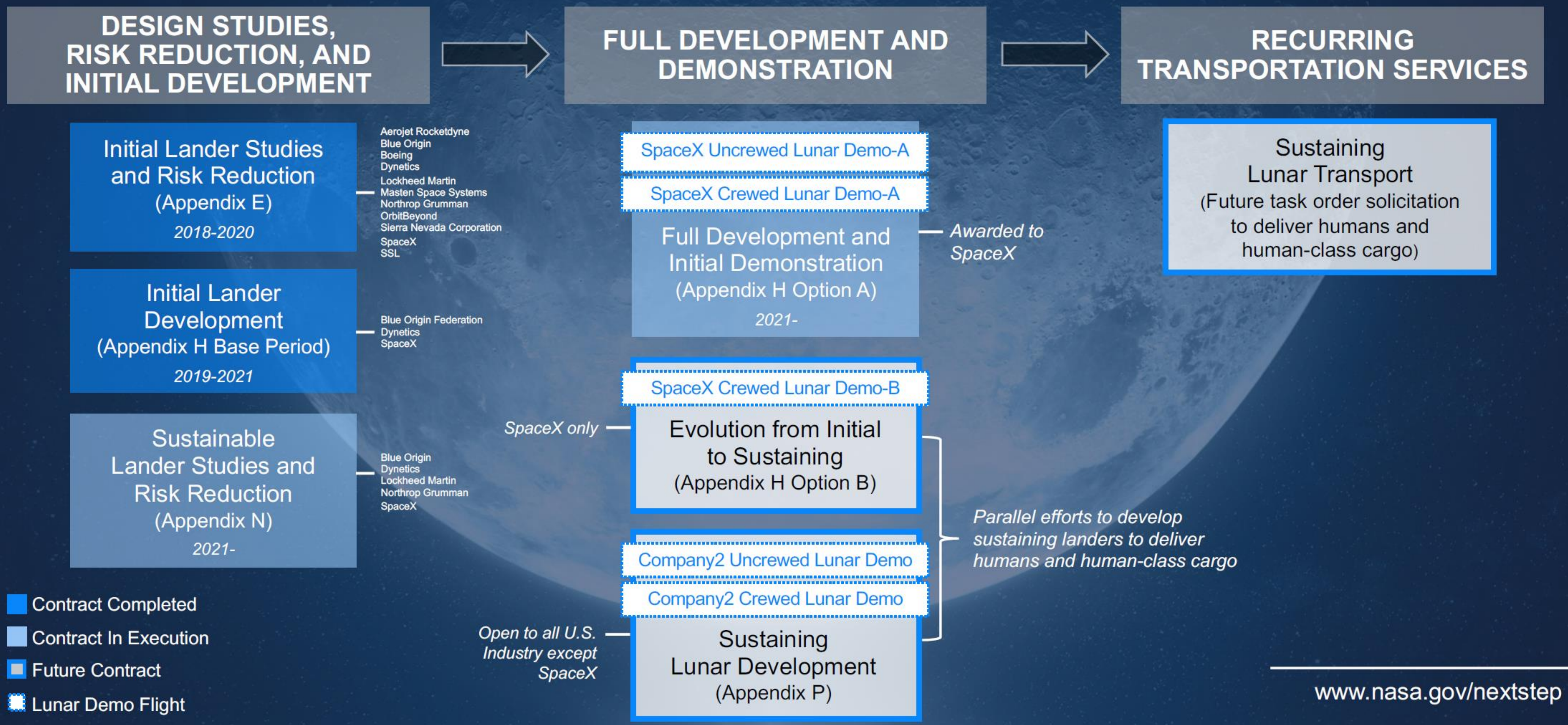
Image Credit: SpaceX

Crew and cargo elevator

Crew cabin VR evaluation

Airlock

Human Landing System (HLS) Procurement Path



HUMANS

in lunar orbit

In the unique lunar environment, new truths of our solar system can be unlocked. For the first time, humans will establish a long-term outpost in lunar orbit where they can live and work: Gateway.

Initial Gateway Science Payloads

Gateway's orbit will offer unique opportunities for heliophysics, human health research, space biology and life sciences, astrophysics, and fundamental physics investigations. As new modules are added, science capability will increase.

Heliophysics Environmental Radiation Measurement Experiment Suite (HERMES): NASA's space weather instrument suite will observe lower energy solar particles critical to scientific investigations of the Sun including the solar winds

European Radiation Sensors Array (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 at higher energies with a focus on space weather

ESA's Internal Dosimeter Array (IDA): Instruments including those provided by Japan Aerospace Exploration Agency (JAXA) will inform for improvements in radiation physics models for cancer, cardiovascular, and central nervous system effects, helping assess crew risk on exploration missions

CAPSTONE CubeSat

Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment

- Will demonstrate how to enter and operate in a Near Rectilinear Halo Orbit (NRHO), the unique orbit where Gateway will operate
- Will test a new navigation capability to help validate Gateway operational models
- Targeting launch NET June 6

Pictured left: The Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) team performs a full mission rehearsal. The CAPSTONE CubeSat will provide data about the unique Gateway orbit and demonstrate innovative navigation technology.

Commercial Lunar Payload Services

Our very first surface missions to the Moon under Artemis will be accomplished through Commercial Lunar Payload Services, or CLPS.

- 14 CLPS providers are currently on contract and eligible to bid on payload deliveries to the Moon
- Through CLPS, we will send a host of exciting and ground-breaking science and technology payloads to the lunar surface.
- NASA solicits bids from CLPS companies and awards contracts to deliver science, exploration, and technology payloads to the lunar surface.

