

NASA'S AMBITIOUS MOON MISSION *ARTEMIS-I*



SLS-Orion Lift Off (Image credit: NASA)

Anand Kumar Sharma

AFTER 50 years of Apollo Moon landings, NASA is getting ready to send humans back to the lunar surface. As a preparatory action, NASA under the Artemis program has sent the first unmanned capsule Orion around the back of the Moon.

The first test flight of lunar exploration under Artemis program, Artemis-I, will provide the foundation for human exploration to deep space. It is envisaged to establish a long-term lunar colony as a stepping stone to even more ambitious future expeditions to Mars, and beyond. NASA hopes that by 2025 it will land the first woman and first person of colour on the Moon. The program has taken more than a decade in development, and so far, an expenditure of at least \$37 billion in design, fabrication, and testing facilities.

Artemis-I is the first integrated test flight of NASA's Space Launch System (SLS) rocket and the Orion spacecraft. The flight took off successfully on 16 November 2022 at 01:47 AM, EST (12.17 PM IST) from the Kennedy Space Centre's Launch Pad 39B, from where the Apollo-10 was launched 53 years ago.

Over the course of the mission, the Orion spacecraft will travel 450,000 km from Earth and 64,000 km beyond the far



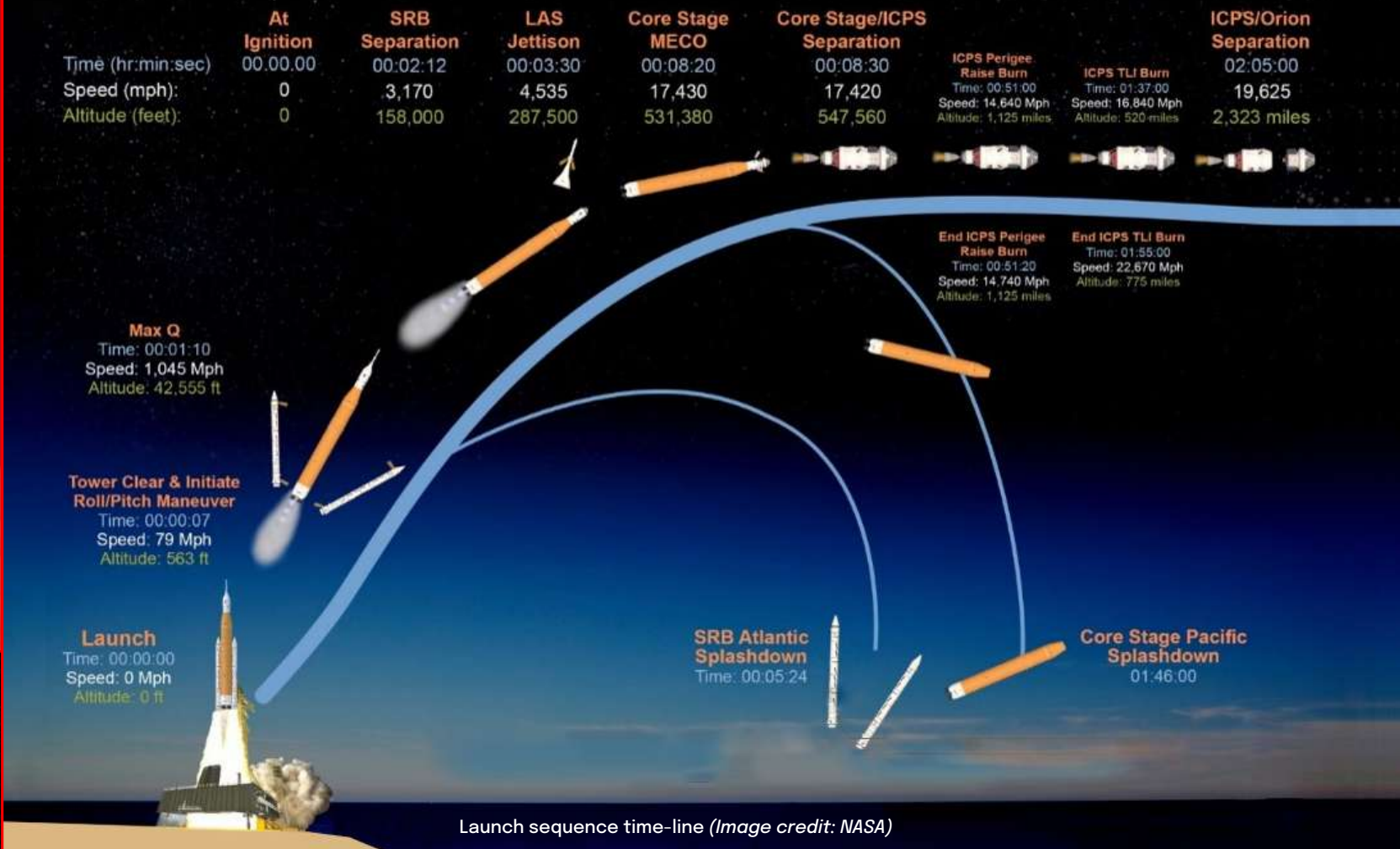
Orion Spacecraft (Image credit: NASA)

side of the Moon. Orion will stay in space longer than any human spacecraft and return back faster and hotter than ever before.

