National Aeronautics and
Space Administration

ORION

2016

In December 2014, Orion embarked on its first journey to space for Exploration Flight Test 1. Test data from this successful space flight has helped prepare for Exploration Mission-1, Orion's next launch aboard the Space Launch System (SLS) rocket which will propel the uncrewed spacecraft into a distant retrograde orbit around the moon. A series of increasingly challenging missions will follow as America's new Orion spacecraft will send astronauts to explore farther into our solar system than we've gone before, including to Mars.

Our partners, small and large continue to play a vital role in our success. Together, NASA, Lockheed Martin, and hundreds of suppliers and small businesses across the country are approaching the end of Orion's development phase having successfully tackled many of the toughest engineering challenges associated with deep space travel.

The contributions from the NASA/ESA industry and small business partnership is helping to create the world's strongest and most diversified space program. The team's skills and dedication are critical as we pursue new ways of doing business, new efficiencies, and new directions that will give us new capabilities for deep-space exploration.

Our network of suppliers and small businesses around the globe helps us to improve communication, resolve issues, meet schedules, and deliver quality materials and products. These companies bring innovation, efficiency and affordability to the program and consistently go above and beyond to ensure mission success.

In 2016, we delivered more space flight hardware than in the history of the program and for the first time ever, we now have three Orion crew modules in various stages at the Neil Armstrong Operations and Checkout building at Kennedy Space Center. Additionally, we conducted more large-scale system tests than ever before to ensure we are ready for our first cislunar flight on Exploration Mission-1 in 2018. Not long after that flight, we will conduct a second test in 2019 of the Launch Abort System during ascent to ensure that we can save crew lives in the event of an emergency during launch and ascent. These next two critical flights tests position us for our first crewed flight in 2021 — Exploration Mission-2. Flight hardware for the EM-2 SLS is already in production and the Orin team is already working on long-lead procurements for that flight.

All of our work and successful accomplishments to date have well positioned Orion to support NASA's exploration missions into deep space. Exploration Missions 3 through 5 will establish the architecture and systems that will enable us to journey beyond our Earth-moon system; and Exploration Missions 5 through 9 will further demonstrate capabilities needed to journey onward to Mars.

ORION MAIN ENGINE ARRIVES IN EUROPE

The main engine for the European Service Module that will power NASA's Orion spacecraft was shipped from NASA's White Sands facility and has arrived at Airbus Space and Defence assembly hall in Bremen, Germany.

Read the full story: **bit.ly/2gPhxMQ**

Inside the Neil Armstrong Operations and Checkout Building high bay at NASA's Kennedy Space Center in Florida, the Orion crew module adapter (CMA) for Exploration Mission 1 (EM-1) is in a clean room with protective walls secured around it. The adapter will undergo propellant and environmental control and life support system tube installation and welding. The adapter will connect the Orion crew module to the European Space Agency-provided service module.

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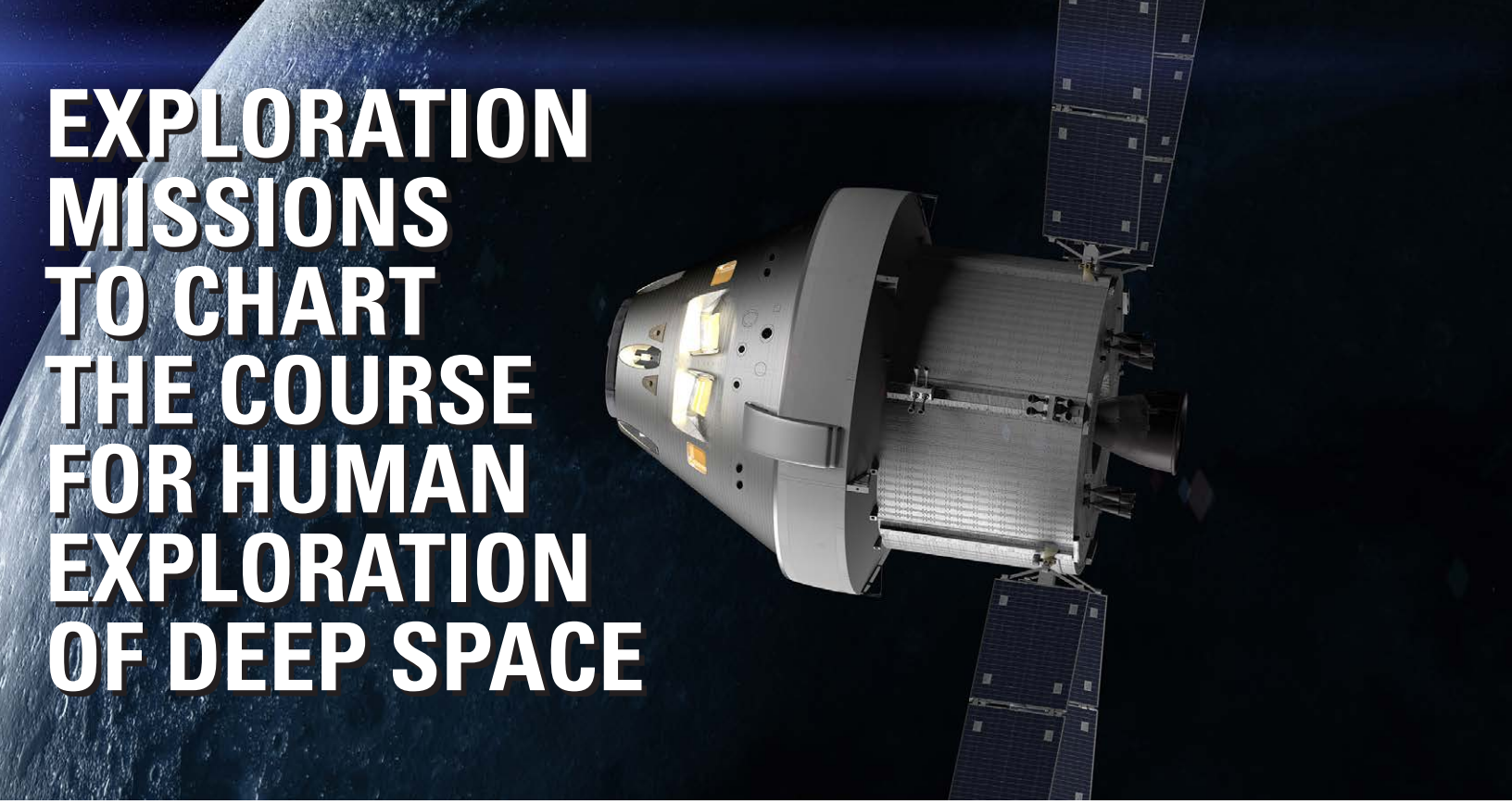
ORION

NOVEMBER 2016

ENTERING THE PROVING GROUND OF SPACE

EXPLORATION MISSIONS TO CHART THE COURSE FOR HUMAN EXPLORATION OF DEEP SPACE



The early missions for NASA's Deep Space Exploration Systems will pave the way for future missions over the next several decades. On Exploration Mission-1, the Orion spacecraft will be launched by the Space Launch System (SLS) and travel more than 40,000 miles beyond the moon to an area that is only about three to five days away from Earth, yet farther than any of the Apollo astronauts ever traveled. With flight hardware already in production for the first two Exploration Missions, NASA has established integrated human exploration objectives combining the efforts aboard the International Space Station, SLS and Orion, and other capabilities needed to support human missions on the journey to Mars.

The journey to Mars crosses three thresholds, each with increasing challenges as humans move farther from Earth, starting with Earth reliant exploration aboard the space station in low-Earth orbit, through the proving ground of cislunar space, and culminating with Earth independent exploration where human missions to the Mars system are possible. The exploration objectives are grouped into three cross-cutting categories, transportation, working in space, and staying healthy, which will support human exploration in deep space throughout the thresholds.

Work is already underway on an initial set of objectives in low-Earth orbit to mature many systems needed for deep space habitation and exploration. Proving ground missions will build on those accomplishments in two phases that will demonstrate our exploration systems and validate our exploration capabilities. These objectives will inform future flight test objectives and enable planners to begin building the detailed profiles and trajectories for the missions in the near-term through the end of the 2020s.

The period of exploration in the proving ground will begin with the first integrated launch of SLS and Orion, (Exploration Mission-1) anticipated in 2018, and will extend through the 2020s. The first phase will focus on demonstrating the safe operation of the integrated SLS rocket and Orion spacecraft and other exploration operations to support short-duration objectives in cislunar space.

The second phase will confirm that the agency's capabilities can perform for long duration Mars class missions and will culminate at the end of the 2020s with a one-year mission in cislunar space before venturing on crewed missions beyond the Earth-moon system.

What we learn in the proving ground will pave the way for Earth independence by helping break our reliance on the logistics and supply chain, and reduce our dependence on ground control. This stage will enable explorers to identify and pioneer innovative solutions to technical and human challenges that could only have been discovered or engineered in deep space.

Read the full story: **go.nasa.gov/2huANOY**

Watch the Orion Backstage food lab video featuring NASA Orion engineer Jessica Vos and food scientist Takiyah Sirmons: **bit.ly/2gKmarh**

SPACE FOOD BARS WILL KEEP ORION WEIGHT OFF AND CREW WEIGHT ON

When astronauts in the Orion spacecraft travel beyond the moon to explore deep space destinations, they'll need a robust diet to keep them healthy and sharp. Feeding the crew on deep-space missions presents several unique challenges that NASA scientists are working to tackle.

Orion has limited room inside it to accommodate the supplies astronauts will need during their missions. Because flights to deep space will not rely on resupply spacecraft to deliver what astronauts need and dispose of trash, the Orion crew will have to take everything they need with them and bring it all back home.

To help reduce the amount of supplies Orion will carry for its crew, scientists are developing a variety of food bars that astronauts can eat for breakfast during their spaceflight missions. In the United States, it's common for people to substitute an energy bar or shake for breakfast, or to skip the meal all together. Food scientists determined that developing a single calorically dense breakfast bar can help meet mass reduction requirements.

The food bars, which are being developed in coordination with NASA's Human Research Program have been tested by crew members inside HERA (Human Exploration Research Analog), the agency's three-story habitat at Johnson Space Center designed to serve as an analog for the isolation and remote conditions in exploration scenarios. The ground-based missions have provided helpful feedback on the flavor, texture and long-term acceptability of the bars that food scientists are using to hone the range of options available.

While scientists continue to improve the food bars and expand the variety of options available, NASA also is working to develop regenerative ways to feed the crew on longer missions, including on the journey to Mars. Scientists are also looking at packaging food items to keep them edible and nutritious in conditions where there are temperature fluctuations, such as the surface of Mars.

