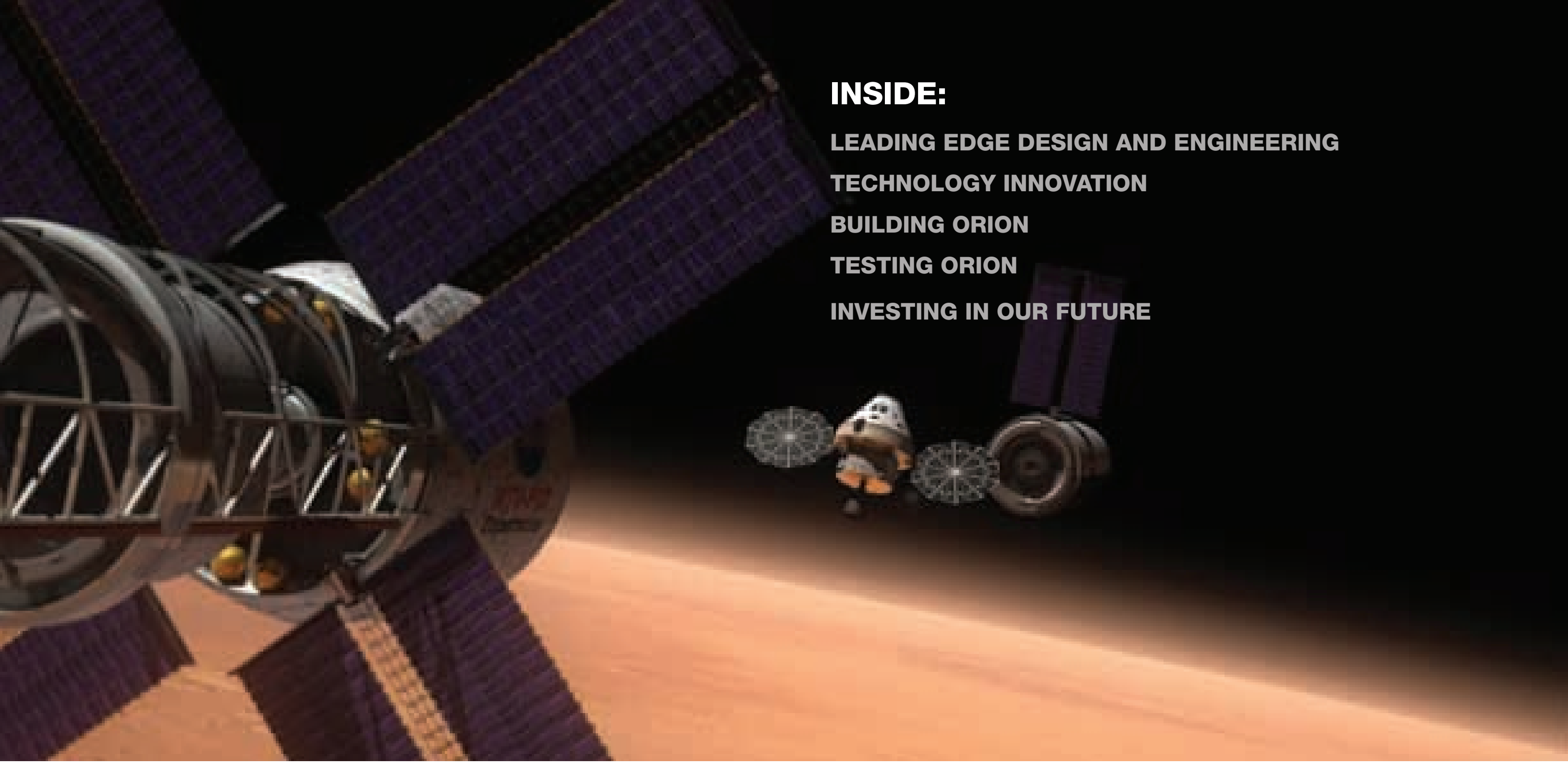
National Aeronautics and
Space Administration

orion

AMERICA'S NEXT GENERATION SPACECRAFT



INSIDE:

LEADING EDGE DESIGN AND ENGINEERING

Drawing from more than 50 years of spaceflight research and development, Orion is designed to meet the evolving needs of our nation's space program for decades to come.

As the flagship of our nation's next-generation space fleet, Orion will push the envelope of human spaceflight far beyond low Earth orbit.

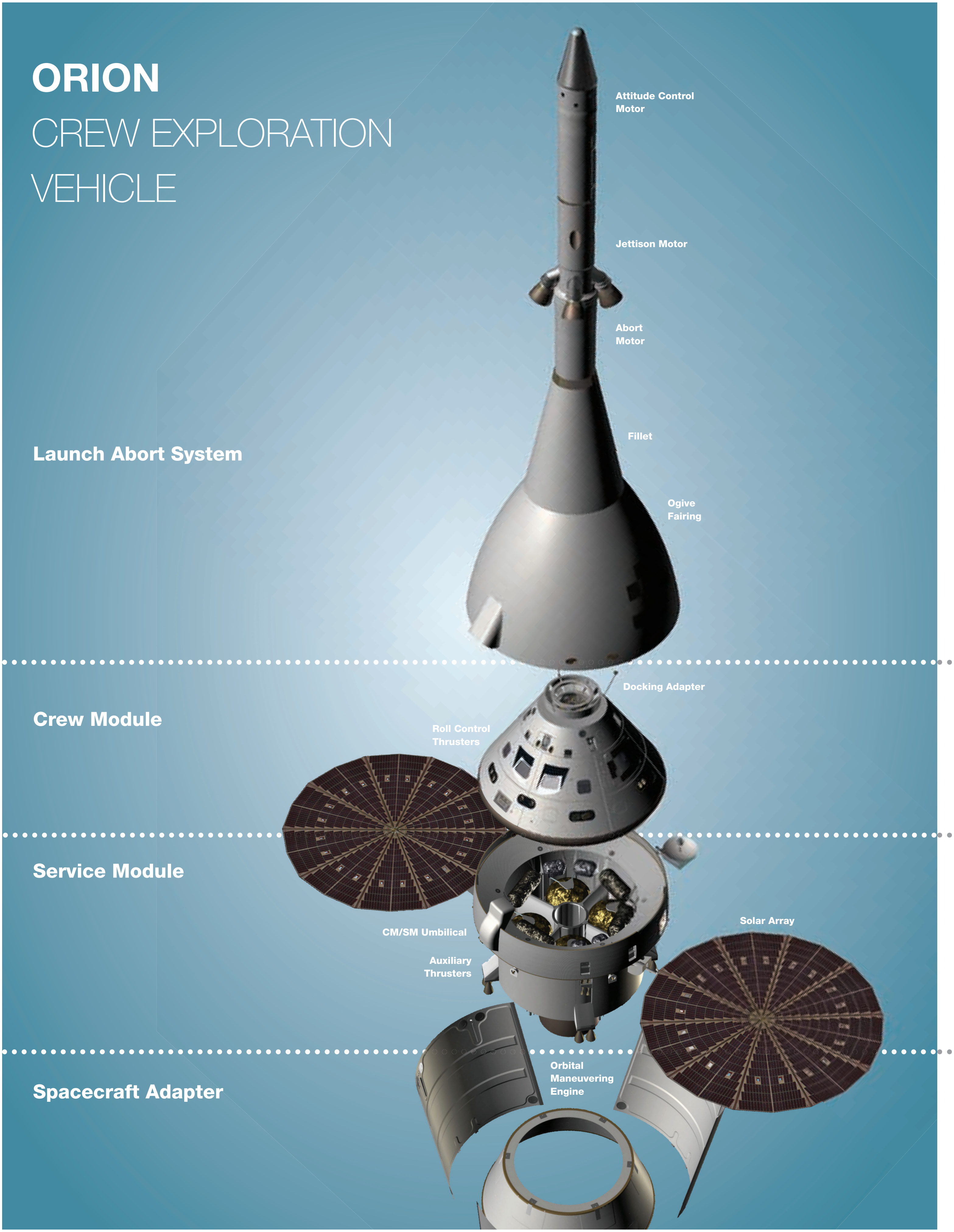
Orion may resemble its Apollo-era predecessors, but its technology and capability are light years apart. Orion features dozens of technology advancements and innovations that have been incorporated into the spacecraft's subsystem and component design.

To support long-duration deep space missions of up to six months, Orion engineers developed a state-of-the-art spacecraft with unique life support, propulsion, thermal protection and avionics systems.

Building upon the best of Apollo and shuttle-era design, the Orion spacecraft includes both crew and service modules, a spacecraft adaptor, and a revolutionary launch abort system that will significantly increase crew safety.

Orion's crew module is much larger than Apollo's and can support more crew members for short or long-duration spaceflight missions. The service module is the powerhouse that fuels and propels the spacecraft as well as the storehouse for the life-sustaining air and water astronauts need during their space travels. The service module's structure will also provide places to mount scientific experiments and cargo.

Orion is capable of supporting low Earth orbit missions or transporting astronauts on a variety of expeditions beyond low Earth orbit – ushering in a new era of space exploration. Orion can carry astronauts to the International Space Station, deliver cargo for resupply, and remain on orbit under its own power supply to serve as an emergency escape vehicle for the crew onboard.


ORION
CREW EXPLORATION
VEHICLE
Launch Abort System
Attitude Control
Motor
Jettison Motor
Abort
Motor
Fillet
Ogive
Fairing
Crew Module
Docking Adapter
Roll Control
Thrusters
Service Module
Solar Array
CM/SM Umbilical
Auxiliary
Thrusters
Spacecraft Adapter
Orbital
Maneuvering
Engine

The test vehicle is readied for launch at White Sands Missile Range's Launch Complex 32E.

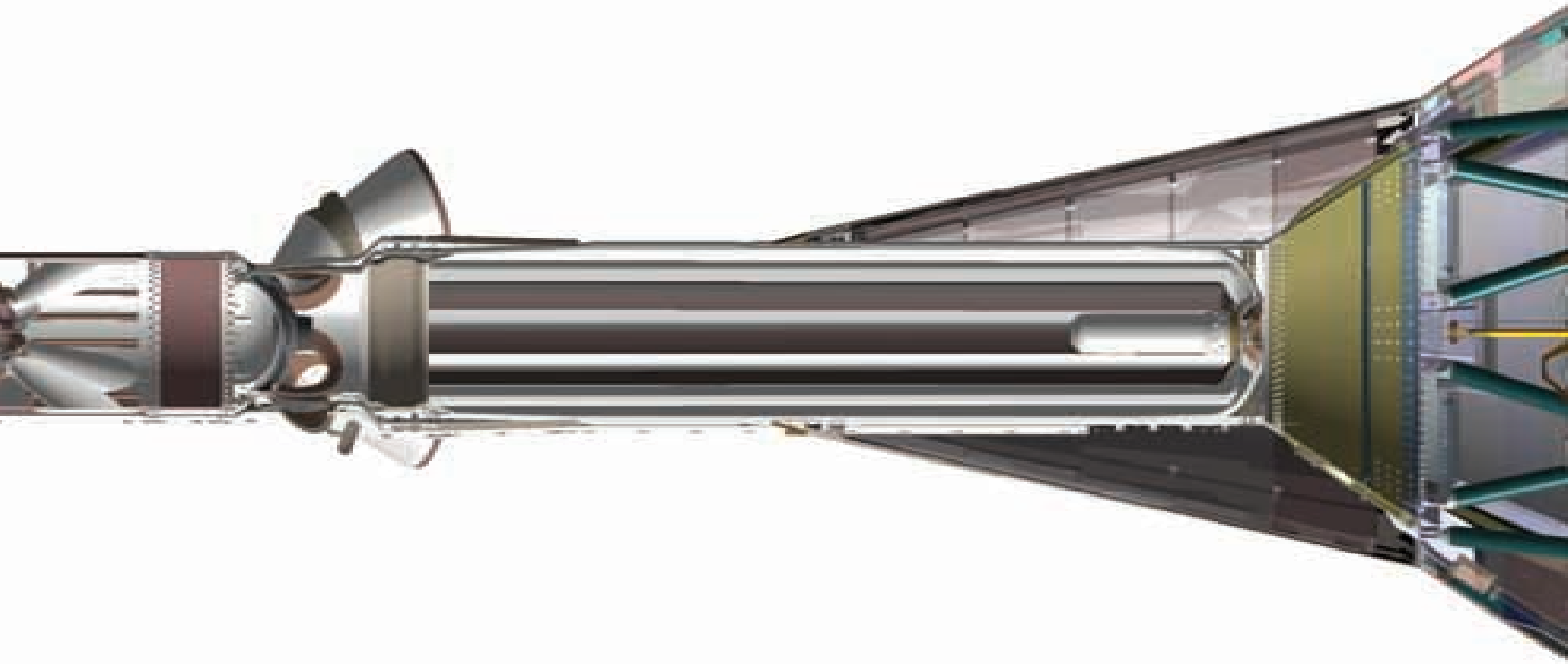
The launch abort system, positioned on a tower atop the crew module, activates within milliseconds to propel the crew module to safety in the event of an emergency during launch or climb to orbit. The system also protects the crew module from dangerous atmospheric loads and heating, then jettisons after Orion is through the initial mission phase of ascent to orbit.

