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NASA's Artemis II Test Flight: Lessons Learned

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Abstract

Through Artemis, NASA, along with its industrial and international partners, is undertaking an increasingly complex series of test flights to return humans to the Moon with the goal of constructing a Moon Base and establishing a sustainable, enduring presence on the surface to prepare for the human exploration of Mars. As the bridge between the Artemis I uncrewed test flight and additional test flights that will enable enduring human exploration of the lunar surface, the Artemis II mission – the first crewed flight under Artemis – provided critical human-in-the-loop operational and scientific data. This paper provides an overview of some of the major outcomes of the Artemis II test flight, from the in-flight performance and handling of NASA's Space Launch System (SLS) rocket and Orion spacecraft to groundcrew operations and dedicated scientific investigations. During the nearly 10-day mission, the crew, which included three NASA astronauts and one Canadian Space Agency (CSA) astronaut, conducted manual and automated spacecraft operations; monitored and evaluated Orion's life-support, propulsion, power, thermal, communication, and navigation systems; performed a proximity operations demonstration; and, assessed habitability and crew interfaces. Artemis II demonstrated an essential balance between crew decision-making and ground support that builds on decades of human spaceflight experience. The analysis of this flight is feeding forward into future Artemis missions. Mission control, including the new Orion Mission Evaluation Room and Science Evaluation Room, played a critical role in monitoring and controlling systems, providing analysis and support for crew decision making. The systems tested during Artemis II also inform how the crew and ground teams can effectively and efficiently work together during human exploration of the lunar South Pole under Artemis.

Keywords: Artemis II, NASA, Moon, Test Flight, Orion, SLS

1. Introduction

Following NASA's successful Artemis II mission, engineers began data analysis to assess how key systems and subsystems on the Orion spacecraft, SLS (Space Launch System) rocket, and systems at the launch pad at the agency's Kennedy Space Center in Florida performed. The Artemis II test flight began a new era of exploration, laying the groundwork for the third Artemis mission next year, lunar surface missions, a Moon Base, and future missions to Mars.

The SLS rocket that launched the Artemis II mission also performed well, meeting its mission objectives. While engineers continue studying the data, an early assessment indicates the rocket accurately placed Orion where it needed to be in space. At main engine cutoff, when the core stage's RS-25 liquid engines shutdown, the spacecraft was traveling at over 18,000 miles per hour, achieving its insertion velocity for orbit, and executing a precise trajectory for its intended location.

Following the launch of Artemis II, engineers conducted a detailed assessment of the launch pad and mobile launcher. Lessons learned from Artemis I successfully hardened and reinforced ground support equipment, ensuring the mobile launcher and launch pad sustained only minimal damage in the wake of the powerful booster ignition.

Using data from the first crewed mission under the Artemis program, NASA continues preparing the hardware and teams to launch Artemis III in 2027 ahead of subsequent missions to the Moon's surface beginning in 2028.

2. Space Launch System

In its initial configuration, called the Block 1 configuration, SLS can send 59,000 pounds (27 metric tons) to the Moon in a single launch. Using two solid rocket boosters and four RS-25 liquid fuel engines, SLS produces a maximum thrust of more than 8.8 million pounds (39,100 kilonewtons).

SLS's first flight was an uncrewed test flight, launching an Orion spacecraft outfitted with sensors, on a 25-day mission into lunar orbit and back. The mission proved out the vehicle's capability to launch the spacecraft and provided critical data to the engineers who designed, built, and tested the rocket. While the Artemis I SLS performed incredibly accurately and precisely, refinements were made to the SLS platform, such as the addition of strakes to the core stage's intertank, to provide the safest flight possible for astronauts.

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The Artemis II mission was the second flight of an SLS. The mission lasted 9 days, 1 hour, and 32 minutes, and traveled 694,481 miles (1.12 million kilometers). The mission's maximum distance from Earth was 252,756 miles (406,770 million kilometers), eclipsing the Apollo 13 distance record by 4,111 miles (6,616 kilometers). During the mission, the astronauts performed a thorough checkout of the spacecraft in Earth orbit and cislunar space.

3. Artemis II Launch and Flight

On April 1, 2026, at 6:35 p.m. Eastern Daylight Time, the four RS-25 liquid engines and twin solid rocket boosters lifted the Artemis II SLS rocket, Orion spacecraft, and four astronauts off the launch pad and began accelerating to Earth orbit. Two minutes and 7 seconds into flight, the twin solid rocket boosters separated, and the vehicle continued to orbit. RS-25 main engine cutoff (MECO) occurred at T+8:01. Core stage separation occurred seconds later. The core stage followed its suborbital trajectory to a safe disposal in the Pacific Ocean.

