National Aeronautics and Space Administration

Propulsion With the Space Launch System

Educator Guide

Educator Guide	
Educators and Students	Grades 6 to 8

Contents

Preface

Propulsion With the Space Launch System was published by NASA's Office of STEM Engagement as part of a series of educator guides to help middle school students reach their potential to join the next-generation STEM workforce. The activities can be used in both formal and informal education settings as well as by families for individual use. Each of these activities is aligned to national standards for science, technology, engineering, and mathematics (STEM), and the NASA messaging is current as of September 2019.

STEM Education Standards

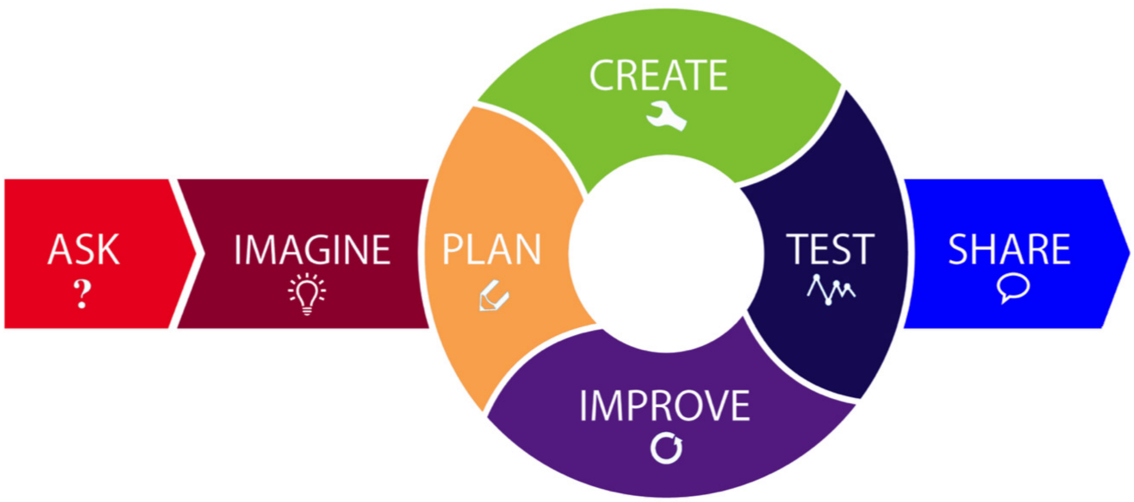
The STEM disciplines matrix shown below aligns each activity in this module to standards for teaching STEM according to four primary focus areas within each discipline. The four focus areas for science were adapted from the Next Generation Science Standards (NGSS) middle school disciplinary core ideas. The four focus areas for technology were adapted from the International Society for Technology in Education (ISTE) Standards for Students. The four focus areas for engineering were adapted from the National Science Teaching Association (NSTA) and NGSS science and engineering practices. The four focus areas for mathematics were adapted from the Common Core State Standards (CCSS) for Math middle school content standards by domain. Find additional matrices in the Appendix: STEM Standards and Practices.

Activity	STEM Disciplines															
	Science				Technology				Engineering				Math			
	NGSS Disciplinary Core Ideas				ISTE Standards for Students				NSTA and NGSS Practices				CCSS Content Standards by Domain			
	Physical Sciences	Life Sciences	Earth and Space Sciences	Engineering, Technology, and the Application of Sciences	Knowledge Constructor	Innovative Designer	Computational Thinker	Global Collaborator	Ask Questions and Define Problems	Develop and Use Models	Plan and Carry Out Investigations	Construct Explanations and Design Solutions	Ratios and Proportional Relationships	The Number System	Statistics and Probability	Geometry
Design a Foam Rocket With Stabilizing Fins	✓			✓	✓	✓		✓	✓	✓		✓				
Track the Altitude of a Rocket					✓		✓	✓						✓		
Build a Multistage Balloon Rocket	✓			✓		✓	✓	✓	✓	✓	✓	✓			✓	
Optimize a Water Rocket Engine	✓			✓				✓	✓	✓	✓	✓			✓	

Engineering Design Process

The engineering design process (EDP) is crucial to mission success at NASA. The EDP is an iterative process involving a series of steps that engineers use to guide them as they solve problems. The steps outlined below can be used by student teams to solve the challenges in this activity guide. Learn more about the EDP with NASA's Educator Professional Development Collaborative at https://www.txstate-epdc.net/models-of-the-engineering-design-process/.