The crew module is the transportation capsule that provides a safe habitat for the crew, provides storage for consumables and research instruments, and serves as the docking port for crew transfers. The crew module is the only part of Orion that returns to Earth after each mission.

The service module supports the crew module from launch through separation prior to reentry. It provides in-space propulsion capability for orbital transfer, attitude control, and high altitude ascent aborts. When mated with the crew module, it provides the water, oxygen and nitrogen needed for a habitable environment, generates and stores electrical power while on-orbit, and maintains the temperature of the vehicle's systems and components.

This module can also transport unpressurized cargo and scientific payloads.

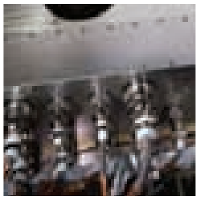
The spacecraft adapter connects the Orion Crew Exploration Vehicle to the launch vehicle and protects service module components.



ORION TECHNOLOGY INNOVATIONS

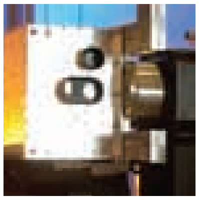
Propulsion:

Abort Motor, Attitude Control Motor, High Burn Rate Propellant for Solid Rocket Motors



Avionics:

Algorithmic Autocode Generation, ARINC-653 / DO-178 Standard Operating System, Baseband Processor, High Speed/High Density Memory Devices, Honeywell HX5000 Northstar ASIC

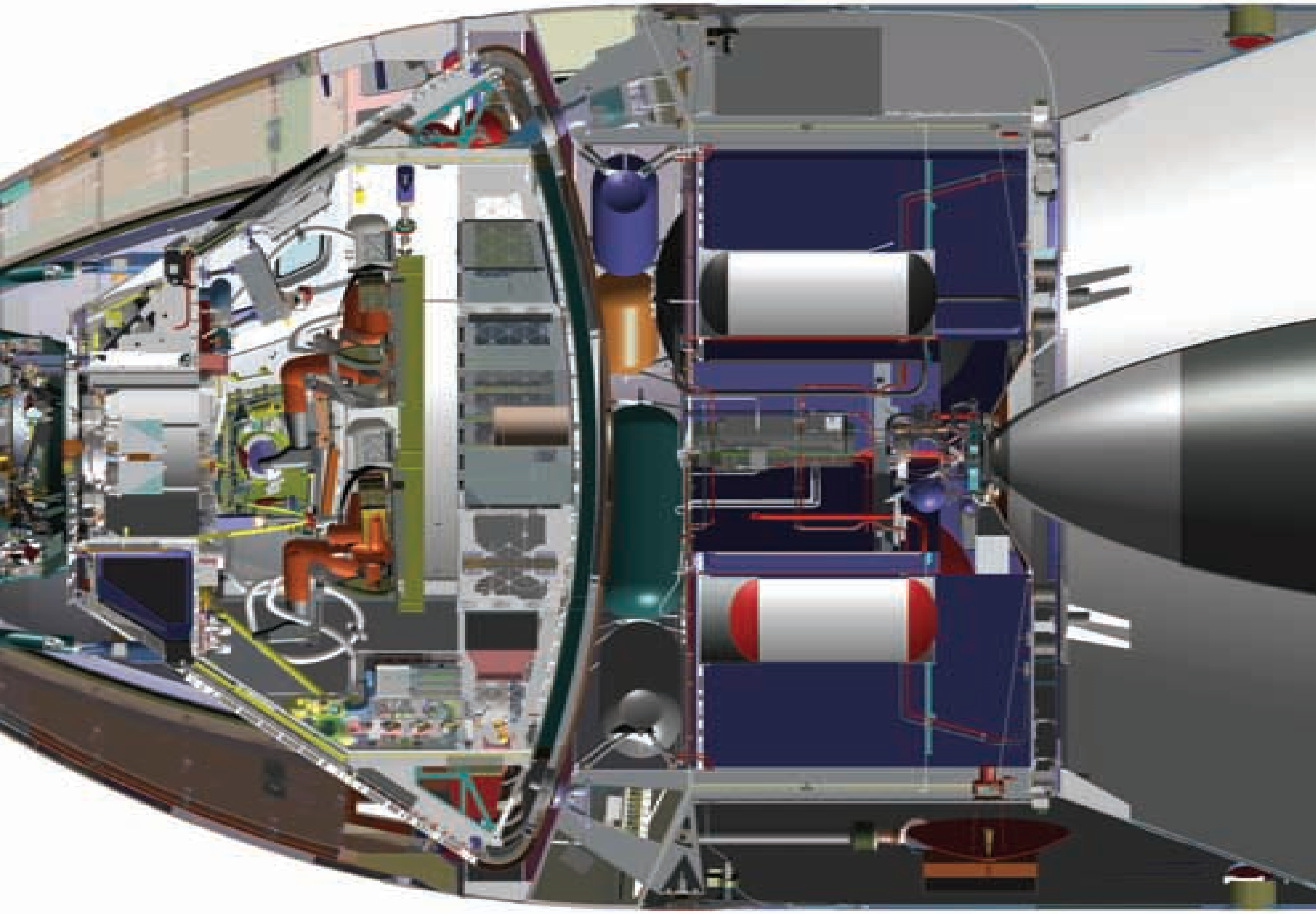


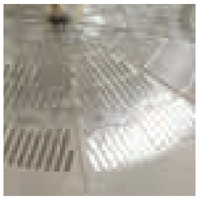
Navigation:

Atmospheric Skip Entry, Autonomous Rendezvous and Docking, Fast Acquisition GPS Receiver, High Density Camera Sensors

Communications:

C3I - Standard Communications, Communication Network Router Card, Digital Video Recorder





Power:

Column Grid Array Packaging (CGA),

Direct Energy Power Transfer System

Life Support & Safety:

Backup and Survival Systems,

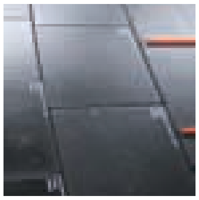
Closed Loop Life Support,

Contingency Land Landing,

Enhanced Waste Management,

Environmental Control, Hazard

Detection, Isolation and Recovery



Thermal Protection System:

Ablative Heatshield with Composite

Carrier Structure

Structures:

Composite Spacecraft Structures,

Human Rated Spacecraft Primary

Structures Development

A NASA-INDUSTRY TEAM EFFORT

Creating a next-generation space transportation system is an undertaking of astronomical proportions. Orion's design team has incorporated cutting-edge technology garnered through collaborative efforts with every NASA center and hundreds of industry experts across the country.

The Orion Project Office, located at Houston's Johnson Space Center, is leading this historic development effort. As the home of America's Astronaut Corps and Mission Control, the center is responsible for Orion's crew module, crew training, and mockup facilities.

Known for its expertise in testing and launch systems, Langley Research Center in Hampton, Virginia, in partnership with Marshall Space Flight Center in Huntsville, Alabama, is leading development of the Orion launch abort system.

Glenn Research Center in Cleveland, Ohio, leads development of the Orion service module and spacecraft adapter, and has reconditioned an existing facility to support the entire suite of environmental qualification tests for the integrated Orion vehicle.

The newly renovated Operations and Checkout facility will host the manufacture and assembly of the Orion spacecraft on site at the Kennedy Space Center in Florida. With new renovations underway to create a 21st century spaceport, Kennedy will take the lead for Orion's pre-flight processing and launch operations.

On the west coast, Dryden Flight Research Center in Edwards, California, leads Orion's flight test vehicle integration and operations and coordinates with White Sands Test Facility on the design, construction and management for the launch and ground facilities at White Sands Missile Range, near Las Cruces, New Mexico.

Engineers at Glenn Research Center calibrate a scale model of the launch abort system to acquire field velocity and surface pressure data to validate turbulence modeling.

Engineers at Ames Research Center in Moffett, California, conduct wind tunnel tests to simulate various launch abort conditions the spacecraft might encounter, and performs testing of the Orion heatshield in the Ames arc jet facility.

NASA's Michoud Assembly Facility in New Orleans, Louisiana, has been instrumental in fabricating and constructing the Orion spacecraft test vehicle to be used in ground and flight test operations.

