National Aeronautics and
Space Administration

How Far Will It Go?

A Lesson in Graphing

ARTEMIS

Common Core State Standards for Mathematics

Mathematical Practices

- **MP 2:** Reason abstractly and quantitatively.
- **MP 4:** Model with mathematics.
- **MP 5:** Use appropriate tools strategically.
- **MP 6:** Attend to precision.

Measurement and Data

- **K.MD.A.1:** Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object.

- **K.MD.A.2:** Directly compare two objects with a measurable attribute in common, to see which object has “more of”/”less of” the attribute, and describe the difference.

- **1.MD.A.2:** Express the length of an object as a whole number of length units, by laying multiple copies of a shorter object (the length unit) end to end; understand that the length measurement of an object is the number of same-size length units that span it with no gaps or overlaps. Limit to contexts where the object being measured is spanned by a whole number of length units with no gaps or overlaps.

- **2.MD.A.1:** Measure the length of an object by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.

- **2.MD.A.3:** Estimate lengths using units of inches, feet, centimeters, and meters.

Next Generation Science Standards

K-PS2 – Motion and Stability: Forces and Interactions

Standards

K-PS2-1: Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

K-PS2-2: Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.

Discplinary Core Idea

PS2.A: Forces and Motion
- Pushes and pulls can have different strengths and directions.

- Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.

PS2.B: Types of Interactions
- When objects touch or collide, they push on one another and can change motion.

PS3.C: Relationship between Energy and Forces
- A bigger push or pull makes things speed up or slow down more quickly.

CROSSCUTTING CONCEPTS:
Cause and Effect
- Simple tests can be designed to gather evidence to support or refute student ideas about causes.

NASA's Moon to Mars

Teacher Notes

Working with U.S. companies and international partners, NASA is pushing the boundaries of human exploration forward to the Moon and on to Mars. NASA is working to establish a permanent human presence on the Moon within the next decade to uncover new scientific discoveries.

NASA is also working with companies to address the challenges of living in space, such as using existing resources, disposing of trash, and more. Missions to the Moon are about 1,000 times farther from Earth than missions to the International Space Station (ISS) located in low-Earth orbit, requiring systems that can reliably operate far from home, support the needs of human life, and still be light enough to launch. These technologies will become increasingly more important for the 34 million mile trip to Mars.

Exploration of the Moon and Mars is intertwined. The Moon provides an opportunity to test new tools, instruments, and equipment that could be used on Mars to help us build self-sustaining outposts away from Earth. Living and working in lunar orbit for months at a time will also allow researchers to understand how the human body responds in a true deep space environment before committing to the years-long journey to Mars.

With the work underway, NASA will move deeper into the solar system to achieve ambitious exploration goals and to develop a permanent presence at the Moon and prepare humanity for future exploration to Mars.

The Space Launch System

NASA's Space Launch System (SLS) is a powerful, advanced launch vehicle for a new era of human exploration beyond Earth's orbit. With its unprecedented power and capabilities, SLS is the only rocket that can send Orion, astronauts, and large cargo to the Moon on a single mission. Offering more payload mass, volume capability, and energy to speed missions through space than any current launch vehicle, SLS is designed to be flexible and evolvable and will open new possibilities for payloads, including robotic scientific missions to places like Saturn and Jupiter. SLS will be NASA's first exploration-class vehicle since the Saturn V took American astronauts to the Moon.

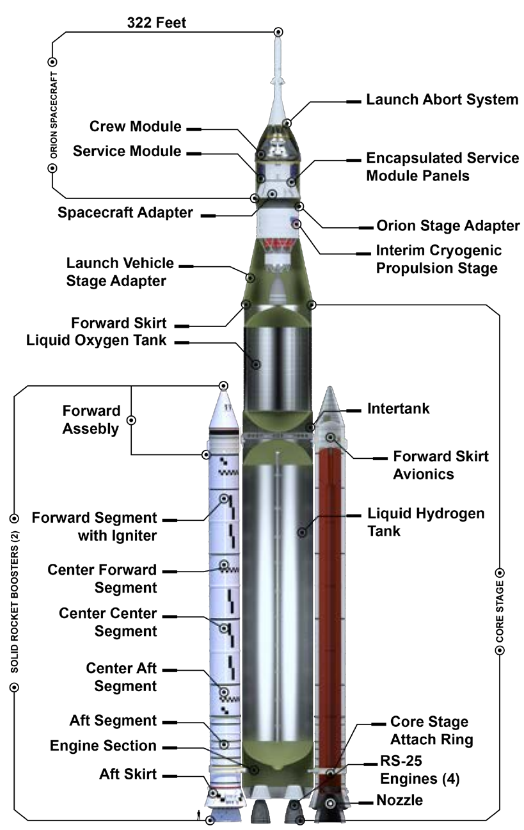
This next wave of human exploration will take explorers farther into the solar system — developing new technologies, inspiring future generations, and expanding our knowledge about our place in the universe.