The Interim Cryogenic Propulsion Stage (ICPS) performed two engine burns. The first was a perigee raise maneuver, which put Orion in a stable orbit. The next burn was the apogee raise burn, which placed the Orion spacecraft in an orbit with an apogee of approximately 38,000 nautical miles where astronauts could check out the spacecraft.

After the apogee raise burn, the Orion spacecraft separated from the ICPS. The spent stage was then used as the target for the proximity operations demonstration, a test of the manual handling characteristics of the Orion spacecraft using ICPS as a target.

Preliminary ascent and orbital insertion data are:

- Insertion velocity: 27,227.75 feet per second (ft/s) actual; 27,252.68 ft/s, predicted; 99.9% accuracy
- Initial orbit apogee: 1199.2 nautical miles, actual; 1200 nautical miles, predicted; 99.9% accuracy
- Initial orbit perigee: 15.07 nautical miles, actual; 15 nautical miles, predicted; 99.5% accuracy
- The RS-25 engines temporarily throttled back as the vehicle went supersonic and again at solid rocket booster separation
- The solid rocket booster exhibited nominal performance, separating at T+2:07.5
- From power-up through T-0, the SLS flight software accepted 1,444 commands from the ground
- During ascent, the SLS flight software sent approximately 500,000 commands to the SLS systems

Following the proximity operations demonstration, the Orion spacecraft performed a departure burn, followed by a disposal burn by the ICPS, which placed the stage on an atmospheric disposal trajectory over the Pacific Ocean. After the disposal burn, four CubeSats were deployed from the Orion Stage Adapter (OSA), which was mated to the ICPS. The CubeSats were developed through partnerships with Argentina, Germany, Saudi Arabia, and South Korea. Preliminary data indicate they were deployed within the environmental conditions expected. The team defers to the payload developers to provide information on their spacecraft performance and missions.



Fig. 1. Earth setting behind Moon's horizon as seen from lunar farside on Flight Day 6

The Orion spacecraft reached a maximum distance from Earth of 252,756 statute miles, surpassing the previous record set during the Apollo 13 mission in 1970 by 4,101 statute miles. The mission had a closest approach to the Moon of 4,067 statute miles.

Preliminary data indicate that SLS performed as expected, hitting orbital insertion targets with 99.5% to 99.9% accuracy. The ICPS also delivered the Orion spacecraft to the proper target with a high degree of precision and accuracy. The individual systems behaved as expected, and overall flight performance was nominal.

4. Wet Dress Rehearsal

A key milestone before launch was the wet dress rehearsal (WDR).

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The mobile launcher carrying the SLS and Orion rolled out to Launch Complex 39B on January 17. At the pad, teams completed connections between the pad systems and the mobile launcher and conducted a series of planned engineering tests on the ground, SLS, and Orion systems to prepare for the first Wet Dress Rehearsal (WDR-1), which began on January 31, 2026 (Figure 2). The 48-hour test was delayed two days from its initial start due to an abnormal cold weather system that settled over much of Florida. The predicted temperatures, winds, and associated windchills would have produced an unsafe operational environment for the pad teams, including the closeout crew.

WDR-1 officially commenced at 8:13 p.m. EST on January 31. The time was chosen to mimic the timing of the opening of the first Artemis II launch window, providing higher probability of similar conditions across the vehicle during the test and following launch attempt.

During the test, teams successfully filled all tanks in both the core stage and ICPS, and the closeout crew successfully rehearsed closure of the command module and launch abort system hatches. However, multiple technical issues occurred across the integrated launch vehicle and ground systems infrastructure. Liquid hydrogen (LH2) leaks were detected at the mobile launcher's tail service mast umbilical (TSMU), the interface between the mobile launcher and SLS. In addition to the LH2 leak, a valve associated with the crew module hatch pressurization had to be replaced, and dropouts of audio communication channels had to be resolved.

Despite the challenges, the team was able to perform the terminal countdown portion of the test, which encompasses the final 10 minutes of the launch countdown. At T-5 minutes 15 seconds, when the core stage LH2 tank was pressurized for flight, the leak rate of the LH2 spiked beyond preset acceptable limits. A hold was called, and the test was terminated.



Fig. 2. Artemis II SLS prior to first Wet Dress Rehearsal

4.1 Post Wet Dress Rehearsal

Post-test repairs replaced seals at the SLS TSMU interface. Discussions with the seal vendor led to process improvements, and the leaks seen on Artemis I and the Artemis II WDR-1 were not seen again. Other adjustments across the SLS rocket, Orion spacecraft, and ground systems hardware and procedures were made.

Following WDR-1, a tanking test was conducted to assess the new seals. As the LH2 loading progressed from slow fill to fast fill, a pressure difference was detected across one of the filters in the ground system lines. The filter was believed to be partially blocked. To prevent any foreign object debris (FOD) from reaching the launch vehicle, a hold was initiated and flow of LH2 to the vehicle was stopped.