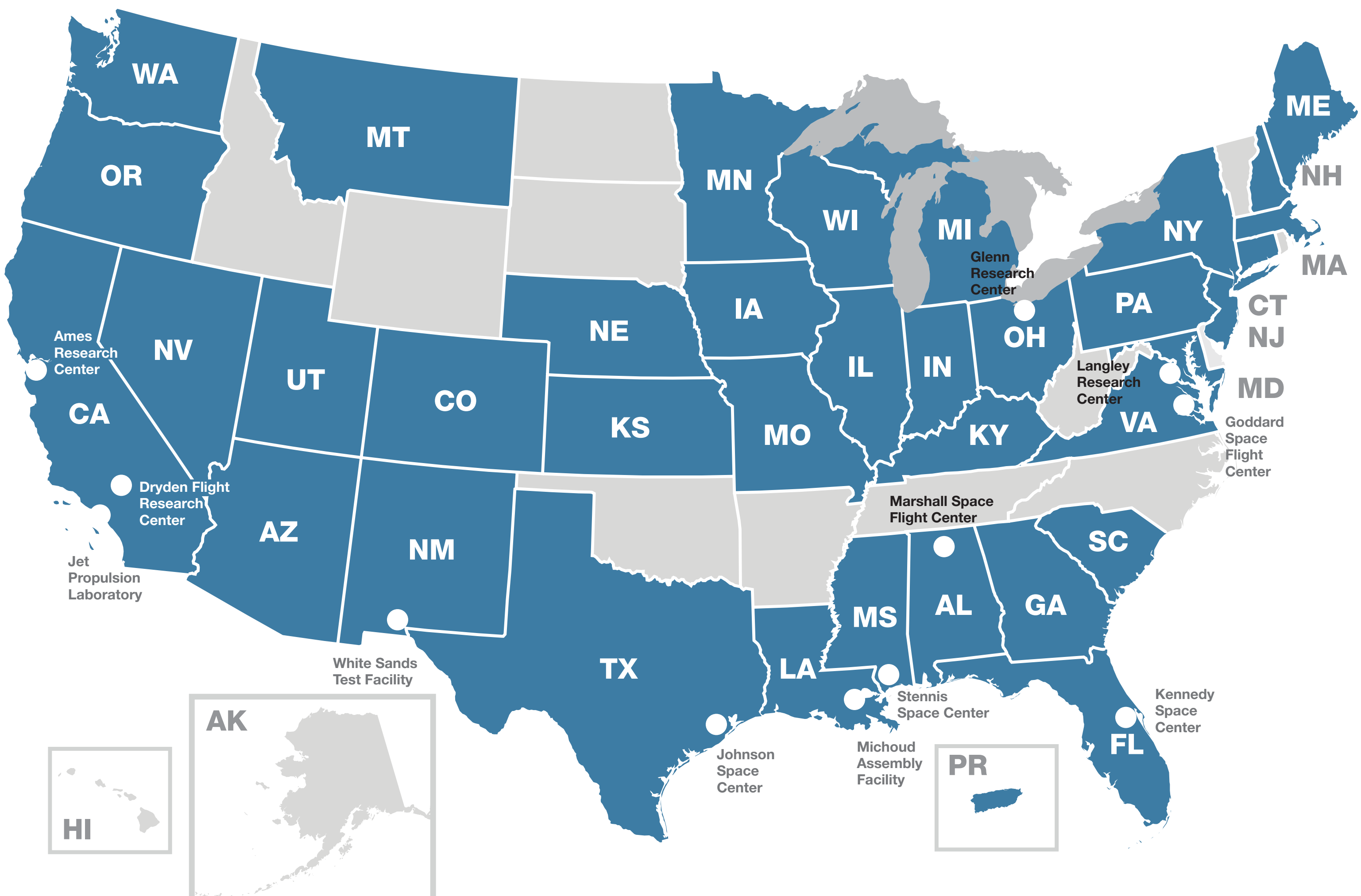
ORION TEAM MEMBERS ACROSS THE NATION

Supported by team members across the country, Lockheed Martin Space Systems Company leads the development effort as NASA's prime contractor for the Orion Crew Exploration Vehicle.

The Lockheed Martin-led industry team includes a network of major and minor subcontractors and small businesses working at 88 facilities across the country. In addition, the program contracts with more than 500 small businesses across the United States through an expansive supply chain network.

Lockheed Martin facilities in California, Colorado, Florida, Louisiana and Texas help support Orion's design and development work. Additionally, Lockheed Martin has independently invested in a network of Exploration Development and System Integration Labs that spans from Arizona to Virginia. These labs conduct early risk mitigation and system–level analyses to help reduce project costs, schedule and risk.

Subcontractor facilities have been instrumental in the design, fabrication and testing of myriad components and subsystems for Orion.



ATK's facilities in Utah and Maryland tested the abort and attitude control motors for Orion's launch abort system. Aerojet's propulsion center in California has provided ongoing testing and verification for Orion's powerful motors and engines and United Space Alliance's Thermal Protection Facility in Florida has painstakingly handcrafted all of Orion's thermal tiles.

Hamilton Sundstrand's engineers in Connecticut, Illinois and Houston have developed Orion's intricate life-support and power systems, while Arizona-based Honeywell has developed intelligent avionics and software that support data, communications and navigation.

In addition to large aerospace contractors, small businesses from all socioeconomic interests have provided specialized skills and engineering services critical to Orion's development. Risk management, life cycle cost, systems analysis, and propulsion trade studies are just a few examples of their expertise. Additionally, small businesses support all of the spacecraft's systems with design, development and manufacturing of advanced space flight hardware.

CREW SAFETY AND TRAINING

The Reconfigurable Operational Cockpit Mini Dome is one of three domed facilities in the Systems Engineering Simulator. It features a 160-degree horizontal viewing angle and 60-degree vertical viewing angle and includes the seated version of the Orion cockpit with hand controllers and simulated displays.

Astronaut safety and comfort have been designed into the Orion spacecraft every step of the way. More commonly known as “form, fit & function” Orion’s human factors engineering compares and evaluates spacecraft design to help prepare astronauts and engineers for test flights and future missions, improve overall system performance, and reduce the risk of operator error.

Mockups and simulators allow for system design evaluations and training in mission-like conditions. These simulations provide crewmembers with an opportunity to alert engineers to potential issues with crewmember reach, instrumentation and display design, control interaction, and visual blind spots that could prevent the crew or ground-based support from successfully operating the spacecraft.

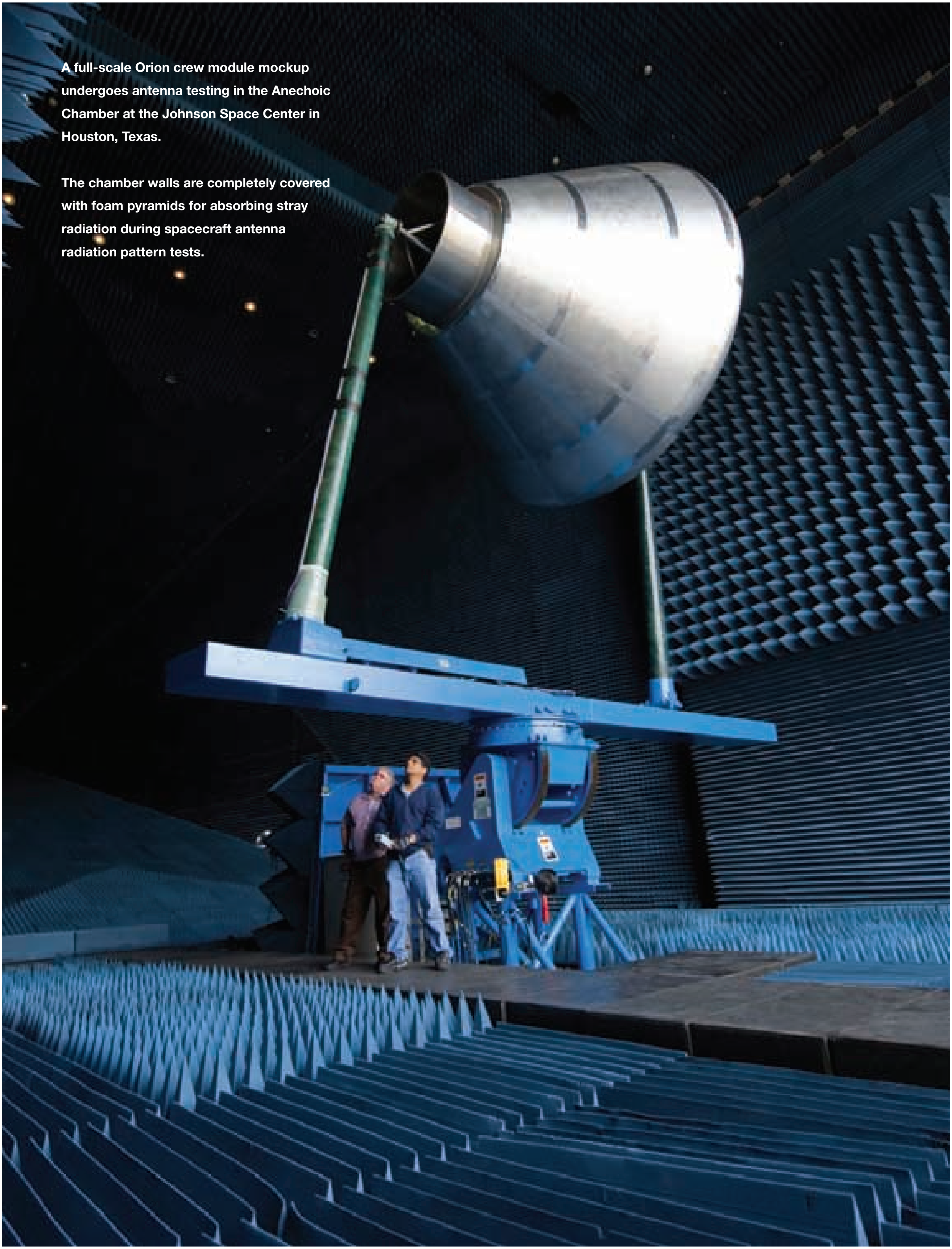
In June 2010, the Orion team successfully completed the Phase 1 Safety Review to comply with NASA’s Human Rating Requirements for space exploration in low Earth orbit and beyond. The safety review process is a rigorous and comprehensive look at the design and operational concepts to assure that all safety requirements have been adequately met. System safety requirements address potentially catastrophic failures that could result in loss of crew or loss of mission during launch, ascent to orbit, in-space operations, reentry, landing, and recovery operations.

Thoroughly reviewing spacecraft designs and operations for possible causes of such catastrophic failures, and designing proper solutions for them, is a critical part of NASA’s human rating program. The Orion team earned the approval from NASA’s Constellation Safety and Engineering Review Panel upon completion of their evaluation, an essential requirement for the Orion program to move forward to the Critical Design Review and Phase 2 Safety Review.

The Exploration Development Lab’s command and pilot station allows Orion engineers to optimize equipment and control placement through a series of evaluation exercises.

The medium fidelity Orion mockup, located at Houston’s Johnson Space Center.

View of the low fidelity mockup’s instrument panel.



A full-scale Orion crew module mockup undergoes antenna testing in the Anechoic Chamber at the Johnson Space Center in Houston, Texas.

The chamber walls are completely covered with foam pyramids for absorbing stray radiation during spacecraft antenna radiation pattern tests.

TAKING COMMAND AND CONTROL

Often described as the "brains" of a spacecraft, the avionics system consists of a wide variety of standard and complex electronics assembled into various independent systems – each responsible for performing specific critical functions. The power and data unit, tracking and communication radios, video processing unit, onboard data network, and display units are just some examples of the controls, computers, and sensors that comprise Orion's avionics systems. State-of–the-art phased array antennas and data encoding techniques are being used to transmit higher data rates while using less power and mass than other human rated spacecraft.

The Orion team demonstrated an integrated modular technology approach to avionics by maximizing the benefits of various individual technologies and combining them into one system to create a highly reliable, safe and agile avionics system. A single network supports all of Orion's data and communications with less mass, power and cost than a multisystem network.

Moving data at a rate 1,000 times faster than current systems on shuttle and station, Orion's Time Triggered Gigabit Ethernet is an innovative software technology built upon a reliable commercial data bus that has been hardened to be resilient to space radiation. This system ensures the reliability for Orion's safety-critical flight control devices.

The crew module test article used for Orion's first flight test, Pad Abort 1 included Honeywell avionics and Lockheed Martin software for onboard control of abort sequencing and inertial navigation. The testing and installation of the three pallet-mounted avionics systems for the flight test was performed at Dryden Flight Research Center in Edwards, California.

The pallets include a vehicle management computer system based on integrated modular avionics technology developed for the Boeing 787, a space-integrated GPS/INS (SIGI), and a remote interface unit that works between the vehicle computers and all analog parts of the system.

Honeywell engineers perform avionics system testing.

Ball Aerospace technicians perform closeout operations on the STORRM rendezvous and docking sensor assembly.

STORRM Tech Note:

STORRM provides three times the range of the shuttle docking system with a docking camera that has 16 times the resolution of the current shuttle sensors.

Technicians guide the second STORRM docking system toward Space Shuttle Endeavour's cargo bay.

STORRM Highlight:

This new technology will make it easier and safer for spacecraft to rendezvous and dock to the International Space Station.

UNPRECEDENTED TECHNOLOGY INNOVATION

A PERFECT STORRM

Providing a much safer and simpler autonomous rendezvous and docking process for the crew of future spacecraft, the Sensor Test for Orion Relative Navigation Risk Mitigation (STORRM) Development Test Objective brings innovation to mission-critical guidance and navigation technology.