Commercial Lunar Payload Services Vendors

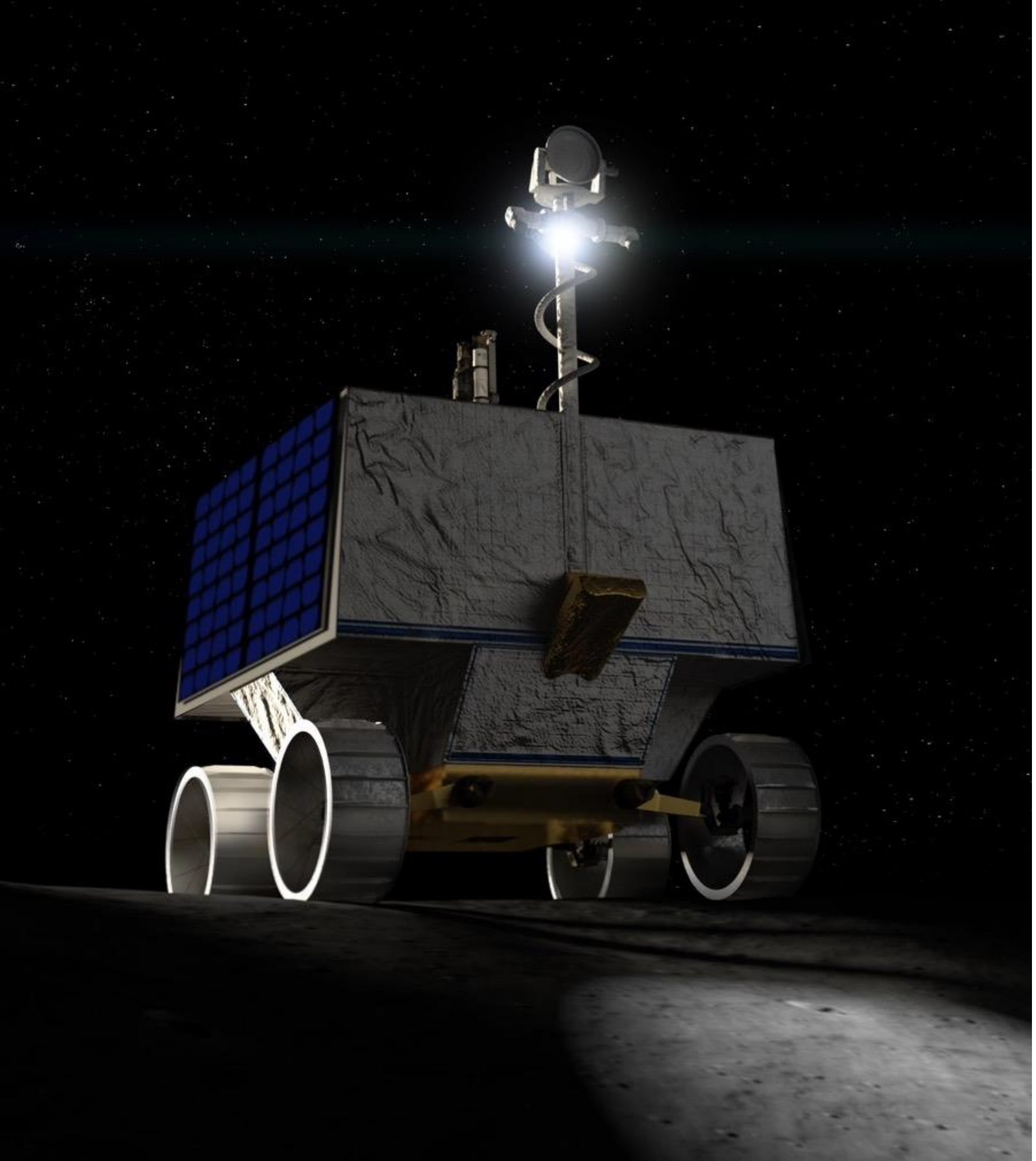
NASA
ARTEMIS

ASTROBOTIC
DEEP SPACE SYSTEMS
DRAPER
FIREFLY AEROSPACE
intuitive MACHINES
MOON EXPRESS
LOCKHEED MARTIN
ORBITBeyond
Masten
SPACEX
SNC SIERRA NEVADA CORPORATION
BLUE ORIGIN
ceres robotics
Tyvak
A Terran Orbital Corporation

Commercial Lunar Payload Services: 2022 Missions

Astrobotic will carry 11 payloads to Lacus Mortis, a larger crater on the near side of the Moon.

Intuitive Machines will carry six payloads to Oceanus Procellarum, a scientifically intriguing dark spot on the Moon.



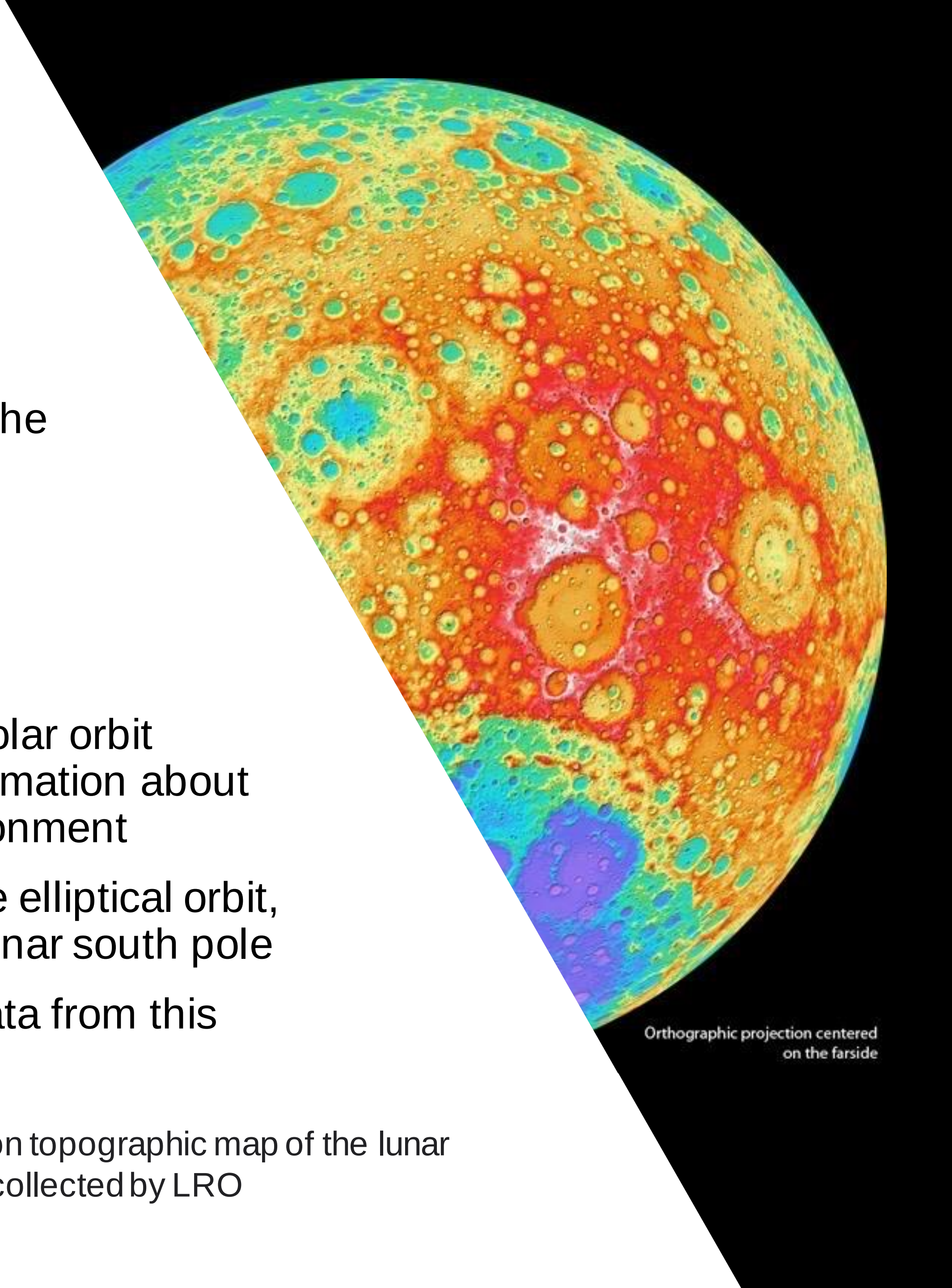
Volatiles Investigating Polar Exploration Rover (VIPER)