Read the full story: **go.nasa.gov/2gnd1Ae**

SOLAR ARRAYS: TAKE TWO

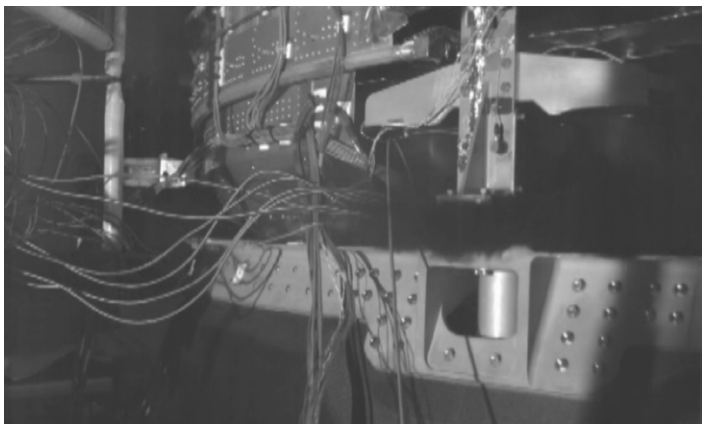
ESA (European Space Agency), Airbus Defence and Space, and NASA service module team successfully completed the second solar panel deployment test at NASA Glenn's Plum Brook Station. The deployment test was conducted after a series of acoustic and vibration tests to ensure the arrays will successfully deploy on orbit after being launched on the powerful Space Launch System rocket.

ORION'S SHOCK FACTOR

Engineers recently completed pyroshock testing with a full-scale test version of the Orion service module at the Space Power Facility at NASA Glenn's Plum Brook Station. During the tests, engineers fired powerful pyrotechnics to simulate the shocks the service module will experience as Orion separates from the Space Launch System rocket.

The service module is an essential part of the spacecraft. It will propel, power and cool Orion during spaceflight in addition to providing air and water for the crew.

Watch video of the testing: **bit.ly/2hx60yb**



ORION'S CREW MODULE ADAPTER GETS A LIFT

The Orion crew module adapter (CMA) for EM-1 was lifted for the first and only time, Nov. 11, during its processing flow inside the Neil Armstrong Operations and Checkout Building high bay at the agency's Kennedy Space Center in Florida.

Technicians with Lockheed Martin, the Orion crew module manufacturer, lowered the adapter onto a test stand for secondary structure outfitting. The CMA was moved into a temporary clean room at the end of November for propellant and environmental control and life support system tube installation and welding.

Read the full story: **go.nasa.gov/2hmNXgq**

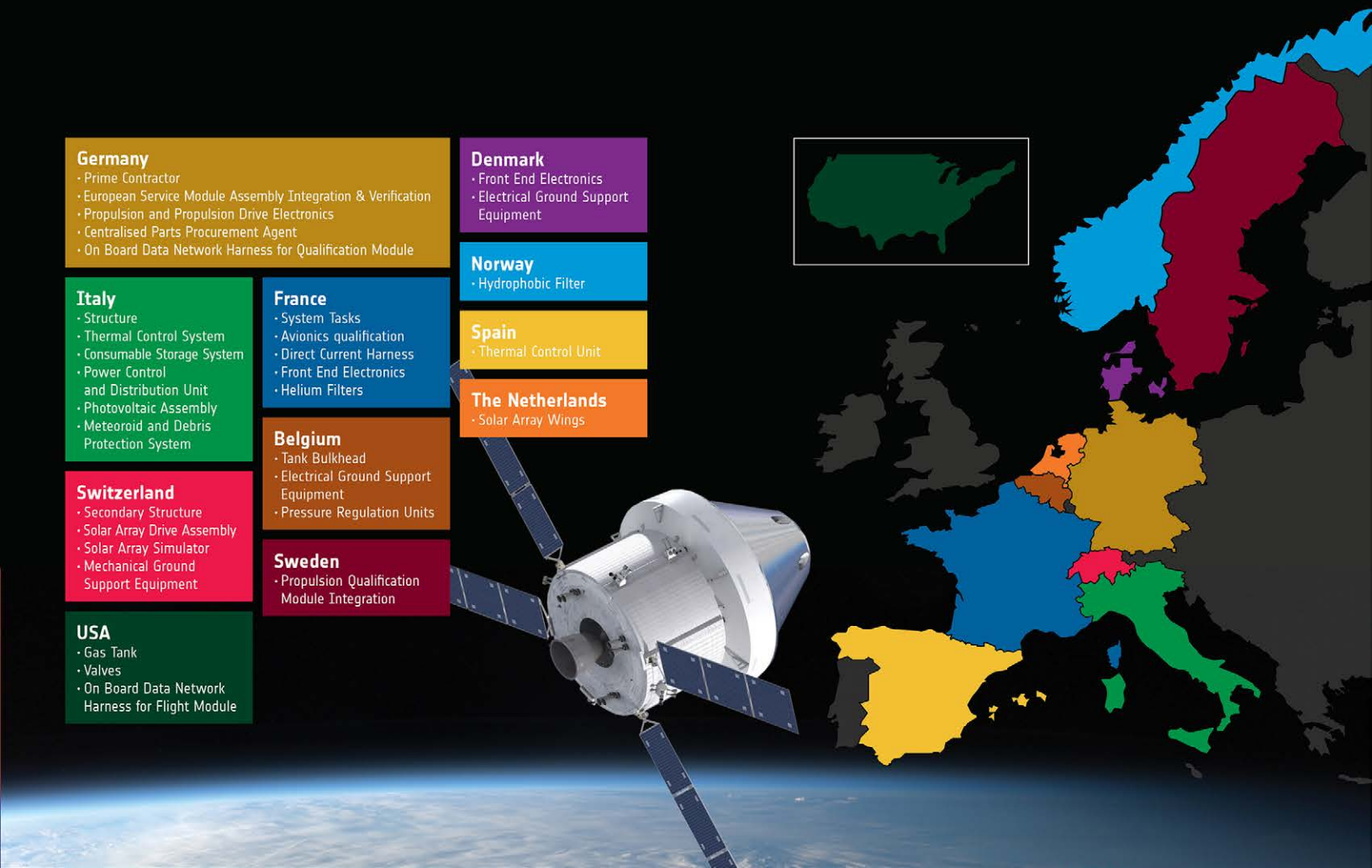
ORION'S EUROPEAN SERVICE MODULE: AN INTERNATIONAL UNDERTAKING

As the first European service module for NASA's Orion spacecraft is being assembled in Bremen, Germany, suppliers all over Europe and the United States are delivering their components that will form the chassis and supply life support and propulsion to the Orion crew module.

Companies from 11 countries have built spacecraft-specific parts for Orion or supplied their proven space hardware to construct the spacecraft that will fly farther than any other human-rated spacecraft.

The prime contractor to ESA (European Space Agency) for the European Service Module is Airbus Defence and Space, a European multinational company that has put its Bremen facility in charge of the service module program. As ESA's direct interface, Airbus is responsible for the complete package, assembling the parts in its Bremen halls and verifying that the components work as expected. The Airbus Orion team orders all parts for the European Service Module, keeps track of orders and ensures parts get shipped to the right place at the right time.

Read more about all the countries involved: **bit.ly/2gKFPYc**



ONE HOT RECOVERY TEST

A functional test of Orion's crew module recovery mechanism (CMRM) was completed in the Panel Test Facility (PTF) at NASA's Ames Research Center in California this month. After Orion missions, recovery personnel will use the CMRM to capture and handle the crew module after it splashes down in the ocean. Since the mechanism must function shortly after splashdown, it can be hot during this operation. The PTF functional test ensured that the CMRM will operate correctly even when still very hot from the heat of re-entry. The test was successful, demonstrating end-to-end CMRM operation at temperatures near 400 degrees Fahrenheit – higher than those expected during an actual Orion mission.

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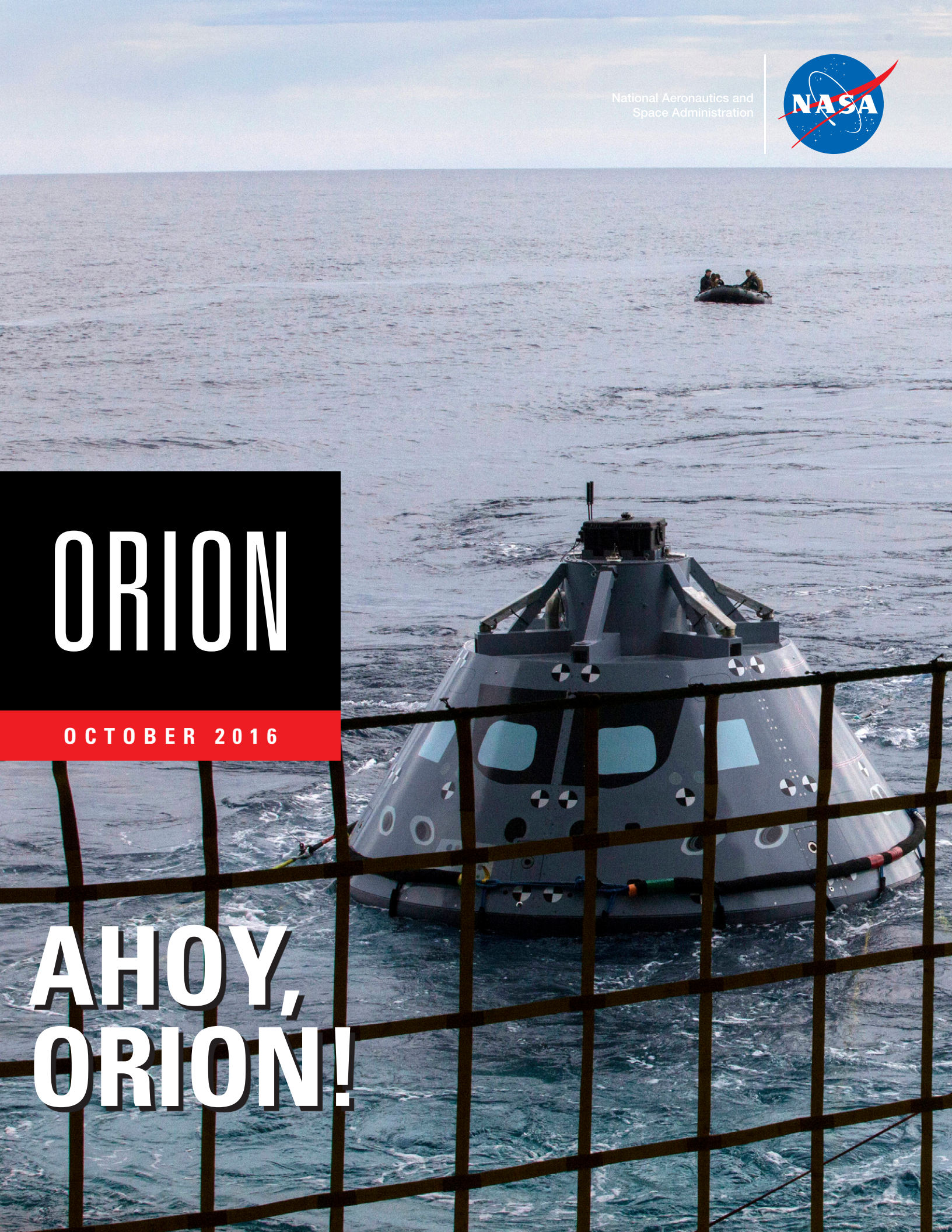


ORION

OCTOBER 2016

AHOY, ORION!

U.S. Navy divers and other personnel practice recovery of the Orion test article into the well deck of the USS San Diego during Underway Recovery Test-5.