This new docking navigation system prototype consists of an eye-safe lidar Vision Navigation Sensor, or VNS, and a high-definition docking camera, as well as the avionics and flight software. The STORRM docking camera provides a resolution 16 times higher than the current shuttle docking camera. This next-generation system also provides data from as far away as three miles – three times the range of the current shuttle navigation sensor.

STORRM resulted from a collaborative technology demonstration development effort led by the Orion Project Office at Johnson Space Center with Langley Research Center, Lockheed Martin Space Systems and Ball Aerospace Technologies Corp. The project is also a first technology development collaboration of NASA's three human spaceflight initiatives: space shuttle, space station and Orion.

Five retro-reflectors that serve as targets for the VNS were installed on the space station's visual docking target during the STS-131 shuttle mission in May 2010. The STORRM hardware was installed in Endeavour's cargo bay in August 2010 to be tested by astronauts aboard STS-134 targeted to launch early 2011.

Above: The STORRM reflective elements were installed on the PMA-2 visual docking target by ISS crewmember Soichi Noguchi during STS-131 docking operations.

Below: Technicians install the first of two STORRM boxes between the orbiter docking system and crew module aboard Space Shuttle Endeavour.

SOLAR ARRAY Tech Note:

Orion's solar cells are made with gallium arsenide, a semiconductor with a greater saturated electron velocity and mobility than that of silicon. Their high efficiency and resistance to heat and radiation have made these the preferred solar cells for powering satellites and other spacecraft.

HARNESSING THE POWER OF THE SUN

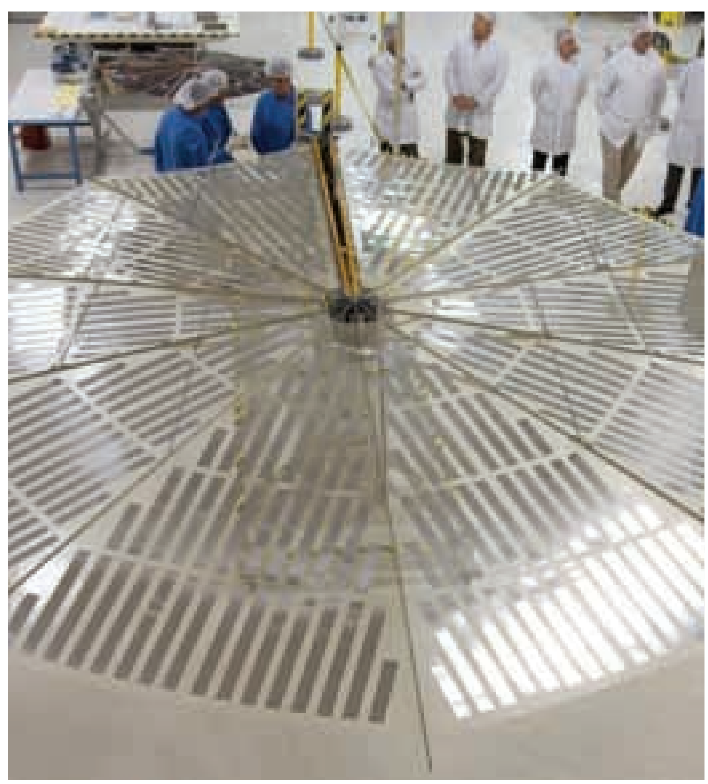
Providing power for our nation's next-generation spacecraft, Orion's UltraFlex solar arrays will support all of the electrical power needs for life support, propulsion and communications systems, and other electrical systems for both Earth-orbiting and deep space missions. Rechargeable lithium-ion batteries will store that power for use when the vehicle is away from sunlight.

The UltraFlex solar array concept was developed by Alliant Techsystems (ATK) and selected for NASA's New Millennium Program Space Technology 8 (ST-8) Project. By building and testing a full-sized array, the ST-8 project successfully demonstrated that UltraFlex is ready to transition for use on Orion. A smaller version of the UltraFlex array powered the highly successful Mars Phoenix Lander mission.

Using advanced, high-strength materials and an innovative design, the UltraFlex solar array configured for Orion will provide over 25 times the strength and 10 times the stiffness of ATK's conventional rigid panel solar arrays, at less than one-fourth the weight. The arrays are also microthin and remain folded up like an accordion fan until deployed on orbit. These features help the stowed arrays fit within a very small volume on Orion, and also greatly help reduce the spacecraft's launch mass.

Each of the two circular solar arrays for Orion unfold to approximately 19 feet in diameter and provide over 6,000 watts of power – enough to power about six three-bedroom homes. The individual solar cells on UltraFlex are very efficient – they are able to convert nearly 30 percent of the sun's energy into electricity.

For deep space missions, NASA and ATK will continue to further develop and test the UltraFlex system to ensure the arrays can withstand high structural loads which occur when Orion accelerates toward its destination.



ORION TAKES SHAPE

The first Orion crew module test vehicle is being built at the Michoud Assembly Facility in New Orleans, Louisiana, by the same experienced team that has supported NASA's human spaceflight programs for decades. Using the latest advancements in manufacturing and lean processing techniques, the team has been able to enhance Orion's crew safety features, optimize its structural integrity and minimize cost.

One such technical advancement is self-reacting friction stir welding, a next-generation manufacturing process that creates seamless welds by fusing metals to produce a stronger and more durable joint than those produced by conventional welding techniques.

An important series of leak and proof pressure tests conducted in August 2010 demonstrated Orion's weld strength and advanced aluminum-lithium alloy based structural design. The spacecraft tolerated maximum flight operating pressures as it was incrementally pressurized with breathing air up to 15.55 pounds per square inch – or 1.05 atmospheres.

Test engineers monitored and collected data from 600 channels of instrumentation to support structural margin assessments and confirm structural integrity – one step toward ensuring the spacecraft can withstand the harsh environments of space on long-duration missions.

Built to spaceflight specifications, this full-sized vehicle will endure more rigorous ground and flight testing. Pressure, static vibration, acoustics and water landing loads assessments will validate the production processes and manufacturing tools vital to ensuring crew safety. These test results will be used to correlate test data with analytical models of Orion's flight design engineering.

FRICTION STIR WELDING: STRONGER BY DESIGN

First used by NASA on the space shuttle's external tank, next-generation friction stir welding is now being used to build the Orion spacecraft at NASA's Michoud Assembly Facility.

The Michoud welding team employs a self-reacting friction stir weld technique that produces superior bonds and allows for the joining of aluminum-lithium alloys that cannot be welded by traditional means. The process uses frictional heat to transform the metals from a solid state to a plastic-like state before reaching the melting point, and then stirs them together under pressure to complete the bond. This type of welding ensures optimal structural integrity for the harsh environments of space flight.

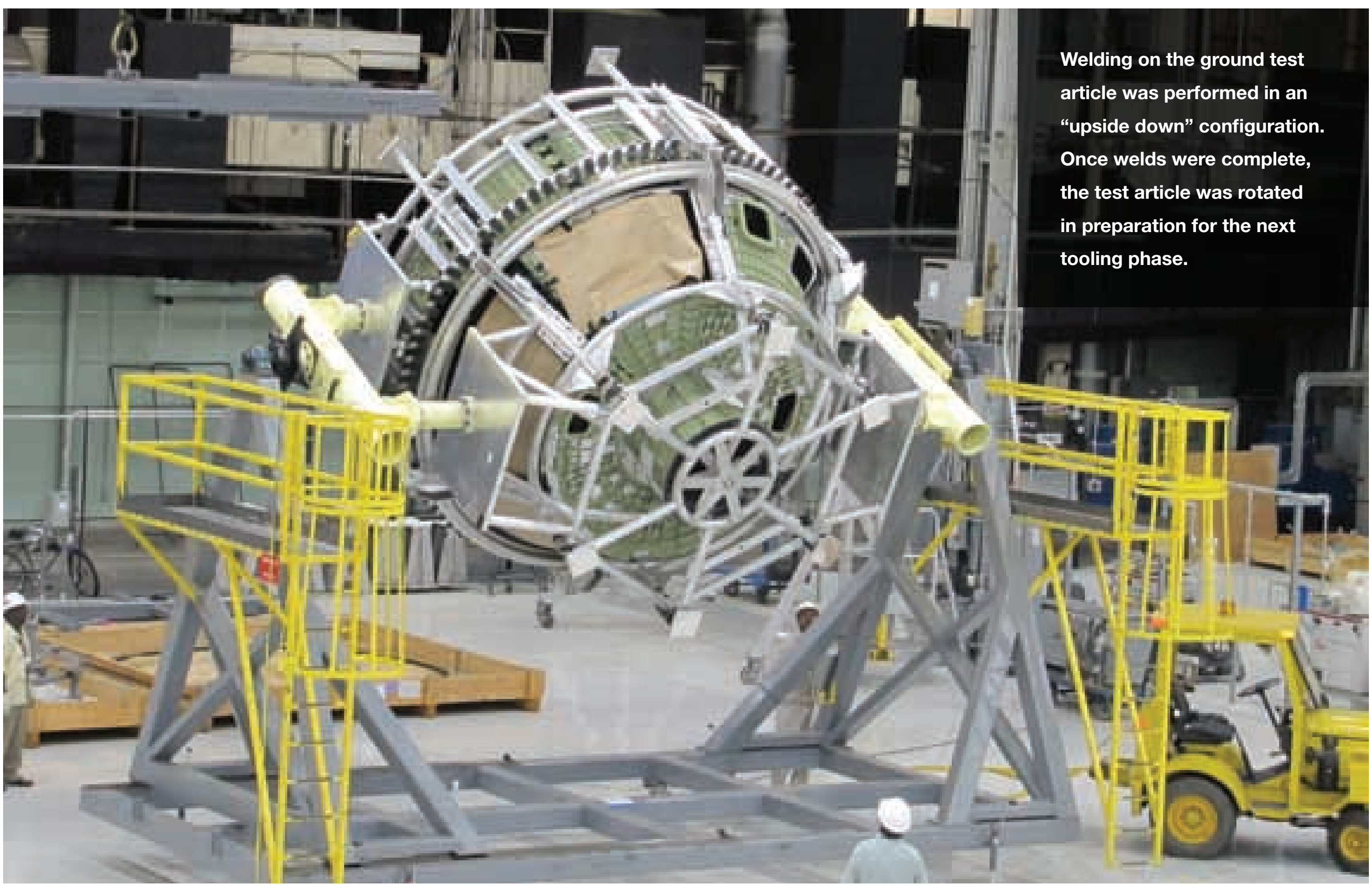
The welds take place on a Universal Weld System II (UWS II) which is part of the National Center for Advanced Manufacturing, managed by the University of New Orleans in partnership with NASA and the State of Louisiana. The UWS II includes a 22-foot diameter turntable, friction stir weld head and a modular t-grid floor. The system affords virtually unlimited five-axis welding on fixture-mounted hardware. In April 2010, the Michoud team completed a noteworthy 445-inch circumferential weld, joining the forward cone assembly and crew tunnel to the aft assembly which completed the structural framework of the spacecraft.

The Welding Institute is a British research and technology organization that designed and patented this innovative welding process, which is applicable to aerospace, shipbuilding, aircraft and automotive industries.