- VIPER is the first surface resource mapping mission on another celestial body
- At the South Pole of the Moon, this mobile robot will get a close-up view of the distribution and concentration of water ice that could eventually be harvested to sustain human exploration on the Moon, Mars — and beyond
- NASA awarded a task order to Astrobotic to deliver the agency's VIPER to the lunar South Pole in late 2023 as part of the Commercial Lunar Payloads Services program

Lunar Reconnaissance Orbiter (LRO)

- Seven powerful instruments
- Collects a treasure trove of data, mapping the lunar surface
- Enables groundbreaking discoveries, created a new picture of the Moon as a dynamic and complex body
- Set up a scientific framework to challenge and improve our understanding of processes throughout the solar system

- Launched June 2009
- Three years in a low polar orbit collecting detailed information about the moon and its environment
- Transitioned to a stable elliptical orbit, passing low over the lunar south pole
- Active and returning data from this orbit today



Pictured right: High resolution topographic map of the lunar surface, constructed by data collected by LRO

NASA

Backup

Lunar Terrain Vehicle

L T V

An unpressurized rover will expand exploration area, enable groundbreaking discoveries, and provide autonomous or remote operations when crew are not on the surface.

Pictured left: Artist's render of LTV on the lunar surface

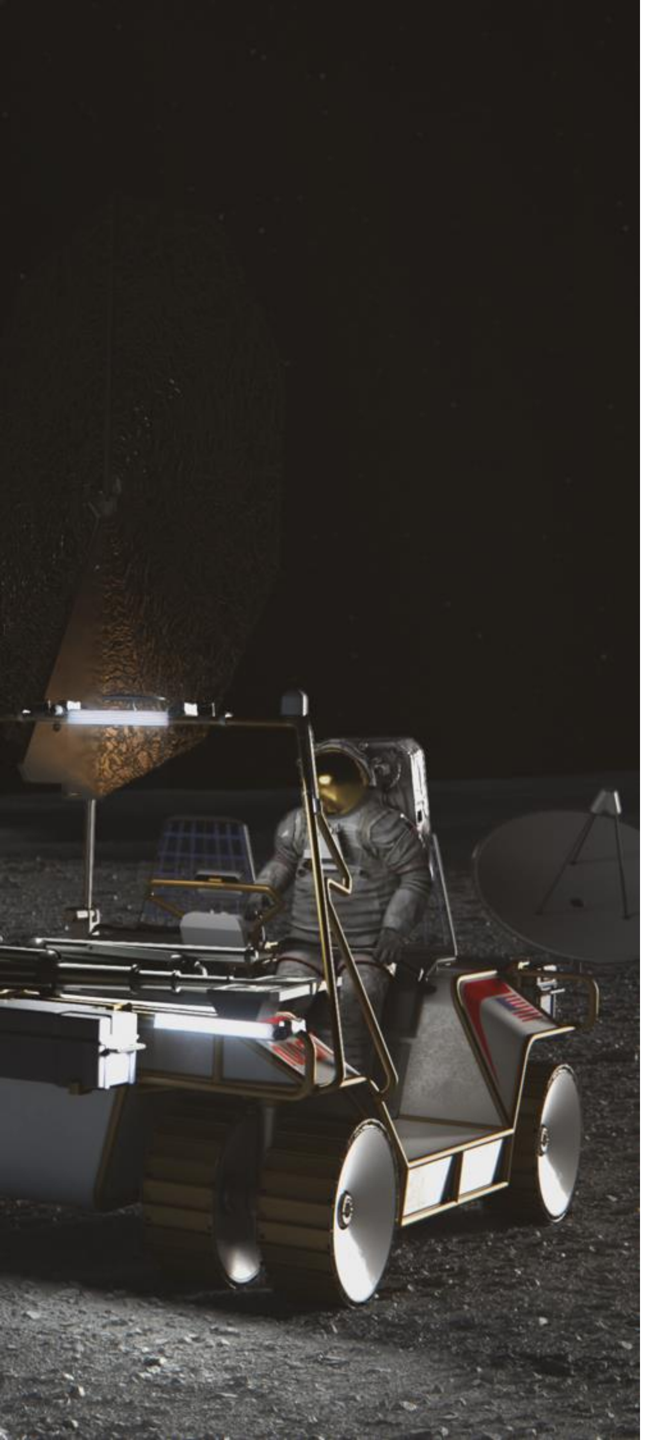
Pictured here: Astronaut Eugene A. Cernan, commander, makes a short checkout of the Lunar Roving Vehicle (LRV) during the early part of the first Apollo 17 extravehicular activity (EVA) at the Taurus-Littrow landing site.