RS-25 Engine

Artemis I, the first integrated test flight of SLS and Orion, will use the SLS Block 1 configuration which stands 322 feet (ft.), taller than the Statue of Liberty, and weighs 5,750,000 pounds (lbs.). SLS will produce 8,800,000 (lbs.) of maximum thrust, more lift than any current launch vehicle and 15 percent more than the Saturn V rockets that launched astronauts on journeys to the moon.

Part of this thrust, approximately 2,000,000 lbs., will be generated by 4 RS-25 engines. Designed and built by Aerojet Rocketdyne of Sacramento, California, RS-25 engines helped power the space shuttle over three decades through 135 missions, accumulating more than 3,000 starts and one million seconds of ground test and flight operation time.

While each shuttle used three RS-25 engines, each SLS mission requires four. Powered by liquid oxygen and liquid hydrogen and employing high performance fuel and oxidizer turbopumps, the RS-25 has the power and efficiency to carry larger payloads without increasing launch vehicle size – ideal for missions more ambitious and challenging than any NASA has ever attempted in the past.



Block 1 Crew configuration cutaway

WHAT IS THE RS-25 ENGINE?

FOR THREE DECADES, THE RS-25 ENGINE PROPELLED THE SPACE SHUTTLE. NOW, THIS POWERFUL ENGINE HAS BEEN SELECTED FOR THE SPACE LAUNCH SYSTEM (SLS) FOR ITS HIGH PERFORMANCE AND RELIABILITY.

WHEN SPACE LAUNCH SYSTEM IS LAUNCHED, ITS **4** RS-25 ENGINES FIRE NON-STOP FOR **8.5** MINUTES. THESE PROVEN ENGINES, PLUS **2** SOLID ROCKET BOOSTERS, MAKE SLS THE MOST POWERFUL ROCKET

IN THE WORLD.

THE ROAD TO LAUNCH

DESIGNED & BUILT BY AEROJET ROCKETDYNE IN CALIFORNIA → ASSEMBLED & TESTED IN MISSISSIPPI → INTEGRATED WITH CORE STAGE IN LOUISIANA → TRANSPORTED BY BARGE TO FLORIDA FOR LAUNCH

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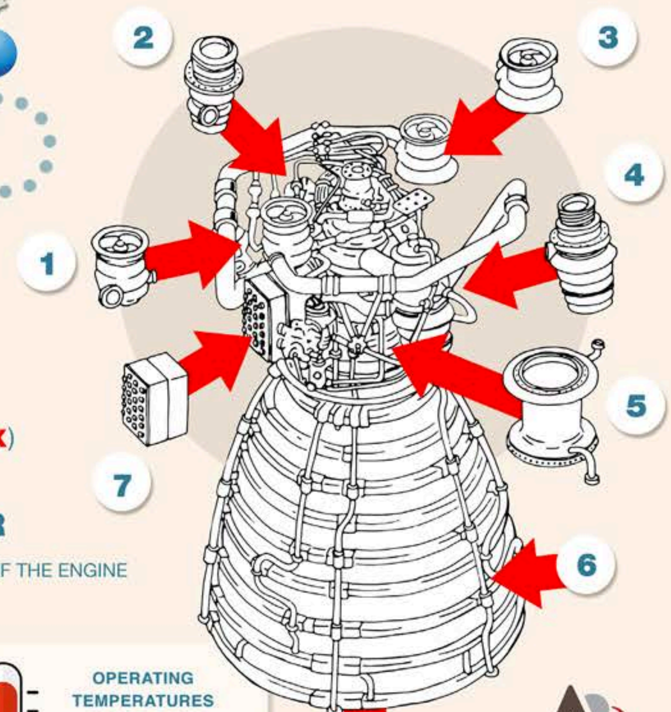
Sooo...

HOW DOES IT WORK?



