

A photograph of a Space Shuttle in orbit above Earth. The shuttle is oriented vertically, with its nose pointing towards the top of the frame. The Earth's horizon is visible in the background, showing a blue sky and white clouds. The shuttle's solar panels are extended horizontally on either side of the main body. The shuttle's external tank and solid rocket boosters are visible at the top of the frame.

SUNDAY, JULY 19 2020

SPACE DAY

**Celebrating the innovations and
technology that will bring us back to
the moon... and beyond.**



196 Main St
Windsor, VT 05089
www.americanprecision.org
802-674-5781

Why does the American Precision Museum celebrate Space Day?

- **Innovation.** We celebrate innovation and ingenuity here, and new ways to solve problems (like creating machine tools to improve precision). As air and space programs create new and better technology and make new discoveries, we all benefit.
- **Jobs.** Space and Air programs invest billions of dollars in the US economy, and create millions of jobs in manufacturing related fields.
- **Precision history.** As we look back to the past at APM, we also like to show you the present and imagine the future. What NASA, Space-X and Boeing are able to do would not be possible without precision manufacturing.

From these perspectives, we'd like to share with you some of NASA's most cutting edge missions and some of the technology being used to make them happen. This packet includes freely available images from NASA's galleries - specifically what a person who appreciates precision might find interesting.

TABLE OF CONTENTS:

Innovation & Business

Commercial Crew: SpaceX

COMMERCIAL CREW PROGRAM - Space-X and Boeing are working on partnership with NASA to supply the ISS. The goal is to have safe, reliable and cost-effective access to and from the International Space Station and foster commercial access to other potential low-Earth orbit destinations.

NASA selected Boeing and SpaceX in September 2014 to transport crew to the International Space Station from the United States. These integrated spacecraft, rockets and associated systems will carry up to four astronauts on NASA missions, maintaining a space station crew of seven to maximize time dedicated to scientific research on the orbiting laboratory. Launches are ongoing - SpaceX's Dragon has had 22 trips to the ISS so far.

Artemis Mission

The **ARTEMIS MISSION** to return to the moon is being built and tested at sites across the nation, and scheduled to launch in 2024. "We will build sustainable elements on and around the Moon that allow our robots and astronauts to explore more and conduct more science than ever before."

- **Overview**
- **Orion**
- **xEMU Suit**
- **SLS**

Mars Rover Perseverance

The **MARS ROVER PERSERVERANCE** (and its helicopter Ingenuity) is scheduled to launch for the Red Planet around July 30th 2020. "The mission takes the next step by not only seeking signs of habitable conditions on Mars in the ancient past, but also searching for signs of past microbial life itself. The Mars Perseverancerover introduces a drill that can collect core samples of the most promising rocks and soils and set them aside in a "cache" on the surface of Mars. The mission also provides opportunities to gather knowledge and demonstrate technologies that address the challenges of future human expeditions to Mars."

Psyche Mission

The **PSYCHE MISSION**, scheduled to launch in 2022, is a mission to explore an asteroid made entirely of metals. Because scientists believe Earth's core is made of metals like this one, research on Psyche may answer questions about how planets form.

SPACE DAY AT APM: NASA INNOVATION

Where do we see NASA's benefits today?

NASA's fundamental research can be traced to ongoing innovation.

NASA'S WORK ON THESE TECHNOLOGIES

- Advanced composite structures
- Chevrons
- Laminar flow aerodynamics
- Advanced computational fluid dynamics (CFD) and numeric simulation tools

- Advanced composite structures
- Chevrons
- Laminar flow aerodynamics
- Advanced computational fluid dynamics (CFD) and numeric simulation tools
- Advanced ice protection system

WAS TRANSFERRED FOR USE HERE



Boeing
747-8

Boeing
787

TODAY'S BENEFITS

16%
more fuel-efficient/reduced
CO₂ emissions

30%
noise reduction

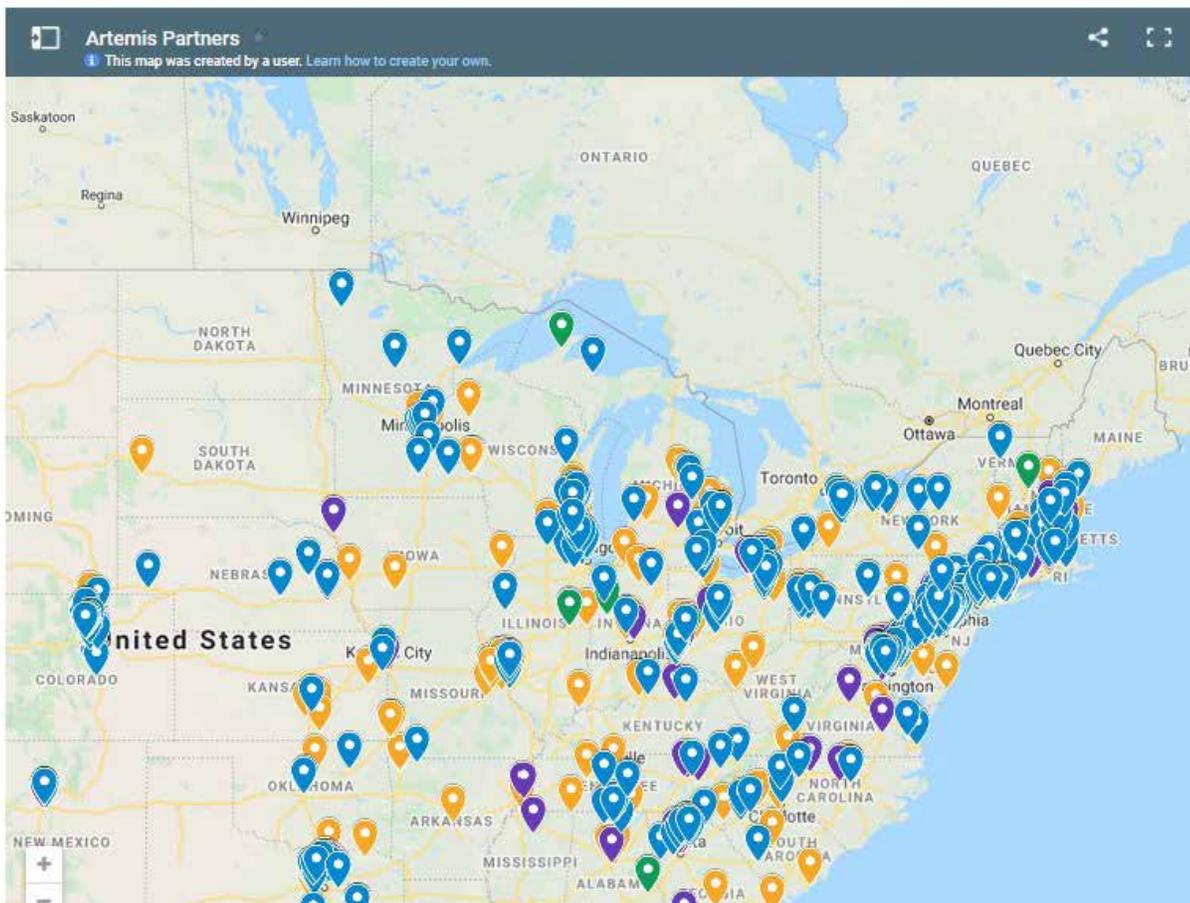
30%
lower NO_x emissions

20%
more fuel-efficient/reduced
CO₂ emissions

28%
lower NO_x emissions

60%
smaller noise footprint

SPACE DAY AT APM: ARTEMIS CONTRACTS



NASA Prime Contractors Aerojet Rocketdyne, Boeing, Jacobs, Lockheed Martin, and Northrop Grumman currently have over 3,800 suppliers contributing to Orion, the SLS rocket, and the lunar spaceport at Kennedy. With NASA investments, additional U.S. companies, including small businesses, are advancing technologies and systems needed for a sustained presence on the Moon by 2028.