1. ASK: Identify the problem, requirements that must be met, and the constraints that must be considered.
2. IMAGINE: Brainstorm solutions and research what others have done in the past.
3. PLAN: Select and sketch a design.
4. CREATE: Build a model or a prototype.
5. TEST: Evaluate solutions by testing and collecting data.
6. IMPROVE: Refine the design.
7. SHARE: Communicate and discuss the process and solutions as a group.



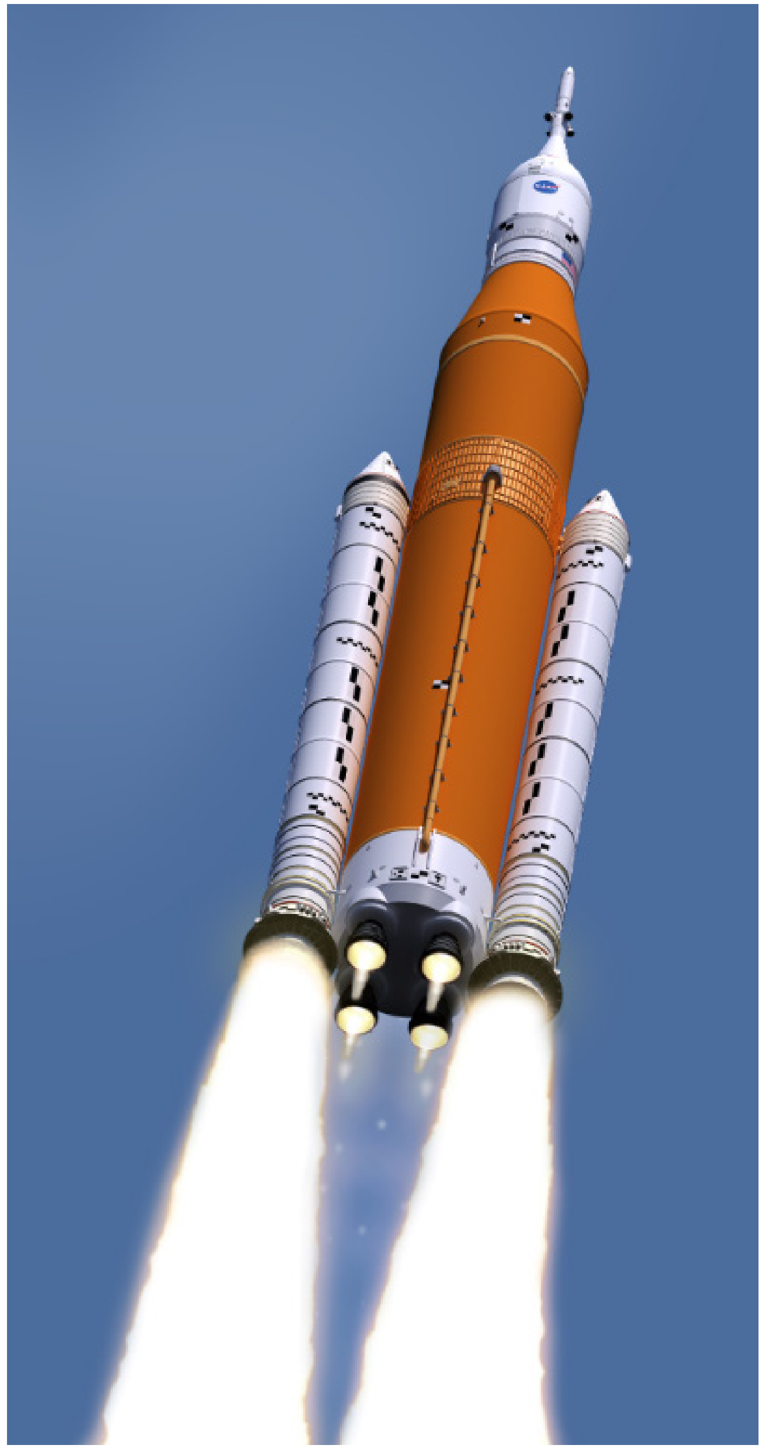
Tip: In order to manage the dynamics within each team, it may be helpful to assign each student within the group a specific task, such as materials manager, design engineer, fabrication engineer, communications specialist, or team manager. Having each team member in charge of a different element of the task may reduce internal conflict within teams.

