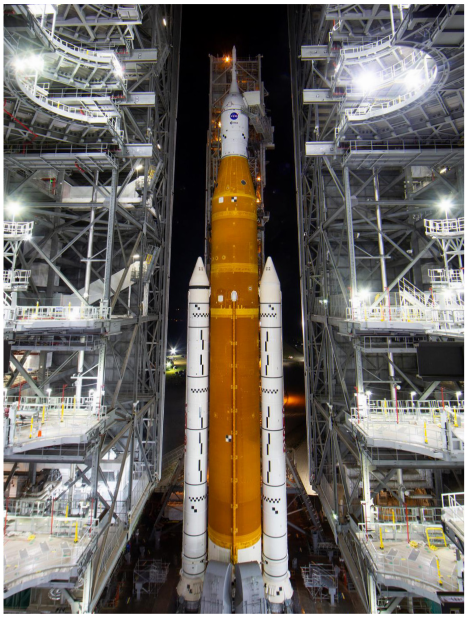
National Aeronautics and Space Administration



How Far Will It Go?

A Lesson in Graphing

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.

Artemis Program

Teacher Notes

With NASA's Artemis campaign, we are exploring the Moon for scientific discovery, technology advancement, and to learn how to live and work on another world as we prepare for human missions to Mars. We will collaborate with commercial and international partners and establish the first long-term presence on the Moon.

America's Rocket for Deep Space Exploration

NASA's SLS (Space Launch System) is a super heavy-lift rocket that provides the foundation for human exploration beyond Earth orbit. With its unprecedented capabilities, SLS is the only rocket that can send NASA's Orion spacecraft, four astronauts, and large cargo directly to the Moon on a single mission.

Offering more payload mass, volume, and departure energy than any other single rocket, SLS can support a range of mission objectives, while reducing mission complexity. The SLS rocket is designed to be evolvable, which makes it possible to increase its capability to fly more types of missions, including human missions to the Moon and Mars and robotic scientific missions to the Moon, Mars, and the outer planets.

SLS is designed for deep space missions and will send Orion or other cargo to the Moon, which is nearly 1,000 times farther than where NASA's International Space Station resides in low Earth orbit. The high-performance rocket provides the power to help Orion reach a speed of 24,500 mph—the speed needed to send it to the Moon.

SLS is part of NASA's backbone for deep space exploration, along with the Orion spacecraft, supporting ground systems, advanced spacesuits and rovers, and commercial human landing systems.