Lunar Terrain Vehicle

L T V

"Without it, the major scientific discoveries of Apollo 15, 16, and 17 would not have been possible; and our current understanding of lunar evolution would not have been possible."

- Harrison Schmitt, geologist and lunar module pilot Apollo 17, on the Lunar Roving Vehicle



Lunar Terrain Vehicle

L T V

Requirements definition is currently in-work:

- Ability to traverse from one landing zone to another and increase exploration range beyond the maximum suited walking distance
- Reusable and rechargeable for approximate 10-year service life
- Remote operation from Human Landing System, the Gateway, Earth
- Interface with future science instruments and payloads for utilization or pre-deployment of assets
- Ability to survive eclipse periods

Pictured left: Artist's render of LTV on the lunar surface

Developing LTV: Survive the Night

The lunar South Pole is massively cratered, with areas that are bathed in sunlight and shrouded in darkness. The craters are brutally cold but elevated areas can grow extremely hot.

These extremes present new challenges.

- Like many spacecraft, the Lunar Terrain Vehicle (LTV) will be solar powered
- Analysis indicates a “follow the sun” strategy will not be feasible in the Moon’s South Pole regions
  - NASA has initiated a new study to identify options for addressing lunar night survival
  - Potential design solutions will be generated by an internal team and Industry partners
    - LTV will need to survive up to 100 hours of darkness with at least a 10-year lifespan

Pictured left: Apollo 15 mission commander David R. Scott with the Lunar Roving Vehicle on the edge of Hadley Rille (Rima Hadley) during the first moonwalk of the mission.

Apollo Mission Sample Collection

	Apollo 11	Apollo 12	Apollo 14	Apollo 15	Apollo 16	Apollo 17	Total
Mission Class	G	H	H	J	J	J	---
Hours on surface	21.5	31.5	33.5	67	71	75	299.5
Number of EVAs	1	2	2	3	3	3	14
Mode of transportation	Walking	Walking	Walking with MET	LRV	LRV	LRV	---
Approximate max distance from landing site	0.062 km	0.45 km	1.4 km	4.7 km	4.4 km	7.5 km	18.5 km
Number of samples	58	69	227	370	731	741	2,196
Weight of samples (kg)	21.8	34.3	42.3	77.3	95.7	110.5	381.7
Mass of Tools & Sample Containers (kg)	22.85	29.17	43.07	50.29	53.03	45.69	---

Mission Classes
G: The initial lunar landing mission
H: Precision manned lunar landing demonstration and systematic lunar exploration.
J: Extensive scientific investigation of Moon on lunar surface and from lunar orbit.

MET: Modular Equipment Transporter
LRV: Lunar Roving Vehicle

ARTEMIS

Base Camp

A truly sustainable infrastructure on the lunar surface

ARTEMIS BASE CAMP

A truly sustainable infrastructure on the lunar surface

- A pressurized rover expands exploration range
- A surface habitat enables longer duration stays
- Supported with small logistics landers including commercial lunar payloads services
- A wide range of opportunities for international partnerships
- Science investigations, technology demonstrations, and operational analogs for Mars missions

Pressurized Rover

Artist's illustration

Provides pressurized mobile habitation to enable long-range surface exploration in shirtsleeve environment and quick and easy access to surface.

- Habitation for 30 days for 2 crew
- Rear suitport allows astronaut egress and ingress of the vehicle via the spacesuits, leaving the suits outside the pressurized volume
- Provides volume for spares and logistics
- Power generation and energy storage for lunar environment
- Dust and radiation protection
- Reuse for multiple missions of 10-year lifetime
- Capability also identified in current concepts for first human mission to Mars