Introduction and Background

NASA's Space Launch System, or SLS, is an advanced launch vehicle that provides the foundation for human exploration beyond low Earth orbit. With its unprecedented power and capabilities, the SLS is the only rocket that can send the Orion spacecraft, astronauts, and large cargo to the Moon on a single mission. The SLS team is producing NASA's first exploration-class rocket built since the Saturn V.

To fill NASA's future needs for deep space missions, the SLS is designed to evolve into increasingly more powerful configurations and offer more payload mass, volume capability, and energy to speed missions through space than any current launch vehicle. This flexible design will open new possibilities for payloads, including robotic scientific missions to places like Mars, Saturn, and Jupiter.

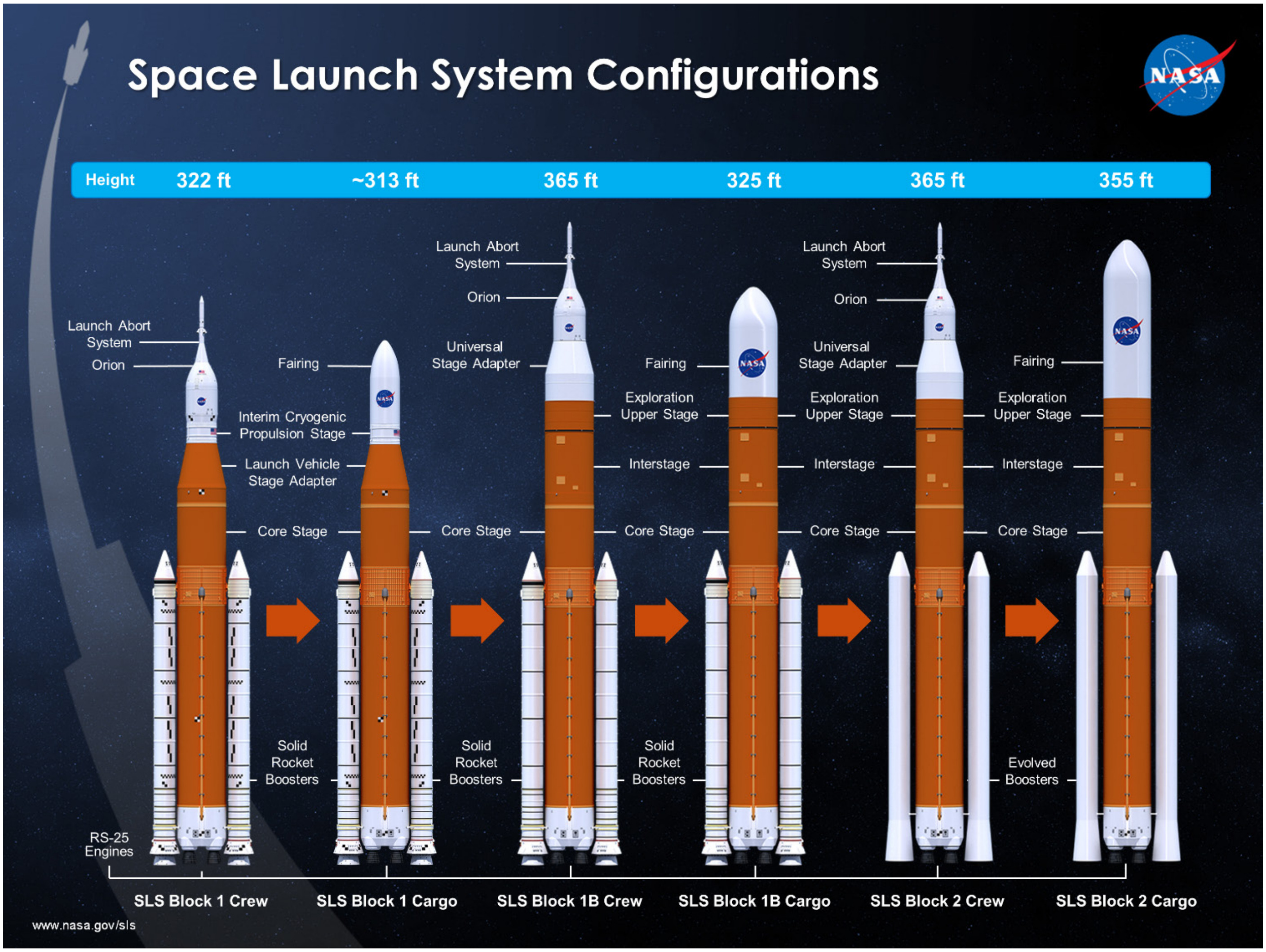
This evolvable design concept allows NASA to provide the Nation with a rocket able to pioneer new human spaceflight missions and revolutionary scientific missions in the shortest time possible, while continuing to develop configurations that are more powerful. The next wave of human exploration will take explorers farther into the solar system—developing new technologies, inspiring future generations, and expanding our knowledge about our place in the universe.