The Gateway will be a small spaceship in orbit around the Moon with components from U.S. companies, as well as international partners. The Gateway will provide access to more of the lunar surface than ever before with living quarters for astronauts, a lab for science and research, ports for visiting spacecraft, and more.

Through NASA's Commercial Lunar Payload Delivery Services (CLPS), American companies of varying sizes will bid on delivering science and technology payloads to the surface of the Moon.

Tipping Point awards support industry-developed space technologies that can foster the development of commercial space capabilities and benefit future NASA missions. A technology is considered at a tipping point if an investment in a demonstration will significantly mature the technology and bring the technology to market for both government and commercial applications.

NASA's Announcement of Collaboration Opportunity (ACO) helps reduce the development cost of commercial space technologies and accelerate their infusion into future missions.

The Game Changing Development (GCD) program identifies and rapidly matures high-impact capabilities and space technologies.

NASA's Small Business Innovation Research (SBIR) program provides an opportunity for small companies and research institutions to participate in government-sponsored research and development efforts in key technology areas.

While the Artemis Partners map highlights the United States, this endeavor reaches internationally.

<https://www.nasa.gov/content/artemis-partners>

SPACE DAY AT APM: SPACE-X

New era of human spaceflight

NASA astronauts will blast off from American soil for the first time in almost nine years when the SpaceX Crew Dragon launches atop a Falcon 9 rocket to the International Space Station (ISS). In 2014, NASA allocated \$8.5 billion to SpaceX and Boeing to develop crew capsules

Boeing CST-100 Starliner
Crew: 7
Height: 5.0 metres



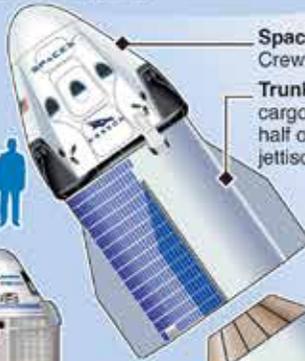
Reusable self-flying capsule, launched by ULA Atlas V rocket. Starliner is designed to fly up to 10 missions to ISS



SpaceX Crew Dragon
Crew: 7. Height: 8.1 metres

Trunk: Carries unpressurized cargo. Solar panels cover half of surface. Trunk jettisoned prior to re-entry

Second stage: Contains avionics and flight control computers



SpaceX Falcon 9 rocket

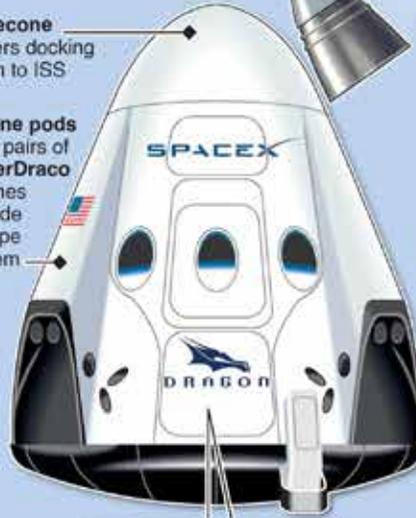


Inter-stage adapter

Merlin 1D Vac engine: Generates 801kN (81,700kg) of thrust in vacuum

Nosecone
Covers docking hatch to ISS

Engine pods
Four pairs of SuperDraco engines provide escape system

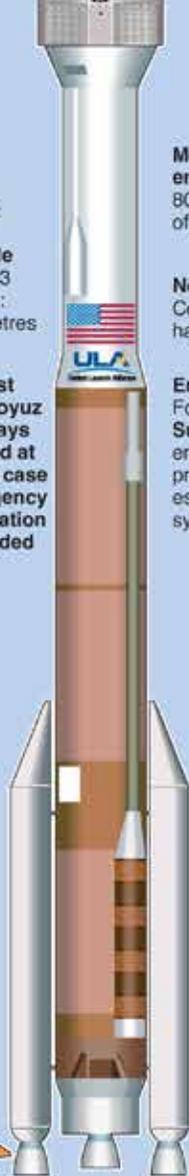


Landing legs



Soyuz crew module
Crew: 3
Height: 7.5 metres

At least one Soyuz is always docked at ISS in case emergency evacuation is needed



Soyuz 2-1a launch vehicle
Roscosmos' Soyuz has been ferrying crew to ISS since November 2000
Cost: Up to \$86m/seat

ULA Atlas V rocket
Dec 2019: Unmanned test flight of Boeing Starliner fails to reach ISS
Cost: \$90m/seat

May 27, 2020: Doug Hurley (above left) and Bob Behnken (right) will be first two NASA astronauts to fly Crew Dragon to ISS

Falcon 9 reusable first stage: Nine Merlin 1D engines, each with sea-level thrust of 654kN (66,700kg)
Cost: \$58m/seat

SPACE DAY AT APM: ARTEMIS



The tip of the A of Artemis points beyond the Moon and signifies that our efforts at the Moon are not the conclusion, but rather the preparation for all that lies beyond.

BLUE EARTH CRESCENT +

The crescent shows missions from our audience's perspective. From Earth we go. Back to Earth all that we learn and develop will return. This crescent also visualizes Artemis' bow as the source from which all energy and effort is sent.



The Moon is our next destination and a stepping stone for Mars. It is the focus of all Artemis efforts.

RED TRAJECTORY +

The trajectory moves from left to right through the crossbar of the "A" opposite that of Apollo. Thus highlighting the distinct differences in our return to the moon. The trajectory is red to symbolize our path to Mars.

A +

The A symbolizes an arrowhead from Artemis' quiver and



With the Artemis program, NASA will land the **first woman and next man on the Moon by 2024**, using innovative technologies to explore more of the lunar surface than ever before. We will collaborate with our commercial and international partners and establish sustainable exploration by the end of the decade. Then, we will use what we learn on and around the Moon to take the next giant leap – **sending astronauts to Mars.**