Surface Habitat

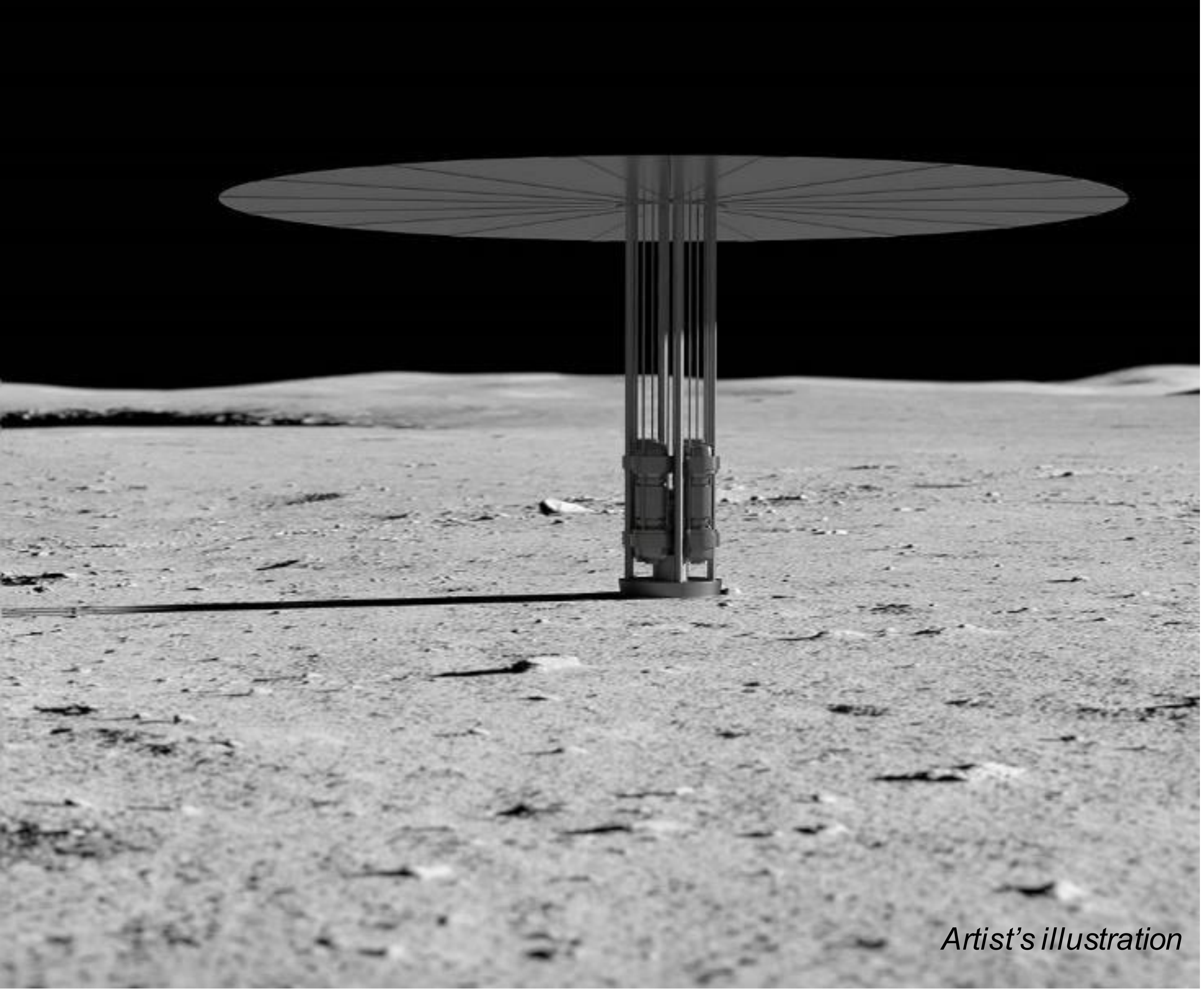
Artist's illustration

Will be a primary asset to achieve a sustained lunar presence.

NASA is working with industry to develop conceptual designs for the Surface Habitat.

- 2-4 crew – medical, exercise, galley, crew quarters, stowage
- 30-60 day capable habitat
- EVA capable via air lock with suit maintenance capability
- Power generation, recharge capability for surface assets
- Communication hub for surface assets
- Reuse for multiple missions of 15 year lifetime

Fission Surface Power



Artist's illustration

Modular nuclear fission power source

Common requirement for Artemis Base Camp and initial human missions to Mars

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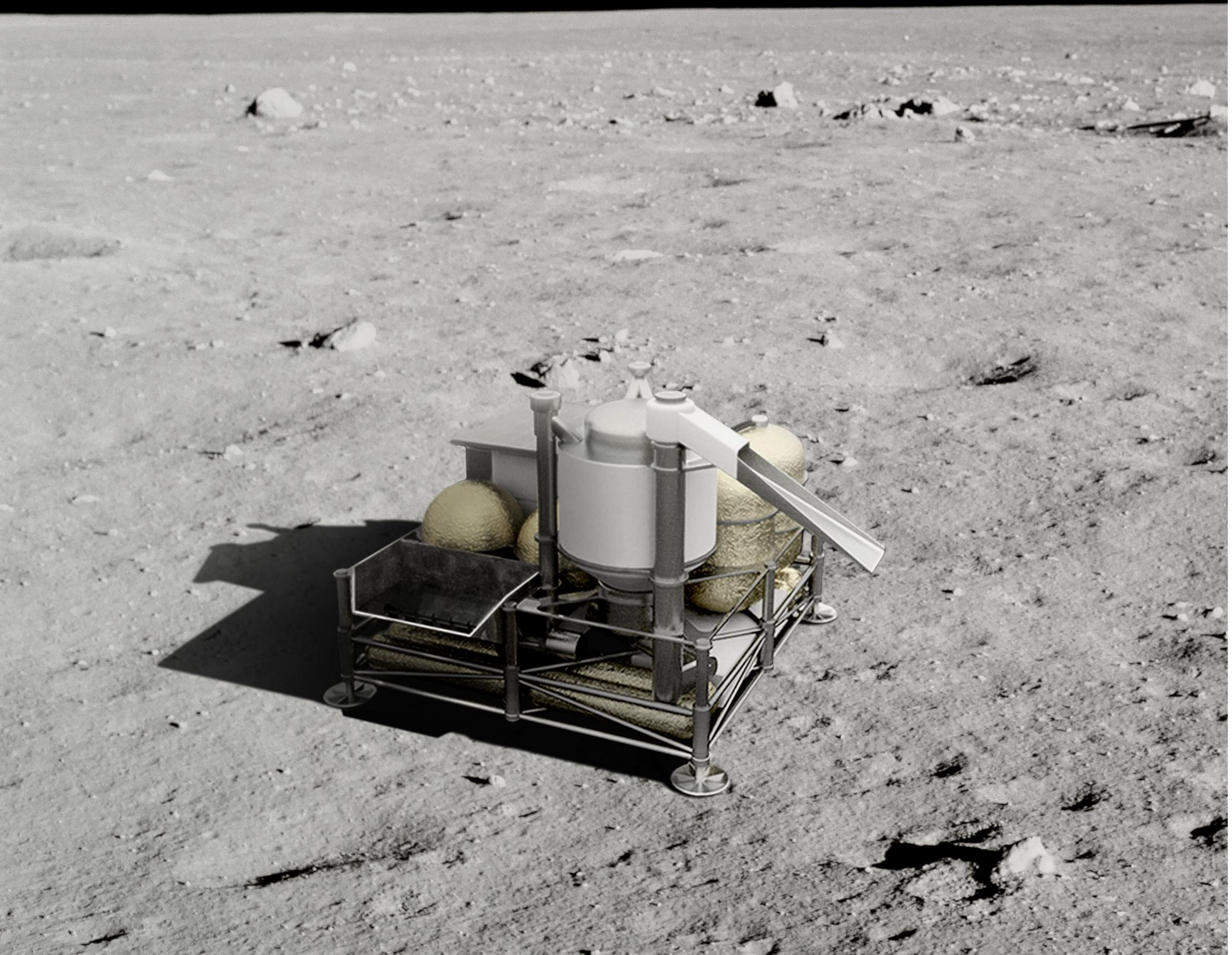
- Surface architecture depends on power capability delivered with landers
- Power level dependent on propellant type and transfer strategy
- Near-term demonstration on the lunar surface can provide reliable power to human landers, habitats, and ISRU systems continuously through eclipse periods and provide a proving ground to extend the capability as a power source that will enable Mars exploration