Artist's rendering of NASA's Space Launch System. (NASA)

Rocket Configurations

The first SLS vehicle configuration is called Block 1. It weighs 2.6 million kg (5.75 million lb) when fueled and stands 98 m (322 ft) tall. That is taller than the Statue of Liberty. The SLS will produce 39.1 million newtons (8.8 million lb) of thrust at liftoff, equivalent to more than 160,000 Corvette engines. The initial Block 1 configuration of the SLS can send more than 26 metric tons, or 57,000 lb, to orbits beyond the Moon. It will be powered by twin five-segment solid rocket boosters and four RS–25 liquid propellant engines. After reaching space, the Interim Cryogenic Propulsion Stage (ICPS) is capable of sending Orion on to the Moon. Using the Block 1 configuration, the first SLS mission, Artemis I, will launch an uncrewed Orion spacecraft to a stable orbit beyond the Moon and bring it back to Earth. This mission will demonstrate the integrated system performance of the SLS rocket, the Orion spacecraft, and ground support teams prior to a crewed flight. The second SLS mission is Artemis II, and it will launch Orion with a crew of up to four astronauts to a distance near the Moon that is farther than humans have ever ventured.



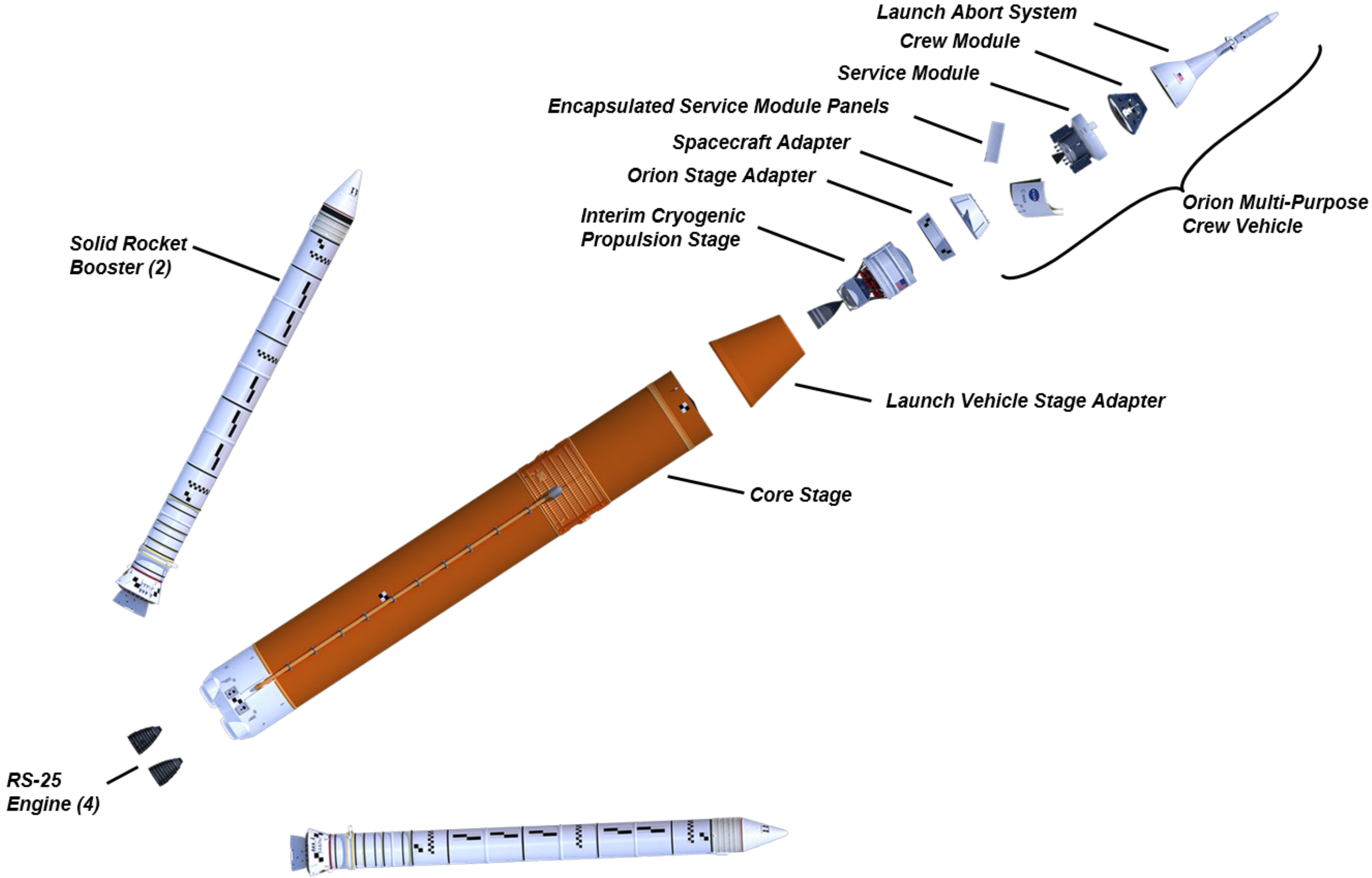
Space Launch System (SLS) configurations. (NASA)