The Artemis Mission is an ambitious project that features

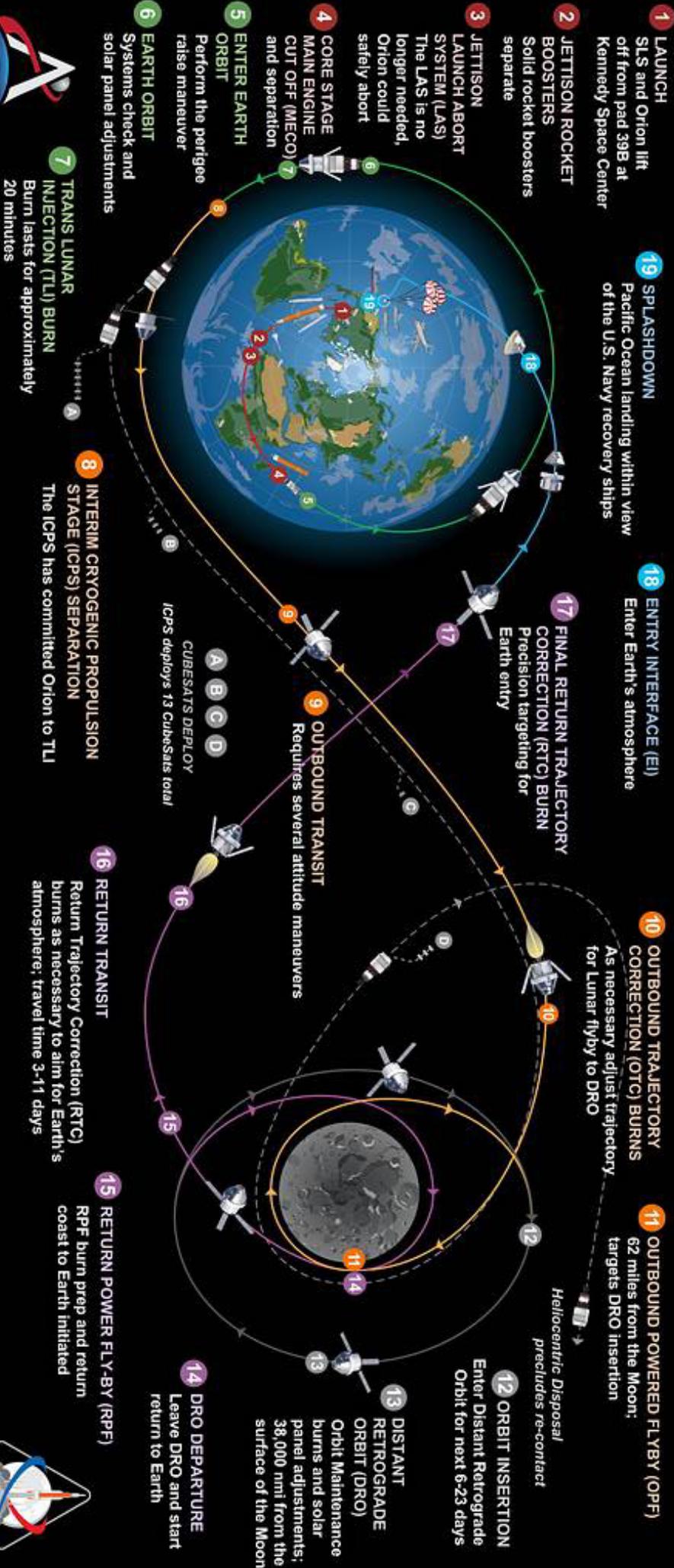
- new ground launch systems,
- space launch systems,
- a new lunar craft names Orion,
- a lunar outpost named Gateway,
- lunar landers,
- and new Exploration Extravehicular Mobility Units (xEMUs)

SPACE DAY AT APM: ARTEMIS

<https://www.nasa.gov/sites/default/files/thumbnails/image/artemis-1-update.jpg>

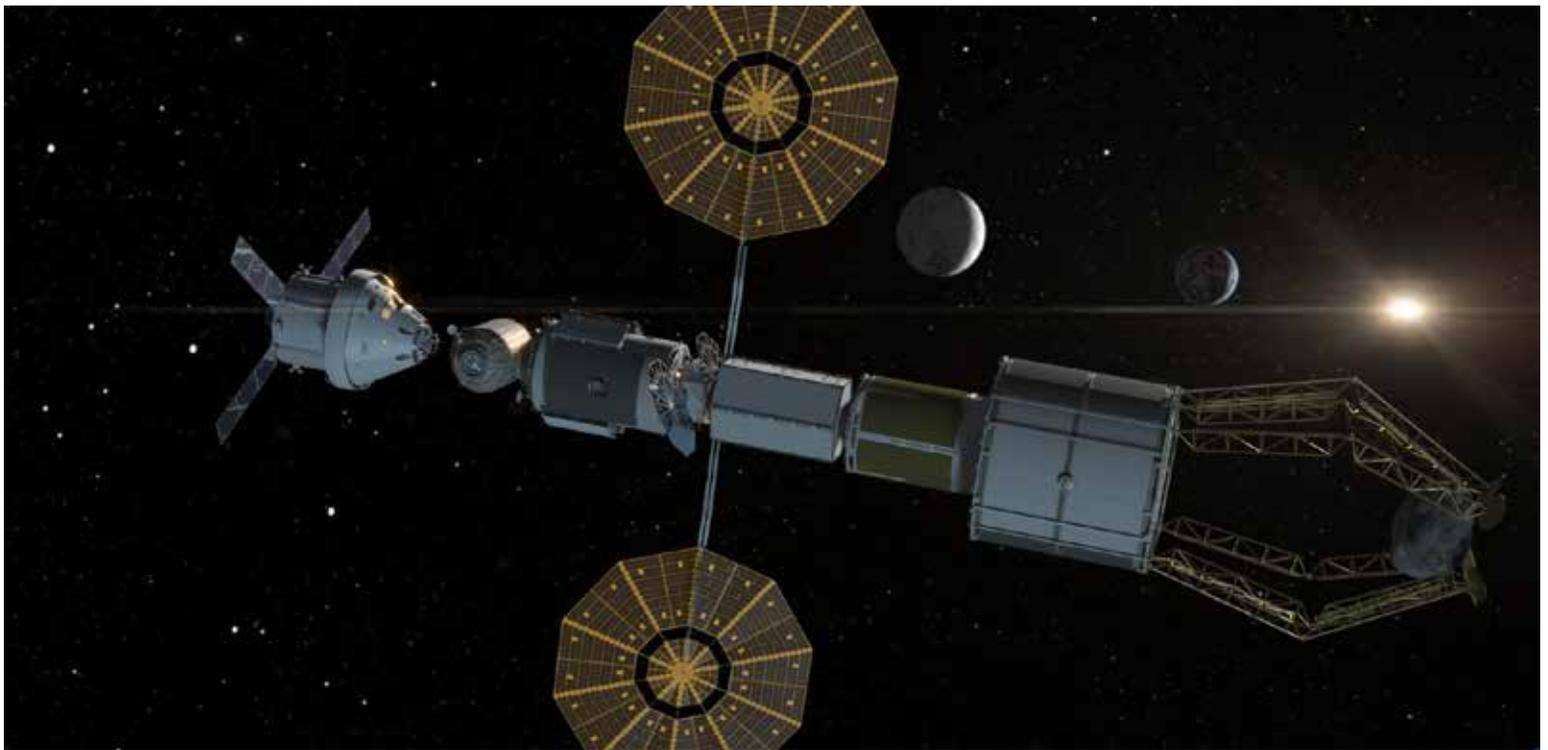
ARTEMIS I

The first uncrewed, integrated flight test of NASA's Orion spacecraft and Space Launch System rocket, launching from a modernized Kennedy Spaceport



Total distance traveled: 1.3 million miles – Mission duration: 26-42 days – Re-entry speed: 24,500 mph (Mach 32) – 13 CubeSats deployed

SPACE DAY AT APM: ORION



Images from: <https://www.nasa.gov/exploration/systems/orion/gallery/index.html>

SPACE DAY AT APM: ORION

SPACECRAFT TESTING

ORION

THE VACUUM CHAMBER IS ROUGHLY THE SIZE OF THE U.S. CAPITOL ROTUNDA (100 FEET IN DIAMETER, BY 122 FEET TALL).

