National Aeronautics and
Space Administration

NASA's DEEP SPACE EXPLORATION PLANS

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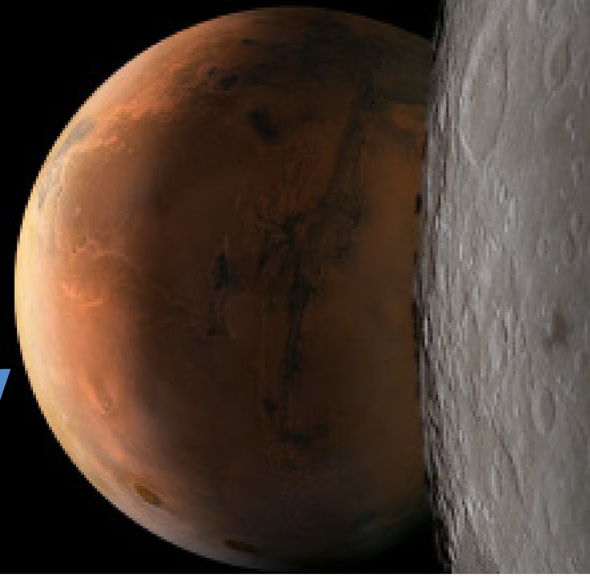
EXPLORING THE SECRETS OF THE MOON AND BEYOND FOR THE BENEFIT OF HUMANITY



The Artemis era is here, heralding a future of long-term human exploration in deep space. Through Artemis, the United States will lead an international and commercial coalition to advance scientific research, maintain our national posture, and inspire a new generation of explorers: the Artemis Generation.

The three pillars of rationale for exploration: science, inspiration, and national posture.

While maintaining American leadership in human and robotic lunar exploration NASA will build a global alliance to explore deep space as one. NASA and its partners will explore more of the Moon than ever before with highly trained astronauts and advanced robotics. We will collaborate with our partners to establish the first long-term presence on the Moon, learn how to live and work away from home, and prepare for future human exploration of the Red Planet. This is America's Moon to Mars exploration approach. Ultimately, what we build, test, and discover at the Moon will determine the human capacity to live and work in deep space for longer periods of time, setting NASA on a steady path to send the first astronauts to Mars.

MOON TO MARS ARCHITECTURE

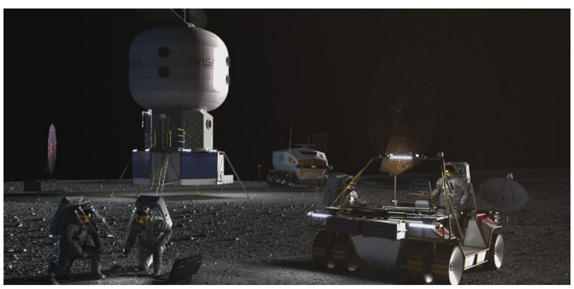
To successfully achieve a lasting human presence in deep space, NASA strategically prioritizes hardware development by beginning with the agency's widely recognized blueprint for exploration and its supporting Moon to Mars objectives that were developed with input from experts across the world. Each objective is decomposed through a systems engineering process to arrive at architectural elements, like rockets, spacecraft, rovers, spacesuits, communications relays, and more—that will be incrementally developed and delivered to the Moon and Mars for long-term, human-led scientific discovery in deep space.

The architecture itself is organized by segments that allow NASA to break the architecture down into manageable pieces to focus and prioritize its analysis work and coordinate with partners. The architecture segments—Human Lunar Return, Foundational Exploration, Sustained Lunar Evolution, and Humans to Mars—are described below.

ARCHITECTURE SEGMENTS

HUMAN LUNAR RETURN

Initial capabilities, systems, and operations necessary to re-establish human presence and initial utilization (e.g., science) on and around the Moon.



FOUNDATIONAL EXPLORATION

Expansion of lunar capabilities, systems, and operations supporting complex orbital and surface missions to conduct utilization (e.g., science) and Mars-forward precursor missions.

SUSTAINED LUNAR EVOLUTION

Enabling capabilities, systems, and operations to support regional and global utilization (e.g., science), economic opportunity, and a steady cadence of human presence on and around the Moon.

HUMANS TO MARS

Initial capabilities, systems, and operations necessary to establish human presence and initial utilization (e.g., science) on Mars and continued exploration.