RS-25 Core Stage Engine

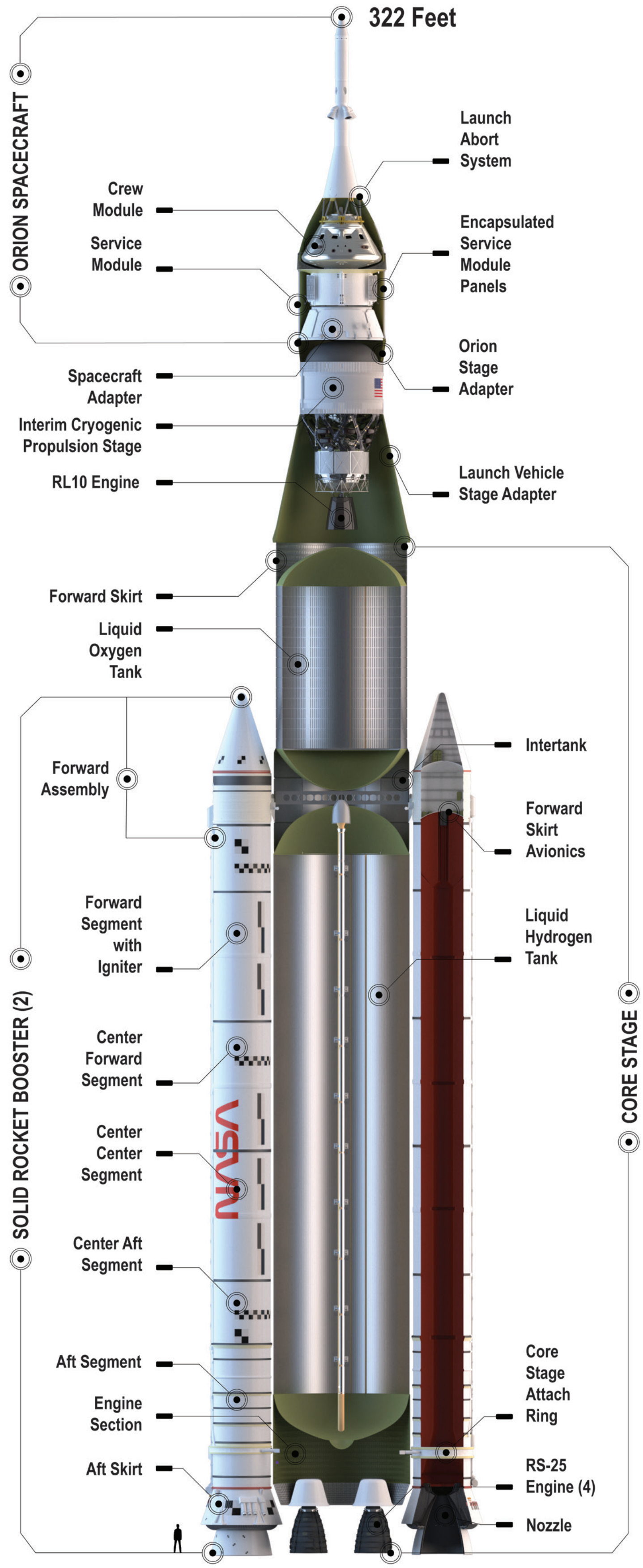
NASA's SLS (Space Launch System) core stage is powered by RS-25 engines that combine proven performance with advanced engineering and technology. SLS will launch astronauts on the Artemis missions to the Moon and eventually expeditions to Mars.

The SLS rocket has four RS-25 engines fueled by liquid hydrogen and liquid oxygen. The four engines provide about 2 million lbs. of thrust for the eight-minute climb to Earth orbit.

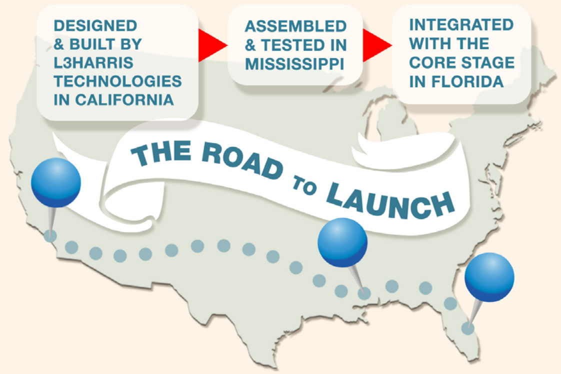
The SLS Program began with an inventory of 16 RS-25 flight engines – built by L3Harris Technologies – transferred from the shuttle program. During the Space Shuttle Program, the RS-25 underwent several design updates to improve service life, durability, reliability, safety, and performance. SLS takes advantage of that technology investment and experience and builds on it using contemporary technologies and processes to improve manufacturability, affordability, and performance.

Engine manufacturer L3Harris is producing 24 new RS-25 engines. The new engines will use a simplified design, new manufacturing technologies, new inspection technologies, and processes that reduce handling and support labor, hardware defects, and production time.

One of the most promising technologies is selective laser melting (SLM). This technology uses a high-energy laser and metal powder to produce parts more quickly and at lower cost than is possible with conventional manufacturing methods. Because they are made of fewer separate parts, engine design is simplified, and manufacturing time and cost is reduced.


322 Feet
ORION SPACECRAFT
Launch Abort System
Crew Module
Encapsulated Service Module Panels
Service Module
Orion Stage Adapter
Spacecraft Adapter
Interim Cryogenic Propulsion Stage
RL10 Engine
Launch Vehicle Stage Adapter
Forward Skirt
Liquid Oxygen Tank
Intertank
Forward Assembly
Forward Skirt Avionics
Forward Segment with Igniter
Liquid Hydrogen Tank
Center Forward Segment
CORE STAGE
Center Center Segment
SOLID ROCKET BOOSTER (2)
Center Aft Segment
Core Stage Attach Ring
Aft Segment
Engine Section
RS-25 Engine (4)
Aft Skirt
Nozzle
NASA

WHAT IS THE RS-25 ENGINE?



