Why and How NASA is Returning to the Moon

October 2022
Artemis is the twin sister of Apollo and goddess of the Moon in Greek mythology. Now, she personifies our path to the Moon as the name of NASA’s program to return astronauts to the lunar surface including the first female on the Moon.

When they land, Artemis astronauts will step foot where no human has ever been before: the Moon’s South Pole.

With the horizon goal of sending humans to Mars, Artemis begins the next era of exploration.
“The United States will Maintain its Leadership in Space Exploration and Space Science”

“Remain a global leader in science and engineering by pioneering space research and technology that propels exploration of the Moon, Mars, and beyond.”

“U.S. human and robotic space exploration missions will land the first woman and person of color on the Moon, advance a robust cislunar ecosystem, continue to leverage human presence in low-Earth orbit to enable people to live and work safely in space, and prepare for future missions to Mars and beyond.”

— The White House U.S Space Priorities Framework, Dec 2021

United States Space Priorities Framework
NASA 2022 Strategic Plan
2023 NASA Budget Request
Artemis: A Foundation for Deep Space Exploration
Artemis I: 2022
Uncrewed Flight Test
Space Launch System & Orion Spacecraft

Artemis II: 2024
Crewed Flight Test
Space Launch System & Orion Spacecraft

SpaceX Uncrewed Demo
Uncrewed Starship Demonstration to the lunar surface

Artemis III: 2025
Crewed Starship Demonstration to the lunar surface
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
ARTEMIS I

The First Uncrewed Integrated Flight Test of NASA’s Orion Spacecraft and Space Launch System Rocket

1. LAUNCH
   SLS and Orion lift off from pad 39B at Kennedy Space Center.

2. PERIGEE RAISE MANEUVER
   Systems check with solar panel adjustments.

3. INTERIM CRYOGENIC PROPULSION STAGE (ICPS) SEPARATION AND DISPOSAL
   ICPS commits Orion to moon at TLI.

4. TRANS LUNAR INJECTION (TLI) BURN
   Maneuver lasts for approximately 20 minutes.

5. OUTBOUND POWERED FLYBY (OPF)
   60 nmi from the Moon; targets DRO insertion.

6. LUNAR ORBIT INSERTION
   Enter Distinct Retrograde Orbit.

7. DISTANT RETROGRADE ORBIT
   Perform half or one and a half revolutions in the orbit period 38,000 nmi from the surface of the Moon.

8. DRO DEPARTURE
   Leave DRO and start return to Earth.

9. RETURN POWERED FLYBY (RPF)
   RPF burn prep and return coast to Earth initiated.

10. RETURN TRANSIT
    Return Trajectory Correction (RTC) burns as necessary to aim for Earth’s atmosphere.

11. CREW MODULE SEPARATION FROM SERVICE MODULE

12. ENTRY INTERFACE (EI)
    Enter Earth’s atmosphere.

13. SPLASHDOWN
    Pacific Ocean landing within view of the U.S. Navy recovery ship.

CUBESATS DEPLOY
   ICPS deploys 10 CubeSats total

MISSION DURATIONS:
   Total: 26–42 days
   Outbound Transit: 8–14 days
   DRO Stay: 6–19 days
   Return Transit: 9–19 days

03/28/2022
Artemis II Mission Highlights:

**First crewed flight of SLS and Orion**

- Fly up to four astronauts to cislunar space for the first time in more than 50 years
- Return the crew safely after the mission
- Perform a lunar flyby
- Perform rendezvous and proximity operations
- Retrieve spacecraft
ARTEMIS II
First Crewed Test Flight to the Moon Since Apollo

1. LAUNCH
   Astronauts lift off from pad 39B at Kennedy Space Center.

2. PERIGEE RAISE MANEUVER

3. APOGEE RAISE BURN TO HIGH EARTH ORBIT
   Begin 24 hour checkout of spacecraft.

4. PROX OPS DEMONSTRATION
   Orion proximity operations demonstration and manual handling and
   EVA assessment for up to 2 hours.