THE AMOUNT OF ALUMINUM REQUIRED TO BUILD THE VACUUM CHAMBER EQUALS ABOUT 1,000,000,000 SODA CANS.

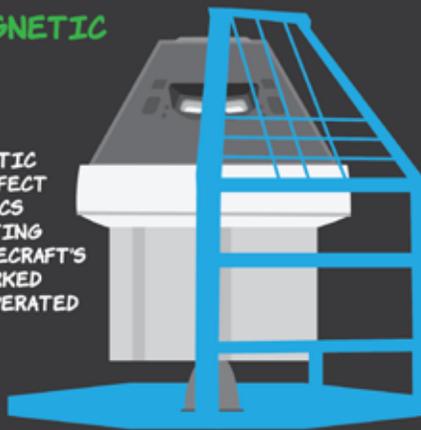
THE ORION SPACECRAFT, CONSISTING OF THE CREW AND SERVICE MODULES, ACED ITS TESTS IN EXTREME SPACE CONDITIONS AT THE WORLD'S PREMIER SPACE ENVIRONMENTS TEST FACILITY AT NASA'S PLUM BROOK STATION.

THERMAL -VACUUM TESTING

THIS TESTING ENSURES ORION'S THERMAL CONTROL SYSTEM PERFORMS CORRECTLY IN THE VACUUM OF SPACE AT EXTREME FLIGHT CONDITIONS (-250°F TO 300°F).

ELECTROMAGNETIC IMMUNITY

ALL ELECTRONIC COMPONENTS HAVE AN ELECTROMAGNETIC FIELD THAT CAN AFFECT OTHER ELECTRONICS NEARBY. THIS TESTING ENSURED THE SPACECRAFT'S ELECTRONICS WORKED PROPERLY WHEN OPERATED AT THE SAME TIME.



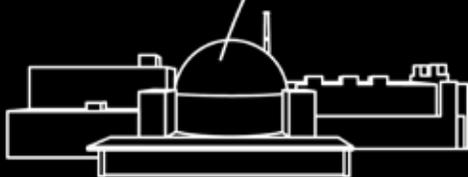
AIR PRESSURE



TEMPERATURE



ELECTROMAGNETIC



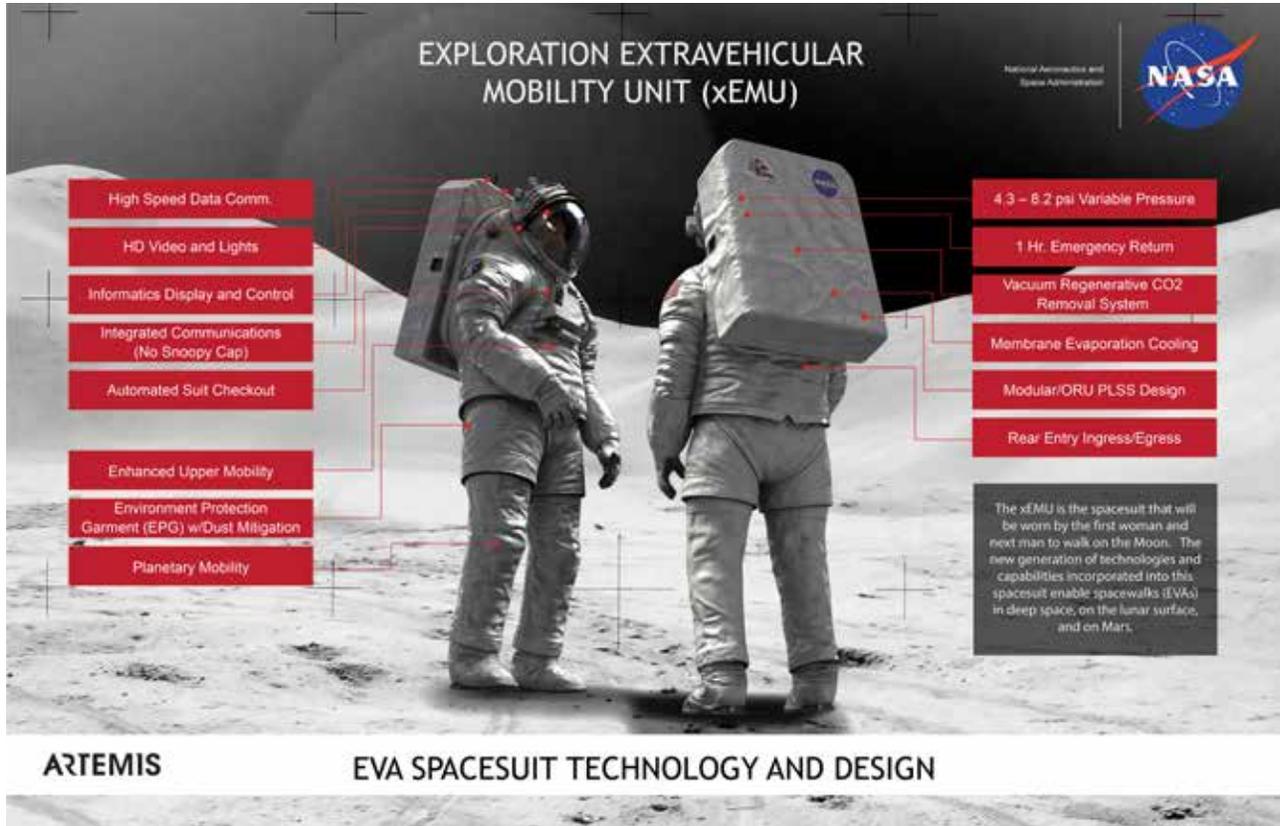
PLUM BROOK STATION



SANDUSKY, OHIO



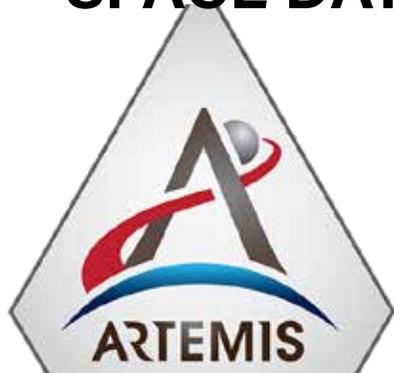
SPACE DAY AT APM: ARTEMIS AND SUITS



Exploration EMU (xEMU) Development Unit. Computer-aided design (CAD) graphic rendering side view. The xEMU is an improved design for increased mobility necessary for the Artemis program. The xEMU project patch which will eventually be replaced with the EVA patch.

Images from:
<https://www.nasa.gov/suitup/spacesuit-gallery>
and
<https://www.nasa.gov/suitup/gallery>

SPACE DAY AT APM: ARTEMIS AND SUITS



Above left: Photo of Upper Torso assembly without Thermal Micrometeoroid Garment cover layer and above right: with the layer. The shoulder is an improved design for increased mobility necessary for the Artemis program. The pink anodizing of the aluminum is a protective layer and the distinctive color helps engineers to identify this prototype. *From <https://www.nasa.gov/suitup/spacesuit-gallery>*



SPACE DAY AT APM: ARTEMIS' SLS



One of the segments of the SLS on the road for assembly - it's huge.