1 2 3 4 FOUR POWERFUL TURBOPUMPS

PERFORM MUCH LIKE GIANT HEARTS, CREATING IMMENSE PRESSURE THAT CONTROLS THE FLOW OF LIQUID HYDROGEN (**LH_2**) AND LIQUID OXYGEN (**LOX**) INTO THE COMBUSTION CHAMBER

5 MAIN COMBUSTION CHAMBER

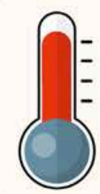
COMBINES **FUEL** AND **OXYGEN** IN THE "BELLY" OF THE ENGINE

6 NOZZLE

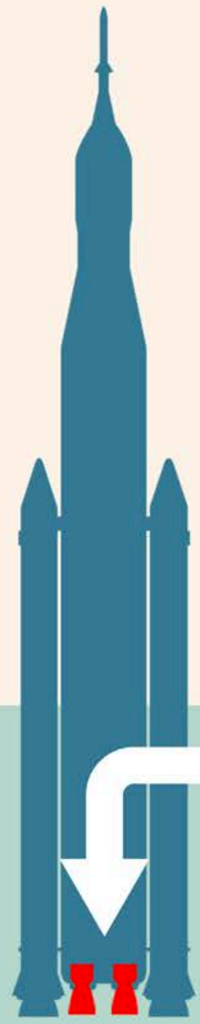
DIRECTS THE **FLOW** AND INCREASES THE **VELOCITY** OF THE EXHAUST

7 ENGINE CONTROLLER

MONITORS ENGINE CONDITIONS AND **OPERATES** THE VALVES, PUMPS AND ACTUATORS THAT CONTROL THRUST



OPERATING TEMPERATURES RANGE FROM **-423°F TO 6000°F**



* WEIGHT IS APPROXIMATE

FOUR RS-25 ENGINES ON THE CORE STAGE GIVE SPACE LAUNCH SYSTEM **2 MILLION** OF ITS **8.8 MILLION** POUNDS OF MAXIMUM THRUST

EACH OF RS-25'S FOUR TURBOPUMPS HAS DOZENS OF TURBINE BLADES. JUST **1 BLADE** THE SIZE OF A QUARTER ON THE HIGH PRESSURE FUEL TURBOPUMP GENERATES MORE HORSEPOWER THAN A WHOLE CORVETTE ENGINE.

FUN FACT:

HOT GASES EXIT THE RS-25 NOZZLE AT **13X THE SPEED OF SOUND**, OR FAST ENOUGH TO TRAVEL FROM LOS ANGELES TO NEW YORK CITY IN 15 MINUTES.

ARTEMIS

Green Run Test for SLS

The first eight minutes of every Artemis mission with NASA's SLS rocket begins with core stage and solid rocket boosters producing 8.8 million pounds of thrust to launch the agency's Orion spacecraft to the Moon. Before its first flight, NASA tests the rocket's 212-foot tall core stage – the tallest rocket stage the agency has ever built – with a "Green Run" test on Earth before launch day to help ensure mission success and pave the way for future Artemis missions carrying crew to the Moon. These lunar missions will be a stepping stone to prepare for human exploration of Mars.

During the Green Run testing, engineers installed the core stage that will send Orion to the Moon in the B-2 Test Stand at NASA's Stennis Space Center near Bay St. Louis, Mississippi, for a series of eight tests. These tests built like a crescendo over several months. The term "green" refers to the new hardware that must work together to power the stage, and "run" refers to operating all the components together simultaneously for the first time. Many aspects are carried out for the first time, such as fueling and pressurizing the stage, and the test series culminates with firing up all four RS-25 engines to demonstrate that the engines, tanks, fuel lines, valves, pressurization system, and software can all perform together just as they will on launch day.

Core Stage

B-2 Test Stand

The SLS core stage includes state-of-the-art avionics, miles of cables and propulsion systems, and two huge liquid propellant tanks that collectively hold 733,000 gallons of liquid oxygen and liquid hydrogen to power the four RS-25 engines. Together, they will produce more than 2 million pounds of thrust to help send Artemis I beyond Earth's orbit to the Moon.

The test program for the core stage at Stennis began with installing the stage in the test stand. Then, engineers turned the components on one by one through a series of initial tests and functional checks designed to identify any issues. Those tests and checks culminate in an eight-minute-long test fire, mimicking the full duration of the stage's first flight with ignition, ascent, and engine shutdown. The results of this test provide important data to confirm how the system reacts as the fuel is depleted from the propellant tanks.