5. INTERIM CRYOGENIC PROPULSION STAGE (ICPS) DISPOSAL BURN

6. HIGH EARTH ORBIT CHECKOUT
   Life support, exercise, and habitation equipment evaluations.

7. TRANS-LUNAR INJECTION (TLI) BY ORION’S MAIN ENGINE
   Lunar free return trajectory initiated with European service module.

8. ICPS Earth disposal

9. LUNAR FLYBY
   4,000 nmi (mean) lunar farside altitude.

10. TRANS-EARTH RETURN
    Return Trajectory Correction (RTC) burns as necessary to aim for Earth’s
    atmosphere; travel time approximately 4 days.

11. CREW MODULE SEPARATION FROM SERVICE MODULE

12. ENTRY INTERFACE (EI)
    Enter Earth’s atmosphere.

13. SPLASHDOWN
    Ship recovers astronauts and capsule.

14. PROXIMITY OPERATIONS DEMONSTRATION SEQUENCE

15. CORE STAGE MAIN ENGINE CUT OFF
    With separation.
Artemis III Highlights:
First woman on the Moon

• First humans on the Moon’s South Pole
• Return the crew safely home after the mission
• First moonwalk in more than 50 years
  • Rock and soil samples
  • Atmosphere samples
  • Geological data
  • Photos and videos
ARTEMIS III
Landing on the Moon

1. LAUNCH
SLS and Orion lift off from Kennedy Space Center.

2. JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABDORT SYSTEM

3. CORE STAGE MAIN ENGINE CUT OFF
With separation.

4. ENTER EARTH ORBIT
Perform the perigee raise maneuver. Systems check and solar panel adjustments.

5. TRANS LUNAR INJECTION BURN
Astronauts commit to lunar trajectory, followed by LOF's separation and disposal.

6. ORION OUTBOUND TRANSIT TO MOON
Requires several outbound trajectory burns.

7. ORION OUTBOUND POWERED FLYBY
60 nmi from the Moon.

8. NHRO INSERTION BURN
Orion performs burn to establish rendezvous point and executes rendezvous and docking.

9. LUNAR LANDING PREPARATION
Crew activates lander and prepares for departure.

10. LANDER UNDOCKING AND SEPARATION

11. LANDER ENTRIES LOW LUNAR ORBIT
Descends to lunar touchdown.

12. LUNAR SURFACE EXPLORATION
Astronauts conduct week-long surface mission and extra-vehicular activities.

13. ORION REMAINS IN NHRO ORBIT
During lunar surface mission.

14. LANDER ASCENDS TO LOW LUNAR ORBIT

15. LANDER PERFORMS RENDEZVOUS AND DOCKING

16. CREW RETURNS IN ORION
Orion undocks, performs orbit departure burn.

17. ORION PERFORMS RETURN POWERED FLYBY
80 nmi from the Moon.

18. FINAL RETURN TRAJECTORY CORRECTION (RTC) BURN
Precision targeting for Earth entry.

19. CREW MODULE SEPARATION FROM SERVICE MODULE

20. ENTRY INTERFACE (EI)
Enter Earth's atmosphere.

21. SPLASHDOWN
Ship recovers astronauts and capsule
Human Landing System (HLS) Starship
Artemis III Concept of Operations

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, including the first woman.
Two crew live in the landing system cabin for 6.5 days on the lunar surface

Goal of up to four moonwalks, with reserves for a fifth contingency moonwalk

Collect a variety of samples to return to Earth for later research:

- Rock samples to help date the sequence of impact events on the Moon
- Core tube samples to capture ancient solar wind trapped in regolith layers
- Paired samples of material within and outside a permanently shadowed region
The ARTEMIS Science Objectives

- Study Planetary Processes
- Understand Volatile Cycles
- Interpret the Impact History of the Earth-Moon System
- Reveal the Record of the Ancient Sun
- Observe the Universe from a Unique Location
- Conduct Experimental Science in the Lunar Environment
- Investigate and Mitigate Exploration Risks to Humans
The Lunar Surface Innovative Initiative works across industry, academia and government through in-house efforts and public-private partnerships to develop transformative capabilities for lunar surface exploration.

