National Aeronautics and Space Administration

NASAfacts

The J–2X Engine

Powering NASA's Ares I Upper Stage and Ares V Earth Departure Stage

NASA's Ares launch vehicles, which will carry explorers to the moon in the coming decades, will be powered in part by the J–2X engine, which draws its heritage from the Apollo-Saturn Program.

The new engine, being designed and developed for NASA's Constellation Program, will power the upper stages of both the Ares I rocket and Ares V heavy cargo launch vehicle. The Constellation Program is responsible for developing a new family of U.S. crew and heavy-lift cargo launch vehicles and related systems and technologies for exploring the moon and destinations beyond.

Powered by liquid oxygen and liquid hydrogen, the J–2X is an evolved variation of two historic predecessors — the powerful J–2 upper stage engine that propelled the Apollo-era Saturn IB and Saturn V rockets to the moon in the 1960s and 1970s, and the J–2S, a simplified version of the J–2 developed and tested in the early 1970s but never flown.

The J–2X will measure approximately 185 inches long and 120 inches in diameter at the end of its nozzle. It will weigh approximately 5,450 pounds. With 294,000 pounds of thrust in its primary operating mode, the engine will enable the Ares I upper stage to place the Orion spacecraft in low-Earth orbit. By changing the mixture ratio of liquid oxygen to liquid hydrogen, the J–2X can operate in a secondary mode of 242,000 pounds of thrust, required to power the Ares V Earth departure stage from Earth orbit toward the moon.

The J–2X is being designed and will be built by Pratt & Whitney Rocketdyne of Canoga Park, Calif., for the Ares Projects at NASA's Marshall Space Flight Center in Huntsville, Ala. The J–2X builds on the legacy of the Apollo-Saturn Program and relies on nearly a half-century of NASA spaceflight experience, heritage hardware and technological advances.

Test firing of a Saturn V second stage rocket in April 1966. The rocket used a cluster of five J–2 engines. (NASA/SSC)

Ares I Upper Stage Engine

Ares I is the human-rated launch system that will deliver the Orion spacecraft, with up to six astronauts on board, to Earth orbit. The launch vehicle also could carry small payloads to orbit. The Ares I rocket with the Orion spacecraft on top are expected to start transporting crews to the International Space Station by 2015 and to begin flying lunar missions later in the decade.

The launch vehicle's second, or upper, stage is powered by the J–2X engine. The J–2X will ignite approximately 127 seconds after liftoff, following separation of the vehicle's first stage, which occurs at an altitude of about 36 miles. The engine will operate in primary mode for approximately 465 seconds, long enough to burn approximately 105,500 gallons (302,200 pounds) of propellant. It will shut down just as the Ares I upper stage reaches an altitude of 80.5 miles.

Concept image of the J–2X engine. (NASA/MSFC)

Shortly after J–2X engine cutoff, the Orion crew exploration vehicle will separate from the upper stage. After separation, Orion's engine will ignite to insert the capsule into low-Earth orbit. There, Orion will rendezvous with the International Space Station or with the Earth departure stage of the Ares V heavy cargo launch vehicle for missions to the moon. The Ares I upper stage with its J–2X engine attached will then re-enter Earth's atmosphere and splash down in the Indian Ocean. The upper stage and J–2X engine will not be reused.

Ares V Earth Departure Stage Engine

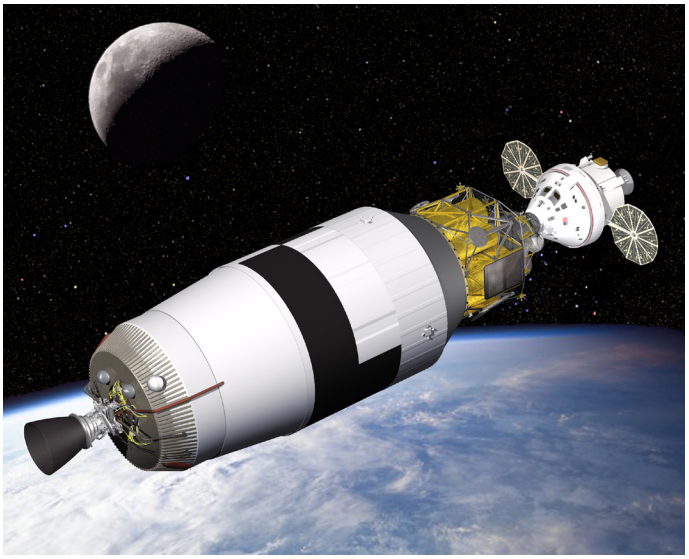
Ares V is the heavy-lift cargo vehicle that will carry the lunar lander or other large hardware and supplies to orbit in support of missions to the moon and beyond. The lunar lander will ferry astronauts between the Orion crew module and the moon beginning in about 2020.