The next planned evolution of the SLS, the Block 1B crew vehicle, will use a new, more powerful Exploration Upper Stage (EUS) to enable more ambitious missions to the proving ground of space near and beyond the Moon, where NASA will test systems needed for future missions to Mars. In a single launch, the Block 1B vehicle can carry the Orion spacecraft along with exploration systems such as a small deep space habitat module, or it can fly dedicated missions carrying larger exploration systems or science spacecraft under a payload fairing. The Block 1B crewed configuration will be approximately 111 m (364 ft) tall, which is taller than the Saturn V rocket that took astronauts to the Moon.

A later evolution, Block 2, will provide 52.9 newtons (11.9 million lb) of thrust and will be the workhorse vehicle for assembling a human mission to Mars and sending cargo to the Moon, Mars, and other deep space destinations. SLS Block 2 will be designed to lift more than 45 metric tons (99,000 lb) to deep space.

Rocket Technologies

The Boeing Company in Huntsville, Alabama, is developing the SLS core stage, including the avionics that will control the vehicle during flight. Towering more than 60 m (200 ft) tall with a diameter of 8.41 m (27.6 ft), the core stage will store 2.76 million L (730,000 gal) of super-cooled liquid hydrogen and liquid oxygen that will fuel the RS–25 engines for the SLS. The core stage is being built at NASA’s Michoud Assembly Facility in New Orleans using state-of-the-art manufacturing equipment, including a friction stir welding tool that is the largest of its kind in the world. At the same time, the rocket’s avionics computer software is being developed at NASA’s Marshall Space Flight Center in Huntsville, Alabama.