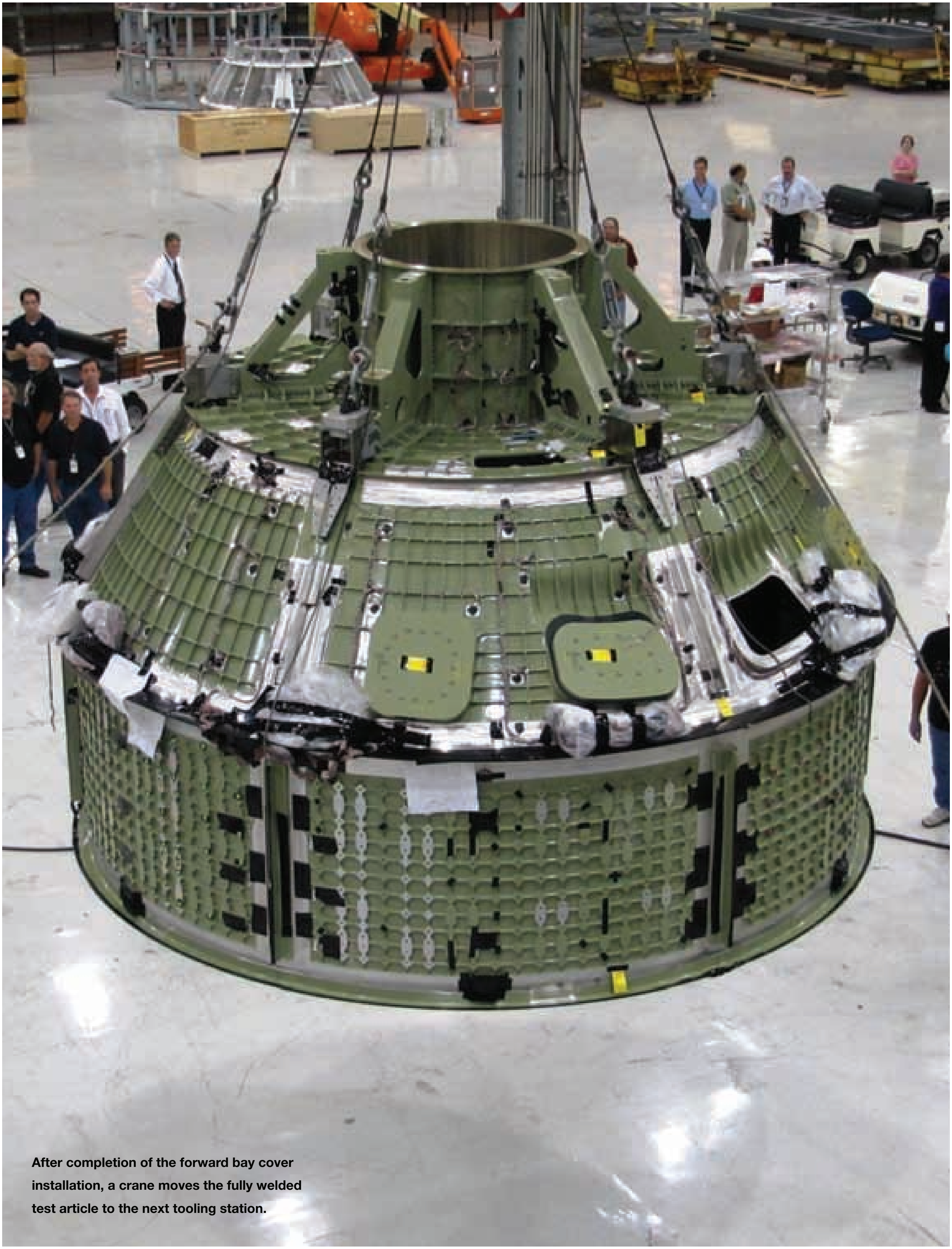
The final friction stir weld joined the forward cone assembly and crew tunnel to the aft assembly. The weld was 445 inches in length and took 38 minutes to complete.

Orion's manufacturing and welding integrity tests were conducted at the NASA Michoud Assembly Facility, leveraging advanced technology and a diverse workforce experienced in all of NASA's human spaceflight programs. Recent engineering graduates supporting the Lockheed Martin team also gained hands-on experience by designing elements of the successfully tested Orion spacecraft.

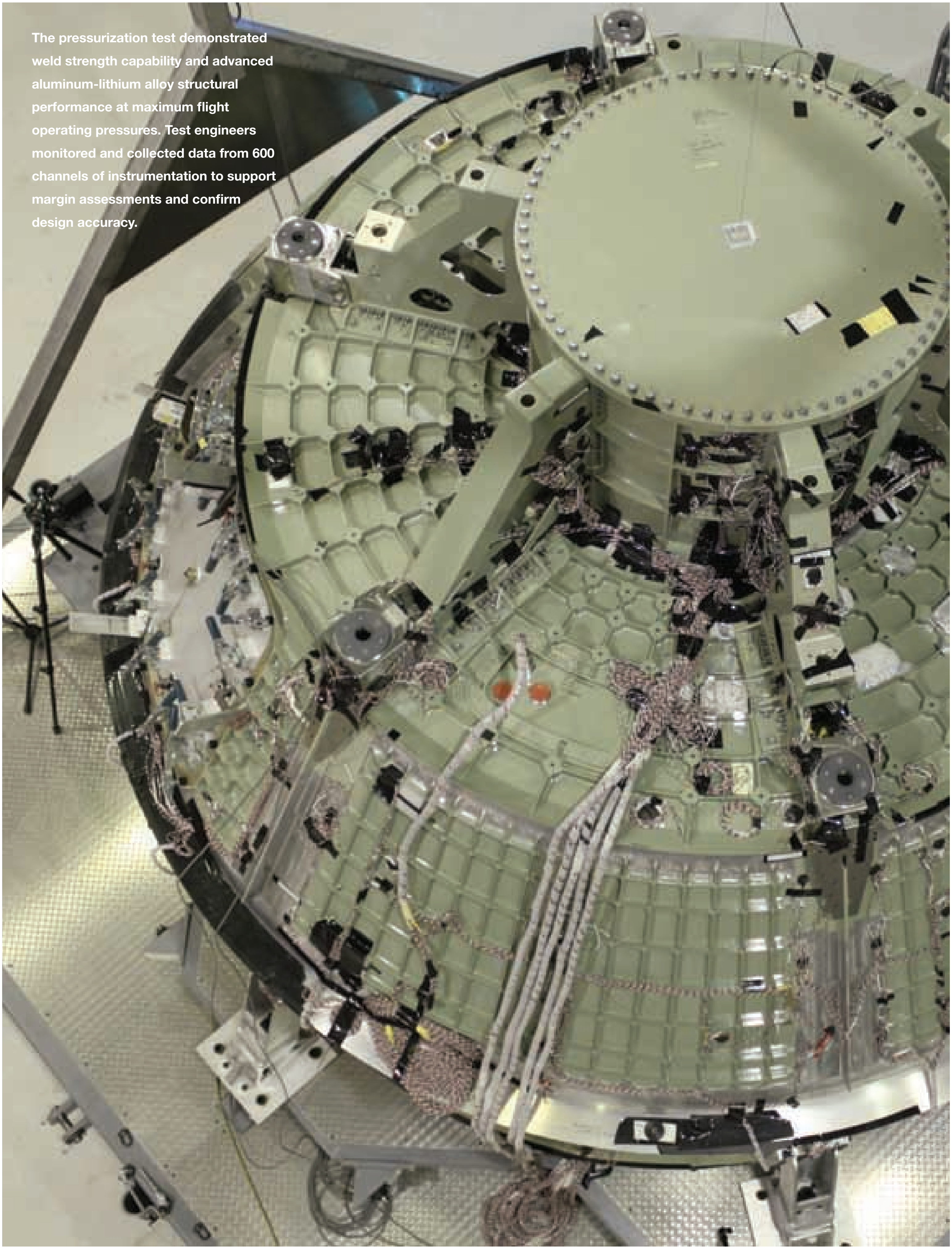
A weld technician works inside the vehicle.



Welding on the ground test article was performed in an "upside down" configuration. Once welds were complete, the test article was rotated in preparation for the next tooling phase.



After completion of the forward bay cover installation, a crane moves the fully welded test article to the next tooling station.



The pressurization test demonstrated weld strength capability and advanced aluminum-lithium alloy structural performance at maximum flight operating pressures. Test engineers monitored and collected data from 600 channels of instrumentation to support margin assessments and confirm design accuracy.

The Orion heat shield carrier structure is lowered onto a support frame for additional processing at Lockheed Martin's composite development facility in Denver, Colorado.

Thermal Protection System Tech Note:

TenCate's composite materials are also used in commercial aircraft, radomes, satellites, general aviation, oil & gas, medical and high-end industrial applications structure.

MISSION CRITICAL THERMAL PROTECTION SYSTEMS

On return from a deep space mission, the Orion spacecraft will experience extreme temperatures as it streaks through the Earth's atmosphere at an astonishing 24,545 miles per hour – more than 7,000 miles per hour faster than the space shuttle's reentry speed.

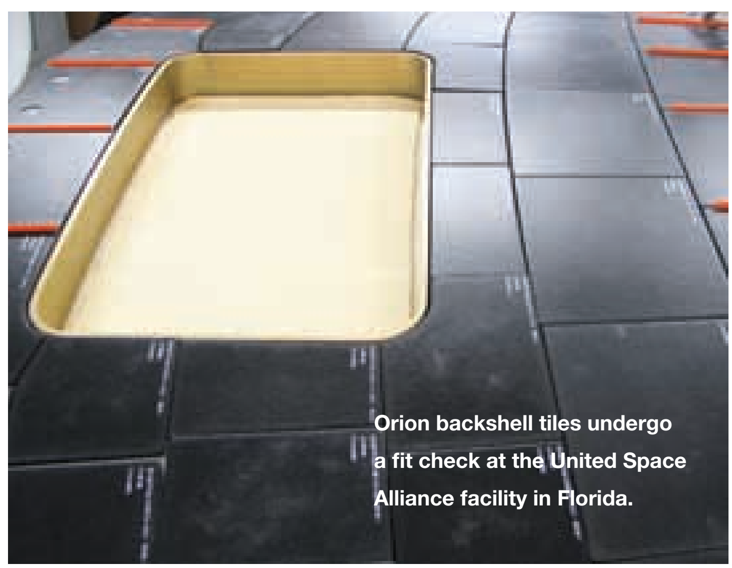
To protect the spacecraft and crew from these blistering temperatures - capable of melting iron, steel or chromium - Orion's thermal protection system team advanced the development, fabrication, and materials needed to optimize crew safety during spaceflight and reentry.

The team created the world's largest heat shield structure to provide the foundation for Orion's thermal protection system for reentry. The five meter heat shield, located at the base of the spacecraft, is designed to endure the extreme heat and deflect it from the crew module. The underlying heat shield carrier structure was fabricated with a cutting edge, high-temperature composite material system developed by Lockheed Martin in partnership with TenCate Advanced Composites, saving mass and cost over conventional metal structures.

This heat shield outer surface will be covered with Avcoat, an ablative material system applied by Textron Defense Systems, which was also used on the Apollo spacecraft. As Orion moves through the Earth's atmosphere, it could generate surface temperatures as high as 6,000 degrees Fahrenheit. However, the protective Avcoat gradually erodes off of the heat shield holding the maximum surface temperature to around 3,000 degrees Fahrenheit.

Providing additional crew module protection, Orion's backshell is also made of the new high-temperature composite material system and is covered with AETB-8 tiles which are the latest generation of space shuttle tiles. The AETB-8 tiles provide protection from the excessive reentry heat as well as the Micro Meteoroid Orbital Debris environment which could be encountered while Orion is in low Earth orbit. These new AETB-8 tiles were created using the best materials and the best manufacturing processes adapted from the Space Shuttle Program. The same skilled shuttle tile team from United Space Alliance will manufacture and install the AETB-8 tiles onto Orion's backshell at the Thermal Protection Facility at Kennedy Space Center.