HUMAN LUNAR RETURN ELEMENTS

SPACE LAUNCH SYSTEM

The Space Launch System (SLS) is an evolvable rocket that will provide heavy-lift capability to deliver Orion and its crew, supplies, and other payloads safely to the Moon. In 2022, NASA's Artemis I flight test successfully demonstrated the rocket's capability to send Orion on a lunar trajectory.

Future evolutions of SLS will feature a more powerful upper stage and larger payload volume to send large elements to the Moon, along with Orion and its crew.

ORION SPACECRAFT

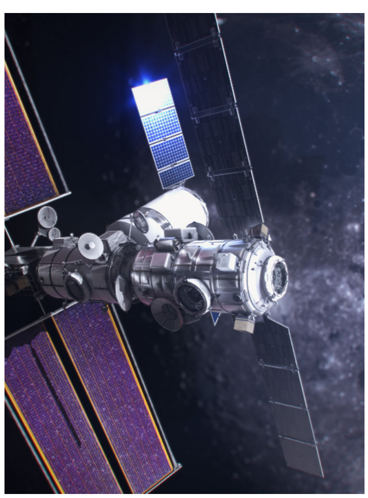
Orion transports up to four astronauts between Earth and lunar orbit and sustains them for up to 21 days. It also provides supplemental power and life-support systems to Gateway while docked to the lunar space station.

Orion launches from Earth atop the SLS, as it did in the Artemis I flight test, and includes the crew module, service module, and launch abort system.

EXPLORATION GROUND SYSTEMS

Exploration Ground Systems (EGS) provides the ground infrastructure to process and launch SLS and Orion, and also provides recovery capabilities when Orion returns to Earth. EGS uses the Vehicle Assembly Building (shown left) to stack and integrate SLS with its payloads, including Orion.

The Mobile Launcher is another key EGS capability that secures the SLS stack for transportation to Launch Pad 39B atop the crawler-transporter. The Mobile Launcher will be upgraded in future segments to accommodate the evolved SLS.



GATEWAY

The Gateway includes several modules that are incrementally launched and assembled in lunar orbit. In the *Human Lunar Return* segment, the Power and Propulsion Element (PPE) and Habitation and Logistics Outpost (HALO) are launched together, along with three science instrument suites on a commercial rocket to the near-rectilinear halo orbit.

I-HAB, the International Habitat provided ESA (European Space Agency) and JAXA (Japan Aerospace Exploration Agency) then joins PPE and HALO for additional habitation volume. This segment also sees the first Gateway Logistics Module delivery with supplies to outfit the station. ESA, JAXA, and the Canadian Space Agency will all provide Gateway elements for later segments of the lunar architecture.

DEEP SPACE LOGISTICS

Deep Space Logistics leads the commercial deep space supply chain to transport cargo, payloads, equipment, and consumables to enable exploration of the Moon and Mars. Logistics flights supply Gateway with critical cargo deliveries to maximize the length of crew stays aboard Gateway.

At least one logistics delivery is anticipated for each 30-day Artemis expedition aboard Gateway, and additional capabilities may be added in future segments. An illustration of a commercial logistics module is shown in the image to the left.

HUMAN LANDING SYSTEM

The Human Landing System (HLS) will transport astronauts and their cargo between lunar orbit and the surface. Crew will board the HLS either from Orion or from Gateway.

In this segment, HLS provides the habitable volume, consumables, and design features to allow crew to conduct moonwalks. Later segments will include additional cargo delivery options and habitation on the surface. A commercial provider has been selected for the Artemis III and Artemis IV missions (illustration shown, left). NASA will work with multiple providers to procure landers, and, eventually, landing services for Artemis V and beyond.

xEVA SYSTEM

The Exploration Extravehicular Activity System (xEVA) includes the lunar surface spacesuit, tools, and vehicle interface equipment that crew will need to conduct moonwalks, collect samples, and deploy science instruments and technology demonstrations.

NASA has two spacesuit providers on contract who can bid to provide spacesuits as services to the International Space Station or to Artemis missions.