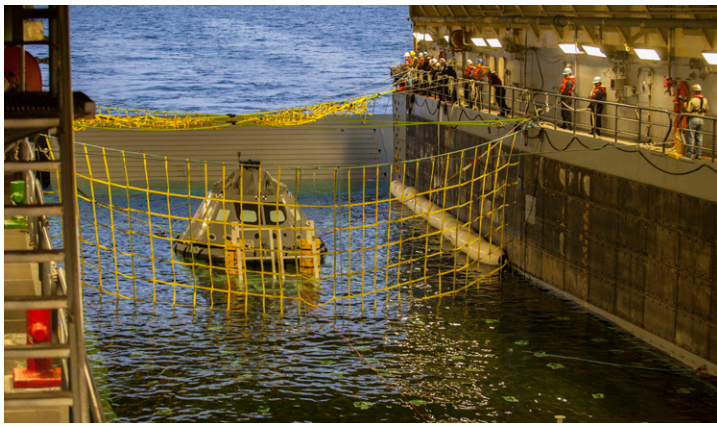
NAVY TEAM TO BE FIRST TO WELCOME ORION HOME FROM SPACE

NASA and the U.S. Navy conducted testing in October off the coast of California using the USS San Diego, various watercraft and equipment to practice for recovery of Orion on its return from deep-space missions. The testing, called Underway Recovery Test, or URT-5, is the first major integrated test in a series of tests to prepare the recovery team, hardware and operations to support recovery of the Orion spacecraft using a U.S. Navy ship. The term “underway” refers to recovery tests done when a ship is at sea. The testing included first time use of new capsule attachment hardware. The new Orion spacecraft will have five attach points, two more than were on the crew module for Exploration Flight Test-1 in December 2014. The testing allows the team to gather loads data for the new design and demonstrate and evaluate recovery processes, procedures, hardware and personnel in open waters.

(Left to right) Orion team members Tom Walker, Rachel Davis (Lockheed Martin), Jeremy Vander Kam, and Tara Radke are shown representing Orion during URT- 5 test operations in San Diego.

In the well deck of the USS San Diego, recovery team members monitor a portion of URT- 5.

U.S. Navy divers and other personnel in a Zodiac boat secure a harness around a test version of the Orion crew module during URT-5 in the Pacific Ocean off the coast of California.



Read the full Orion Underway Recovery Test-5 story: **bit.ly/OrionURT5**

Read more about diver training in NASA's Neutral Buoyancy Lab in Houston that prepared the team for URT-5 operations: **bit.ly/URT-5_NBL**

Watch the latest "Orion Backstage" featuring one of the divers who took part in recent recovery operation activities in the NBL: **youtube.com/watch?v=QR0orgqkLi0**

NASA BEGINS TESTS OF ORION PARACHUTES FOR CREWED MISSIONS

NASA successfully kicked off a series of tests Sept. 30 to qualify Orion's parachute system for flights with astronauts, a milestone that will help the agency safely return crew to Earth from deep-space missions.

In the skies above the Arizona desert, a C-17 aircraft dropped a dart-shaped test article out of its cargo bay from 35,000 feet, or more than 6.5 miles, in altitude over the U.S. Army Yuma Proving Ground in Yuma to examine how the parachute system performed when conditions provided the highest dynamic pressure the parachutes have endured before.

When returning from missions in space, the parachute sequence normally begins at an altitude of 24,000 feet with the main parachutes fully deployed at about 4,000 feet.

Read the full story: **bit.ly/ParachuteTests**

TILE BLOCK FITTING ON ORION HEAT SHIELD

Tile blocks have been prefitted around the Orion Exploration Mission-1 crew module heat shield inside the Neil Armstrong Operations and Checkout Building high bay at NASA's Kennedy Space Center in Florida.

The heat shield is one of the most critical elements of Orion and protects it and the future astronauts inside from searing temperatures experienced during reentry through Earth's atmosphere when they return home.

For Orion's next space flight, the top layer of Orion's heat shield that is primarily responsible for helping the crew module endure reentry heat will be composed of approximately 180 blocks, which will be made of an ablative material called Avcoat designed to shed away as it heats up.

Orion is being prepared for its flight on the agency's Space Launch System in late 2018. Orion is the exploration spacecraft designed to carry astronauts to destinations not yet explored by humans, including an asteroid and NASA's Journey to Mars. It will have emergency abort capability, sustain the crew during space travel and provide safe re-entry from deep space return velocities.

ORION HEAT SHIELD LEAVES NASA LANGLEY FOR FLORIDA

The heat shield from Orion's Exploration Flight Test-1 embarked on a journey along the East Coast, beginning at NASA's Langley Research Center in Virginia and making its way to NASA's Kennedy Space Center in Florida where it will be assessed for future needs.

Before its departure, the heat shield was used as part of the Orion drop test series to better understand what the spacecraft and astronauts may experience when landing in the Pacific Ocean after deep-space missions.

WHAT'S SHAKIN', ORION?

How do you know if a spacecraft can hold up to the intense vibrations of launching atop the world's most powerful rocket? You shake it on the world's most powerful vibration table.

Engineers at NASA Glenn's Plum Brook Station in Sandusky, Ohio recently finished a series of tests on a full-size test version of Orion's service module to verify that it can withstand the vibrations it will experience when it launches and travels into space atop the Space Launch System (SLS) rocket.

The 13-ton service module is an essential part of the spacecraft. It will propel, power and cool Orion in addition to providing air and water for the crew.

NASA's SLS rocket will produce more than eight million pounds of thrust during launch, and like all spacecraft, Orion will get a good shaking during ascent. Although NASA has designed Orion and its service module to endure launch and ascent vibrations as Orion travels into space, testing on the ground helps to verify those designs before the mission.

Earlier this summer, the service module test article, which was provided by ESA (European Space Agency) and built by Airbus Defence & Space, was placed on a mechanical vibration table in Plum Brook's Space Power Facility. At 22-feet wide and 55,000-pounds, the table is the world's most powerful spacecraft shaker system. Engineers ran a total of 98 vibration tests throughout the summer.

The vibration tests were part of a series of crucial checks being performed at the Space Power Facility to verify the service module for Orion's first flight atop SLS.

The test article's next stop is the assembly high bay area, where engineers will fire pyrotechnics to simulate the shocks the service module will experience as Orion separates from the SLS rocket.

Read the full article: **bit.ly/OrionShakeTest**

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MEET ORION'S DEEP DIVE TEAM

A group of U.S. Navy divers, Air Force pararescumen and Coast Guard rescue swimmers are practicing Orion underway recovery techniques in the Neutral Buoyancy Laboratory (NBL) at NASA's Johnson Space Center in Houston.

ORION TEAM DIVES INTO RECOVERY OPERATIONS

A group of U.S. Navy divers, Air Force pararescuemen and Coast Guard rescue swimmers practiced Orion underway recovery techniques Sept. 20-22 in the Neutral Buoyancy Laboratory (NBL) at NASA's Johnson Space Center in Houston to prepare for the first test flight of an uncrewed Orion spacecraft with the agency's Space Launch System rocket during Exploration Mission 1 (EM-1).

A test version of the Orion spacecraft was lowered into the water in the NBL. Divers wearing scuba gear used ground support equipment and zodiac boats to swim or steer to the test spacecraft. They placed a flotation collar around Orion and practiced using the new tow cleat modifications that will allow the tether lines to be connected to the capsule. The tether lines are being used to simulate towing Orion into the well deck of a Navy recovery ship.

Training at the NBL will help the team prepare for Underway Recovery Test 5 (URT-5), which will be the first major integrated test in a series of tests to prepare the recovery team, hardware and operations to support EM-1 recovery.

The recovery team, engineers with NASA's Ground Systems Development and Operations program and Orion manufacturer Lockheed Martin, are preparing for URT-5, which will take place in San Diego and aboard the USS San Diego in the Pacific Ocean off the coast of California in October.

Read the full article: bit.ly/NavyDivers_NBL

More images: flickr.com/photos/nasaorion

CONGRESSIONAL GUESTS SEE ORION UP CLOSE

NASA's Johnson Space Center Director Ellen Ochoa gave U.S. Senator Ted Cruz (R-TX) a pilot's perspective of how it feels to be an astronaut inside the Orion spacecraft mockup at Johnson on Aug. 8.

U.S. Senator Gary Peters (D-MI), a member of the Senate Commerce Committee's Space, Science and Competitiveness Subcommittee, visited the Neil Armstrong Operations & Checkout (O&C) building for a tour and program update on Orion and deep space exploration on Sept. 9. The senator got a sneak peek at the Exploration Mission-1 spacecraft that is now undergoing clean room operations in the O&C.

U.S. Senator Marco Rubio (R-FL) visited the Florida Space Coast on Aug. 19, to participate in an industry space roundtable organized by the Aerospace Council of the Economic Development Commission of Florida's Space Coast. During the discussion where Jules Schneider, deputy of Orion Kennedy Operations represented Lockheed Martin, and in a media interview event that followed, Senator Rubio discussed Orion and voiced support for America's space exploration program.

Photo (L to R): Joe Mayer, Lockheed Martin; John Couch, vice president of Futuramic Tool & Engineering; U.S. Senator Gary Peters; Scott Wilson, Orion Production Operations manager; and Jules Schneider, Lockheed Martin senior manager for Orion Assembly, Integration & Production.

Photo (L to R): Dale Ketchum, Space Florida; Joe Mayer, chair of the EDC Aerospace, Aviation, and National Security Council and Lockheed Martin Government Relations director; U.S. Senator Marco Rubio; and Julie Roslin, EDC of Florida's Space Coast. (Photo Credit: EDC of Florida's Space Coast)

Photo (Top to bottom): Mark Geyer, NASA Johnson Space Center deputy director, Ellen Ochoa, NASA Johnson director, U.S. Senator Ted Cruz

HEAT SHIELD PREPS FOR EM-1 FLIGHT

Orion's heat shield has been uncrated and secured on a stand in the Neil Armstrong Operations and Checkout (O&C) Building at the agency's Kennedy Space Center in Florida to begin the work to prepare it for EM-1.

In the O&C, technicians will apply the Avcoat, a type of thermal protection that wears away as it heats up (a process known as ablation), to the EM-1 heat shield in a different way than was done for Orion's 2014 flight test. Blocks of Avcoat will be bonded to the heat shield rather than filling individual honeycomb cells. The way the structure is attached to the crew module for the EM-1 heat shield has been simplified. Several different types of instrumentation also will be installed on the heat shield to gather data on heating and performance.

After the thermal protection system has been applied and inspected, engineers and technicians will put the heat shield through a thermal cycle test. The thermal cycle test ensures the thermal protection blocks are properly bonded and will perform as expected when they are exposed to the extreme temperatures during the mission. The heat shield will be attached to the Orion crew module in the summer of 2017.

Read the full story at: bit.ly/EM1_HeatShield

EUROPEAN TEAM WORK PROGRESSES ON ORION SERVICE MODULE

NASA Orion Program Manager Mark Kirasich, (second from left) visited Witzenmann GmbH, a German manufacturer developing service module components for Airbus Defence and Space and ESA (European Space Agency) on Sept. 13.

Also on Sept. 13, NASA Orion team members joined ESA and Airbus representatives for a visit to OHB in Sweden to witness the progress of the ESA service module Propulsion Qualification Motor build and to support a media event. Two Swedish television stations covered the visit as well as radio and several web and print media reporters. Pictured left to right are Philippe Deloo (ESA), Ann Over (NASA), Dr. Mark Michaelis (Airbus) and Susan Motil (NASA) with the OHB team.

ARE THESE STOWAWAY ASTRONAUTS?