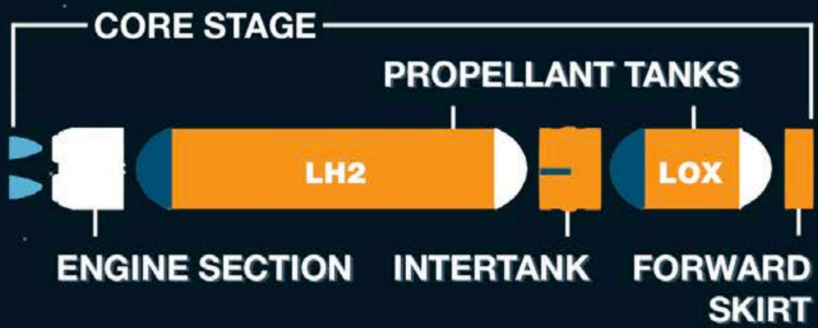
Historically, other NASA rockets built to carry astronauts have used main propulsion test articles to test the integrated engines and main propulsion system. The SLS program is performing the core stage testing with flight hardware. Once the validation of the core stage is complete, the entire stage is checked out, refurbished as needed, and then shipped to NASA's Kennedy Space Center in Florida for the Artemis I launch. The next time the core stage engines roar to life will be on launch pad 39B at Kennedy.

SPACE LAUNCH SYSTEM (SLS)

ARTEMIS TESTING: TEST LIKE YOU FLY

National Aeronautics and Space Administration

TESTING THE WORLD'S LARGEST ROCKET STAGE



GREEN: New, untested rocket hardware

GREEN RUN: First full test of all the SLS core stage **FLIGHT HARDWARE**

WHY GREEN RUN?

The **CORE STAGE** is the complex, **NEW** part of the SLS rocket. It helps launch every SLS mission, beyond Earth's orbit and to the Moon.

WHAT IS TESTED?

- Three flight computers, more than 50 avionics units, navigation and control systems, and flight software controlling the first **8 MINUTES** of flight.
- Two propellant tanks containing more than **700,000 GALLONS** of fuel.
- Propulsion systems with **18 MILES** of cables and more than 500 sensors and systems. These complex systems feed fuel to **4 RS-25 ENGINES** that fire at the same time to produce **1.6 MILLION LBS OF THRUST**.

OBJECTIVE: Ensure success of the first flight of SLS and the Orion Spacecraft—Artemis I—and future missions to support landing astronauts on the Moon in **2024**.

WHERE IS THE TEST?

NASA's **B-2 TEST STAND** at Stennis Space Center in Mississippi.

www.nasa.gov/SLS

The Challenge

Test whether the amount of air in a balloon changes the distance it will travel on a fishing line.

- Collect data from multiple tests
- Create a graph to visualize the variation

MATERIALS

- Plastic Straws
- Oblong Party Balloons
- Cellophane Tape
- Masking Tape
- Nylon Monofilament Fishing Line
- Scissors
- Binder Clips
- Rocket Figure
- Chart Paper
- Graph Paper
- Markers, Crayons, Pencils
- Ruler/Measuring Tape/Yardstick
- Objects for Nonstandard Measurement *(interlocking cubes, paperclips, pennies,etc.)*
- Chairs (2)

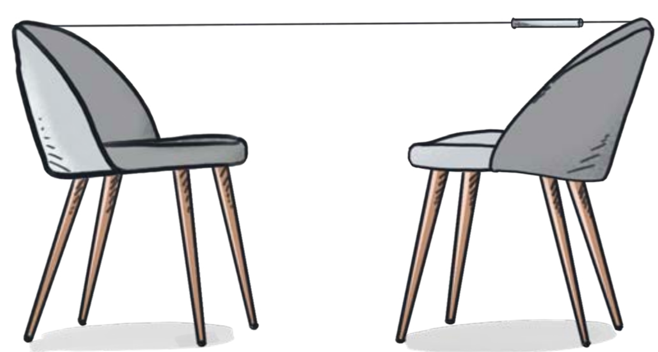
Background

Long before the development of modern rockets, Sir Isaac Newton described the principles of rocket science in three laws of motion.

A simplified explanation of his third law of motion helps young students understand how rockets work. This law states that every action has an equal and opposite reaction.

When a rocket expels fuel or propellant out of its engine, the rocket moves in the opposite direction. The rocket pushes the propellant out, and the propellant then pushes the rocket. The propellant comes out of the engine; this is the action. The rocket lifts off the launch pad in the opposite direction; this is the reaction.

In this activity, the rocket is a balloon propelled by air. The greater the propellant (number of breaths), the greater the action and, thus, the greater the reaction. Students will experiment with different amounts of air and measure the distance the rocket travels.