The primary goals for Artemis-I mission are to demonstrate the capabilities of Orion-rocket systems in a spaceflight environment, lunar insertion and a safe re-entry, descent, splashdown, and recovery prior to the first crewed flight of Artemis-II.

The debut flight of Artemis was scrubbed twice earlier on 29 August 2022 and 3 September 2022, after technical snags were detected during countdown. On August 29 at T-40 minutes an issue with the bleed line of one of the rocket's four RS-25 engines (Engine 3) was noticed. The second attempt on 3 September 2022 was also thwarted just a few minutes before

The Artemis I SLS Mission



taking off due to liquid hydrogen fuel leak while loading into the core stage of the rocket. There was a hold at T-10 minutes on 16 November 2022 also due to a leak and ethernet switch. These issues were, however, fixed within the launch window.

Artemis Program

NASA's Artemis program – named after the goddess Artemis, the twin sister of Apollo in ancient Greek mythology – aims to return astronauts to the moon's surface by 2025. The main objective of this mission is to thoroughly test the integrated systems before crewed missions.

The Orion spacecraft carried three astronaut-like mannequins equipped with sensors to collect data about how the flight vibrates and accelerates the body during a trip to the Moon. The first mannequin named "Captain Moonikin Campos" occupied the commander's seat. Campos is named after "Arturo Campos" who had worked at NASA for the Apollo and Space Shuttle programs. The commander's seat is equipped with two radiation sensors inside the Crew Survival System Suit, which astronauts wear during launch, entry, and other dynamic phases of their missions.

Alongside Moonikin Campos there are two phantom torsos: Helga and Zohar. They will participate in the Matroshka AstroRad Radiation Experiment (MARE) to

measure the radiation exposure during the mission. Zohar is shielded with a Astrorad radiation vest while Helga is without vest. The test will provide valuable data on radiation levels during missions while testing the effectiveness of the vest. In addition to the three mannequins, Orion has also carried two Lego® dogs, NASA's Snoopy the dog and ESA's Shaun the Sheep.

Artemis-II

Artemis-II will be the test flight mission with a crew of four astronauts aboard Orion for about 21 days. The mission is currently planned during 2024. The crewed spacecraft will perform a lunar flyby test and return to Earth. After separation of Orion from Interim Cryogenic Propulsion Stage (ICPS), the crew will use onboard cameras and will perform various checkouts of the spacecraft's life support systems as well as an in-space rendezvous and proximity operations with the spent ICPS as a target. This will provide enough performance data and operational experience for rendezvous, proximity operations, docking, and undocking.

Following Artemis-I and II, Artemis-III will be the second crewed Artemis mission and the first crewed lunar landing mission of the Artemis program. The launch is currently scheduled in 2025. Thereafter NASA intends to

launch crewed missions about once every year establishing surface capabilities and building Gateway.

The Orion Spacecraft

The Orion spacecraft is built by lead contractor Lockheed Martin for NASA. The spacecraft has three main components. From top to bottom these are: launch abort system, crew module, and service module. The launch abort system is designed to whisk away the spacecraft and crew to safety in the event of any untoward incident on launch. A 5-m diameter crew module is equipped with the advanced habitation, avionics, and life support. The service module at the bottom provides the oxygen, water, power, and thermal control to the crew module.