Go backstage with Orion engineers to see how they are working with astronauts to develop safe shelter from space radiation during deep-space exploration missions aboard the Orion spacecraft. Using the stowage bags on board that will contain supplies, food and water, in combination with Orion's seats will allow astronauts making the shelter to strategically place denser bags in areas of the vehicle with less radiation-protecting materials.

Read the full feature article: **bit.ly/OrionRadiationProtection**

Also read about Lockheed Martin's collaboration with StemRad Inc. to develop a vest astronauts could wear to protect against radiation exposure in deep space: **bit.ly/LM_RadiationVest**

Watch the Orion Backstage video: **youtu.be/70GrihLXmSs**

National Aeronautics and
Space Administration

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AUGUST 2016

ORION GETS FIRED UP!

Left to right: Howard Hu (NASA), Robert Decoursey (NASA), Cheryl Rehm (Aerojet Rocketdyne), Roger McNamara (Lockheed Martin), Jim Paulsen (Aerojet Rocketdyne), Sasha Ellis (NASA) and Don Mahr (Aerojet Rocketdyne) pose in front of the Orion Jettison Motor test stand following the test firing.

AEROJET ROCKETDYNE COMPLETES SUCCESSFUL JETTISON MOTOR TEST

You often don't think that something the size of a college dorm refrigerator is capable of lifting two schools buses off the ground, but that is exactly the case with Orion's jettison motor. At the end of August, representatives from NASA, Lockheed Martin, Aerojet Rocketdyne and local congressional staff including Representative Bera (D-CA), Rep. Matsui (D-CA) and Rep. McClintock (R-CA) gathered to watch the third development jettison motor for Orion generate 45,000 pounds of thrust during a 1.5 second test firing in Sacramento, California.

One and half seconds may seem like an extremely short time, but that is all the time required to separate Orion's launch abort system (LAS) from the crew module. The LAS consists of three solid rocket motors: the abort motor that pulls the crew module away from the launch vehicle; the attitude control motor that is used to steer the crew module following an abort; and the jettison motor, which separates the launch abort system from the crew module.

This most recent test of the jettison motor provided Aerojet Rocketdyne and Lockheed Martin key data, including pressure, temperature, thrust, acceleration and strain measurements to ensure their readiness to begin manufacturing the qualification and flight production motors for Exploration Mission-1 (EM-1).

Senior leadership from NASA, Lockheed Martin and Aerojet Rocketdyne welcome Congressman Ami Bera (at right) to watch the jettison motor test.

To watch video of the test, visit: http://bit.ly/OrionJettisonTestVideo

Read how Orion's Launch Abort System Motor Gets Fired-Up About the Journey to Mars at: http://bit.ly/OrionFiredUp

Astronauts Stephanie Wilson, Karen Nyberg and Rick Mastracchio check out Orion's docking hatch.

HATCHING NEW IDEAS FOR SPACECRAFT DESIGN

Engineers and astronauts conducted testing in a representative model of the Orion spacecraft at NASA's Johnson Space Center to gather the crew's feedback on the design of the docking hatch and on post-landing equipment operations. The testing, shown here with astronauts Stephanie Wilson, Karen Nyberg and Rick Mastracchio (L to R), was done to evaluate the equipment used during egress to ensure that a fully suited crew member carrying survival equipment can get out of the spacecraft through the docking hatch if necessary.

While the crew will primarily use the side hatch for entry and exit on Earth and the docking hatch to travel between Orion and a habitation module on long-duration deep space missions, the crew will need to be able to exit out of the docking hatch if wave heights in the Pacific Ocean upon splashdown are too high. The work is being done to help ensure all elements of Orion's design are safe and effective for the crew to use on future missions on the journey to Mars.

Orion Backstage Video: **http://bit.ly/OrionHatchBackstage**

Astronaut Anne McClain and Orion engineers and astronauts evaluate radiation sheltering procedures inside the Orion mockup at Johnson Space Center in Houston.

ORION CREW LEARN HOW TO SHELTER IN SPACE

Radiation shelter evaluations were conducted in a full-scale Orion mockup at NASA's Johnson Space Center in August to determine the amount of time astronauts would need to complete crew cabin reconfiguration to create a safe haven from deep-space radiation in the event of a solar particle event.

The Orion crew will take shelter in the central stowage bays, which can accommodate four crew members. The stowage components double as radiation shielding blocks when they are strategically repositioned at specific locations around the crew cabin to optimize protection. The cabin reconfiguration is an operations intense process that requires about 30 to 60 minutes to complete.

Spaceflight veteran Dr. Don Pettit participated in the exercises to provide real-time feedback from an astronaut's perspective. The radiation protection team assessed the desired mass density and material properties best suited for radiation shielding to meet requirements.

As part of an ongoing international collaboration between Lockheed Martin and StemRad Israel, the radiation protection design team is working on the development of a personal radiation shield that could provide radiation protection comparable to that inside the Orion shelter but with improved mobility of crew during solar particle events, which can occur anytime and on very short notice.

Astronaut radiation protection is essential to human exploration of deep space because astronauts will be traveling outside the protection of the Earth's magnetosphere and exposed significantly harsher radiation beyond Earth's orbit. Without adequate protection, the crew could experience detrimental health effects including increased risk for certain cancers.

Orion is NASA's first stand-alone spacecraft to implement radiation protection engineering as an integral part of the design process from the very early development stages of the preliminary design review.

Read the facts: http://bit.ly/OrionRadiationFS

ORION SPLASHDOWN TESTS KEEP ASTRONAUTS SAFE

Ellen Ochoa, director, NASA Johnson Space Center speaking with attendees of a NASA Social at the Orion splashdown test taking place Aug. 25 at NASA's Langley Research Center.

Onlookers gathered near the Hydro Impact Basin at NASA's Langley Research Center in Hampton, Virginia, applauded and cheered as they witnessed the simulated water landing of the Orion spacecraft, through the use of a 7.2-ton mockup covered with sensors capable of detecting forces that the structure and its astronaut crew would experience.

The drop was the ninth in a series of 10 tests taking place at Langley's Landing and Impact Research Facility. It was designed to simulate one of the Orion spacecraft's most stressful landing scenarios, a case where one of the capsule's three main parachutes fails to deploy. That would cause Orion to approach its planned water landing faster than normal and at an undesirable angle.

Under ideal conditions, the Orion capsule would slice into the water of the Pacific Ocean traveling about 17 miles per hour. Thursday's test had it hitting the pool at about 20 mph, and in a lateral orientation. Instead of being pushed down into their seats, astronauts in this scenario would splashdown to the side.

The tests at Langley — along with many others across the agency — are leading up to the first integrated flight of the Space Launch System (SLS) and Orion known as Exploration Mission-1. There will be no crew on EM-1, but it will prepare the way for future missions with astronauts as NASA pushes ahead on its journey to Mars.

To read the full article, visit: http://bit.ly/OrionSplashdown

A COOL TEST FOR CREW SAFETY

The third and final Launch Abort System (LAS) abort motor igniter qualification static test firing was successfully performed at the Orbital ATK test facility in Promontory, Utah, the morning of August 9. This igniter was conditioned by cold temperature cycles (25-35 degrees Fahrenheit) and vibration testing prior to the cold condition static test.

Conducting igniter static tests is part of the design, development, test and evaluation program. Igniters are tested to validate engineering models, and verify predicted performance after subjection to the expected extreme pre-operating and flight conditions. The three igniter tests consisted of nominal, hot (95-105 degrees Fahrenheit) and cold temperature extremes to qualify the igniter prior to operational production.

This test is a significant milestone for Orion and an important step forward on the path to full qualification of the abort motor for the LAS. A full-scale abort motor static test firing is planned for mid-2017.

HOT SHOT DELIVERY!

The heat shield that will protect the Orion crew module during reentry after the spacecraft's first uncrewed flight atop NASA's Space Launch System rocket in 2018 arrived at the agency's Kennedy Space Center in Florida on Aug. 25. The heat shield arrived aboard NASA's Super Guppy aircraft at Kennedy's Shuttle Landing Facility, and was offloaded and transported to the Neil Armstrong Operations and Checkout Building high bay.

The heat shield was designed and manufactured by Lockheed Martin in the company's facility near Denver. Orion's heat shield will help it endure the approximately 5,000 degrees F it will experience upon reentry. The heat shield measures 16.5 feet in diameter and is the world's largest structure of its kind.

NASA PREPARES FOR ORION EUROPEAN SERVICE MODULE PROPULSION QUALIFICATION TESTING

Engineers are preparing for tests to qualify the propulsion subsystem, including the main engine, for Orion's European-built service module that will propel the spacecraft during different phases of flight in deep space. They will test engineering units of the spacecraft elements that will fly on Orion's first test flight with NASA's Space Launch System rocket in late 2018, moving the agency another step forward on its journey to Mars.

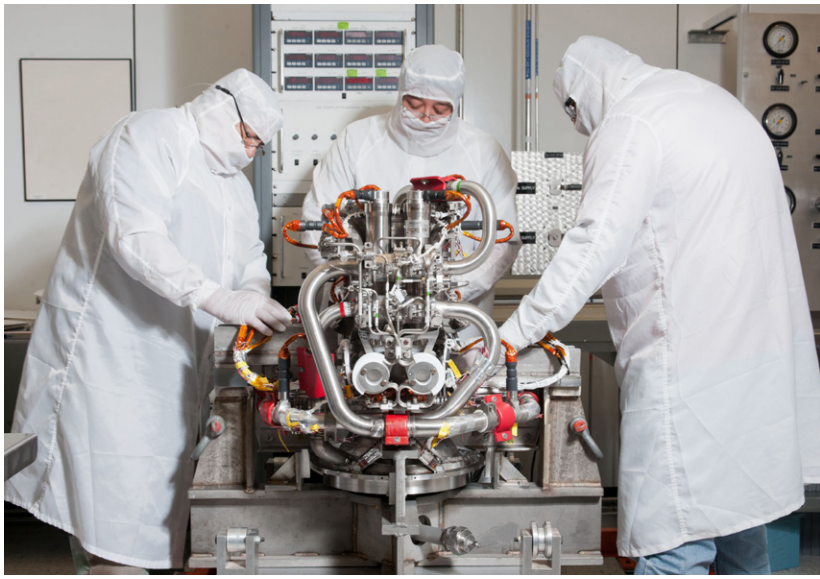
NASA is scheduled to test a propulsion qualification module including flight-like test units of the engine, propellant systems, and propulsion control units at the agency's White Sands Test Facility (WSTF) in New Mexico beginning in spring 2017.

Orion's service module main engine is a modified Orbital Maneuvering System (OMS) engine initially used on the space shuttle. NASA is repurposing the OMS engines for use in the European service module.

The Propulsion qualification module that will be used for testing is currently being assembled by ESA contractor, Airbus Defence and Space. It is scheduled for delivery to WSTF later this year. It consists of several helium tanks, propellant tanks, thrusters and flight-representative equipment such as piping, electronics, pressure control assemblies, a pressure regulation unit and propellant isolation equipment.

Data from the testing at WSTF will support verification of the proper operation of the service module propulsion system.

The propulsion team at White Sands Test Facility in Las Cruces, New Mexico, will test the engine for Orion's European Service Module.



While the main engine and test facilities are prepared for the spring hot-fire, the main engine for flight has been refurbished and acceptance tested at WSTF, and was shipped to NASA's Johnson Space Center in Houston for vibration testing. The vibration testing is helping to ensure the engine can withstand the loads induced by launch on the SLS rocket. Following testing at Johnson, the flight engine will be supplied to ESA to integrate into the Orion European service module for flight.