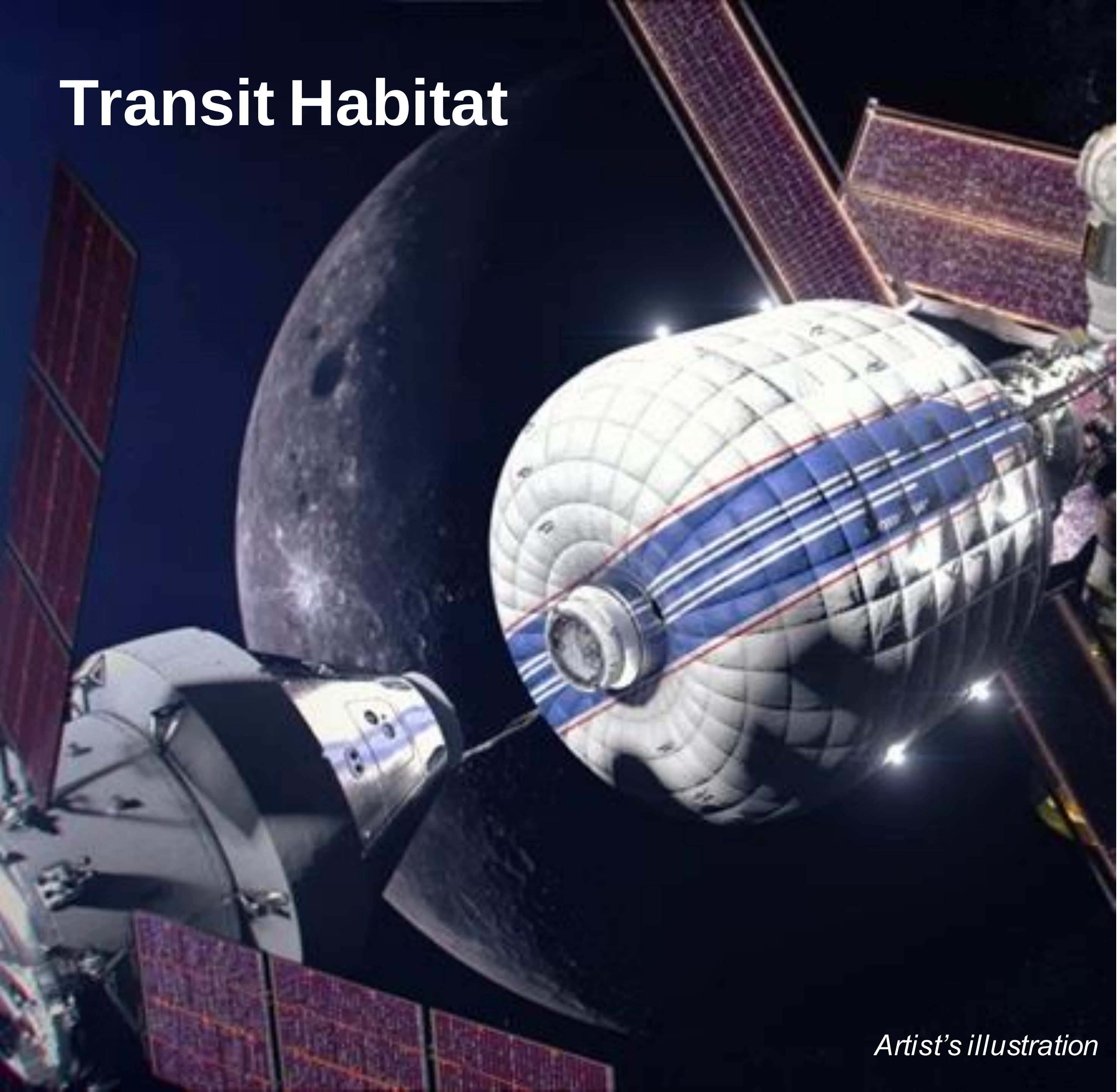
In-Situ Resource Utilization



An Artemis Base Camp ISRU Pilot Plant to demonstrate a scalable capability to extract and use lunar-based resources

- **Resource Mapping/Estimation:** Enable global and detailed local and subsurface mapping of lunar resources and terrain, especially for water in permanently shadowed craters, for science, future exploration, and commercial use
- **Oxygen Extraction:** Enable extraction and production of oxygen from lunar regolith to provide 10's of metric tons per year, for up to 5 years with little human involvement and maintenance, for reusable surface and ascent/descent transportation.
- **Water Mining:** Enable cislunar commercial markets through extraction of water resources to provide 100's of metric tons of propellant per year for reusable landers and cislunar transportation systems
- Lunar Surface Construction for building of roads, launch/landing pads, dust free zones, foundations, blast protection, radiation shielding, shade structures, unpressurized shelters, and even pressurized habitats.