Images in this section from <https://www.nasa.gov/exploration/systems/sls/multimedia/images.html>



ARTEMIS

SPACE LAUNCH SYSTEM

EXPLORATION UPPER STAGE

Sending Astronauts and the Largest Cargo to Deep Space

National Aeronautics and Space Administration



The Exploration Upper Stage (EUS) will replace the Interim Cryogenic Propulsion Stage (ICPS) as the SLS in-space stage on the evolved SLS Block 1B rocket, allowing NASA to send astronauts and large/heavy cargo to the Moon in a single launch.

ICPS:

DRY WEIGHT
7,690 lbs

FUELED WEIGHT
71,605 lbs



The **SINGLE-ENGINE ICPS** provides roughly

25,000
POUNDS OF THRUST

RL10 x 1

EUS:

DRY WEIGHT
28,940 lbs

FUELED WEIGHT
250,000 lbs



The **FOUR-ENGINE EUS** provides more than

97,000
POUNDS OF THRUST

RL10 x 4



TRANS-LUNAR INJECTION (TLI) is when the in-space stage of SLS performs the propulsive maneuver necessary to set the Orion spacecraft and cargo on a trajectory that will send them to the Moon.

SLS BLOCK 1 with **ICPS** can launch more than

26 METRIC TONS to the Moon

SLS BLOCK 1B with **EUS** can launch more than

37 METRIC TONS to the Moon

The evolved **SLS BLOCK 1B** rocket utilizes core stage and boosters identical to the **SLS BLOCK 1** to escape Earth's gravity, but **EUS's** greater size and four engines enable it to launch

42% MORE CARGO TO THE MOON

SPACE DAY AT APM: ARTEMIS' SLS

SPACE LAUNCH SYSTEM STACKING THE SLS BOOSTERS

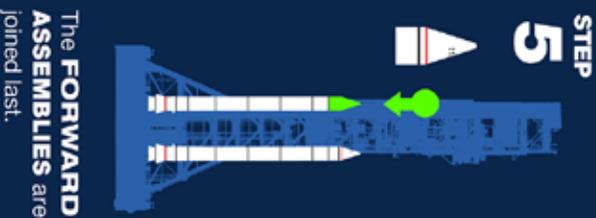
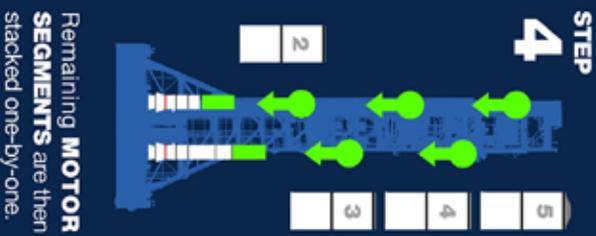
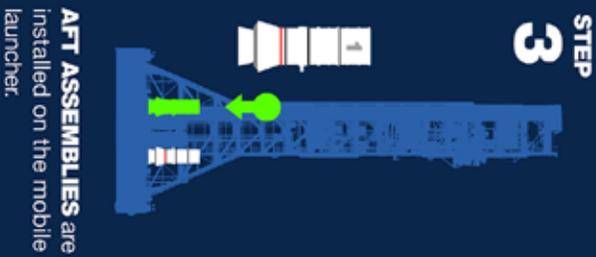
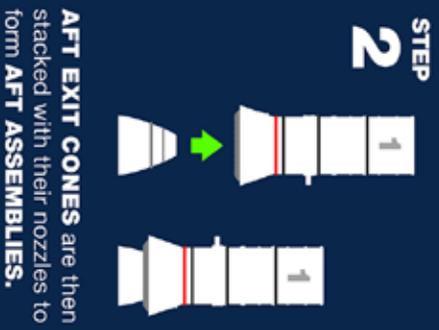
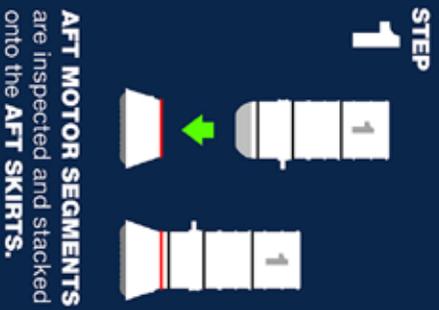
National Aeronautics and
Space Administration



Starting from the bottom up, each booster is built with an **AFT ASSEMBLY**, **MOTOR SEGMENTS** and a **FORWARD ASSEMBLY**.



Stacking begins with the **AFT ASSEMBLY** at the Rotation, Processing and Surge Facility at Kennedy Space Center.



At 177 feet tall, the **SOLID ROCKET BOOSTERS** are taller than a 16-story building, weigh 1.6 million pounds each and are the first elements of SLS to be installed on the mobile launcher at Kennedy's Vehicle Assembly Building.

Once boosters are assembled, the **SLS CORE STAGE** is lowered to the mobile launcher and joined to the two boosters, which carry **THE ENTIRE 5.75 MILLION-POUND FUELED WEIGHT OF THE SLS LAUNCH VEHICLE**.