Multiple mitigation techniques were exercised, including letting the filter warm up. Scanning of the filter using spectroscopy was performed in an attempt characterize the blockage. The spectrometer was calibrated with helium and nitrogen backgrounds. However, its signal became nosier when looking at the LH2-rich sample, which prevented engineers from fully diagnosing the problem.

To properly protect the vehicle, the team decided not to attempt to load the vehicle any further. However, some of the test objectives were accomplished with the propellant that had not boiled off during draining operations, including verification of the replacement seals.

Following the test, teams replaced a filter in ground support equipment that was suspected to be the cause of the reduced LH2 flow during the partial tanking test. Proper environmental conditions were then reestablished, and a second wet dress rehearsal was conducted.

2.4 Second Wet Dress Rehearsal

The second wet dress rehearsal commenced on February 19 and concluded on February 21. It was an incredibly successful test, with LH2 leak rates peaking at approximately 2.1 percent, which occurred briefly at pre-pressurization of the tanks during the terminal count portion of the test. Outside that excursion, the average leak rate was less than 1%, the lowest seen during the Artemis era and on the ground systems-SLS system. WDR-2 also successfully tested

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SLS, Orion, and ground systems procedures. A key portion of the test involved holding the countdown after entering terminal count and then proceeding to the designated test cutoff point at T-33 seconds. At the cutoff point, the count was recycled to T-10 minutes and repeated to prove the system's capabilities to recycle, as well as the capabilities of ground teams to repeat the countdown and associated tasks. Terminal count resumed, and a final nominal cutoff was given at T-29 seconds. The test was complete.

While refilling the onboard helium tanks on the ICPS after WDR-2, flow of the helium to the vehicle became inhibited. Troubleshooting commenced at the pad, but due to limited access to that area above the core stage at Launch Complex 39B, a rollback to the Vehicle Assembly Building (VAB) was required to fix the issue, pushing the Artemis II launch out of the March launch window.



Fig. 3. Artemis II vehicle and mobile launcher return to Vehicle Assembly Building following second wet dress rehearsal.

4.3 Post-Wet Dress Processing

Once inside High Bay 3 of the VAB, the SLS's ICPS umbilical was disconnected and the area investigated. Analysis supported by ground testing showed that during the flow of helium to the upper stage, a seal at the interface between the ground umbilical and SLS became dislodged, blocking the flow.

Instead of replacing the seal, the team decided to redesign a portion of the interface and remove the seal entirely. In its place, another seal was reinforced, and evaluation on test stands and the flight hardware proved it to be a viable solution.

With the launch vehicle in the VAB, teams took the opportunity to work on other areas of the vehicle, including:

- Requalification of the flight termination system (FTS), as required by the U.S. Space Force's Eastern Range
- Replacement of batteries on the core stage flight termination system and the FTS
- Replacement of the liquid oxygen (LOX) TSMU seal
- Charging of the SHMS CubeSat (formerly called Space Weather CubeSat-1) payload

Upon completion of the work, the vehicle was rolled out to Launch Complex 39B during the overnight and morning hours of March 20.

Once pad connections were completed, the launch campaign began on March 30 with a successful liftoff at 6:35 p.m. EDT April 1.

5. Orion Spacecraft

After its 694,481-mile journey around the Moon and back, the agency's Orion spacecraft successfully reentered Earth's atmosphere and splashed down off the coast of San Diego on April 10. The crew and spacecraft were safeguarded by Orion's thermal protection system as they traveled nearly 35 times the speed of sound during reentry. Initial inspections of the system found it performed as expected, with no unusual conditions identified. Diver imagery of the spacecraft's heat shield initially taken after splashdown and further inspections on the recovery ship found the char loss behavior observed on Artemis I was significantly reduced, both in terms of quantity and size. Performance also was consistent with arc jet facility ground testing performed after Artemis I.

Airborne imagery of Orion's crew module also was obtained during reentry. This imagery will provide insight into the timing of when minimal char loss occurred as well as other heat shield data.

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Fig. 4. Artemis II crew, Luis Saucedo, NASA's acting Orion vehicle integration manager and Richard Scheuring, NASA Flight Surgeon, inspect Orion vehicle on 11 April 2026

The crew module was returned to NASA Kennedy for additional examination of the heat shield during Orion de-servicing in the Multi-Payload Processing Facility. Teams conducted detailed inspections, retrieved post-flight data, removed reusable components such as avionics, and eliminated remaining hazards such as excess fuel and coolant.

The heat shield was transported to NASA's Marshall Space Flight Center in Huntsville, Alabama, for sample extraction and internal X-ray scans to provide further insight into the system and material behavior.