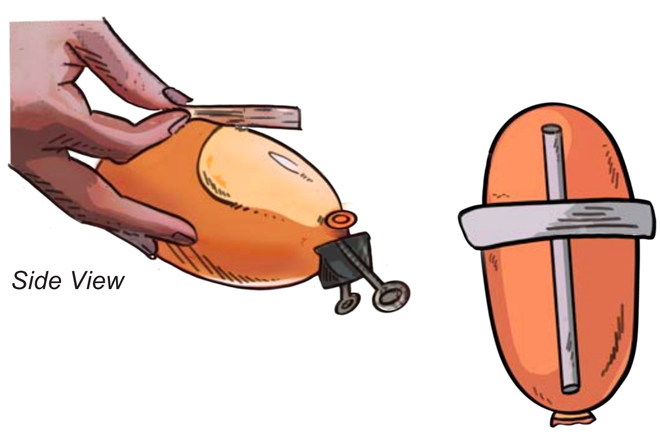
Procedure

1. Show students a video of a rocket launch (NASA has a channel on YouTube; search for NASA rocket launch). Note where the engines are located and where the flames/fire exit the rocket.

2. Ask students if they know how a rocket works. Explain to them they will be conducting a science experiment to determine how the amount of air in a balloon changes the distance the rocket will travel. Students, just like the astronauts in space and scientists on Earth, will conduct an experiment to gather this information. Each time the students conduct the experiment, there will be a different amount of air in the balloon.

3. Thread the fishing line through the straw, then attach each end of the line to the back of two classroom chairs. Pull the chairs apart to stretch the line tightly.

4. Inflate a balloon using one breath and keep it tightly closed using a binder clip while carefully taping the balloon to the straw.



Side View

Top View

5. Draw a vertical line on chart paper to create two columns. Label the two columns **“Number of Breaths”** and **“Distance Traveled.”**

6. Place a **“1”** on the chart under **“Number of Breaths.”**

7. Ask students to determine from where we should launch the balloon (far to one end of the fishing line). Mark (masking tape) the location of the front of the balloon on the floor to indicate the launch point.

8. Launch the balloon.

9. Once the balloon comes to a stop, mark the location of the front of the balloon on the floor.

10. Have a student measure, using nonstandard measurement or ruler/measuring tape/yardstick, how far the balloon traveled from its starting point.

11. Record this measurement on the chart under **“Distance Traveled”** next to the **“1”** recorded in the **“Number of Breaths”** column. Include the unit of measurement *(e.g., cubes, inches, centimeters, etc.).*

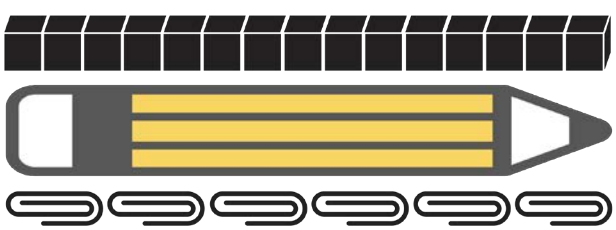
12. Ask the students what they think will happen if we use two breaths.

Non-Standard Units

Any item that can be used to measure something, e.g. paper clips, blocks, finger, spaces, handspans, feet.

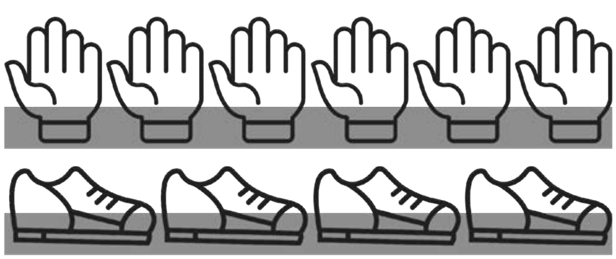
Examples

The pencil is 15 blocks long.



The pencil is 6 paper clips long.

The bar is 6 handspans long.



The bar is 4 ‘feet’ long.

Number of Breaths	Distance Traveled
1	

13. Perform the experiment using two breaths.

14. Perform the experiment using 4 breaths.

15. Ask students to estimate how far 10 breaths would take the balloon. Have them give reasons for their estimates.

16. Perform the experiment with 10 breaths to determine how close the estimates were.

17. Have students graph (pictograph, line graph, bar graph, etc.) the data collected.

Extensions:

- Encourage students to think of other forms of nonstandard measurement to determine the distance the balloon traveled. Use one or more of their suggestions and repeat the experiment.
- Have students consider how they might use the data from this activity to predict how far the rocket (balloon) would go if there were two engines. Three engines. Four engines. Have them graph this new data.
- Have students apply what they learned in this experiment. Ask students to consider whether the amount of fuel in a rocket determines how far it travels. Ask students to consider other factors such as size and weight that may affect the distance a rocket travels.