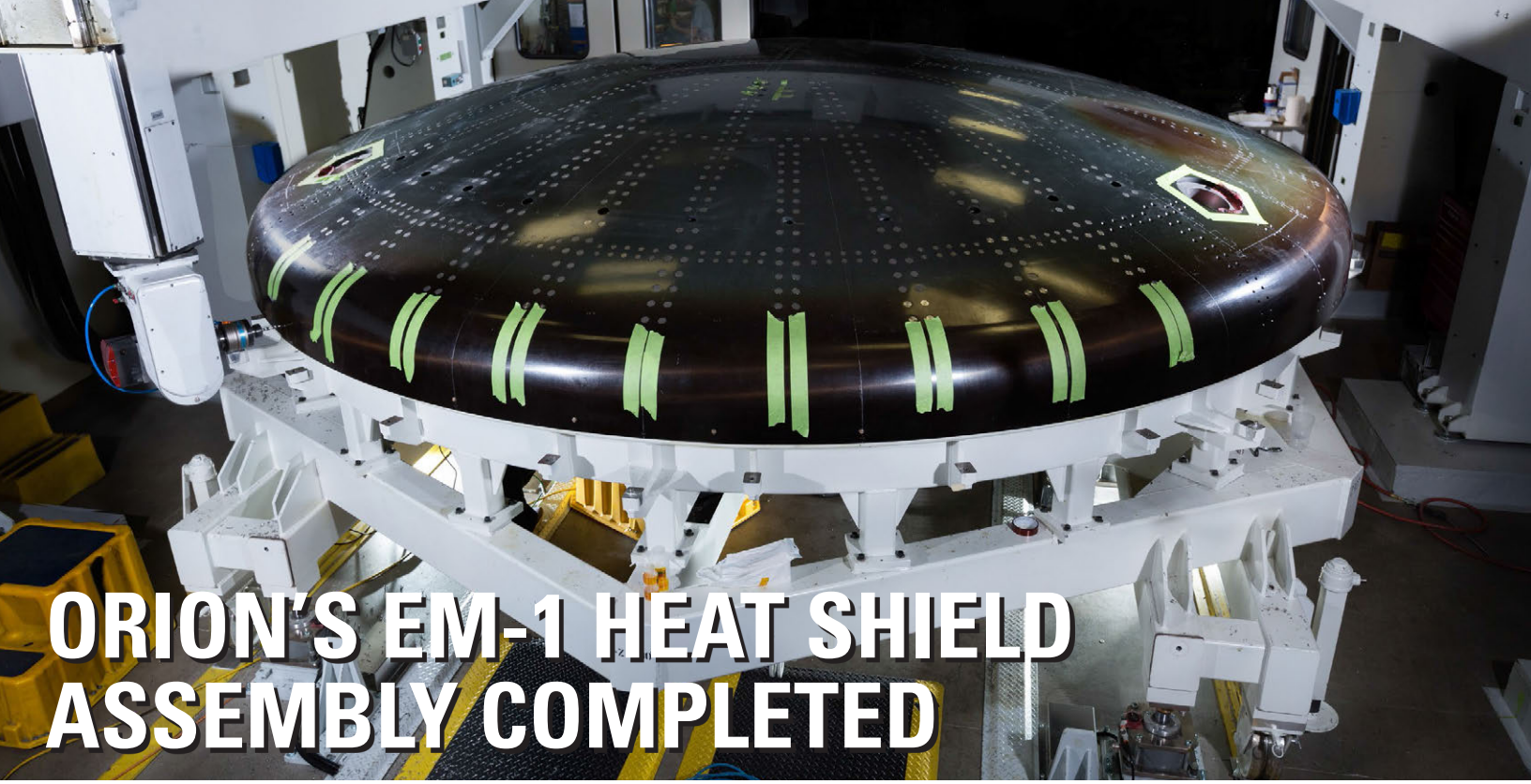
National Aeronautics and Space Administration

NASA

ORION

JULY 2016

NOW THIS IS COOL!



ORION'S EM-1 HEAT SHIELD ASSEMBLY COMPLETED

In mid-July, the Orion team completed the heat shield structure for NASA's Exploration Mission-1 (EM-1) at Lockheed Martin's Space Systems Company Waterton facility near Denver. The completed structure then underwent static loads testing, proving it can endure the 350,000-pound load the spacecraft will experience during its next flight beyond the moon and back.

At 16.5 feet in diameter, the heat shield for Orion Exploration Flight Test-1 (EFT-1) was the largest composite heat shield ever built. And now, the team has completed the second. The structure is comprised of a titanium sub-structure joined with an advanced high-temperature resin and graphite fiber laminate coated with an ablative thermal protection system required to survive re-entry thermal conditions and water landing impacts.

The EFT-1 heat shield exceeded performance expectations, withstanding temperatures well in excess of 4,000 degrees Fahrenheit as Orion blasted through Earth's atmosphere at 20,000 mph and enduring the strains of a dynamic water impact landing. After a picture perfect landing in the Pacific Ocean, the Orion recovery team held the spacecraft at sea for a "heat soak" test to ensure the heat shield would remain water tight long after splashdown.

Since EFT-1, the Orion team has improved production and performance of the heat shield based on data collected from the first space flight. The EM-1 heat shield has been optimized to shed more than 1,250 pounds from the EFT-1 structural design. In addition, the team has been able to reduce the EM-1 heat shield fabrication cost and schedule by as much as 30 percent, with an additional 15 percent cost and schedule reduction anticipated for the Exploration Mission-2 (EM-2) heat shield due to streamlined tooling and lean manufacturing processes. The team is already coordinating the logistics for a static test article build, which will be the model for the EM-2 heat shield.

The heat shield skeleton assembly process involves match drilling 205 individual parts and inserting fasteners in more than 1,200 holes. This is followed by skin-to-skeleton mating operations requiring 3,000 additional holes and fasteners across the entire structure. A dedicated team of manufacturing engineers stayed the course, working around-the-clock over several months to deliver the EM-1 heat shield assembly on time and under cost. The completed structure will be shipped to NASA's Kennedy Space Center in late August for final assembly and integration onto the Orion spacecraft.

Related Videos:

Meet Orion heat shield engineer Molly White:
bit.ly/2b0O3UW

See and hear the Orion launch and entry experience:
bit.ly/2aPZccs

ROCKY EXERCISE DEVICE IS A REAL KNOCKOUT!

While engineers across NASA and industry are working to build the Orion spacecraft and Space Launch System rocket that will venture to deep space, NASA's Human Research Program team is building a compact, action-packed exercise device to maintain crew strength during multiyear missions in microgravity.

As astronauts travel beyond the Earth and moon on the journey to Mars, keeping them healthy in space will be critically important. They will need to be in top physical form when they arrive at their destination so they can effectively pioneer new frontiers and must also be able to quickly readjust to Earth's gravity upon their return home.

The design team took the necessary elements of exercise equipment needed to keep astronauts healthy and fit in space and made them exponentially smaller, lighter and more robust, while still providing a healthy dose of benefits for the crew. The result was ROCKY, the Resistive Overload Combined with Kinetic Yo-Yo Device developed by Zin Technologies of Middleburg Heights, Ohio.

Astronauts will be able to use the device like a rowing machine for aerobic activity and for strength training with loads of up to 400 pounds to perform exercises such as squats, deadlifts and heel raises, as well as upper body exercises like bicep curls and upright rows. The device can be customized with specific workouts for individual astronauts. It will also incorporate the best features from a second device evaluated during the selection process called the Device for Aerobic and Resistive Training, or DART, developed by TDA Research in Denver, under NASA's Small Business Innovation Research Program.

ROCKY will get its first in-space warm up on Exploration Mission-2, the first crewed mission with Orion and SLS. Once Orion is in orbit, the crew seats will be stowed away to provide more interior space for the astronauts inside.

Read the full story at:
bit.ly/ROCKY_Orion

ORBITAL ATK LIGHTS UP NEW IGNITOR

At an historic solid rocket manufacturing and test facility in Elkton, Maryland, Orbital ATK's Upper Stages and Controls team completed a key milestone in the development of the Attitude Control Motor (ACM) for NASA's Orion spacecraft Launch Abort System (LAS).

On June 22 and 23, with Lockheed Martin and NASA on hand, the team successfully completed a series of four static tests on an improved igniter. The test met the required temperature ranges and performed as expected, despite a deliberately inserted error input from the ignition train.

Watch Attitude Control Motor Test Video: **bit.ly/2aSoBSX**

Using data from the successful Orion Pad Abort (PA-1) flight test in 2010, the Orbital ATK team has made the system's unique igniter even more robust by enlarging its throat and increasing its mass flow rate and total energy content. In order for any of that advanced technology to function, a simple but robust ignition train must get the ball rolling, and the ACM's igniter has to light at any time and altitude.

NASA's Langley Research Center manages the launch abort system program with partners and team members including NASA's Marshall Space Flight Center, Lockheed Martin and Orbital ATK. In the event of an emergency during launch or ascent, a powerful launch abort motor -- made by Orbital ATK in Utah – pulls the Orion spacecraft off the Space Launch System (SLS) to propel it out of harm's way. To keep the crew module on the right path, a fast reacting control system is needed to provide variable thrust in any direction. Enter the Attitude Control Motor, or ACM.

Orbital ATK worked with Lockheed Martin to develop the ACM, which has two critical functions. In a mission abort scenario, it must first steer the Launch Abort System and crew module away from the launch vehicle. Then, once cleared from hazards, the ACM orients the crew module for safe parachute deployment.

Watch Pad Abort-1 Flight Test: bit.ly/2bmAocQ

The ACM consists of a solid-propellant gas generator, with eight proportional valves equally spaced around the circumference of the three-foot-diameter motor. In combination, the valves can exert up to 7,000 pounds of steering force to the vehicle in any direction upon command from the crew module. The valves are controlled by a redundant power and control system.

Working under the direction of prime contractor Lockheed Martin, Orbital ATK has continued to develop and test the ACM to meet the most demanding operating parameters. In addition to the 2010 pad abort test, Orbital ATK has performed several successful sub-scale and full-scale ground tests on the ACM, supplied the inert unit which flew as part of Orion's first test flight, Exploration Flight Test-1 (EFT-1) in 2014, and last year concluded a series of high-thrust valve tests, including a successful over-pressure test, HT-10.

The success of the ACM igniter tests confirms that this key subsystem will move onto critical design review in August. The new igniter design will be used on the next ACM development motor test, HT-11, later this calendar year, and will support the ACM qualification tests and EM-2 flight delivery scheduled for 2017.

Watch HT-10 Test Video: bit.ly/2b0TRha

ORION TEAM FORMS PROTECTIVE BOND

A crucial part of preparing NASA's next Orion spacecraft for flight has begun as technicians bond thermal protection system (TPS) tiles to panels that will be installed on the spacecraft's back shell and forward bay cover. The silica tiles are an advanced version of those used on the space shuttle and will protect Orion's crew from the searing heat of re-entry that can reach 5,000 degrees Fahrenheit during return from deep-space missions.