The ceramic tiles on the upper conical backshell of the crew module also performed as expected. Reflective thermal tape, which is expected to burn off upon reentry, is still present in numerous locations. This reflective tape is used to help control vehicle temperatures while in space and serves no function for thermal protection upon reentry.



Fig. 5. Shortly after Artemis II splashdown on Friday, April 10, 2026, U.S. Navy divers captured underwater imagery of the Orion spacecraft's heat shield.
Credit: U.S. Navy

Orion splashed down with precision, just 2.9 miles from the targeted landing site. Initial assessments showed entry interface velocity was within one mile per hour of predictions.

The team continues assessing the hardware and gathering data to support the post-flight investigation of the urine vent line issue during the Artemis II mission.

Teams will work to identify root cause and initiate corrective action for Artemis III.

6. Exploration Ground Systems

Following the launch of the Artemis II crew and rocket Engineers conducted a detailed post-launch pad and mobile launcher assessment,. Application of lessons learned from Artemis I to harden and reinforce ground support equipment at the pad proved successful as the mobile launcher and launch pad sustained minimal damage in the wake of the powerful booster ignition.

In addition to performing washdowns of the mobile launcher and pad ground systems immediately following launch, some components were made more rigid, like elevator doors, while others were made more compliant, such as gaseous distribution panels in the base of the mobile launcher, which were modified to flex with the blast effects. Other components were protected with blast-resistant walls or covers. This allowed the pneumatics system, which involves air and gas, to remain operational postlaunch and the critical cooling and washdown water flows to proceed.

Teams returned NASA's mobile launcher to the VAB to undergo repairs and prepare for future Artemis missions.

The agency's recovery teams, alongside their military partners, successfully conducted recovery operations after the safe splashdown of the crew inside their spacecraft. Navy divers retrieved each crew member and brought them aboard USS John P. Murtha before helping to recover the Orion spacecraft and return to Naval Base San Diego.

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7. Artemis III

Artemis maintains a flexible architecture with the primary objective being the establishment of a lunar base. The flexibility enables the agency to adjust individual missions to best continue the progress of the architecture while driving down risks. A prime example of that is the Artemis III mission.

Originally targeted to be a crewed lunar landing mission, Artemis III was modified in early 2026 to become an Earth-orbit mission that will have astronauts onboard an Orion spacecraft, launched by an SLS, rendezvous and dock with test article versions of both of NASA's Human Landing System (HLS) vehicles – SpaceX's HLS variant of Starship and Blue Origin's Blue Moon Mark 2 crew lander. This critical mission will be the first meeting of the spacecraft in space and will include rendezvous, proximity operations, and intervehicle communications, and docking – all of which will be critical to crewed lunar landings.

Similar in nature to the Apollo 9 mission in 1969, the mission is targeted to launch in 2027. More details about the Artemis III mission will be released in the coming weeks and months.

8. Artemis IV and Beyond

The Artemis IV mission is targeted to launch in early 2028 and will be the first crewed landing on the lunar surface since Apollo 17 in 1972. The SLS rocket hardware for the mission is being prepared right now. The elements of the core stage are mostly completed with integration to follow. The solid rocket booster motor segments are cast, and the RS-25 engines are prepared and in storage. The Artemis IV European Service Module arrived at NASA's Kennedy Space Cetner December 2025 and the Orion Crew module is in final assembly.

Artemis V will also be a crewed landing on the Moon. Targeted for late 2028, much of the SLS rocket hardware is already in development. Structural barrel segments of the core stage are being welded. This mission will be the first to use new-production RS-25 engines, and the first two have successfully completed their acceptance hot fires at Stennis Space Center in Bay St. Louis, Mississippi. The remaining two engines will be tested later this year and early next. The motor segments for the solid rocket boosters will begin casting later this year.

8. Conclusions

Building on the success of the Artemis II crewed lunar flyby mission, NASA along with industry, academic, and international partners is preparing to return astronauts to the lunar surface in 2028 and begin the build-up of a permanent Moon Base.

These activities will test technologies needed for the human exploration of Mars, will help build a sustainable economy on the lunar surface, and will enable the peaceful exploration of space while ensuring the United States remains the leader on the space frontier.

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References

[1] Askins, B.R., NASA's SLS (Space Launch System) Rocket Ready for Artemis II Lunar Mission, 73rd JANNAF Propulsion Meeting, Pittsburgh, Pa., 2026, 1 – 4 June 2026.

[2] Honeycutt, J., Blevins, J., Cianciola, C., Cobb S., NASA Reviews Space Launch System Artemis II Flight Results and Prepares for Artemis III and Beyond, AIAA SciTech, 2026.

[3] Low, L.E. (2026) 'NASA on Track for Future Missions with Initial Artemis II Assessments - NASA,' NASA, 20 April. https://www.nasa.gov/missions/nasa-on-track-for-future-missions-with-initial-artemis-ii-assessments/.