National Aeronautics and Space Administration
NASA
ARTEMIS

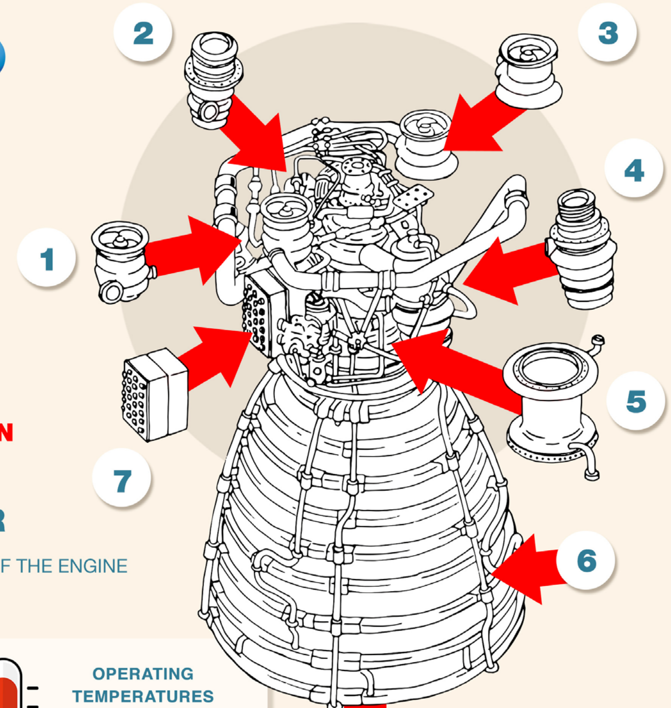
FOR THREE DECADES, THE RS-25 ENGINE PROPELLED THE SPACE SHUTTLE. NOW, THIS POWERFUL ENGINE HAS BEEN SELECTED FOR THE SLS (SPACE LAUNCH SYSTEM) FOR ITS HIGH PERFORMANCE AND RELIABILITY.

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.

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** AND **LIQUID OXYGEN** INTO THE COMBUSTION CHAMBER

5 MAIN COMBUSTION CHAMBER

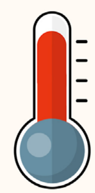
COMBINES **FUEL** AND **OXYGEN** IN THE "BELLY" OF THE ENGINE

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

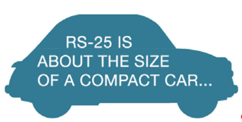


OPERATING TEMPERATURES RANGE FROM

-423°F TO 6000°F

14' TALL

8' DIAM.



* 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.

SLS-5545-2025

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 lbs. of thrust to launch the agency's Orion spacecraft to the Moon. Before its first flight, NASA tested 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 sent Orion to the Moon in the B-2 Test Stand, part of the Thad Cochran Test Stand, at NASA's Stennis Space Center in 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 were carried out for the first time, such as fueling and pressurizing the stage, and the test series culminated with firing up all four RS-25 engines to demonstrate that the engines, tanks, fuel lines, valves, pressurization system, and software could all perform together as they needed to on launch day.

SLS Core Stage

Core Stage for the Artemis I mission in the B-2 Test Stand

The SLS core stage is the tallest stage NASA has ever built. Towering 212 feet with a diameter of 27.6 feet, it stores cryogenic liquid hydrogen and liquid oxygen and all the systems that will feed the stage's four RS-25 engines.

It also houses the flight computers and much of the avionics needed to control the rocket's flight. The core stage is designed to operate for approximately 500 seconds before reaching low Earth orbit and separating from the upper stage and NASA's Orion spacecraft.

The core stage serves as the backbone of the rocket, supporting the weight of the payload, upper stage, and Orion spacecraft, as well as structurally supporting and carrying the thrust of its four RS-25 engines and two five-segment solid rocket boosters attached to the engine and intertank sections.