The first integrated mission of NASA's Space Launch System (SLS) rocket with Orion, Exploration Mission-1, or EM-1, will lift off from Launch Complex 39B at NASA's Kennedy Space Center in Florida. On the mission, the spacecraft will venture 40,000 miles beyond the orbit of the moon, farther than any spacecraft built for humans has ever traveled, testing the systems needed for the agency's journey to Mars. The mission will conclude with Orion re-entering the Earth's atmosphere at 25,000 mph and then slowing down to a gentle splashdown in the Pacific Ocean.

The bonding process began in July and will continue over several months. The work is taking place in the high bay of the Neil Armstrong Operations and Checkout Building where assembly of the Orion crew module's pressure vessel, or underlying structure, has been taking place since it arrived at the Florida spaceport in February. The newly designed tiles incorporate a stronger coating called "toughened uni-piece fibrous insulation," or TUFI coating, and will also be covered with an aluminized coating that improves on-orbit thermal control of the vehicle and gives Orion its shiny new look.

Read the full story at: **bit.ly/OrionTileBonding**

In the Neil Armstrong Operations and Checkout Building at NASA's Kennedy Space Center, technicians have begun bonding thermal protection system tiles to the nine panels that will cover the Orion crew module for the agency's first unpiloted flight test with the Space Launch System (SLS) on the agency's Journey to Mars.

Technicians prepare to bond thermal protection system tiles on the Orion crew module for the agency's Exploration Mission-1 flight with the Space Launch System (SLS) rocket. Orion requires about 1,300 tiles. Many of the Orion tiles are standard, except for those which fit around windows, thrusters or antennae. Along with the spacecraft's heatshield, the tiles will protect Orion from the 5,000 degree Fahrenheit heat of re-entry.

Natalie Oluwo, as Undyne from Undertale, gives Orion's PORT mockup a thumbs up at Comicpalooza.

ORION'S SERVICE MODULE COMPLETES CRITICAL DESIGN REVIEW

NASA and ESA (European Space Agency) conducted a critical design review (CDR) culminating in a final review board June 16 for Orion's European-built service module. The service module is an essential part of the spacecraft that will power, propel, and cool Orion in deep space as well as provide air and water for crew members. The CDR rounds out the latest in a series of reviews for the three human exploration systems development programs that will enable the journey to Mars.

A test version of the Orion service module has been undergoing acoustic and vibration testing at NASA Glenn Research Center's Plum Brook Station in Sandusky, Ohio.

During the review process, technical experts examined the module designs and numerous items were processed and closed out, giving engineers confidence the module design is mature enough to continue with fabrication, assembly, integration and testing.

The recently completed review focused on the overall service module design while discussing differences between Orion's first deep space mission atop the Space Launch System (SLS) rocket and the mission to follow that will carry crew. No new major issues were identified during the review, and the teams worked together to develop a plan for work going forward in areas such as power, solar array management and propellant usage.

The review was conducted at ESA's European Space Research and Technology Centre in Noordwijk, Netherlands with teams from NASA, ESA, Lockheed Martin and Airbus Defence & Space in Bremen, Germany. Lockheed Martin is NASA's main contractor building Orion, and Airbus is ESA's contractor for the service module.

The CDR identified April 2017 as the target for the service module delivery to Kennedy Space Center in Florida. Teams will begin integrating hardware into the rocket before the service module is delivered, and NASA plans to continue to optimize processing when it arrives at Kennedy. Initial results maintain EM-1 launch date no later than November 2018.

Read the full story at: **bit.ly/ServiceModule_DesignReview**

An Orbital Maneuvering System engine that will help propel Orion while in space is undergoing vibration testing at the NASA's Johnson Space Center in Houston.

RELIABLE, LEGACY ENGINE TO POWER ORION SPACECRAFT

An Orbital Maneuvering System engine is outfitted at NASA's Johnson Space Center in Houston before shipment to NASA's White Sands Test Facility in New Mexico.

For more than 50 years, NASA has built upon the trials, tribulations and successes of all its human spaceflight missions to safely evolve to today's more ambitious and demanding missions required for the journey to Mars.

Engineers at NASA's Johnson Space Center in Houston are conducting vibration tests on an Orbital Maneuvering System engine used on the space shuttle before shipping it to the agency's White Sands Test Facility in New Mexico, where it will be fired to qualify the engine for use on Orion's service module. The vibration testing will help ensure the engine can withstand the loads induced by launch on the agency's SLS rocket. This summer, another Orbital Maneuvering System engine will be tested at Johnson before it is supplied to ESA to integrate into Orion's service module, which will power, propel and cool Orion in space, and also provide consumables like air and water for future crews.

ESA and its contractor Airbus Defence & Space are providing the service module for Exploration Mission-1, a 2018 mission of the Orion spacecraft and SLS rocket that will send the spacecraft about 40,000 miles beyond the moon. This Orbital Maneuvering System engine was used on the space shuttle to provide the thrust for orbital insertion, orbit circularization, orbit transfer, rendezvous, deorbit and abort situations and flew on 31 shuttle flights. The engine flying on Exploration Mission-1 flew on 19 space shuttle flights, beginning with STS-41G in October 1984 and ending with STS-112 in October 2002.

Read the full story at: **bit.ly/SMEngine_ShakeTest**

National Aeronautics and Space Administration

ORION

MAY 2016

PERFORMANCE UNDER PRESSURE

Lockheed Martin engineers and technicians prepare the Orion crew module for a series of tests inside the proof pressure cell in the Neil Armstrong Operations and Checkout Building at NASA's Kennedy Space Center in Florida.

ORION SPACECRAFT PASSES PRESSURE TEST SERIES

Engineers at NASA's Kennedy Space Center in Florida recently completed a series of pressure tests on the Orion crew module. The tests confirmed that the weld points of the underlying structure, called the pressure vessel, will protect astronauts during the launch, in-space, re-entry and landing phases of spaceflight.

Orion's pressurized crew module contains the atmosphere that a crew would breathe during a mission. It is also the living and working space for the crew and must withstand the loads and forces experienced during launch and landing.

Orion was tested inside the proof pressure cell in the high bay of the Neil Armstrong Operations and Checkout Building. Lockheed Martin, the manufacturer of the Orion crew module, ran the test at incremental steps over two days to reach the maximum pressure. During each step, the team pressurized the chamber and then evaluated the data to identify changes for the next test parameter. The results revealed the workmanship of the crew module pressure vessel welds and how the welds reacted to the stresses from the pressurization.

Future tests at Kennedy will include a launch simulation and power-on procedure. Orion and its service module also will be sent to NASA Glenn Research Center's Plum Brook Station facility in Sandusky, Ohio, for acoustics and vibration tests.

NASA's Space Launch System will launch Orion on its next flight, Exploration Mission 1 (EM-1), when the spacecraft will travel beyond the moon and back on an uncrewed flight test.

Read the full story about the pressure test series.

A press conference in Germany marks the arrival of the EM-1 flight structure to Bremen and the start of the assembly by Airbus.

ORION SERVICE MODULE ASSEMBLY UNDERWAY AT AIRBUS

Shown in photo from left to right: Jim Free (NASA), Jan Wörner (ESA), Carsten Sieling (Lord Mayor Bremen), Bart Reijnen (Airbus) and Michael Hawes (Lockheed Martin).

Airbus Defence and Space, the world's second largest space company, began assembling the European-built service module for Exploration Mission-1. The service module sits below the crew module and is known as the powerhouse of NASA's next-generation Orion spacecraft.

After the arrival of the flight model structure from Thales Alenia Space Italy, final assembly will be carried out at Airbus Defence and Space's site at Bremen, Germany, where officials from ESA (European Space Agency), NASA, Airbus Defence and Space and partners gave an update on the Orion program's progress on May 19.

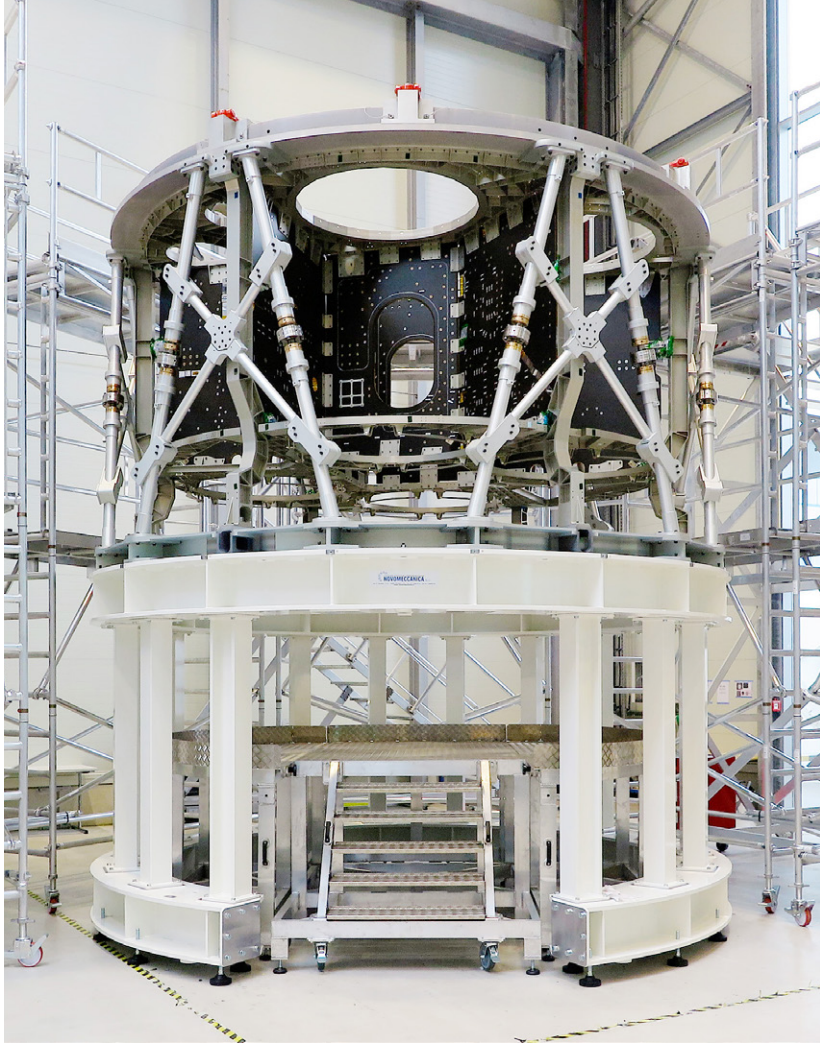
Integrating more than 20,000 parts and components in the flight model ranging from electrical equipment to rocket engines, solar arrays, tanks for propellant and life support consumables as well as hundreds of meters of cables and tubes marks a major milestone for the Orion program.

Continued on next page >

Airbus Defence and Space was chosen by ESA as the prime contractor to develop and build the service module, which will supply propulsion, power, thermal control, air and water for astronauts on missions beyond the moon and to Mars.

In managing the development and construction of the module, Airbus Defence and Space is drawing on its extensive experience as prime contractor of ESA's Automated Transfer Vehicle, which made regular deliveries of experiment equipment, spare parts, food, air and water for the crews on board the International Space Station.

Read the full story about the Orion assembly.



On the right, the primary structure for the Exploration Mission-1 service module is prepared for final assembly at the Airbus Defence and Space facility in Bremen, Germany.

Picture below, Oliver Juckenhöfel, head of the Orion European service module for Airbus Defence and Space hosted 170 team members across the program to exchange information, provide a status of the program, and work on quality and team building. Team members are from Les Mureaux, France; Lampoldshausen & Bremen, Germany; and the United States.