SPACE DAY AT APM: ARTEMIS' SLS

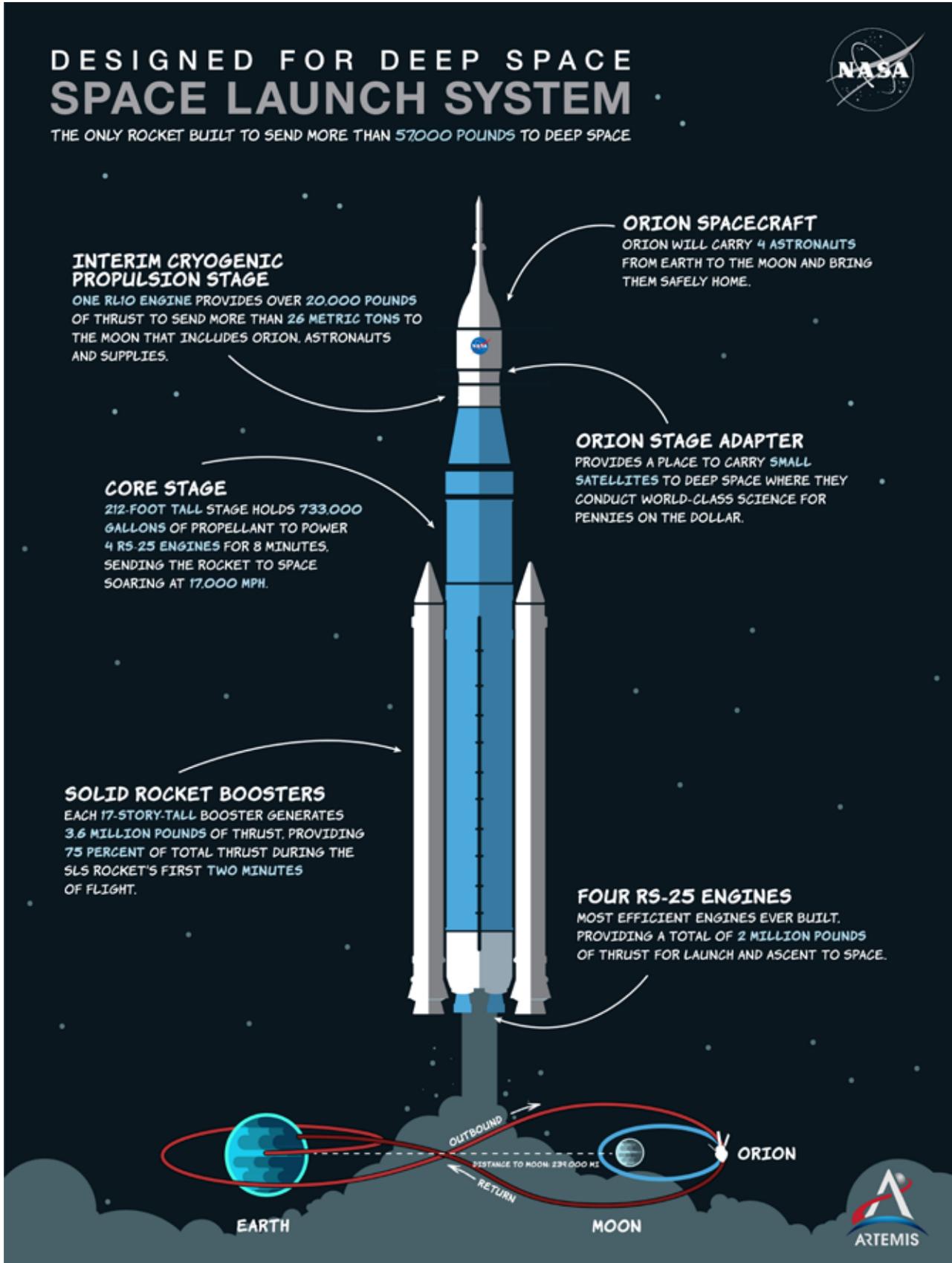


Image from: <https://www.nasa.gov/exploration/systems/sls/multimedia/images.html>



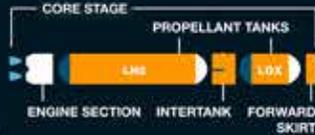
SPACE LAUNCH SYSTEM

LIQUID OXYGEN (LOX) TANK

Structural Testing of the WORLD'S LARGEST ROCKET STAGE

WHAT'S THE OBJECTIVE?

- ✓ Validate design models
- ✓ Verify the structure will withstand predicted loads
- ✓ Validate core stage for Artemis missions



The **LOX TANK** holds **196,000 GALLONS** of LIQUID OXYGEN

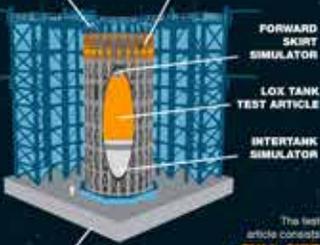


The **LOX TANK** is nested between the **FORWARD SKIRT & THE INTERTANK**, above the liquid hydrogen (**LH2**) tank.



More than **1 MILLION LBS** of special test equipment will apply mechanical loads to the LOX Structural Test Article (**STA**).

About **9 MILLION LBS** of combined force can be applied to the STA via **34 ACTUATORS**, designed to simulate stresses the SLS LOX tank will encounter in flight.



The test article consists of a **FULL-SIZE LOX TANK**, with intertank and forward skirt **SIMULATORS**.

The new test stand has a **REINFORCED CONCRETE FLOOR** with over **1600 ANCHORS**.

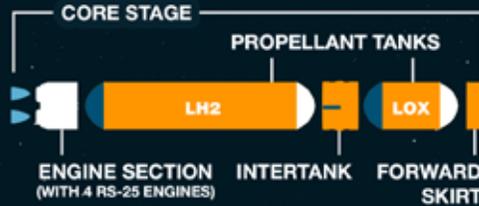
APPROXIMATELY 2,800 INSTRUMENTATION CHANNELS allow engineers to measure strain, deflection, temperature, pressure, sound and video.

24 TEST CASES are required, combining pressure, cryogenic fill, weight, static, shear, and bending loads.



ARTEMIS TESTING: GREEN RUN CHECKLIST

SPACE LAUNCH SYSTEM (SLS) Testing the World's Largest Rocket Stage



A total of eight Green Run tests minimize risk to the **ARTEMIS I** core stage and ensure the flight hardware satisfies design objectives and validates design models:

- TEST 1** Apply forces simulating launch to the unpowered, suspended core stage. ✓
- TEST 2** Turn on and check out core stage avionics. ✓
- TEST 3** Simulate potential issues to test systems that shut down other systems if there's a problem. ✓
- TEST 4** Test main propulsion system components that connect to the engines.
- TEST 5** Test thrust vector controls and check out all the related hydraulic systems.
- TEST 6** Simulate launch countdown to validate timeline and sequence of events.
- TEST 7** Load and drain more than 700,000 pounds of cryogenic propellants.
- TEST 8** Fire all four RS-25 engines for up to 8 minutes.



SPACE DAY AT APM: ARTEMIS NEXT MOON STEP CHALLENGE



YOUR CHALLENGE IS:

TELL US WHAT YOU'D SAY IF YOU STEPPED FOOT ON THE MOON AND CREATE AN IMAGE OF YOUR FOOTPRINT (PHOTO OR ARTWORK)

ENTRIES DUE: July 21, 2020 | 8:59 PM PST

The American Precision Museum is participating in the nationwide challenge for K-12 students to submit a quote of what they would say if they stepped foot on the Moon. They must also create an image of their footprint (actual or drawing). Please register at the web address shown above to submit your quote and image online. The "Next Moon Step" is a summer challenge leading up to an Artemis essay contest this fall, and we're excited to start some out-of-this-world brainstorming now! More information about the Artemis Mission and challenge rules can be found at: <https://www.futureengineers.org/nextmoonstep>

1. Make a footprint in the sand, or draw a footprint on paper.
2. What would you say, in 20 words or less?
2. Take a picture and tag @americanprecisionmuseum or #nextmoonstep

The "Next Moon Step" is a summer challenge leading up to an Artemis essay contest this fall, and we're excited to start some out-of-this-world brainstorming now! When Neil Armstrong first stepped foot on the Moon in 1969, he famously said, "That's one small step for a man, one giant leap for mankind." Now over 50 years later, NASA's Artemis program will return astronauts to the Moon. We want to hear what it means to you!

Your challenge is to create an image of your footprint (photo or artwork) and tell us what you would say, in 20 words or less, if you were the next person to step foot on the Moon. Your entry must be appropriate and original, and must not have been submitted for any other challenge or previously published. Exceptional entries may be marked in the gallery with "NASA gold stars". PLEASE DO NOT include your face or name in your entry. Be sure to check out the [RULES](#) for all details.

Here's some exciting information about the Artemis program, but the [EDUCATION RESOURCES](#) section below has even more information about lunar exploration. NASA's Artemis program has the bold challenge of landing "the first woman and the next man" on the Moon, specifically at the Lunar south pole region by 2024. Working with its industry and international partners, NASA will fine-tune precision landing technologies and develop new mobility capabilities that allow robots and crew to travel greater distances and explore new regions of the Moon. On the Moon's surface, NASA has proposed building a new Artemis Base Camp with habitat and rovers, to test new power systems and more to prepare for future human exploration of Mars.

AN EDUCATION PROGRAM FOR THE INNOVATORS OF TOMORROW

The "Next Moon Step" Challenge is presented in support of NASA's Artemis program. The student challenge is part of NASA's efforts to engage the public in its missions to the Moon and Mars. NASA is returning to the Moon for scientific discovery, economic benefits, and inspiration for a new generation. Working with its partners throughout the Artemis program, the agency will fine-tune precision landing technologies and develop new mobility capabilities that allow robots and crew to travel greater distances and explore new regions of the Moon. On the surface, the agency has proposed building a new habitat and rovers, testing new power systems and much more to get ready for human exploration of Mars. Charged with returning to the Moon in the next four years, NASA's Artemis program will reveal new knowledge about the Moon, Earth, and our origins in the solar system.