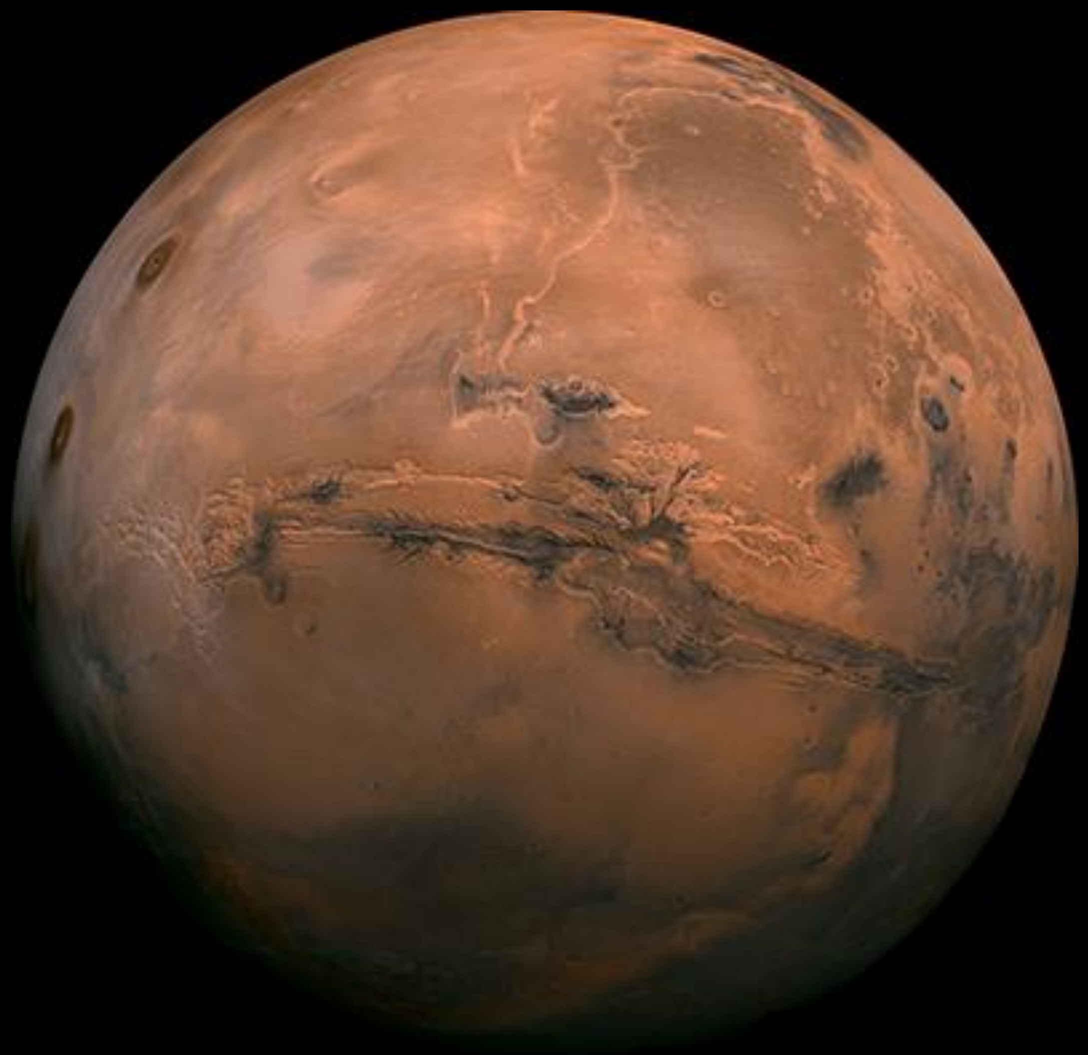
Transit Habitat



Artist's illustration

Reused element with 15-year lifetime for multiple missions

- Keep crew healthy and productive during long duration, deep space stays including:
  - Shakedown missions at Gateway and while free-flying with interim propulsion
  - Lunar-Mars analogs
  - Up to 1100-day Mars transit and orbital stays
- Demonstrate needed capabilities to live for long durations beyond low Earth orbit
- Build on ISS and commercial investment in deep space habitation



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.

STRATEGIC ANALYSIS CYCLE (SAC) 21:
Reference First Human Mars Mission Concept

WHO

Current analysis includes 4 crew

2 remain in Mars orbit while 2 explore the Mars surface

WHAT

- Mars Crew Transport
- Landers and Surface Systems
- Mars Ascent and Earth Return

WHERE

- Cislunar, Deep Space and 5-sol Mars orbit
- Mars Surface

WHEN

- By the late 2030s
- Crew away from Earth ~2.5 years
- ~30 sols on Mars

WHY

Science, Exploration, and U.S. leadership

HOW

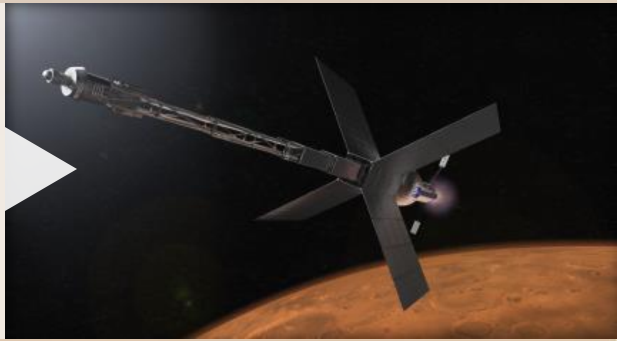
1. *Pre-Deployed Cargo Phase*
2. *Crewed Surface Exploration Phase*
   "Light" Exploration Footprint

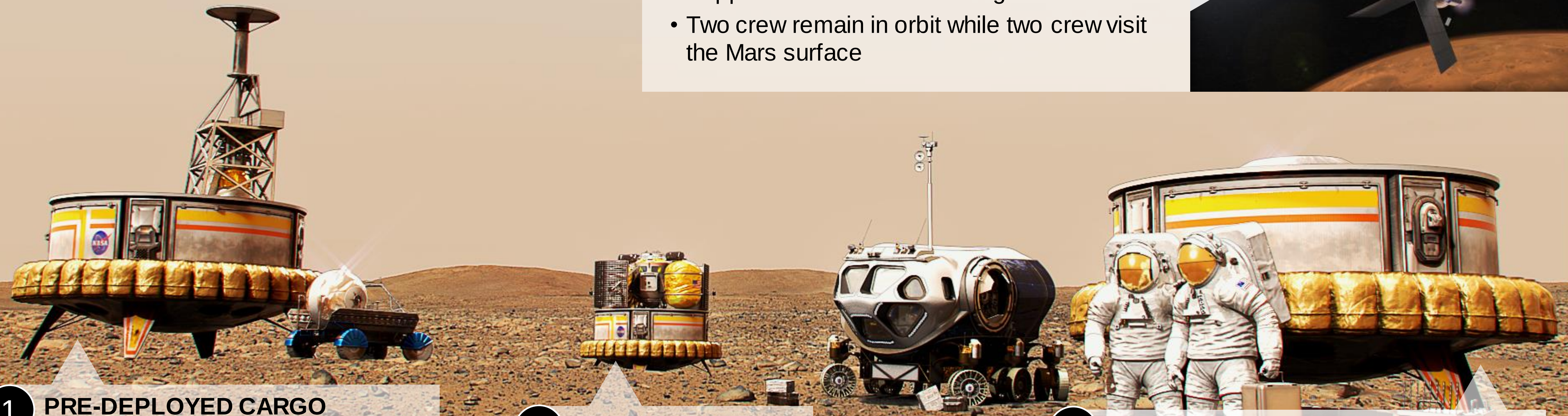
SAC21 First Mars Reference Mission

Reference architecture for *analysis purposes only.* Should not be considered "the plan"