COMM, POSITIONING, NAVIGATION, TIMING

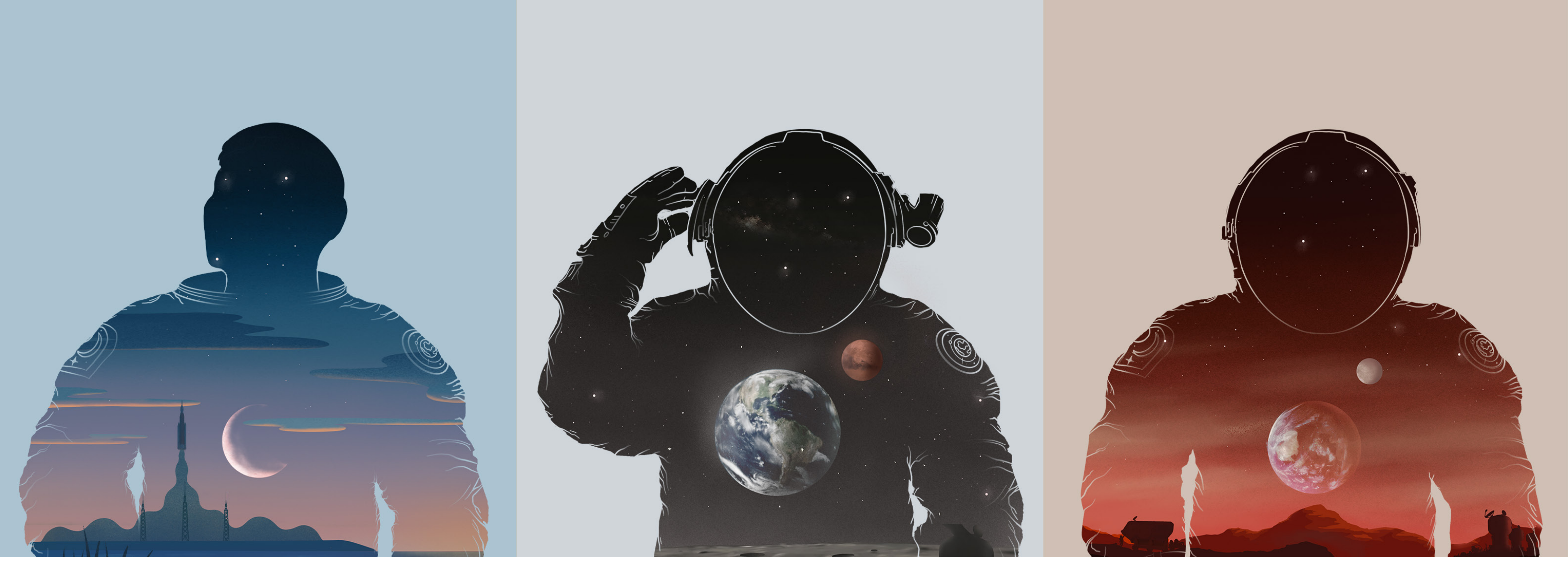
Communication, Positioning, Navigation, and Timing (CPNT) services are provided through a combination of assets on Earth, in lunar orbit, and on the lunar surface. On Earth, upgrades to the Deep Space Network, and global installation of the Lunar Exploration Ground System, will provide continuous coverage of the Moon with support from systems in lunar orbit, including Gateway and the Lunar Communications Relay and Navigation System.

CPNT capabilities will grow throughout this segment and beyond, with opportunity for commercial and international partners to provide enhanced or augmented services.

COMMERCIAL LUNAR PAYLOAD SERVICES

Through the Commercial Lunar Payload Services (CLPS) initiative, NASA is acquiring services from a provider pool of U.S. companies to deliver payloads to the lunar surface.

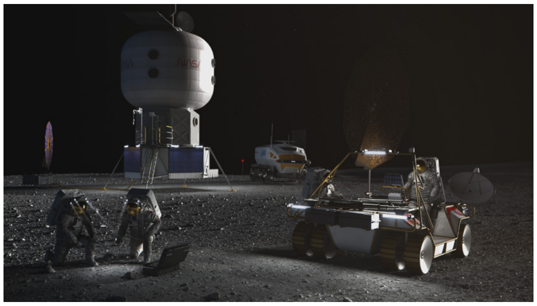
Although some equipment will be delivered to the surface with the crew aboard HLS, CLPS provides an additional capability to deliver cargo and science instruments with commercial providers, supporting a growing lunar economy. NASA's Science Mission Directorate currently has more than 40 U.S. and international science and technology payloads scheduled to be delivered through CLPS providers.



The evolutionary architecture development process described earlier is methodical and deliberate. NASA's intention is to foster transparency so that current and future partners can engage in productive discussions about future collaborations via available, open-source information and shared expectations and objectives.

To reach the required level of maturity for segments beyond *Human Lunar Return*, the process must continue. Through subsequent analysis cycles and annual Architecture Concept Reviews, the Moon to Mars architecture will grow more defined over time. Implementation of the architecture has already begun for the *Human Lunar Return*, with elements in that segment directly traced to Moon to Mars Objectives. Objectives distillation for *Foundational Exploration* and *Sustained Lunar Evolution* has also begun, as shown in Appendix A of the Architecture Definition Document.