National Aeronautics and Space Administration

ORION

APRIL 2016

SPLISH SPLASH!

ORION SPLASHDOWN TEST SERIES UNDERWAY

Engineers at NASA's Langley Research Center in Hampton, Virginia, launched a series of nine drop tests with a full-scale Orion crew capsule outfitted with crash test dummies inside to understand what the spacecraft and astronauts may experience when landing in the Pacific Ocean after deep-space missions. The high-fidelity capsule, coupled with the heat shield from Orion's first flight in space, was hoisted approximately 16 feet above the water and vertically dropped into Langley's 20-foot-deep Hydro Impact Basin during the inaugural test on April 6. The crash test dummies were instrumented to provide data and secured inside the capsule to help provide information engineers need to ensure astronauts will be protected from injury during splashdown. Each test in the series simulates different scenarios for Orion's parachute-assisted landings, wind conditions, velocities and wave heights the spacecraft may experience when touching down in the ocean.

Water-impact testing will help NASA evaluate how the spacecraft may behave when landing under its parachutes in different wind conditions and wave heights. Langley has already conducted dozens of splash tests with a less sophisticated capsule mockup, but this is the first time it will assess the higher fidelity Orion ground test article.

▶ Watch video of the first drop test in the series

THESE DUMMIES ARE SMARTER THAN YOU THINK!

Dummies can actually teach engineers a thing or two. When outfitted with tiny sensors, these mannequins are able to collect data to help Orion engineers better understand and prepare crew members for various splashdown scenarios.

Two test dummies – one representing a 105-pound woman and the other a 220-pound man to assess the impact on different-sized people – were installed in the crew seats of the Orion crew module mockup.

For the initial round of tests, the dummies were not equipped with suits and helmets. After the third test, the dummies were outfitted with spacesuits and helmets to simulate fully suited crew members returning from a deep-space mission. After four vertical drop tests are completed, the capsule will undergo a series of five swing tests with the mock crew.

Collecting data on the dummies with and without suits allows engineers to make comparisons, which will aid in the computer modeling of Orion's splashdown.

Water-impact testing is one of many steps required to ensure Orion will meet the demands of sending humans to deep space for the first time and in the future on the journey to Mars.

▶ Read the full story

ORION'S SOUND CHECK GETS INTENSE

Orion engineers blasted an Orion service module test article with forceful sound and pressure in the Reverberant Acoustic Test Facility (RATF) at NASA Glenn Research Center's Plum Brook Station in Sandusky, Ohio, during a series of acoustic tests that began in April.

The test article was lambasted with more than 150 decibels and 20-10,000 hertz of sound pressure and vibration to simulate the intense sounds the Orion service module will be subjected to during launch and ascent into space atop the agency's Space Launch System (SLS) rocket. This series of tests will verify the structural integrity of Orion's service module for Exploration Mission-1, the spacecraft's first flight atop SLS that will venture to the far side of the moon and back to Earth during a three-week, uncrewed mission in 2018.

Provided by ESA (European Space Agency) and built by Airbus Defence and Space, the service module will power, propel and cool the spacecraft and also supply Orion's crew with air and water. The first crewed mission for Orion and SLS is scheduled to launch as early as 2021.

The Orion service module for EM-1 was delivered by Thales Alenia Space to the Airbus Defence and Space facility in Bremen, Germany, for final assembly and integration work. It will be shipped to the United States for further integration with the other elements that make up Orion at the beginning of next year.

Media coverage of the testing included:

- ▶ **Sandusky Register**
- ▶ **SpaceFlight Insider**
- ▶ **ESA Blog**

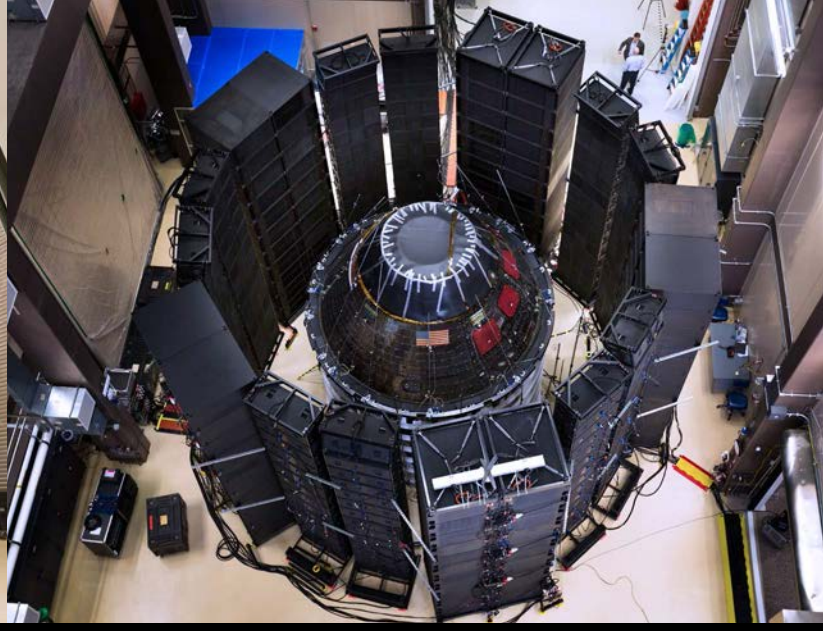
Pictured above: The service module test article sits in the RATF at Glenn's Plum Brook Station ahead of testing. The blue structure sitting on top of the test article is a mass simulator that represents the Orion crew module.

National Aeronautics and Space Administration

ORION

MARCH 2016

ROCKING OUT WITH ORION



MEGAWATTS OF ENERGY TEST ORION'S SOUND STRUCTURE

During the first week of March, the Orion crew module that flew in space on Exploration Flight Test-1 had its own private rock concert. More than 1,500 speakers, generating nearly a megawatt of energy, surrounded the spacecraft and blasted it with sound loads similar to what future Orion missions will experience during launch and ascent.

This new type of acoustic testing, performed in the Reverberant Acoustic Lab of Lockheed Martin Space Systems' Waterton, Colorado, campus, is called direct field acoustic testing. The team is trying it out to see if it is a viable, cost-effective testing mechanism for future Orion missions.

"For a typical acoustic test, we move the spacecraft into a soundproof test chamber, close the door and pump sound through horns to recreate the sound spectrum that the launch vehicle will produce," said Dan Qvale, Orion mechanical test manager at Lockheed Martin. "Direct field acoustic testing allows us to bring the test to the spacecraft instead of having to bring the spacecraft to the test facility. Hundreds of speakers are stacked in a circle around the spacecraft without having to move the vehicle into an acoustics chamber facility."

Future Orion missions, beginning with Exploration Mission-1, will launch aboard NASA's powerful Space Launch System rocket. To simulate the sound loads Orion will experience during launch, the team needed to evaluate a very high level of acoustic loads.

"The sound we subjected Orion to was louder than jet engines or a stadium rock concert," said Shane Roskie, the Orion test engineer and operations manager.

Using the new direct field acoustic testing will allow greater schedule flexibility and decrease testing costs, helping make the test and production of future Orion capsules more affordable and efficient.

Lockheed Martin also invited media to view the test set-up and to speak with Dan Qvale and Shane Roskie. Examples of the resulting media coverage included:

- **Popular Science**
- **FOX31 Denver**
- **CBS Denver**
- **9News**

National Aeronautics and Space Administration

ORION

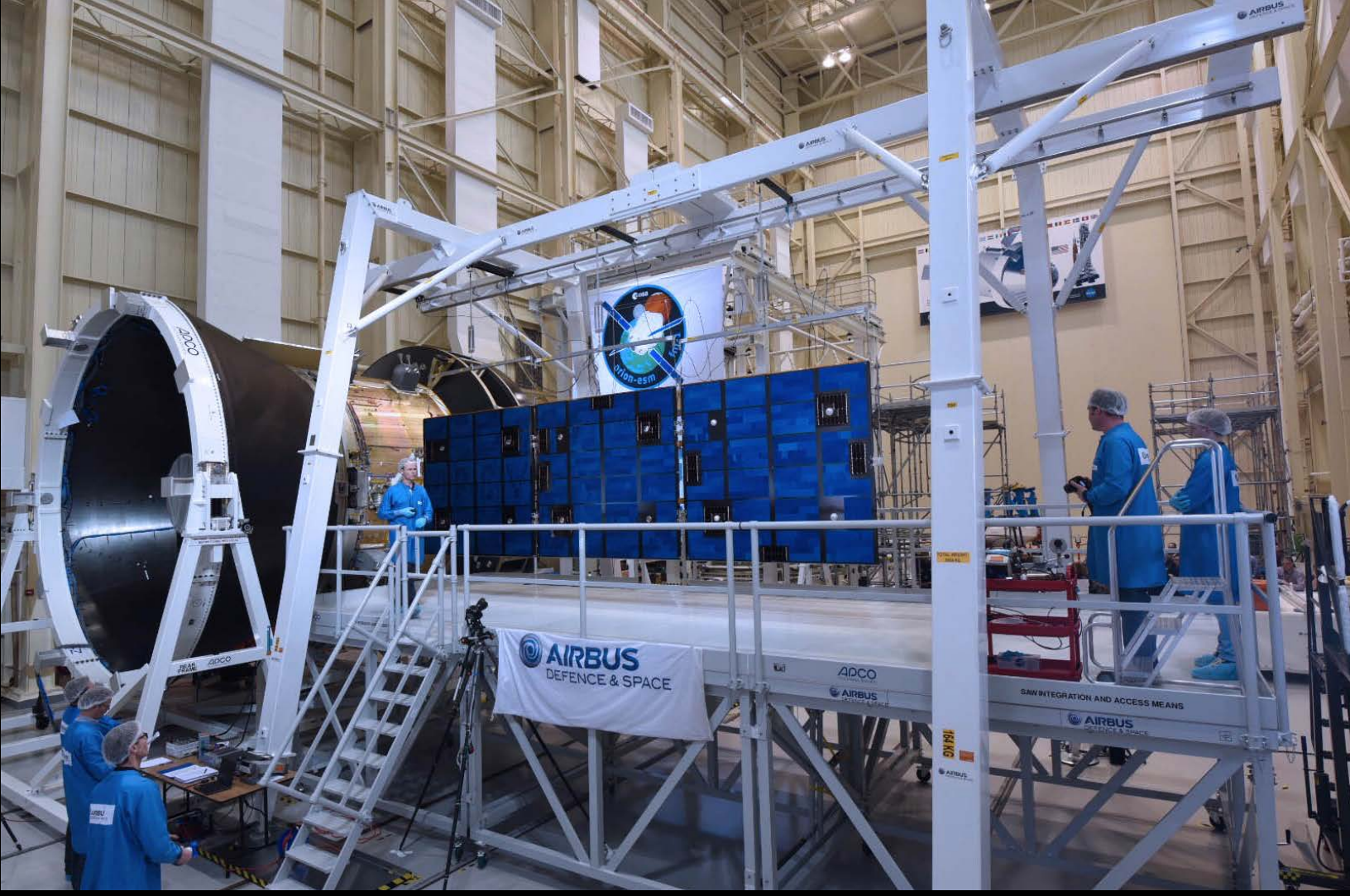
FEBRUARY 2016

ORION EXTENDS ITS REACH

Engineers examine one of Orion's solar array wings after a test at NASA Glenn's Plum Brook Station.