- **In-situ resource utilization** technologies for collecting, processing, storing, and using material found or manufactured on the Moon or other planetary bodies
- **Surface power technologies** that provide the capability for sustainable, continuous power throughout the lunar day and night
- **Dust mitigation technologies** that diminish dust hazards on lunar surface systems such as cameras, solar panels, space suits, and instrumentation
- **Extreme environment technologies** that enable systems to operate throughout the range of lunar surface temperatures
- **Extreme access technologies** that enable humans or robots to efficiently access, navigate, and explore previously inaccessible lunar surface or subsurface areas
- **Excavation and construction technologies** that enable affordable, autonomous manufacturing or construction
Artemis III Candidate Landing Regions

KEY LANDING REGION CONSIDERATIONS

- Proximity to the South Pole
- Gentle slope for landing and moonwalks
- Constant view to Earth for communications
- Continuous sunlight throughout the surface expedition of about 6.5 days
- Landing Accuracy
- Surface data resolution
- Combined mission vehicle capabilities: Space Launch System, Orion spacecraft, Starship Human Landing System

A landing region is approximately 15 km². Each landing region includes multiple potential landing sites.
LUNAR SOUTH POLE

- Long duration access to sunlight
- Direct to Earth communication
- Surface roughness and slope
- Permanently Shadowed Regions and Volatiles
Viewing the Earth from the South Pole
https://svs.gsfc.nasa.gov/4944
Scale of Shackleton Crater

~20 km in diameter, ~4 km deep and ~3x deeper and wider than the Grand Canyon
(and approximate size of the Capitol Beltway as depicted above)
NASA has awarded SpaceX a contract to develop the human landing system that will put the next two Americans on the surface of the Moon. The contract includes one uncrewed and one crewed demonstration mission, the first surface landing of Artemis.
Human Landing System

- Firm Fixed Price Broad Agency Announcement for rapid development and crewed demonstration to return humans to the lunar surface
- Leveraging commercial capabilities to the maximum extent possible; may tailor the traditional NASA program management and systems engineering processes to expedite the schedule
- NASA will not take ownership of the HLS hardware/software
- HLS will launch as commercial payload uncrewed; checkout and testing will occur on orbit prior to any crew launch and egress
- NASA provides certification and technical expertise

The HLS plan is to leverage the speed and operating models of the commercial space industry while applying NASA expertise to ensure safety and mission success
Artemis III Starship HLS Progress

Crew and cargo elevator

Crew cabin VR evaluation

Airlock

Image Credit: SpaceX
On the Surface of the Moon Sustaining Missions

- Extreme Access
- Lunar Dust
- Extreme Environments
- Power
Emergence Of Cislunar Space

Why Cislunar Space?

A Strategic High Ground

• U.S. national interests and leadership
• Geopolitical competition at cislunar/lunar
• National security considerations beyond GEO
• Expand current LEO human presence
• Economic opportunities
• Gateway for exploration of the solar system
• Possible lunar and other resources for future exploration
Moon Before Mars

On the Moon, we can take reasonable risks while astronauts are just three days away from home.

There we will prove technologies and mature systems necessary to live and work on another world before embarking on what could be a 2-3 year mission to Mars.
Mission Needs Drive Design

LOW EARTH RETURN
3 HOURS
3,000°F
17,500 MPH
250 MILES

LUNAR RETURN
3 DAYS
5,200°F
24,700 MPH
240,000 MILES

MARS RETURN
9 MONTHS
6,200°F
26,800 MPH
39,000,000 MILES
ROLE OF U.S. GOVERNMENT IN HUMAN SPACE EXPLORATION

BUILD MOMENTUM
REDUCE RISK
CREATE OPPORTUNITY
Let’s go.
*The time is now.*

We have the capability
We have the purpose
We have the charge
We have the responsibility