The *Humans to Mars* segment studies center around early human missions to Mars to define key areas that will inform long-term investment strategies for the larger architectural components, many of which can find early or prototype development in the lunar segments. The ability to identify common systems and operations for both the Moon and Mars provides an additional level of confidence for the earliest human missions to the Red Planet. Decisions made about the *Humans to Mars* segment will be updated in future versions of the Architecture Definition Document.

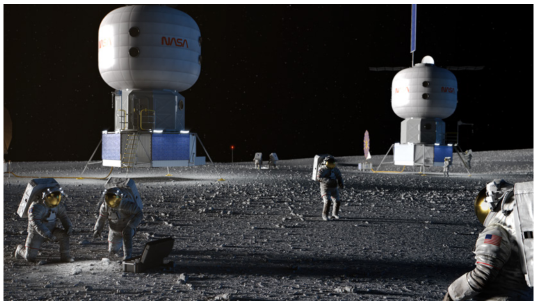


FOUNDATIONAL EXPLORATION

The *Foundational Exploration* segment continues using capabilities established in *Human Lunar Return* and initiates new systems to expand mission durations and surface exploration range, increasing the diversity of scientific sampling and research and prepare for human missions to Mars.

Additions to Gateway and the delivery of habitation and mobility elements on the surface will introduce longer mission timelines, accommodating more opportunities to conduct an array science and demonstrate new technologies. The extended mission durations and co-located assets in orbit and on the surface will help optimize operations to conduct Mars mission simulations. *Foundational Exploration* also will be the starting point for activities and capabilities featured in the *Sustainable Lunar Evolution* segment.

NASA used the same process applied in *Human Lunar Return* to distill Moon to Mars Objectives for *Foundational Exploration*, but work remains to map the Functions and Use Cases to specific elements. The general functional capabilities under analysis now for the lunar surface include unpressurized mobility, pressurized mobility, surface habitation, and cargo transportation. In orbit, Gateway's capabilities will grow with contributions from international partners.



SUSTAINED LUNAR EVOLUTION

In the *Sustained Lunar Evolution* segment, NASA aims to build, together with its partners, a future of economic opportunity, expanded scientific discovery, and greater participation on and around the Moon.

This "open canvas" segment embraces new ideas, systems, and partners to grow beyond *Foundational Exploration*, increasing global lunar science capability, making longer stays for more astronauts and researchers possible, and leading to the large-scale production of goods and services derived from lunar resources.

It is premature to determine specific elements for *Sustained Lunar Evolution* beyond the higher-level capabilities associated with the Moon to Mars Objectives. For this segment, the focus is on expanding power generation and storage; using lunar resources for propellant; crew consumables; construction materials; and expanding mobility and habitation to accommodate larger populations on the lunar surface.

HUMANS TO MARS

Like the previous two segments, the Use Cases and Functions for *Humans to Mars* have not been fully distilled from the Moon to Mars Objectives to arrive at the specific elements needed for the first human missions to Mars.

To support ongoing analysis for *Humans to Mars*, NASA is studying a range of potential mission assumptions to inform system and technology concepts. To illustrate the range of potential Mars architecture solutions, some representative initial assumptions for the current body of analysis work include, at a minimum:

- A light initial exploration footprint: four crew members to Mars orbit with two crew members descending and living on the surface for a 30-sol surface stay;
- Multiple Mars landers, with the first lander(s) pre-deploying cargo to prepare for a later crew landing;
- Modest initial surface infrastructure: minimal surface power and communications infrastructure, but no surface habitat; and
- "All-up mission" approach: crew depart Earth with all the transit propellant they need for the round-trip journey, meaning no propellant will be harvested on Mars for the crew ascent vehicle for early missions.

These assumptions provide a framework for direct architecture comparisons, and all decisions will be made with evolution in mind. More complex mission scenarios will be addressed in subsequent analysis cycles, but the initial step is to define a practical approach to achieve the first human missions to Mars.

The primary Mars systems under study include the transportation system that will carry crew from an orbit in the Earth-Moon neighborhood and back; the entry, descent, landing, and ascent system that will land astronauts on the surface and return them to Martian orbit; the surface systems that will keep crew healthy and productive, allowing them to explore and conduct high-value science on the Red Planet; and the crew support systems that will provide the required logistics, food, and health care throughout their round-trip journey.

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