

Artemis I CubeSats Prepare for Launch on NASA's Space Launch System

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With stacking and integration operations beginning in mid-2020, NASA's Space Launch System (SLS), the agency's new super heavy-lift launch vehicle for crewed and cargo deep space missions, is preparing for its initial flight: Artemis I. The Artemis I mission, a thorough checkout of SLS, the Orion crew spacecraft, and ground processing and launch facilities at Kennedy Space Center (KSC), will also send 13 CubeSats to deep space, marking the first rideshare flight for smallsats to deep space. The Artemis I CubeSat payloads will perform a variety of missions and technology demonstrations in deep space, with several testing innovative propulsion systems. Other missions will search for hydrogen and other volatiles on the lunar surface, possibly paving the way for *in-situ* resource utilization on future Artemis missions. Artemis I payload developers from NASA projects, industry, universities and participants in NASA's Centennial Challenges contest are in the final stages of testing, verification and assembly of smallsat missions for the flight. CubeSats will be deployed along the heliocentric disposal trajectory of the upper stage after Orion separates from SLS. The payloads will be stowed in an adapter known as the Orion Stage Adapter (OSA), located between the SLS upper stage and the Orion spacecraft. The OSA potentially has up to 17 berths available for 6U and 12U CubeSats, although the Artemis I flight has only 6U form factor payloads manifested. The SLS Program provides a secondary payload deployment system (SPDS) for the smallsats, which includes the hardware to integrate the payloads on to the launch vehicle and an avionics unit to control deployment. Dispensers are a commercial off-the-shelf (COTS) model. The system is thoroughly tested at Marshall Space Flight Center (MSFC) in Huntsville, Alabama prior to shipping the OSA with SPDS to KSC. For the Artemis I flight, the OSA with SPDS was tested and shipped to KSC in 2018. CubeSats will be integrated into dispensers at the dispenser vendor site and then shipped to KSC for installation into the SPDS about nine months prior to launch. The remaining elements of SLS are already at KSC at the time of writing or are scheduled to ship to KSC ground processing facilities in 2020. SLS is a flexible system for crew, cargo or combined missions that will evolve into progressively more powerful variants. The initial variant to fly, Block 1, has a lift capability of at least 27 metric tons (t) to trans-lunar injection (TLI). SLS uses a proven, reliable propulsion system consisting of twin solid rocket boosters and four RS-25 liquid hydrogen/liquid oxygen (LH2/LOX) engines (formerly Space Shuttle Main Engines [SSMEs]).

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The Program is using heritage solid rocket booster hardware from the Space Shuttle Program (nose cones, frustums, forward skirts, motor cases and aft skirts). However, the boosters are upgraded with new avionics, new case insulation and are 20 percent more powerful than shuttle-era boosters due to an extra propellant segment. The five-segment SLS boosters will provide more than 75 percent of the Block 1 vehicle's 8.8 million pounds of thrust off the pad. Solid rocket boosters for the Artemis I flight are complete. The forward assemblies were refurbished and the aft skirts were outfitted with thrust vector control (TVC) systems at KSC. Prime contractor Northrop Grumman manufactured propellant segments in Utah and those are preparing to ship to KSC in June 2020. Lighting milliseconds before the boosters, the RS-25 engines have likewise been upgraded for lunar missions. The RS-25s, manufactured by Aerojet Rocketdyne, have all-new computerized controllers and nozzle ablation to mitigate the more extreme temperatures and launch environment of SLS. The vehicle's clean-sheet development is a 212-foot core stage -- the backbone of the rocket. The core stage includes propellant tanks and avionics. The Artemis I core stage, with its four RS-25 engines integrated, is at Stennis Space Center (SSC) undergoing a series of "green run" tests that include avionics power-on, cryogenic propellant tanking and de-tanking and ultimately a hot-firing of the four RS-25s. Following green run testing, the stage will ship to KSC. At that time, the boosters will be stacked on the Mobile Launcher (ML) in the Vehicle Assembly Building (VAB). The core stage will be lifted over the VAB's transfer aisle and lowered between the boosters onto the ML platform. Block 1, the initial variant to fly, uses a modified single-engine Delta Cryogenic Second Stage (DCSS) as its upper stage. Known as the Interim Cryogenic Upper Stage (ICPS), it was complete and delivered to KSC in 2017. The ICPS will be stacked on the core stage along with an adapter that changes diameter from 8.4 m to 5.4 m. The OSA, with the CubeSats in their dispensers and mounted on the interior wall of the ring, will then be stacked on the ICPS. Orion's stage adapter, service module and finally the Orion crew capsule and launch abort system will complete the 98.1 m (322 ft.) vehicle stack. The Block 1 vehicle, with the ICPS upper stage, can also be outfitted with a 5 m-class payload fairing to send deep space infrastructure to the Moon or interplanetary probes deep into the solar system, such as to Jupiter's moon Europa. The second variant to fly, Block 1B, uses the same propulsion system of five-segment solid rocket boosters and four RS-25 engines mounted in the core stage. The ICPS will be replaced by a more powerful four-engine LH2/LOX upper stage, known as the Exploration Upper Stage (EUS). Also available in crew and cargo configurations, the Block 1B vehicle can be outfitted with 8.4 m-diameter payload fairing in 19.1 or 27.4 m lengths. A final evolution, Block 2, will use evolved solid rocket boosters to increase payload lift capability to at least 46 t to TLI. For future flights, mission managers hope to provide rideshare opportunities to smallsats whenever mission parameters allow. Although form factor is limited to 6U for the Artemis I flight, 12U accommodations in the OSA on the Block 1 vehicle are possible for future flights. Options for smallsats on the Block 1B vehicle include a deployment system located on the payload adapter in both crew and cargo variants. Although designed to return NASA's human spaceflight program to the Moon and reliably launch strategic robotic interplanetary missions deep into the solar system, mission and vehicle planners recognize the important contributions smallsats can make to the Artemis program. This paper will provide an update on the SLS Block 1 vehicle's progress toward launch, preparations for CubeSat integration into the vehicle and an overview of the missions and technology demonstrations manifested on the Artemis I flight.