The Lockheed Martin Orion team in Denver, Colorado, will fabricate the high temperature Thermal Protection System Composite Structures for Orion's heat shield and backshell panels.



Orion backshell tiles undergo a fit check at the United Space Alliance facility in Florida.

BUILDING ORION

NASA'S SPACECRAFT FACTORY OF THE FUTURE

Orion's manufacturing and assembly operations will be conducted on site in Kennedy Space Center's historic Operations & Checkout (O&C) building, which recently underwent a two-year renovation effort that resulted in a pristine new spacecraft factory. Lockheed Martin and the Space Florida partnered with NASA to create the state-of-the-art facility that will allow final assembly and checkout of the Orion spacecraft to be completed at the launch site.

The extensive remodel effort replaced everything but the basic structure in the 70,000-square-foot high bay and 20,000-square-foot basement. The facility now boasts 90,000 square feet of air bearing floor space on which small crews can effortlessly maneuver spacecraft hardware in an automated manufacturing setting. Obsolete systems and infrastructure were removed, while modern aerospace manufacturing processes and production support systems were brought online. The high bay is now designated a 100k-class clean room facility for spacecraft processing and features a portable clean room system, a new state-of-the-art heavy lift crane and specially designed epoxy flooring that supports air-bearing pallets.

Originally built in 1964, the O&C can continue its proud heritage of supporting every human spaceflight endeavor since the Gemini Program. The building will offer unparalleled tooling and assembly technology to enable the Orion team to quickly turnaround the reusable parts of Orion or assemble new components prior to launch.

The ability to manufacture and assemble the spacecraft on site is one of the most significant enhancements to the new facility. Cross-country shipment of the vehicle is no longer necessary, resulting in a significant time and cost savings for the program.

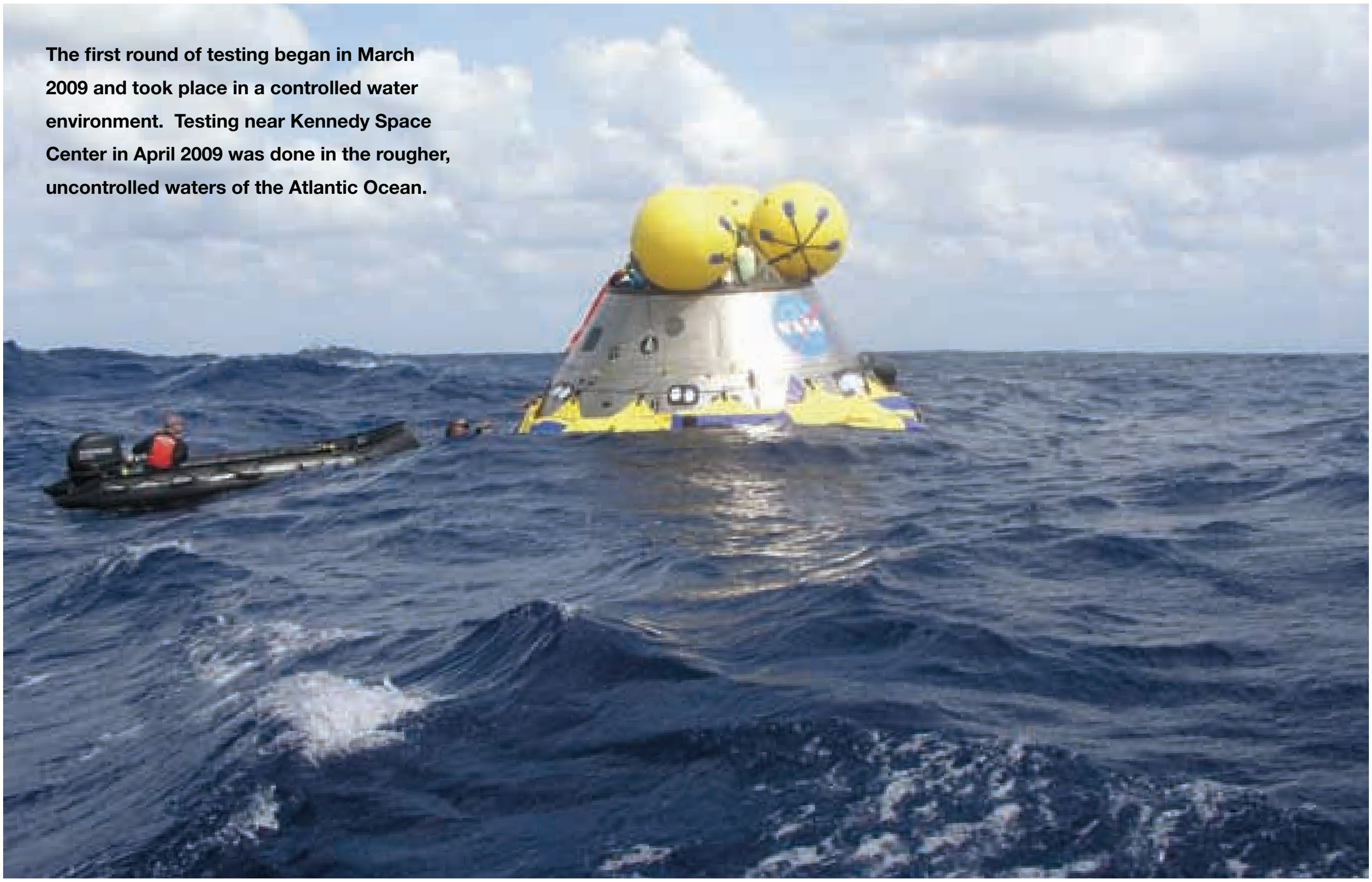
The Operations & Checkout Facility at Kennedy Space Center in Florida will employ lean manufacturing processes to reduce production time and cost.

The facility's 90,000-square-feet of air-bearing floor space enable a small crew to effortlessly maneuver spacecraft hardware across the factory.

TESTING ORION

SAFER SEA OPERATIONS AND RECOVERY

The post-landing Orion recovery test is a series of spacecraft evaluations performed off the coast of Florida by the Constellation Program Ground Operations Project recovery operations team and Orion in collaboration with the U.S. Department of Defense. The tests were designed to assess the performance of the Orion capsule mockup and recovery operations forces in post-landing conditions at sea. Test results will be used to help NASA understand the astronauts' experience in rough waters and will assist the Agency with evaluating procedures, determining supplies, and developing training for rescue and recovery operations.



The first round of testing began in March 2009 and took place in a controlled water environment. Testing near Kennedy Space Center in April 2009 was done in the rougher, uncontrolled waters of the Atlantic Ocean.

Crews spent several days at sea to assess the vehicle's performance in open water landing conditions. The same boats that have been used to recover the space shuttle's solid rocket boosters were used to tow the capsule for these tests.

Members of the U.S. Air Force Reserve's 920th Rescue Wing prepare to perform recovery testing on an Orion mockup. Reservists from the 920th also provide contingency medical and recovery support for all NASA shuttle launches.

The Navy-built Orion mock-up prepares for sea-state testing.

MANY SAFE RETURNS

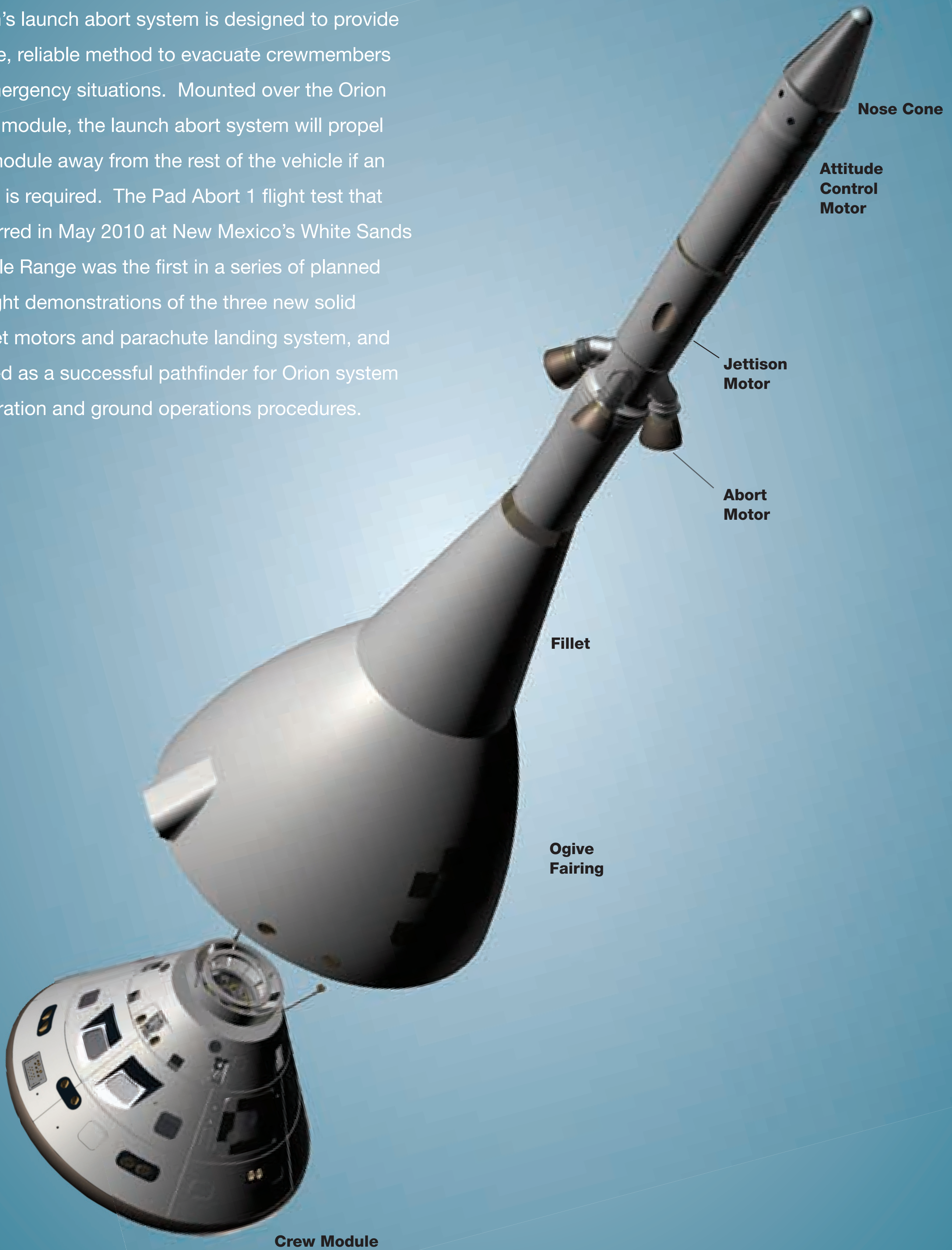
The Orion Crew Exploration Vehicle Parachute Assembly System is designed to ensure a safe landing for astronauts returning to Earth in Orion's crew module. Orion's system is made up of eight parachutes: two mortar-deployed drogues for stabilization and initial speed reduction; three pilots; and three main parachutes, which further reduce the speed of the module to its final descent rate of 25 feet per second.

While the Orion system inherits some of its design from Apollo-era parachutes, there are several new advances. Since Orion's crew module is larger, the drogue chutes are deployed at a higher altitude to provide increased vehicle stability. Orion's parachute system was designed with crew safety in mind: it can withstand the failure of either one drogue or one main parachute, and it can ensure a secure landing in an emergency, as witnessed during the successful Pad Abort 1 flight test. Before the crew actually flies in the vehicle, the system will undergo additional tests to validate the design and demonstrate reliability.