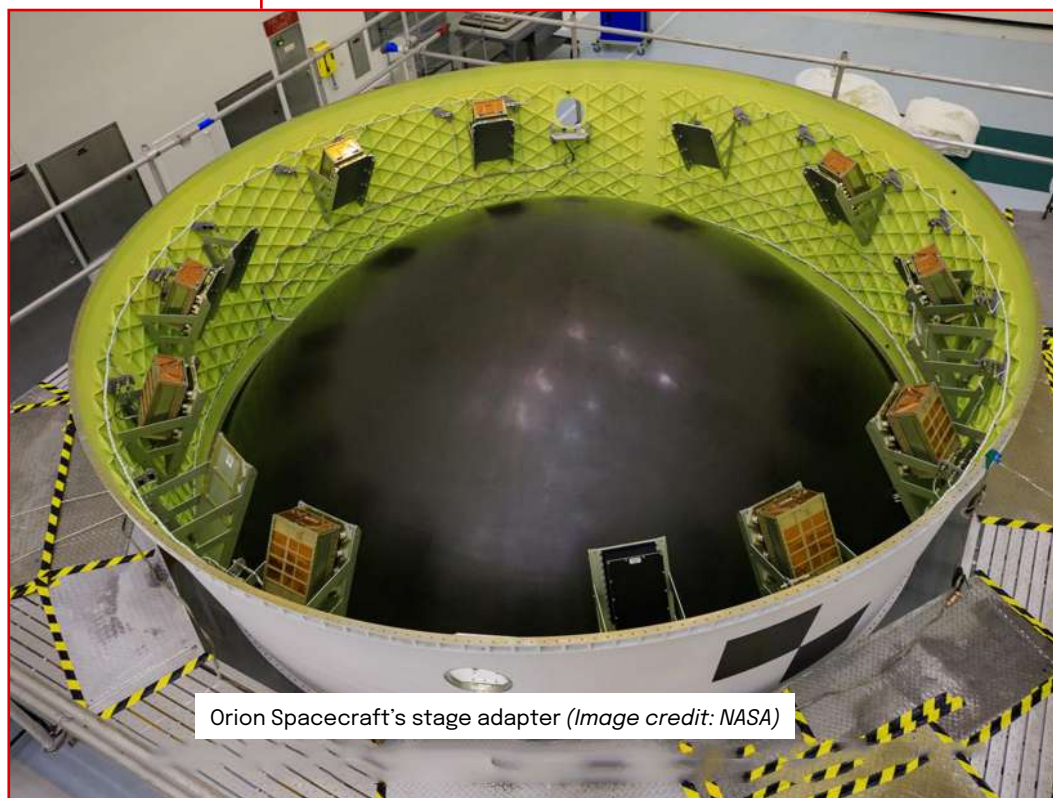
The crew module is the pressurized part of the spacecraft, where crew members will live and conduct some experiments on their journey to the Moon and back to Earth. It is the only portion of spacecraft that will return to Earth at the end of the mission. The bottom of the Orion capsule is covered with a 16.5 feet diameter ablative heat shield. The heat shield will protect the crew module on return to Earth, at a speed of about 40,000 km/hour and enduring temperatures at around 2760°C.

Secondary Payloads: CubeSats

Artemis-I mission also has 10 low-cost small satellites (CubeSats) each measuring 11.1 cm x 22.8 cm x 36.6 cm, and mass not exceeding 14 kg. Each CubeSat is 6U, 1U (unit) = 10 cm x 10 cm x 10 cm. All the CubeSats are mounted at Orion's stage adapter atop the upper stage (ICPS) of the vehicle. These small satellites intend to perform science experiments or technology demonstrations in deep space. They will probe the Moon, asteroids, and the radiation environment of deep space. Each CubeSat has its own propulsion and navigation system. The details of CubeSats are as follows:

1. **Lunar IceCube:** This lunar orbiter is designed by Morehead State University, Kentucky. It will search lunar water in all forms with an infrared spectrometer from a low lunar orbit.
2. **Lunar Polar Hydrogen Mapper (LunaH-Map):** LunaH-Map orbiter is designed by Arizona State University. It will map near-surface hydrogen in craters and other permanently shadowed regions of the lunar South Pole using neutron spectrometers, tracking depth and distribution of hydrogen-rich compounds like water.
3. **OMOTENASHI:** It is world's smallest Semi-Hard Impact lander probe designed by Japanese Aerospace Exploration Agency (JAXA), to study the lunar radiation environment.

4. **LunIR:** LunIR designed by Lockheed Martin, Colorado carries a miniature high-temperature Mid-Wave InfraRed (MWIR) sensor. It will perform a lunar flyby to address Strategic Knowledge Gaps (SKGs) for surface characterization, remote sensing, and site selection observations for the Moon.
5. **EQUULEUS:** This satellite is jointly developed by JAXA and the University of Tokyo. Its primary objective is to demonstrate trajectory control techniques exploiting Sun-Earth Moon dynamics, understanding Earth's radiation environment from Earth-Moon Lagrange-2 point. The satellite will image Earth's plasmasphere in the ultraviolet band; characterize the dust environment in cislunar space; and record lunar impact flashes.
6. **CubeSat for Solar Particles (CuSP):** CuSP is designed by the Southwest Research Institute (SwRI), Texas to study the dynamic particles and magnetic fields that stream from the Sun. It will be used as a proof of concept for the feasibility of a network of stations to track space weather.
7. **Near-Earth Asteroid Scout (NEA Scout):** NEA Scout designed by NASA's Marshall Space Flight Center, Alabama is a technology demonstrator solar sail spacecraft. It is capable of encountering near-Earth asteroid targets through a close (≈ 10 km) flyby and measuring their physical properties using a high-resolution monochromatic camera.
8. **Team Miles:** Team Miles is a nanosatellite designed by Fluid and Reason, LLC, Florida that will demonstrate navigation in deep space using innovative plasma thrusters. It will also test a software-defined radio operating in the S-band for communications from about 40 lakh km away from the Earth.
9. **ArgoMoon:** ArgoMoon is developed by Argotec for the Italian Space Agency (ASI). It will image the Interim Cryogenic Propulsion Stage (ICPS) after separation and provide the mission data for future records.