ARTEMIS

National Aeronautics and Space Administration

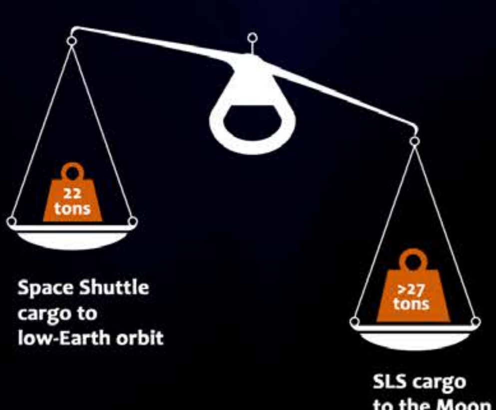
NASA

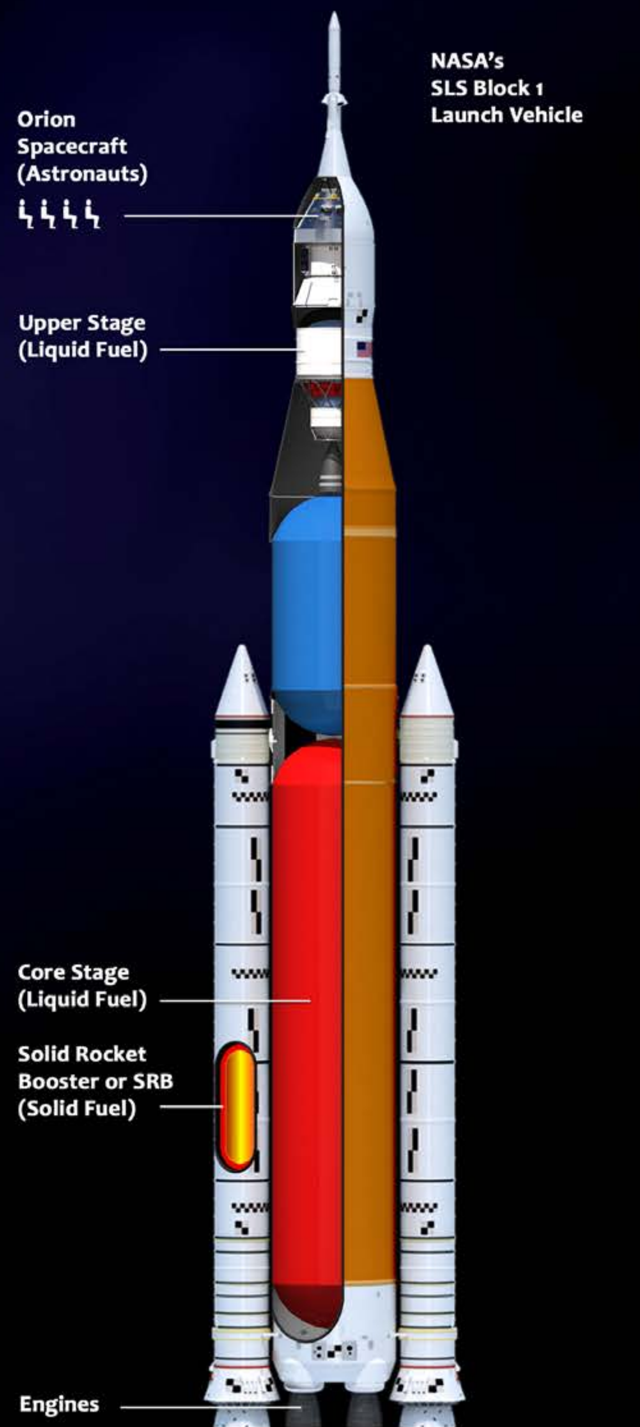
MEET THE ROCKET

If you wonder how NASA's Space Launch System, or SLS, compares to earlier generations of NASA launch vehicles:

SLS will produce 13% more thrust at launch than the space shuttle and 15% more than Saturn V during liftoff and ascent.

SLS will launch more cargo to the Moon than the space shuttle could send to low-Earth orbit.





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For more information:
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