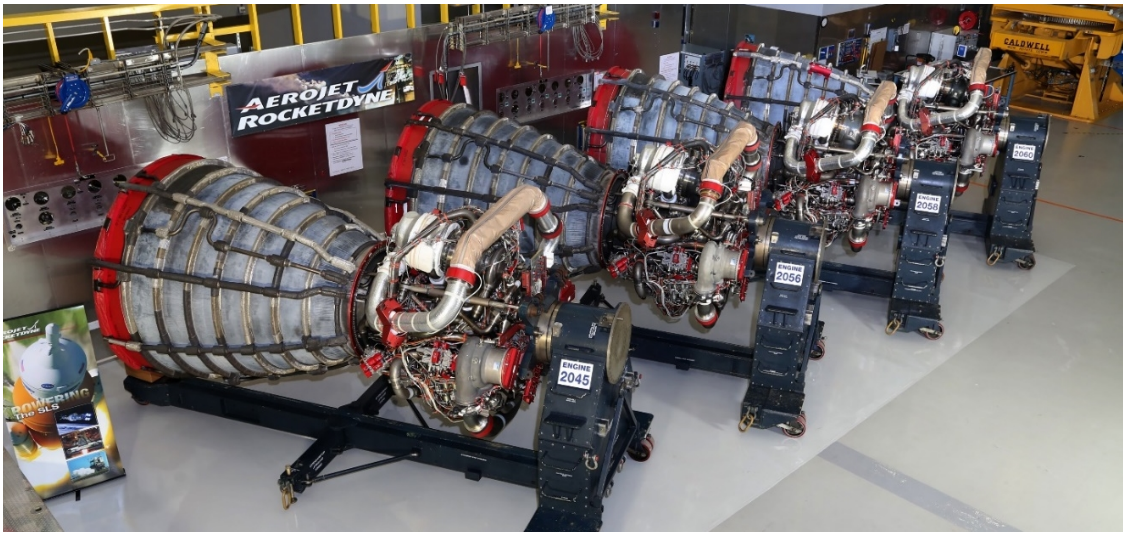
Initial Block 1 Configuration Concept for the Space Launch System. (NASA)

In each configuration, the SLS will continue to use the same core stage design with four RS–25 engines for propulsion. Aerojet Rocketdyne of Sacramento, California, is upgrading an existing inventory of 16 RS–25 space shuttle engines to SLS performance requirements, including a new engine controller, nozzle insulation, and required operation at 1.8 million newtons (418,000 lb) of thrust, instead of the 1.76 million newtons (395,000 lb) of thrust used for the space shuttle.

RS–25 engine undergoing a hot-fire test. (NASA)

Two shuttle-derived solid rocket boosters will be used for the initial flights of the SLS. Each one provides 16 million newtons (3.6 million lb) of thrust. Northrop Grumman is a company headquartered in Dulles, Virginia, and the prime contractor for the boosters. To provide the additional power needed for the rocket, they had to modify the boosters from the shuttle's configuration, which used four propellant segments, to a five-segment version. The design also includes new avionics, propellant design, case insulation, and elimination of the recovery parachutes. Northrop Grumman has successfully completed a full-duration booster qualification ground test.

The initial capability to propel Orion out of Earth's orbit for Artemis I will come from an ICPS, which was modified from the successful second stage of the United Launch Alliance's Delta IV family of rockets. Cryogenic propellants are fluids chilled to extremely cold temperatures and condensed to form liquids that can be used to provide high-energy propulsion. The ICPS will generate 110,093 newtons (24,750 lb) of thrust. The big in-space push comes from one RL–10 engine, which was the Nation's first liquid hydrogen-oxygen engine used in the upper stages of the Apollo-Saturn program.