Concept image of Ares V in Earth orbit. (NASA/MSFC)

The Ares V upper stage, commonly referred to as the Earth departure stage, also will be powered by a J–2X engine. For Ares V missions, the J–2X will be ignited twice — once to put payloads in orbit around Earth and then again to escape Earth orbit to send explorers and hardware to the moon. The J–2X first will ignite approximately 325 seconds after liftoff, following separation of the Ares V first stage from the Earth departure stage at an altitude of about 76 miles. The engine will power the Earth departure stage for about 442 seconds, burning more than 101,000 gallons (290,000 pounds) of propellant to place it in low-Earth orbit.

On lunar missions involving astronauts, Ares V will first loft the Earth departure stage and attached lunar lander to Earth orbit. Once the departure stage and lander achieve a stable orbit, Ares I will deliver the Orion spacecraft with its crew to orbit. Orion will dock with the departure stage and lunar lander. After the two are mated, the departure

stage will fire its J–2X engine a second time to begin translunar injection. This second burn will last approximately 442 seconds to accelerate the mated vehicles to "escape velocity," the speed necessary to break free of Earth's gravity and travel to the moon. Then, the Orion-lunar lander combination will perform a final maneuver to jettison the Earth departure stage and its J–2X engine and place them in orbit around the sun.



Concept image of the Ares V Earth departure stage in orbit, shown with the Orion crew module docking with the lunar lander module and Earth departure stage. (NASA/MSFC)

Heritage Design

The J–2X exemplifies the Constellation Program's goals of seeking commonality between the Ares I and Ares V; using proven hardware and knowledge from 50 years of American spaceflight experience to streamline the hardware development process; and reducing program, technical, and budget risks.

The J–2X engine must operate at much higher temperatures, pressures, and flow rates than the heritage J–2 engine to raise its performance from 230,000 pounds of thrust on the Saturn vehicles to 294,000 pounds on the Ares vehicles. It will meet that goal by using new materials, and new scaled-up component designs.

The fuel and oxidizer turbopumps — the heart of the engine — are based on the J–2S engine developed in the early 1970s. The design has been enhanced, and modern manufacturing methods and materials will be used to meet current NASA design standards for greater performance and safety. The engine's gas generator, itself a small rocket engine that drives the turbopumps, is based on the design for the RS-68 engine now flown on the Delta IV rocket. The RS-68 also serves as the basis for the J–2X control computer, the main propellant injector that controls flow into the main combustion chamber, and the main combustion chamber, itself, where the liquid hydrogen and oxygen are combined to produce thrust. The J–2X exhaust nozzle is cooled by its super-cooled propellants before they go to the turbopumps for combustion. A new nozzle extension nearly 8 feet tall and 10 feet in diameter at its opening enables the engine to meet higher operating efficiency requirements — essentially "miles per gallon."

Engineers at the Marshall Center conduct a battery of tests on the J–2X's workhorse gas generator, the driver for the turbopumps which start the engine for the Ares I rocket upper stage.

Testing, Manufacturing, and Operations

Component testing is important to the development of the J–2X engine. The use of heritage J–2 hardware allowed NASA to begin early testing in 2006 to better understand its performance. Both full-scale and subscale heritage J–2 turbopumps, propellant injectors, gas generators and other key components have undergone rigorous testing at facilities around the country to understand the design issues involved in raising performance. Following this heritage hardware testing, NASA is also testing J–2Xcomponents, including the subscale main injector, full scale gas generator, turbopump subscale parts and full scale assemblies, flex ducts, igniters, electronic controller, valves and actuators.

