



# The J-2X Engine

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



The U.S. launch vehicles that will carry explorers back to the moon will be powered in part by a J-2X engine that draws its heritage from the Apollo-Saturn Program.

The new engine, being designed and developed in support of NASA's Constellation Program, will power the upper stages of both the Ares I crew launch vehicle and Ares V cargo launch vehicle.

The Constellation Program is responsible for developing a new family of U.S. crew and launch vehicles and related systems and technologies for exploration of the moon, Mars and destinations beyond.

The J-2X will measure about 185 inches long and 120 inches in diameter at the end of its nozzle. It will weigh approximately 5,300 pounds. With 294,000 pounds of thrust, the engine will

enable the Ares I upper stage to place the Orion crew exploration vehicle in low-Earth orbit.

The J-2X is being designed by Pratt & Whitney Rocketdyne of Canoga Park, Calif., for the Ares Projects Office 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 space-flight experience, heritage hardware and technological advances.

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.

# NASAfacts



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. Orion is expected to start transporting crews to the International Space Station in 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 126 seconds after liftoff, following separation of the vehicle's first stage, which occurs at an altitude of about 194,000 feet (37 miles). The engine will operate for approximately 465 seconds, long enough to burn more than 102,600 gallons (302,200 pounds) of propellant. It will shut down just as the Ares I upper stage reaches an altitude of 425,000 feet (80.5 miles).

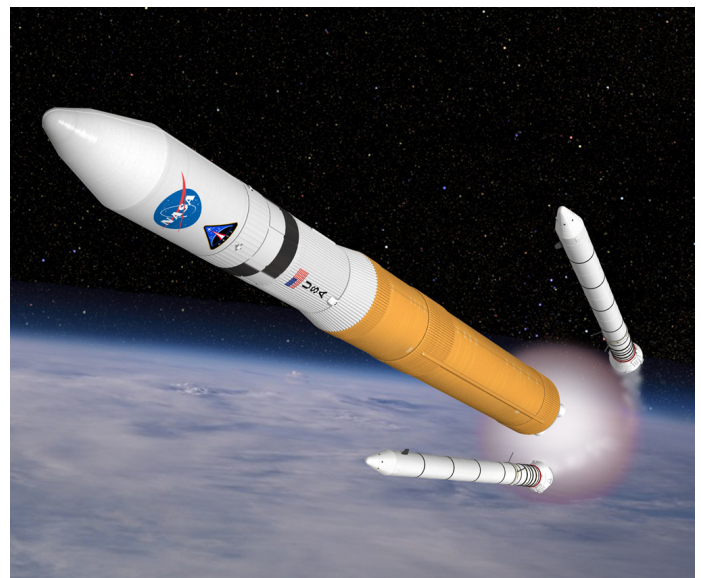


Concept image of the J-2X engine. (NASA/MSFC)

Shortly after J-2X engine cutoff, the Orion capsule 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 rocket 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 400,000 feet (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)

### Turbomachinery

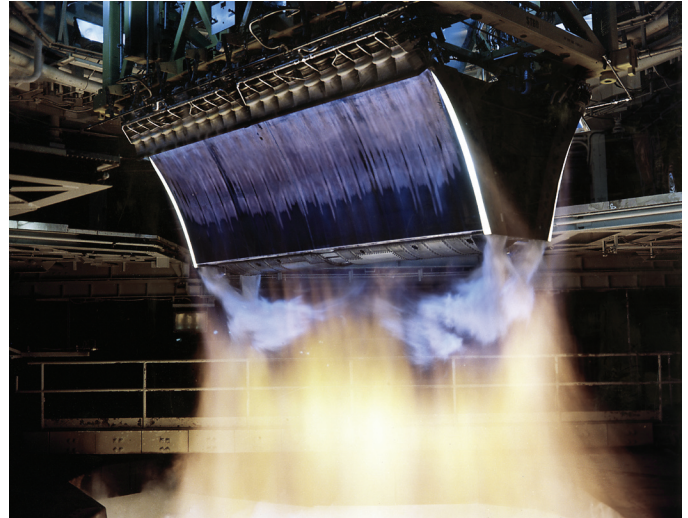
The J-2X power pack – the main power-generating and pumping components of an engine – will use hardware evolved from the J-2S engine. The power pack consists of a gas generator and turbomachinery which includes turbopumps, valves and connecting feed lines and ducts.