Orion Spacecraft's stage adapter (Image credit: NASA)

10. BioSentinel: This CubeSat is developed by NASA's Ames Research Center, California. It will conduct an astrobiology experiment by using single-celled yeast to study the impact of deep space radiation on living organisms over a long period of time.

Besides these functional payloads, Artemis-I has also taken commemorative stickers, patches, seeds and flags from mission participant contractors and space agencies.

Major Mission Milestones

The booster and core stage place Orion in a highly elliptical orbit. After jettisoning the boosters, service module panels, and launch abort system, the core stage engines shut down, the core stage gets separated from the spacecraft, and falls back crashing to the Earth. As the Orion spacecraft orbits Earth, it deploys its four solar arrays, generating around 11 kW power.

The Interim Cryogenic Propulsion Stage (ICPS) first raises the elliptical orbit to make it circular and then gives a big push to the capsule called a trans-lunar injection (TLI) – needed to leave Earth's orbit and travel toward the Moon. After about two hours and three minutes of launch, the upper-stage (ICPS) will separate from the Orion module (Orion + service module), speeding through 28,000-36,000 km/hour. The ICPS then will deploy ten CubeSats at strategic times (approx. L+3 hour 40 minutes to L+8 hour 3 minutes) to targeted deep space destinations.

The outbound trip to the Moon will take several days. Orion will fly about 97 km above the surface of the Moon at its closest approach on day six. It will then use the Moon's gravitational force to propel Orion into a distant retrograde orbit, traveling about 64,000 km past the Moon. This distance is 48,000 km farther than the previous record set during Apollo 13 and the farthest in space any spacecraft built for humans has flown.

The service module will separate from Orion just before re-entry. The reaction control system engines precisely harness the Moon's gravity, accelerating it back towards earth. The crew module's heat shield will be oriented into the direction of travel to save from the peak heating. The module will enter Earth's atmosphere with a speed of about 40,000 km/hour, which will be slowed down to around 480 km/hour by the drag of Earth's atmosphere. This will produce temperatures of approx. 2,800°C.

The first two drogue parachutes of the service module will deploy at 7,600 meters; within a minute its speed will be dropped to about 160 km/hour. This will be followed by deployment of three pilot parachutes that will slow the descent to less than 32 km/hour. The module will make a precise landing (splashdown) near the recovery ship off the coast of San Diego. From there the capsule will be recovered by the NASA team.

Space Launch System

Space Launch System (SLS) is NASA's super heavy-lift launch vehicle that provides the foundation for human exploration beyond Earth's orbit. The SLS is intended to be the successor of Space Shuttle, world's most powerful



Orion Splashdown Test (Image credit: NASA)

rocket to carry heavier payload to deep space. It is designed for human and/or robotic scientific missions to Moon, Mars, Saturn, Jupiter, etc.

The SLS is developed in three major phases with increasing capabilities: Block-1, Block-1B, and Block-2. Block-1 is to be used for the first three flights of Artemis and five subsequent SLS flights are planned to use Block-1B, after that all flights intend use Block-2. The basic SLS design has following components:

- A central core stage housing propellant tanks, engines, avionics, and attach points for a pair of solid rocket boosters.
- Four liquid propellant RS-25 engines powered by cryogenic liquid hydrogen and cryogenic liquid oxygen from the core stage.
- Two five-segment solid-fuel, side-mounted rocket booster motors that provide 75 % of thrust and steering for the rocket during the first two minutes of flight, after which they are jettisoned.
- The core stage operates for approximately 480 seconds, reaching a speed of over 28,000 km/hour (altitude 162 km). Thereafter they get separated from the ICPS, Orion stage adapter, and Orion.
- Above the core stage, the Interim Cryogenic Propulsion Stage (ICPS) provides in-space propulsion. ICPS uses one RL10 engine that initially propels Orion out of Earth's orbit.

After reaching space, the Interim Cryogenic Propulsion Stage (ICPS) injects the Orion onto the Moon. The SLS program has estimated a development cost of US\$ 18 billion, \$10 billion for the SLS rocket, \$6 billion for the Orion spacecraft, and \$2 billion for upgradation of launch pad and other ground facilities at Kennedy Space Center.



Dr Anand Kumar Sharma is Former Distinguished Scientist-ISRO. Address: Anukampa, No. 14-15, 1 Main, 2 Cross, Sri Veerbhadr Nagar (Basava Nagar), Marathahalli Post, Bengaluru-560037.
Email: anukampa2003@yahoo.com