The NASA Johnson Space Center Engineering Directorate manages the parachute system development with design and testing support from the Agency's contractor partners. Parachutes are designed and fabricated by Airborne Systems in Santa Ana, California; the mortars are provided through Lockheed Martin by General Dynamics Ordinance and Tactical Systems located in Seattle, Washington; and project management is performed by Jacobs Engineering's Engineering Science Contract Group in Houston, Texas. Parachute system testing is performed at the U.S. Army Yuma Proving Ground in Yuma, Arizona.

ORION LAUNCH ABORT SYSTEM

Orion's launch abort system is designed to provide a safe, reliable method to evacuate crewmembers in emergency situations. Mounted over the Orion crew module, the launch abort system will propel the module away from the rest of the vehicle if an abort is required. The Pad Abort 1 flight test that occurred in May 2010 at New Mexico's White Sands Missile Range was the first in a series of planned in-flight demonstrations of the three new solid rocket motors and parachute landing system, and served as a successful pathfinder for Orion system integration and ground operations procedures.



The three new solid rocket motors comprising the Orion launch abort system are rolled out to the launch pad in preparation for the Pad Abort 1 flight test.

The crew module test vehicle contains the three avionics pallets and an array of 692 sensors to record all aspects of the Pad Abort 1 flight test.

The abort, jettison, and attitude control motors arrive at White Sands Missile Range in New Mexico in preparation for the Pad Abort 1 flight test.

NASA celebrated a major milestone in the development of Orion's launch abort system by completing ground tests of the system's full-scale motors. The three new solid propellant rocket motors: an abort motor, an attitude control motor, and a jettison motor, work to ensure crew safety when the launch abort system is activated during emergency operations. The completion of the tests allowed for the 2010 demonstration of the entire launch abort system – Pad Abort 1.

In April 2008, the jettison motor became the first full-scale rocket motor test for the Orion crew exploration vehicle. The jettison motor is a solid rocket motor designed to separate the launch abort system from the crew module on a normal launch and to safely propel the abort system away from the crew module during an emergency. The static test firing was conducted by Aerojet Corporation in Sacramento, California.

In November 2008, NASA completed the 5.5-second ground test firing of the launch abort motor. The abort motor will provide a half-million pounds of thrust to lift the crew module off the launch vehicle, pulling the crew away safely in the event of an emergency on the launch pad or during the first 300,000 feet of the rocket's climb to orbit.

The December 2009 attitude control motor test, performed at ATK's facility in Elkton, Maryland, was the sixth in a series of ground tests of Orion's attitude control motor system. The attitude control motor is charged with keeping the crew module on a controlled flight path after it jettisons, steering it away from the launch vehicle in the event of an emergency, and then reorienting the module for parachute deployment.

The second full-scale hot fire test of the abort system's attitude control motor that evaluated the motor's extreme performance capability and ignition system robustness was performed at the ATK facility in Elkton, Maryland.

The launch abort system jettison motor test was conducted at the Aerojet facility in Sacramento, California.

Promontory, Utah: Blasting 500,000 pounds of thrust, Orion's abort motor withstands the test of extreme pressure at ATK's desert-based test facility in Promontory, Utah. This motor is responsible for ejecting the crew module off a launch pad or errant booster in the event of a life-threatening emergency.

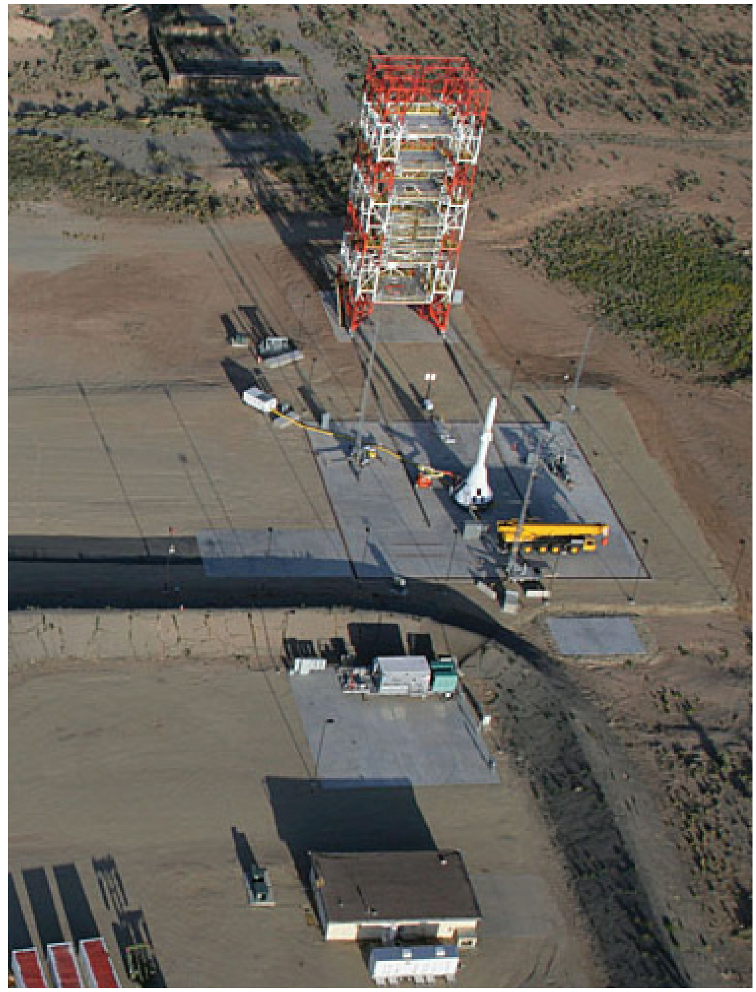
ORION'S FIRST FLIGHT TEST

Pad Abort 1 was the first in-flight demonstration of the Orion crew exploration vehicle's launch abort system. The May 6, 2010 flight test at the U.S. Army's White Sands Missile Range in New Mexico validated the launch abort system, demonstrated the performance of three new rocket motors and the parachute recovery system, and served as a design and development pathfinder for future crew escape systems.

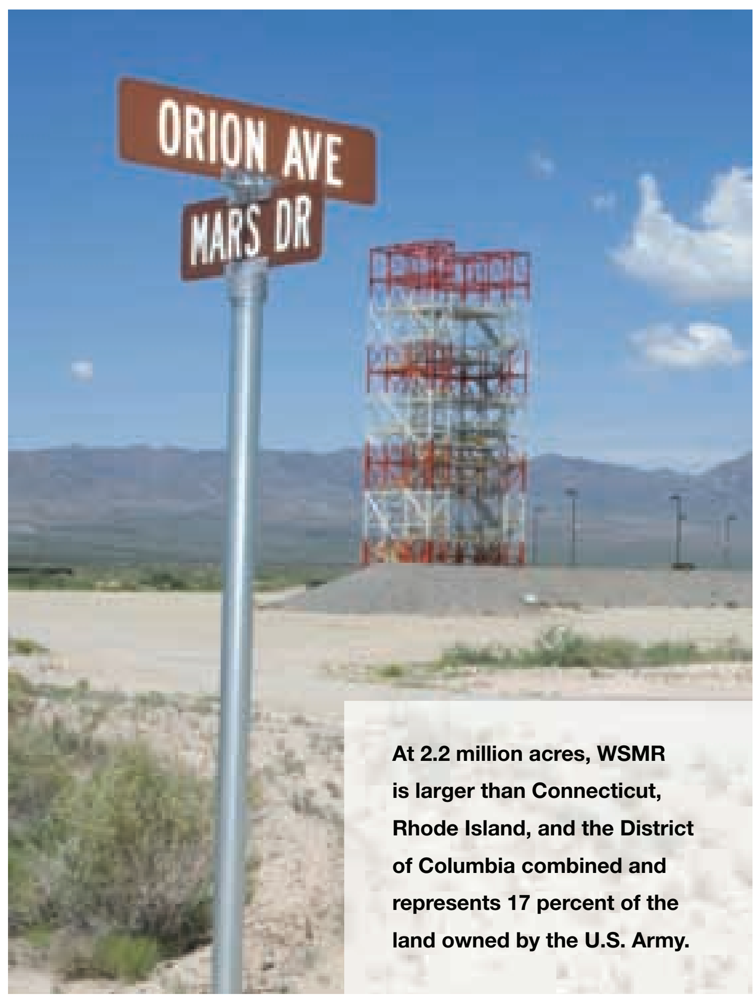
A HISTORIC TEST RANGE

White Sands Missile Range (WSMR) is a multi-service test range, occupying 3,200 square miles just east of Las Cruces, New Mexico. Established in 1945 to test rocket technology emerging from World War II, the site boasts more than 60 years experience in rocket and weapons systems test and development, earning it the title “Birthplace of America’s Missile and Space Activity.”

The missile range has a long history of supporting NASA flight tests, including early tests of the Apollo Program’s crew escape system. In 2010, WSMR’s Orion Abort Flight Test Launch Complex 32E was the site of the successful Pad Abort 1 flight test. The nearby NASA White Sands Test Facility provided design, construction and management for the launch and ground facilities.



Pad Abort 1 operations were supported by engineers working inside NASA’s mobile operations facility located four miles from the launch pad. The facility contained 14 console positions that monitored and launched the flight test.

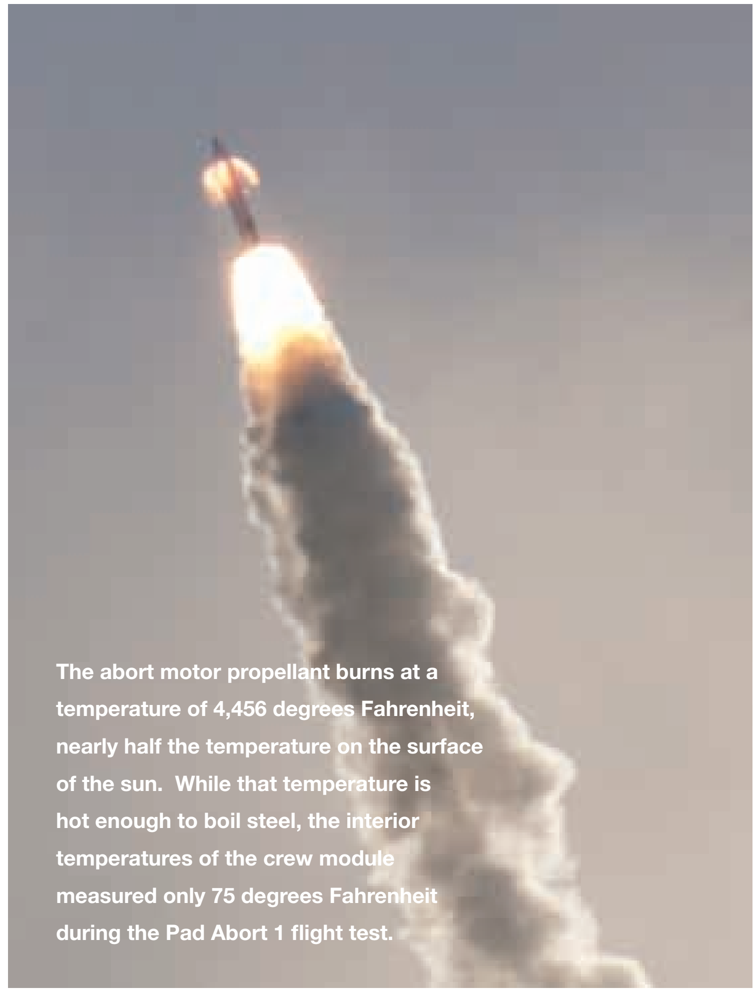


At 2.2 million acres, WSMR is larger than Connecticut, Rhode Island, and the District of Columbia combined and represents 17 percent of the land owned by the U.S. Army.