IN SUPPORT OF NASA'S ARTEMIS PROGRAM



SPACE DAY AT APM: MARS ROVER "PERSERVERANCE"

Features of the new Perseverance Rover

Mastcam-Z
Zoomable Panoramic Cameras

SuperCam
Laser Micro-Imager

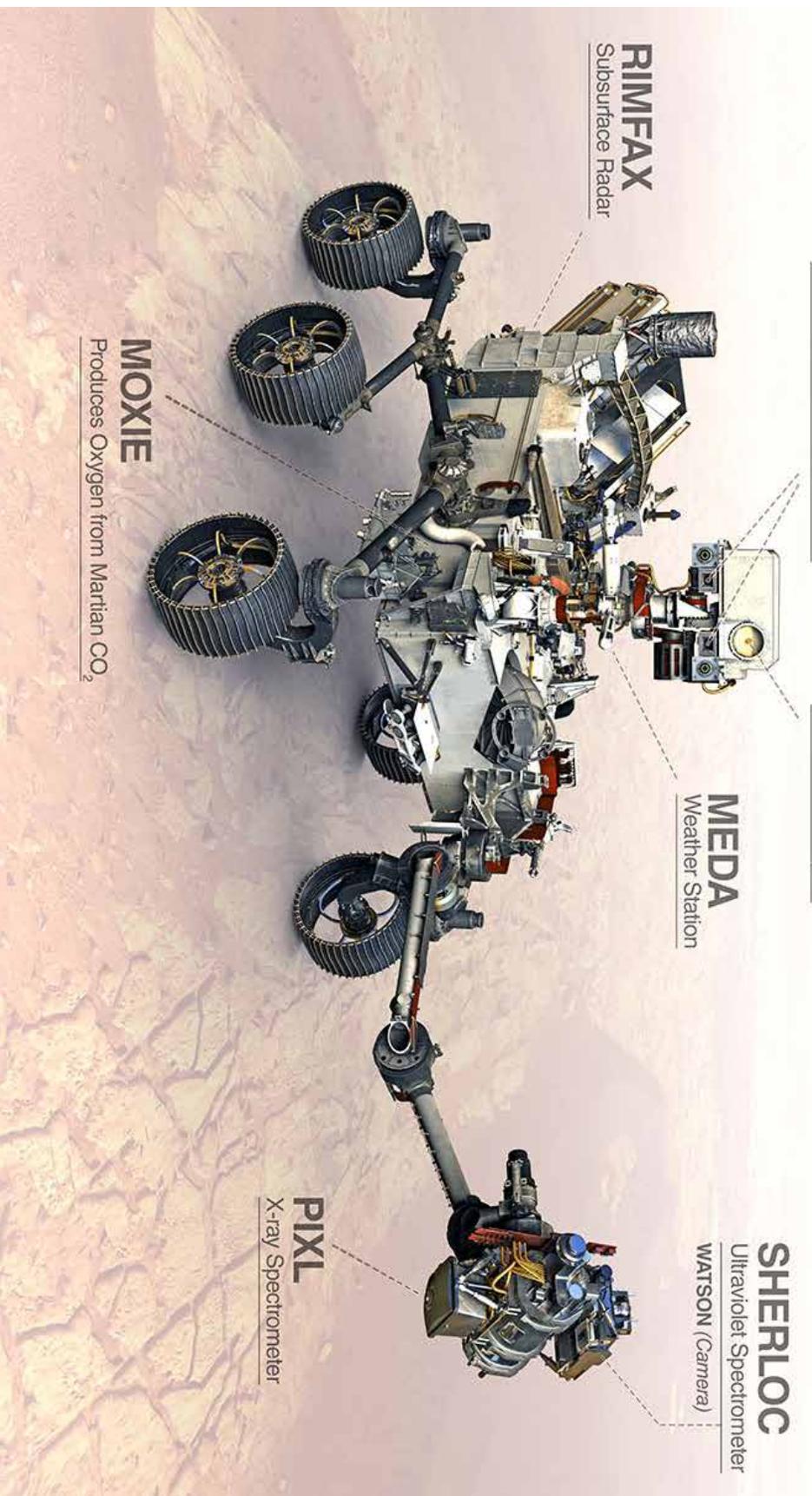
MEDA
Weather Station

SHERLOC
Ultraviolet Spectrometer
WATSON (Camera)

RIMFAX
Subsurface Radar

PIXL
X-ray Spectrometer

MOXIE
Produces Oxygen from Martian CO₂



SPACE DAY AT APM: MARS ROVER "PERSERVERANCE"



Ingenuity: the Perserverance Rover's Helicopter

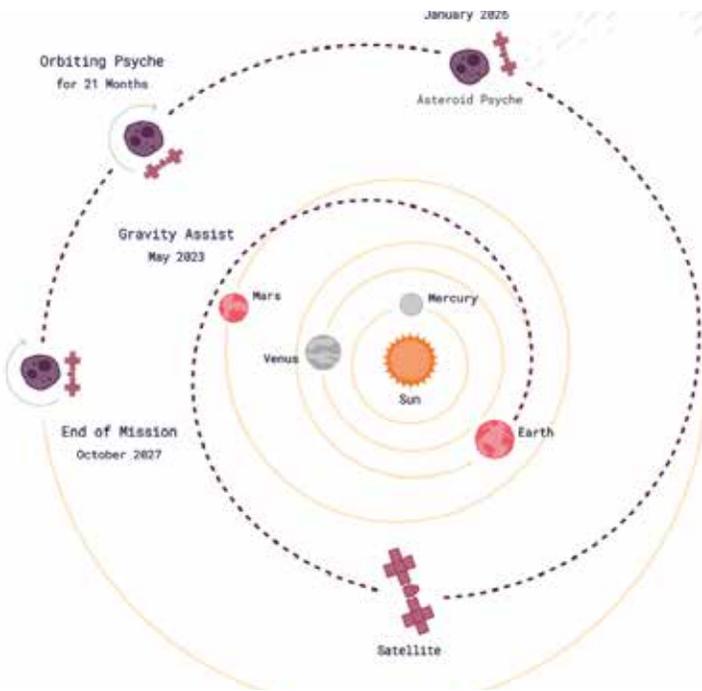


CURIOSITY

PERSEVERANCE

Rover Wheel Design Update

SPACE DAY AT APM: PSYCHE

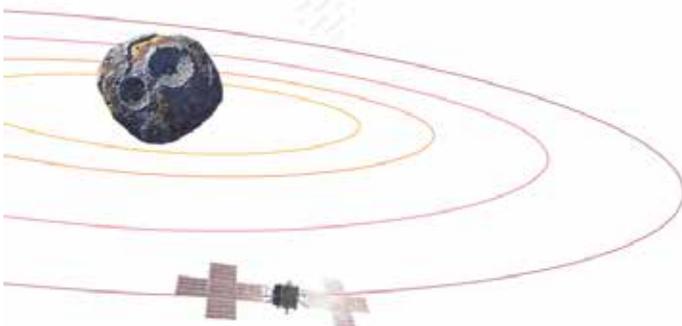


TRAJECTORY

The Psyche spacecraft is targeted to launch in summer 2022 and travel to the asteroid using solar-electric (low-thrust) propulsion, arriving in 2026, following a Mars flyby and gravity-assist in 2023. After arrival, the mission plan calls for 21 months spent at the asteroid, mapping it and studying its properties.