Boeing, the prime contractor for the SLS core stage, uses state-of-the-art manufacturing equipment to build the stage at NASA's Michoud Assembly Facility in New Orleans. Michoud is a unique advanced manufacturing facility where NASA has built spacecraft components for decades, including the space shuttle's external tanks and Saturn launch vehicle stages for Apollo.

SLS (SPACE LAUNCH SYSTEM)

ARTEMIS TESTING:

TEST LIKE YOU FLY

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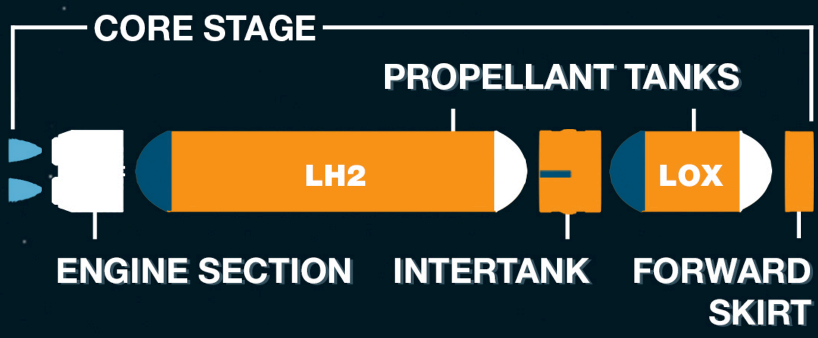
TESTING THE WORLD'S LARGEST ROCKET STAGE



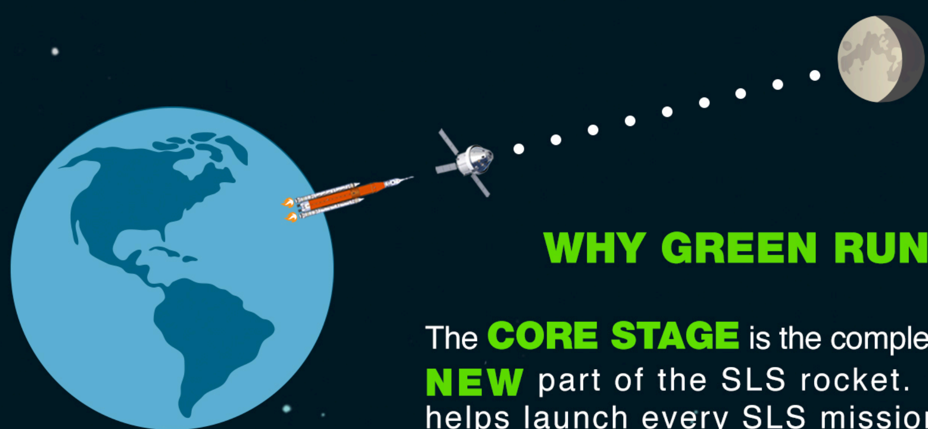
GREEN: New, untested rocket hardware

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

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.



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.

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)

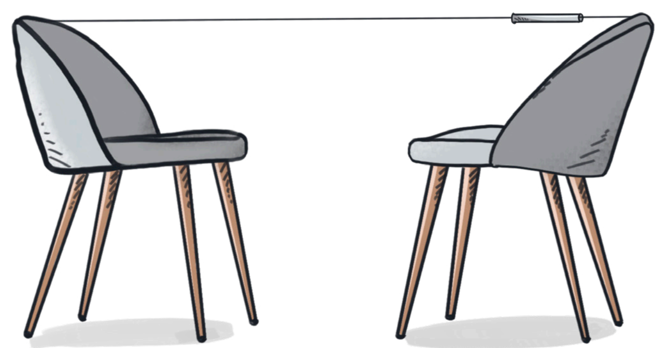
Background

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.



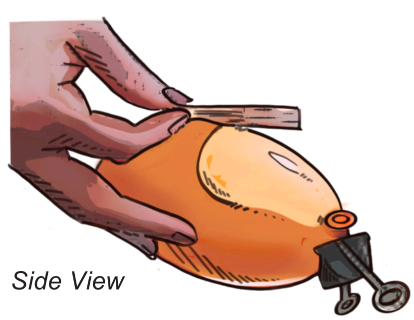
Procedure

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 engine.