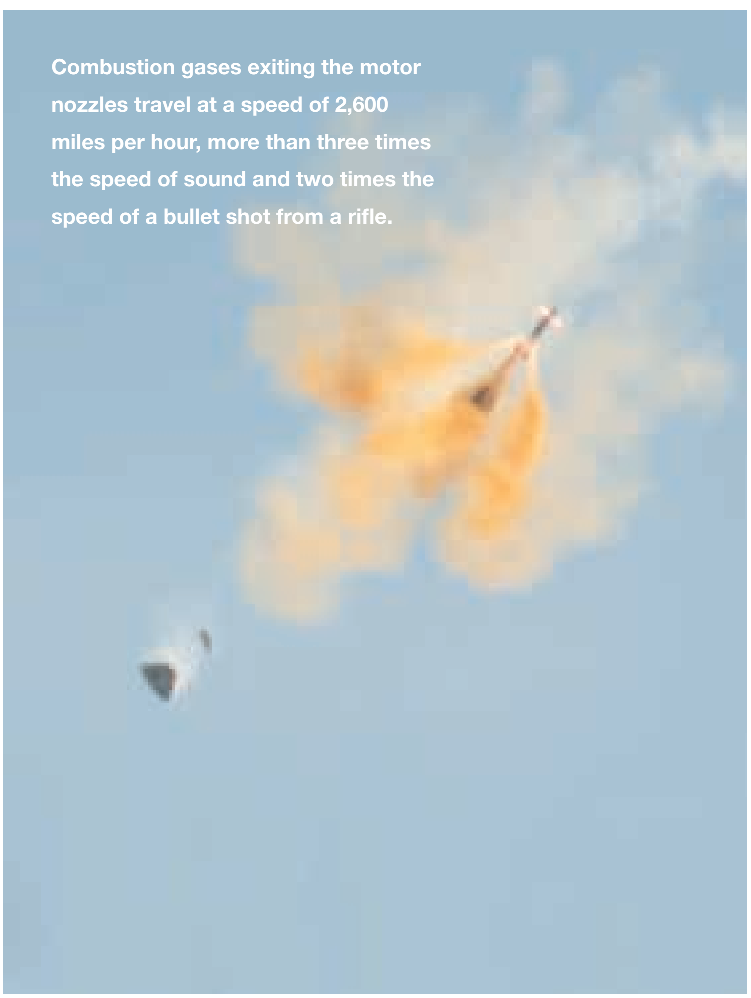
PAD ABORT 1

The launch abort system includes three new solid propellant motors, which all performed flawlessly during Pad Abort 1. During the flight test operations, the abort motor fired with approximately 500,000 pounds of thrust to drive the crew module from the pad; the attitude control motor fired simultaneously and provided the nearly 7,000 pounds of force required to maintain stability and vehicle trajectory, propelling the launch abort system to a height of approximately one mile; and the jettison motor separated the crew module from the launch abort system in preparation for parachute deployment.

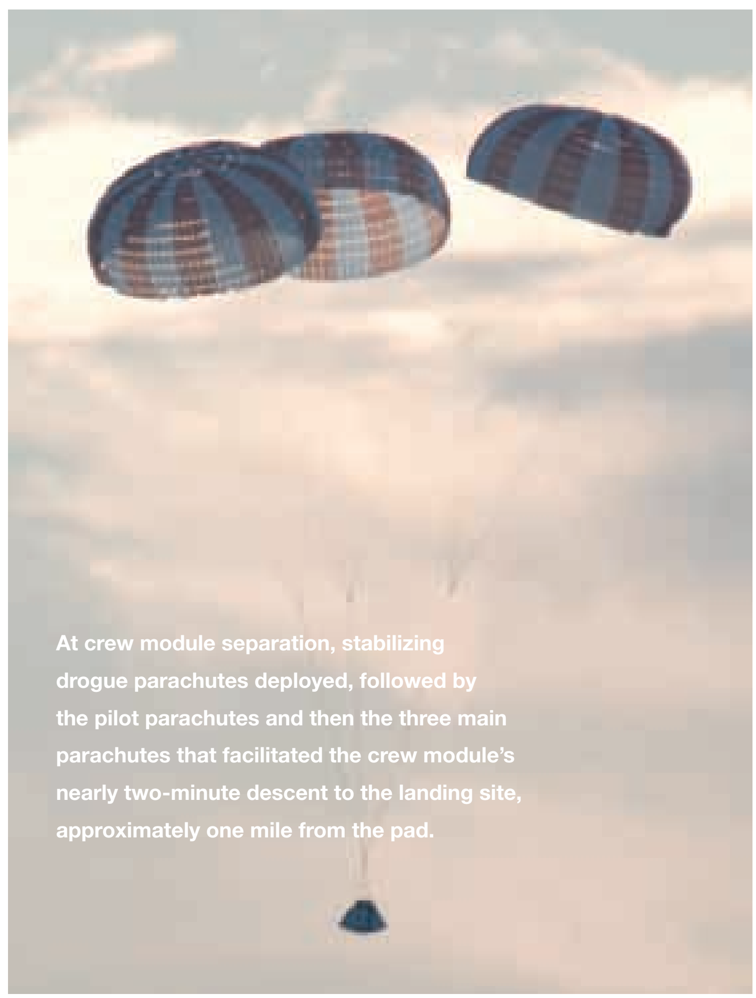
Activated at ground level during the Pad Abort 1 test, Orion's launch abort system propelled the crew module 500 feet in the first three seconds of flight. During the total 97 seconds of flight, the launch abort system reached an altitude of 5,000 feet, traveling at a maximum speed of 600 miles per hour.



The abort motor propellant burns at a temperature of 4,456 degrees Fahrenheit, nearly half the temperature on the surface of the sun. While that temperature is hot enough to boil steel, the interior temperatures of the crew module measured only 75 degrees Fahrenheit during the Pad Abort 1 flight test.



Combustion gases exiting the motor nozzles travel at a speed of 2,600 miles per hour, more than three times the speed of sound and two times the speed of a bullet shot from a rifle.



At crew module separation, stabilizing drogue parachutes deployed, followed by the pilot parachutes and then the three main parachutes that facilitated the crew module's nearly two-minute descent to the landing site, approximately one mile from the pad.

The performance of the parachutes, coupled with the nearly pristine condition of the crew module, provided tangible proof that the launch abort system would save the lives of crewmembers in the event of emergency.

QUALIFYING ORION FOR SPACE FLIGHT

During the initial development of Orion, a series of integrated systems tests are conducted to verify the vehicle's design, reliability, and performance. The tests give engineers an early opportunity to gain a thorough understanding of the preliminary system performance, identify any inconsistencies and modify the design. Orion's ground and flight tests ensure vigorous testing of the hardware in simulated conditions before flight and exposure to the harsh environments of space. Already, a number of successful tests have been conducted and will continue through the development of the vehicle. Later in development, a series of environmental tests will be conducted on the Orion vehicle to complete, or qualify the formal human rating of the systems prior to the first crewed flight.

The NASA Glenn Research Center operates the 6,400-acre Plum Brook Station near Sandusky, Ohio. This 10–square mile facility is home to the NASA's Space Power Facility, currently undergoing renovations to conduct Orion's entire suite of environmental testing. This all-encompassing test facility will help reduce the risk, time and cost of performing these test activities prior to flight.

The Space Environment Simulation Chamber is the world's largest thermal vacuum test chamber and will accommodate development and flight qualification testing of full-scale space flight systems in vacuum and temperature environments ranging from low Earth orbit to deep space to planetary surface conditions. The chamber's wide-ranging capabilities have been extensively used to test launch vehicle payload fairings, orbital hardware including International Space Station systems, and planetary landing systems like the Mars Pathfinder and the Mars Exploration rovers' airbag systems. The chamber is positioned between two attached high bays for processing space flight hardware. A standard-gauge rail system running throughout the facility permits internal transport of hardware between the vacuum chamber and the two high bays.

The vibroacoustic facilities will simulate conditions experienced during launch and ascent including lightning strikes, shock and vibrations. The reverberant acoustic chamber is the largest and most powerful available. The steel-reinforced-concrete chamber will accommodate high-power acoustic testing of large space vehicles and will be one of the largest and most powerful in the world, reaching an overall sound pressure level of 163 dB in the empty chamber. The testing will demonstrate the ability of the vehicle to meet requirements during and after exposure to the acoustic environment in flight. To simulate the vehicle's extreme acceleration through Earth's atmosphere, sound power will be supplied to the chamber—seven times more powerful than standing next to a jet engine or a Formula 1 race car. The facility also houses the highest capacity mechanical vibration test stand to accommodate the full spectrum of vibration environments.

Electromagnetic environmental effects testing will assure a spacecraft's electrical system operates properly when exposed to expected levels of electromagnetic interference throughout the entire mission's cycle, including prelaunch, ascent, on-orbit, and recovery operations.

Once Orion passes all spaceflight qualification testing at the Space Power Facility, the spacecraft will move to the Kennedy Space Center for final assembly and integration prior to flight.

An Orion mockup stopped at the Challenger Center in Tallahassee, Florida, for public viewing along the route from Kennedy Space Center to the Johnson Space Center in Houston, Texas.

INVESTING IN OUR FUTURE

Heeding the call to inspire the next generation of explorers, the Orion team is actively pursuing NASA's education mission by participating in Science, Technology, Engineering and Mathematics (STEM) activities across the country. The STEM Education Coalition is an outreach program designed to foster an awareness of the exciting advancements in science and technology and to inspire students to pursue careers in those fields. Orion's STEM advocates contribute lessons and activities that allow budding engineers to experience aerospace technology first-hand.

The Denver School of Science and Technology First Robotics team, mentored by Lockheed Martin engineers, proudly took second place at the 2010 Denver Regional tournament. Lockheed Martin committed a $1 million dollar grant over five years towards curriculum development and expansion at the Denver school.

A group of onlookers at the Adventure Science Center in Nashville, Tennessee, welcome the arrival of some eye-catching NASA hardware in the form of the Orion launch abort system pathfinder. The brief visit was one stop on a cross-country trip to White Sands Missile Range in New Mexico, where the hardware was used to prepare for Orion's first flight test: Pad Abort 1.

Children talk to Orion volunteers working with the Dr. Ronald E. McNair Educational (D.R.E.M.E.) Science Literacy Foundation.

Glenn Research Center's Mobile Orion Vehicle Explorer (MOVE).

Photo Credit: Lockheed Martin

COMMERCIAL INVESTMENT IN SPACE EXPLORATION

Lockheed Martin's Space Operations Simulation Center in Denver, Colorado, simulates on-orbit docking maneuvers with full-scale Orion and International Space Station mockups. The 41,000 square-foot-facility represents independent commercial investment by Lockheed Martin and the State of Colorado to help mitigate risks early in the development phase of future space exploration missions to low Earth orbit and beyond. The center includes an 18,000 square-foot high bay area currently being used to validate Orion's relative navigation and control design. Other testing and simulation capabilities include: autonomous on-orbit operations for servicing, inspection, capture, and situational awareness; crewed on-orbit simulations for automated control for rendezvous, berthing and docking, and piloted/tele-operated vehicle control; uncrewed exploration activities for planetary landing and hazard avoidance, touch-and-go sampling, small body proximity operations, and sample return and transfer.

We all love what we are doing. This is the type of job that a tremendous number of people want to work on because they realize the end result is amazing. Orion is the kind of program that we'll tell our grandkids about and be proud of working on forever.

Mark McCloskey

Lockheed Martin Senior Production Manager for Orion at Michoud

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