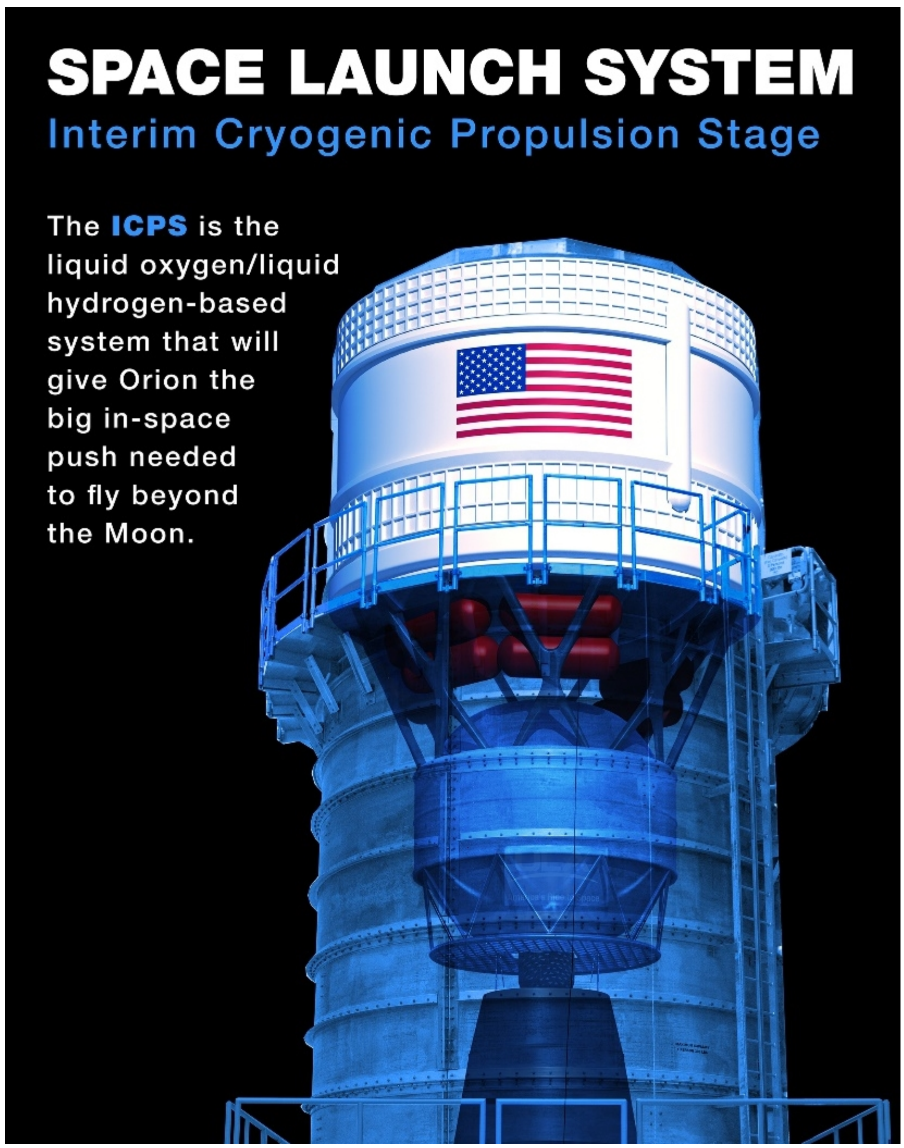


Four RS–25 engines that will power the Space Launch System. (Aerojet Rocketdyne/NASA)

While work progresses on the initial Block 1 SLS, an advanced development team is investing in new systems and technologies that will make the SLS even more powerful, while improving affordability and increasing reliability. This evolved, flexible approach lets the SLS carry out a wide variety of missions sooner, while incrementally increasing the power of the vehicle.

Future configurations of the SLS will include the larger EUS for more capable human and robotic missions to deep space. The EUS will replace the Block 1 ICPS and utilize an 8.4-m- (27.6-ft-) diameter forward liquid hydrogen tank and a smaller diameter liquid oxygen tank.

Reaching the SLS's full potential will require many advanced technologies, including boosters with a significant increase in performance over existing boosters. NASA has engaged with industry teams to research benefits, new technologies, and strategies for liquid and solid advanced boosters that reduce risks while enhancing affordability, improving reliability, and meeting performance goals of the future.



Infographic showing Interim Cryogenic Propulsion Stage (ICPS).

Artist's rendering of Space Launch System liftoff. (NASA)

Infographic summarizing features of the Space Launch System's solid rocket boosters.