ORION SOLAR ARRAY SUCCESSFULLY DEPLOYED

A representative structure of Orion's service module, which is being tested at Plum Brook Station in Sandusky, Ohio, was tilted to a 90-degree angle in preparation for the solar array deployment test.



An international team of engineers successfully deployed an Orion solar array wing inside the Space Power Facility (SPF) at NASA Glenn Research Center's Plum Brook Station in Sandusky, Ohio, on Feb. 29.

The deployment of the 24-foot wing qualification model was an important first step to verify Orion's power system for the spacecraft's first flight atop the agency's Space Launch System (SLS) rocket.

When deployed on orbit, Orion's four solar array wings will span across 63 feet and resemble the ESA (European Space Agency) Automated Transfer Vehicle's X-shaped array. The four panels combined will generate 11 thousand watts, enough power to light up an entire street of homes on Earth. The array is a component of Orion's service module, which is being provided by ESA and built by Airbus Defence and Space to supply Orion's power, propulsion, air and water.

The successful deployment was the first in a series of crucial tests being performed at SPF to verify the Orion service module can withstand the harsh conditions of launch and ascent into deep space. SPF is the only place in the world that can subject the full-scale, flight-like test article to the conditions of launch and ascent. It is home to the world's largest mechanical vibration table and most powerful acoustic chamber.

Throughout spring and fall, engineers will use those facilities to mimic the shaking and noise the service module will experience during its ascent into space. They also will use pyrotechnics to simulate the shock the service module will experience during separation from the SLS rocket. In early fall, the team will conclude the campaign with another solar array wing deployment test.

With the first solar array wing test complete, engineers will waste no time preparing for the next test. They will soon begin stacking the Orion crew module and launch abort system mass simulator on top of the test article and attaching the outer fairings in preparation for acoustic tests to begin this spring.

▶ Read the full story

SIMULATIONS ARE THE REAL DEAL FOR ORION MISSION OPERATIONS TEAM

In early February, flight controllers and astronauts took part in a joint simulation to evaluate the prototype Orion crew display and control system, advanced caution and warning system for flight controllers, and communication protocols. The test was conducted in the Rapid Prototyping Lab (RPL) at NASA's Johnson Space Center in Houston where engineers are creating and evaluating the display and control systems that Orion's crew will use to navigate and operate the spacecraft.

The simulation involved two astronauts and several flight controllers, including a flight director, capsule communicator (CAPCOM) to communicate with the crew, and controllers who manage electrical power subsystems and environmental control and life support elements. Together they worked through a failure scenario in which part of Orion's power system failed. This scenario required troubleshooting to get pumps and other systems back up and running to support the systems the crew needs to survive. Evaluating extreme failure scenarios is a routine part of training for missions in space.

As the RPL continues to build and evaluate the displays for crew, it also is providing hands-on engineering experience for students in Texas. Mechanical engineering students at the University of Texas at Tyler (shown at right), have designed and built a mount to attach the cursor control device that serves as one way to operate Orion's displays. The students delivered their hardware to NASA in February.

As engineers continue to develop Orion's display, controls and software for crewed flights, teams will conduct additional simulations. The RPL will also continue to look for potential ways to include student ingenuity in the lab.

▶ Read the full story

National Aeronautics and
Space Administration

ORION

JANUARY 2016

WE SHIP SPACE SHIPS

Orion's Ground Test Article and Exploration Flight Test-1 Heat Shield ready for water drop tests at NASA Langley Research Center in Virginia.

ORION MILESTONES TO TRACK IN 2016

Throughout 2016, engineers and technicians will continue refining, assembling and testing the Orion spacecraft that will send astronauts to deep-space destinations on NASA's journey to Mars.

In Colorado, Lockheed Martin engineers will evaluate a new acoustic technology called Direct Field Acoustic Testing. The test will use customized, high-energy speakers configured in a circle around the crew module flown in space in 2014 to control how much energy reaches the vehicle. The evaluation of the acoustic testing will determine if the method can produce enough energy to simulate the acoustic loads Orion will experience during launch and ascent on the SLS rocket. In 2016, Engineers at NASA Glenn Research Center's Plum Brook Station will put a structural representation of the Orion service module provided by ESA (European Space Agency) and built by Airbus through a series of crucial tests to verify the structural integrity and ability to withstand the dynamic launch environment atop the SLS rocket.

In the spring, tests at NASA Langley Research Center's Hydro Impact Basin, will mimic some of the most stressful water landing conditions Orion could experience with it returns from deep space and splashes down in the Pacific Ocean. Engineers outfitted a test version of the crew module with Orion's heat shield that flew in space and two test dummies strapped inside to evaluate loads the crew may experience during real missions.

The tests highlighted in 2016 are only part of the overall test plan for Orion and SLS in preparation for their first exploration mission. With the progress made so far, and tests planned at Kennedy in 2017 and 2018 when the rocket and ground systems are ready, NASA is on a path to be ready to launch Exploration Mission-1 in 2018.

▶ **Read the full story**

ORION'S CREW & SERVICE MODULES GET HITCHED

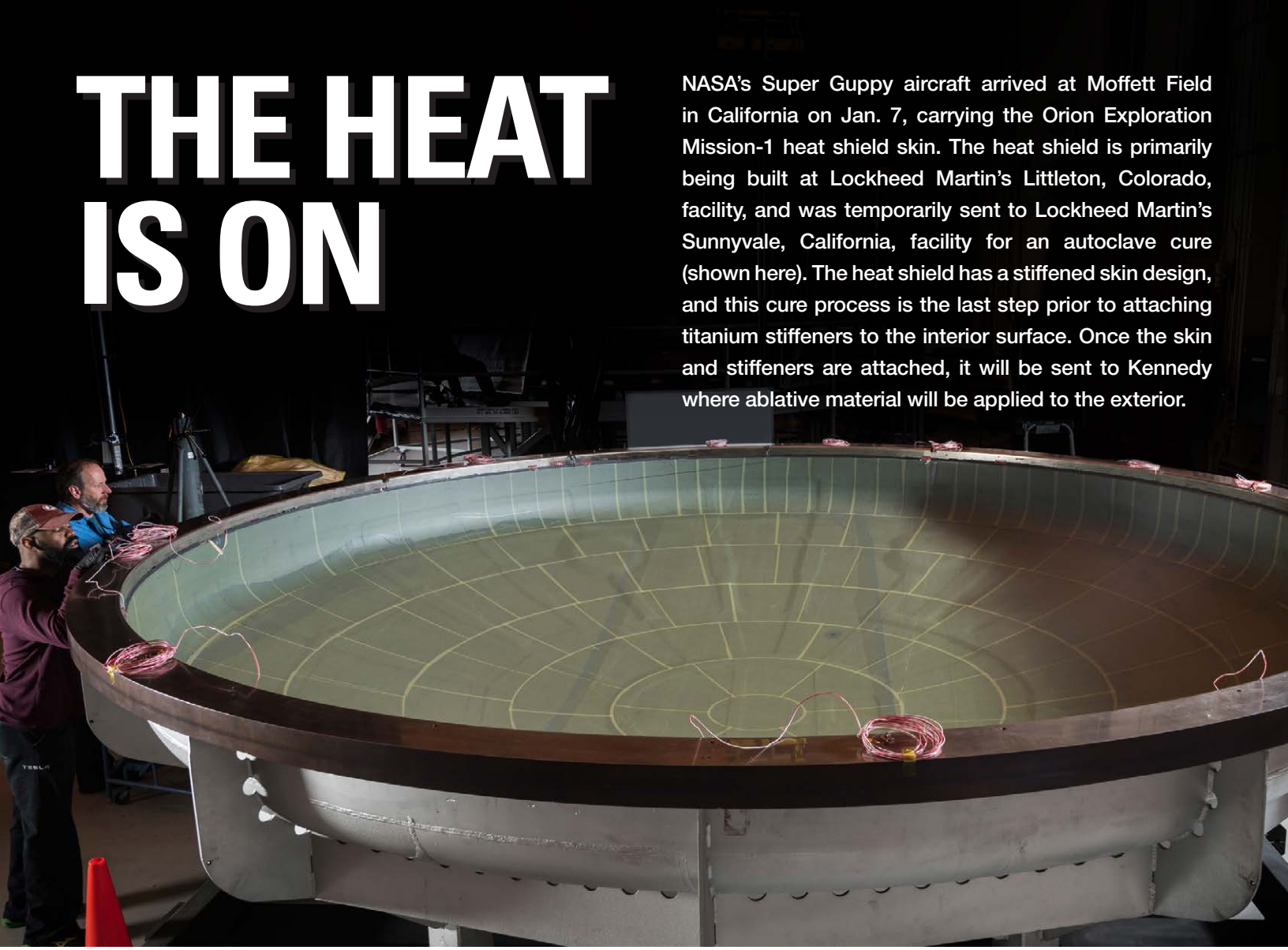
The Orion team at NASA Glenn Research Center's Plum Brook station in Sandusky, Ohio, successfully tested mating operations that will connect the spacecraft's service module to the crew module adapter.

The European service module structural test article (E-STA) is used for testing purposes before installing the real thing. It is as close to the flight version as possible while keeping costs and development time manageable. The structure and weight are the same, while mass equivalents stand in for electronics boxes not needed for the series of tests.
The test article was installed under a test version of the crew module adapter, and sits on the spacecraft adapter that will attach Orion to its launch vehicle. This test marked the first time the European-built hardware has been physically connected to NASA's elements.

The service module will soon be vigorously shaken on the vibration table at Plum Brook's Space Power Facility to recreate the vibrations of launch. The spacecraft test structure will also be subjected to acoustic and shock environments. Built by European Space Agency and Airbus, the European service module will provide electricity, water, oxygen and nitrogen, and thermal control as well as propulsion for the spacecraft.

▶ Read about the Service Module on ESA blog

THE HEAT IS ON



NASA's Super Guppy aircraft arrived at Moffett Field in California on Jan. 7, carrying the Orion Exploration Mission-1 heat shield skin. The heat shield is primarily being built at Lockheed Martin's Littleton, Colorado, facility, and was temporarily sent to Lockheed Martin's Sunnyvale, California, facility for an autoclave cure (shown here). The heat shield has a stiffened skin design, and this cure process is the last step prior to attaching titanium stiffeners to the interior surface. Once the skin and stiffeners are attached, it will be sent to Kennedy where ablative material will be applied to the exterior.

STENNIS PROPULSION TEAM FIRES UP ORION TESTING

It is widely known that rocket engines tested at NASA's Stennis Space Center near Bay St. Louis, Mississippi, will launch NASA's new Space Launch System on its missions. What is not so widely known is that the south Mississippi center also contributes to the propulsion system that will power the Orion crew vehicle once it leaves Earth's atmosphere and separates from the SLS.

In late 2015, Stennis engineers completed a series of tests on a subscale diffuser system, providing valuable data for the final development testing of the engines that will provide the power Orion needs for deep-space missions.

Stennis engineers also concluded a subscale diffuser test series that recorded 38 hot fires for a total of 172.46 seconds. Data gathered from the testing of the subscale configurations now will be used to build a full-scale diffuser chamber at NASA's White Sands Test Facility near Las Cruces, New Mexico, which will be used to provide a simulated space environment during an actual hot fire test series of the Orion service module propulsion system.

▶ **Read the full story**