In this rocket engine system, the turbopumps supply liquid hydrogen fuel and liquid oxygen to the main combustion chamber, where the fuel and oxidizer mix. They burn at very high pressures and temperatures to produce gas, which exits from the nozzle to produce thrust. The gas generator drives the fuel and oxidizer turbopumps.

The J-2S turbopumps and related machinery were demonstrated in the 1990s on an aerospike engine, a linear engine whose nozzle is curved, unlike traditional bell-shaped rocket engine nozzles. The aerospike engine was developed for use by NASA’s X-33 reusable launch vehicle project, a single stage-to-orbit demonstrator vehicle designed to test advanced technologies.

In 2006, the turbomachinery was removed from the X-33 power pack for further testing and analysis to support development of the J-2X. NASA engineers will further upgrade the hardware to meet Ares requirements for safety, reliability and performance. One such upgrade

includes the use of milled channel walls, featuring channels through which propellant can flow, in the engine’s combustion chamber.



Testing of twin linear aerospike engines conducted in August 2001 at NASA’s Stennis Space Center near Bay St. Louis, Miss. (NASA/MSFC)

### Injector Hardware

The J-2X main injector hardware, a major component of the engine, is similar to the J-2 engine injector. The component injects and mixes liquid hydrogen and liquid oxygen in the combustion chamber, where they are ignited and burned to provide thrust. NASA engineers are in the process of upgrading the J-2 injector hardware to meet performance requirements of the J-2X.

Engineers at NASA’s Marshall Center conducted hot-fire tests on subscale injector hardware in 2006 as part of an effort to investigate design options that would maximize performance of the J-2X engine for the Ares upper stages. The initial tests were performed on a variety of subscale injector designs. Data gathered from the tests is being used to design and develop the full-scale J-2X injector. Additional tests are planned.



Subscale main injector hardware hot-fire testing at Marshall in June 2006. (NASA/MSFC)

## Ignition System

The J-2X ignition system also will be a modified version of the system on the J-2 engine. It includes an augmented spark igniter, a component required for in-flight ignition of the liquid hydrogen and liquid oxygen propellants.

Tests of an augmented spark igniter were conducted in 2006 at Marshall. The test apparatus and a similarly designed augmented spark igniter will be used in development of the J-2X engine. During the tests, NASA engineers integrated the igniter assembly — spark plugs, propellant injectors and tube-like ignition torch — and fired it into a vacuum chamber. This simulated the conditions the Ares I upper stage and Ares V Earth departure stage will experience when activated at high altitudes and in low-Earth orbit. For future tests, engineers will chill propellants to minus 260 degrees Fahrenheit prior to injection to simulate conditions between Earth and the moon, where the J-2X will be used to power the Earth departure stage.

## Benefits

By optimizing the state of the art among current engine technologies and drawing on the heritage and knowledge of the J-2 and J-2S engines, NASA engineers aim to deliver a safer and more cost-effective engine for NASA's exploration missions throughout the solar system.

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, upgrades to components will improve engine performance to meet NASA's Ares mission requirements.

## Test Facilities

The first flight demonstration of the J-2X is tentatively planned for 2013 on the first flight of Orion. Testing of the J-2X engine will be conducted at several NASA centers.

Tests of the J-2X power pack and gas generator are planned for 2007. The test series will be conducted on the A-1 Test Stand at NASA's Stennis Space Center in Bay St. Louis, Miss. The test stand was built in the 1960s to test rocket engine stages for the Apollo Program. It was modified in the 1970s to test-fire and prove the flight readiness of all main engines for NASA's space shuttle fleet. The first integrated J-2X engine systems test is scheduled for 2010.



**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)**

## Ares Projects

Marshall manages the Ares Projects Office for NASA's Exploration Systems Mission Directorate in Washington. The projects office reports to 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 upper stage J-2X engine. The production engine will be assembled by Pratt & Whitney Rocketdyne in facilities at Stennis.

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