TRANSIT HABITAT (TH) AND HYBRID NUCLEAR ELECTRIC PROPULSION (NEP) / CHEMICAL STAGE

- Supports four crew on the long mission to Mars
- Two crew remain in orbit while two crew visit the Mars surface





1 PRE-DEPLOYED CARGO

- 25-ton class payload Mars lander
- Ascent vehicle propellant, Fission Surface Power, and surface mobility/propellant transfer system

2 PRE-DEPLOYED CREW ASCENT VEHICLE

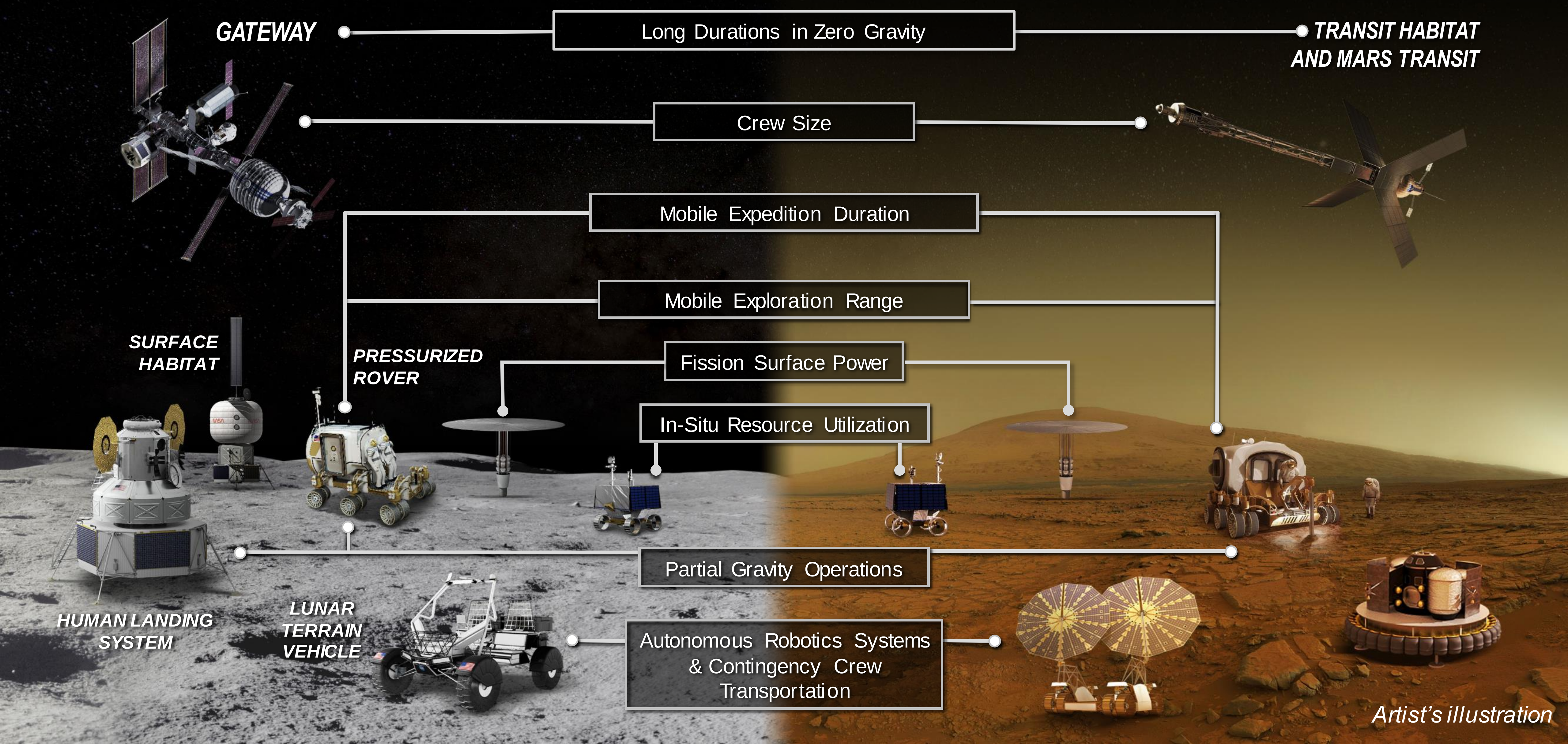
- Partially-fueled

3 CREW

- Two crew land/live in pressurized rover
- Provides habitation and mobility for 30 days
- Supports science and exploration operations

MOON AND MARS EXPLORATION

Operations on and around the Moon will help prepare for the first human mission to Mars



The Moon to Mars Architecture is Inherently Common

IN ORBIT

DEEP SPACE AGGREGATION
Assembling a complex ship in deep space

MARS TRANSIT HABITAT
Round the clock, years-long operations of a Mars-class habitat and life support system

ORBIT TO SURFACE OPERATIONS
Operating an orbiting outpost that deploys a lander and its crew to a planetary surface

COMMERCIAL RESUPPLY AND REFUELING
Leveraging the space logistics supply chain for industry provided cargo deliveries

CREW HEALTH & PERFORMANCE
Studying how the human body and mind adapt to deep space hazards

A roundtrip mission to Mars will take about two to three years—and once the ship's course is set, there's no turning back.

As much as is possible, lunar systems will be designed for dual Moon-Mars operations.

Integrated missions in the lunar vicinity prepare us for successful Mars missions.

ON THE SURFACE

SPACESUIT ADVANCEMENTS
Improving spacesuit design across Artemis missions with astronaut input and private sector innovation

MOBILE OPERATIONS
Living and working 'on the go' inside a mobile habitat for weeks at a time

PLANETARY PROTECTION
Mitigating dust transfer and establishing pristine sample curation protocols

HUMAN ROBOTIC EXPLORATION
Robots pre-positioning surface assets and conducting reconnaissance for astronauts

HUMAN RESILIENCE
Learning how humans can survive and thrive in a partial gravity environment