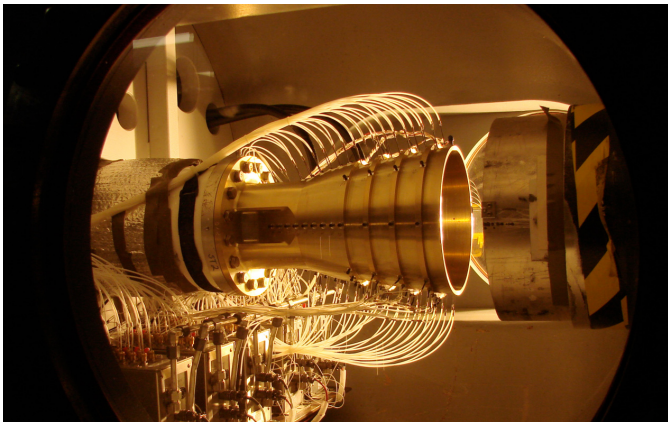
Following component testing, a three year J–2X engine system development test program will include over 200 hot-fire engine tests.

A variety of existing test facilities are needed to support development of the J–2X, including some previously used to test the space shuttle main engine and the Saturn-era engines before that. NASA turned over the A–1 test stand at the John C. Stennis Space Center near Bay St. Louis, Mississippi, to the J–2X program in 2006. It was refurbished and supported heritage J–2S turbopump development testing in 2007 and 2008. The Stennis A–2 test stand will be transferred from the shuttle to the Ares program in

2010. NASA also broke ground in 2007 for a new test stand, designated A-3, at Stennis. It will be used to test engine operation at altitudes simulating a real Ares I mission. The new stand will be ready to support tests in 2011.

The engine completed its critical design review in 2008. This programmatic milestone in the life of NASA hardware demonstrates that the design is ready to begin full-scale fabrication, assembly, integration, and testing. Manufacturing plans include Pratt & Whitney Rocketdyne in-house work, for which facilities and equipment have been configured for the J–2X. Manufacturing also includes subcontracted purchase orders for parts being manufactured around the country.

Engineers are also working to ensure that the J–2X is as simple and operable as possible for NASA's long-term exploration requirements. The J–2X engine and Ares I upper stage and first stage are being designed to accommodate ease of engine maintenance and servicing when attached to the vehicle. Engine assembly will occur at the Stennis Space Center, and assembly planning is being done to assure a lean assembly process for development and flight engines. Pratt & Whitney Rocketdyne will deliver each flight engine to NASA after it has been successfully test fired. Engines will be attached to the Ares I upper stage at NASA's Michoud Assembly Facility in New Orleans, Louisiana. The first completed stages will then return to Stennis with J–2X attached for test firing before delivery to NASA's Kennedy Space Center in Florida for mating with the Ares I first stage and Orion capsule for launch.



Engineers at the Marshall Center conducted more than 1,000 J-2X nozzle start simulations beginning in March 2008. (NASA/MSFC)Ignition System

Benefits

By using current, state-of-the-art engine technologies and drawing on the heritage and knowledge of the J–2, J–2S and RS-68 engines, NASA engineers aim to deliver a safer and more cost-effective engine. This combination of advanced and proven hardware will reduce development and operations costs for the J–2X. It also will reduce the complexity of manufacturing and launch processes for Ares I and Ares V. In addition, J–2X design improvements over the heritage J–2 enable higher engine performance to meet NASA's Ares mission requirements for NASA's exploration missions.

Ares Projects

The Marshall Center manages the Ares Projects for NASA's Constellation Program at the Johnson Space Center in Houston.

The Ares I and Ares V efforts include multiple project element teams at NASA centers and contract organizations around the nation. Pratt & Whitney Rocketdyne is the prime contractor for the Ares I and Ares V J–2X engine.

NASA conducts the last space shuttle main engine test on the Stennis A-1 Test Stand Sept. 29, 2006. The stand was transferred to the Constellation Program in November 2006. (NASA/SSC)

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