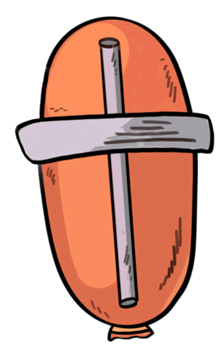
2. Ask students if they know how a rocket works. Explain to them they will be conducting a science experiment to determine how the amount of air in a balloon changes the distance the balloon (rocket) will travel. Students, just like the astronauts in space and scientists on Earth, will conduct an experiment 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 as few breaths as possible (count how many) 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 the number of breaths it took to inflate the balloon under “**Number of Breaths**.”

7. Ask students to determine from where we should launch the balloon (either 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.

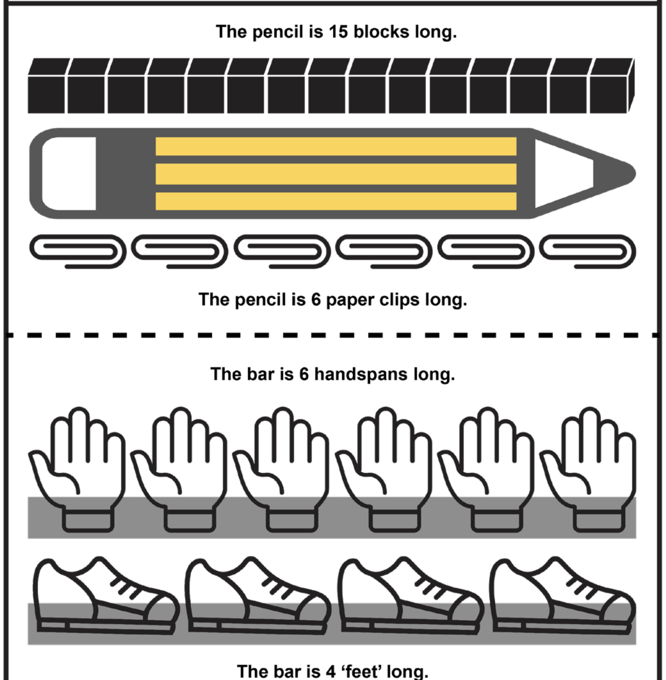
11. Record this measurement on the chart under “**Distance Traveled**” next to the first number recorded in the “**Number of Breaths**” column.

12. Ask students what they think will happen if they use an additional breath from the first number used.

Non-Standard Units

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

Examples



Number of Breaths	Distance Traveled

13. Perform the experiment using this new number of breaths.

14. Perform the experiment using two breaths more than the last experiment run.

15. Ask students to estimate how far 10 breaths would take the balloon. Have them give reasons for their estimates. **NOTE:** If they have already reached 10 breaths, pick a number larger than 10.

16. Perform the experiment with the number of breaths in step above 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.

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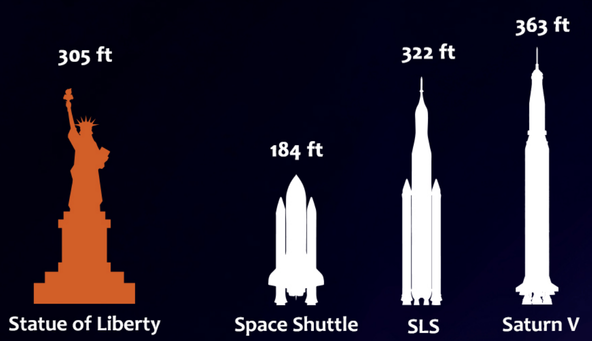
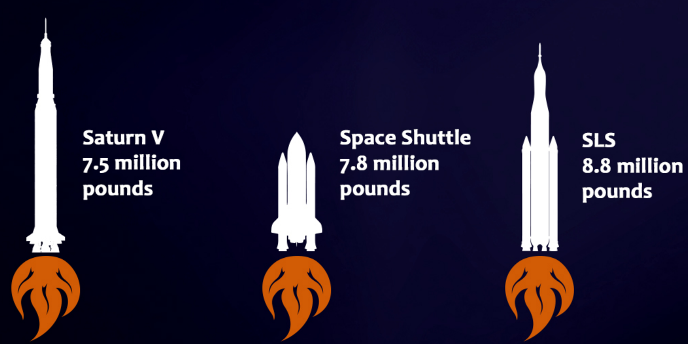
M E E T   T H E   R O C K E T