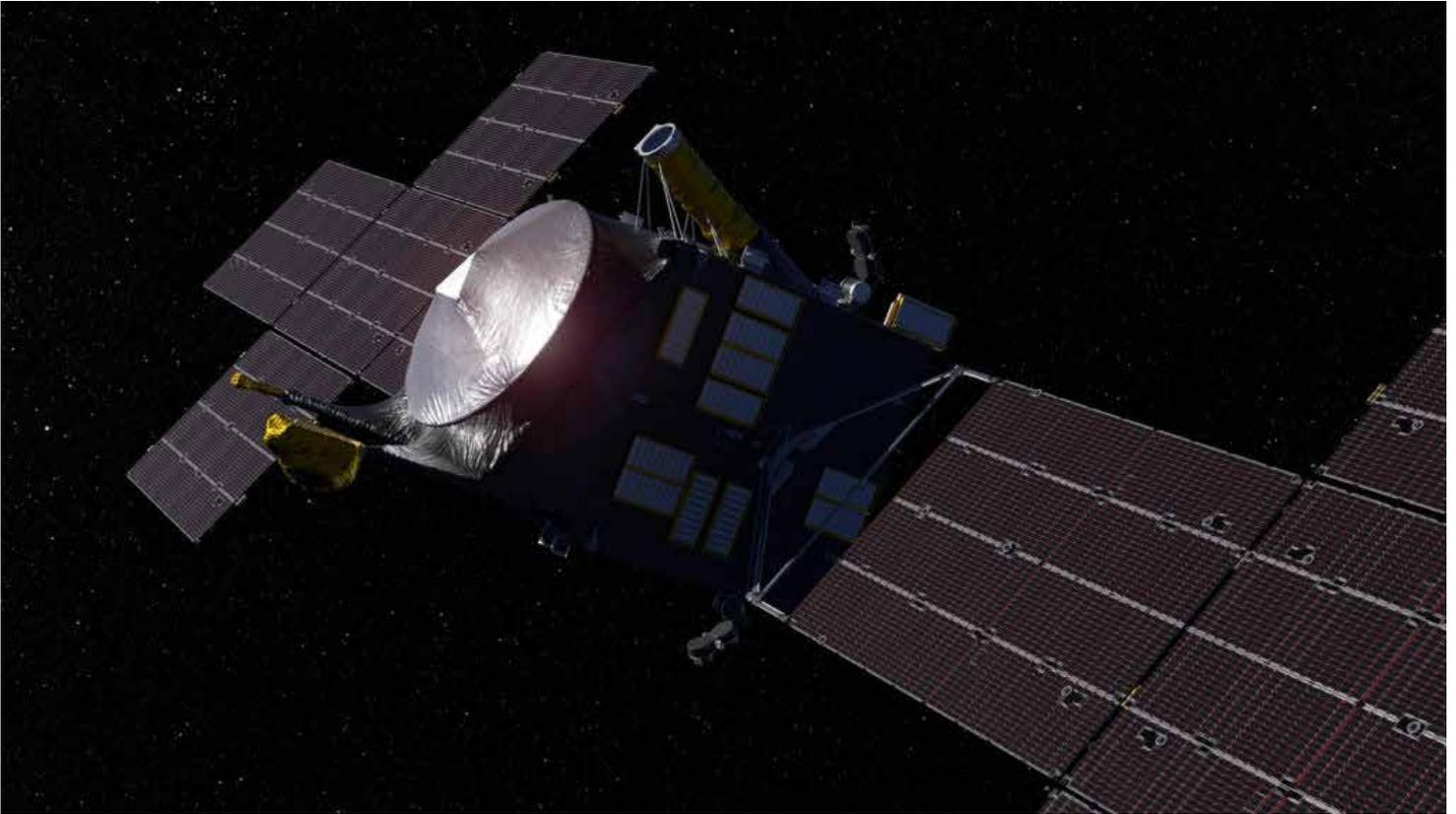
WHERE ARE WE NOW?

A space mission typically has six phases, A-F. The Psyche mission is currently in "Phase C," which lasts until January 2021. In this phase, the mission is focused on final design and subsystem fabrication, assembly, and testing.



Images from <https://psyche.asu.edu>.

SPACE DAY AT APM: PSYCHE



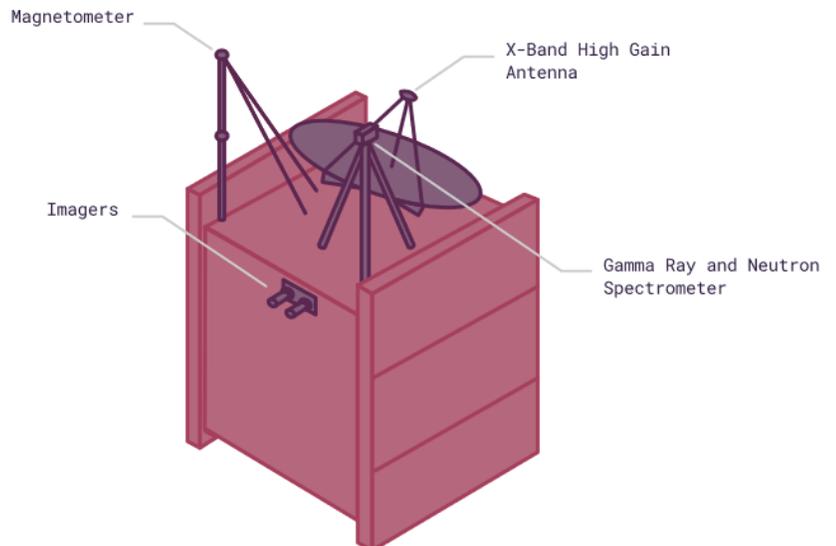
Psyche Spacecraft (Artist's Concept)

This artist's concept, updated as of June 2020, depicts NASA's Psyche spacecraft. The image was created by Peter Rubin.

Arizona State University in Tempe leads the mission. NASA's Jet Propulsion Laboratory in Southern California is responsible for the mission's overall management, system engineering, integration and test, and mission operations. For more information about NASA's Psyche mission go to: <http://www.nasa.gov/psyche> or <https://psyche.asu.edu> Credit: NASA/JPL-Caltech/ASU

FULLY-EQUIPPED

The spacecraft will include a Gamma Ray and Neutron Spectrometer, a Multispectral Imager, a Magnetometer and an x-band radio telecommunications system. The Psyche mission will also test a sophisticated new laser communication technology, called Deep Space Optical Communication (DSOC), that encodes data in photons to communicate between the spacecraft and Earth.





APM would like to thank the Vermont Space Grant Consortium for its continued support of the education program. The Vermont Space Grant Consortium (VTSGC) is an organization consisting of academic institutions, private industry, and public entities. Funded by a grant from NASA's National Space Grant College and Fellowship Program, key goals of the VTSGC are: to build aerospace-related research infrastructure within the state; to promote science, technology, engineering and mathematics (STEM) education among Vermont students; and to train and encourage students to pursue careers in aerospace-related areas.

This aligns with the museum's mission to capture the imaginations of young and old with the spirit of innovation, problem solving and design demonstrated through the dynamic story of the manufacturing industry in America.



Vermont Space Grant Consortium