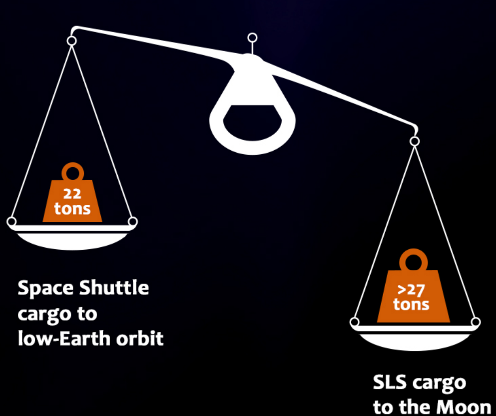
If you wonder how NASA's SLS (Space Launch System) compares to earlier generations of NASA launch vehicles:

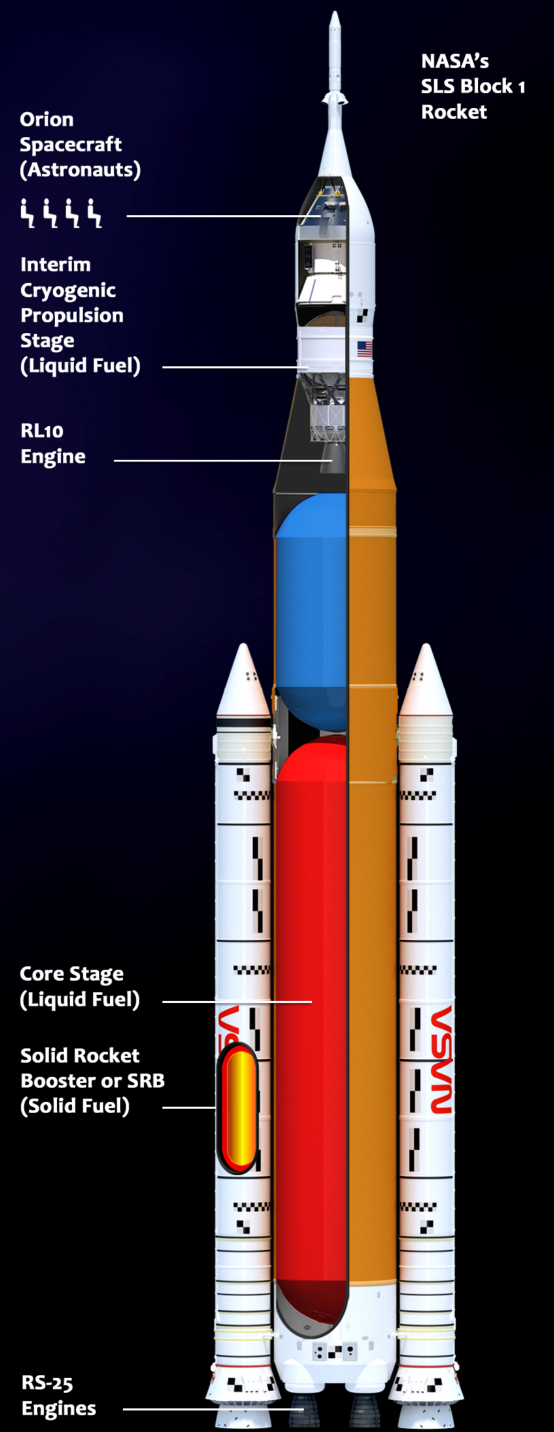


SLS produces 13% more thrust at launch than the space shuttle and 17% more than Saturn V during liftoff and ascent.



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





National Aeronautics and Space Administration

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www.nasa.gov

SLS 5534 2025

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