

National Aeronautics and Space Administration



MARSHALL

SPACE FLIGHT CENTER



2020 Marshall Star Year In Review



January 6, 2021

Director's Corner: Paying it Forward in 2021

As we enter the first few days of 2021, my mind is focused on you: the Marshall team. For me, you are a bright star in a dark time.

You have made Marshall Space Flight Center's 60th year, a year that seemed burdened by some of humanity's greatest challenges, into a series of incredible successes. You have done all we've asked to help keep one another safe and healthy, and still execute our missions. It is your vigilance and dedication that allows me to brag about all you have accomplished throughout this chaotic time. While a majority of the workforce enters the new year under mandatory telework status, we do so with the promise of a brighter future in what lies ahead.

I know there are those who continue on-site work every day as we – together – further our mission. That includes protecting, managing, and maintaining our facilities and maintaining continuous contact with astronauts to manage science in low-Earth orbit aboard the International Space Station. Each one of us has a role in Marshall's missions, but we each also have an important duty to protect one another's wellbeing. For all you do safely, no matter where you do it, I want to say, "Thank you."

Your hard work is paying forward to 2021 in even more ways. The Green Run test series for the Space Launch System is teaching us valuable things about America's rocket, which will take the first woman and next man to the Moon. The first launch of the SLS will happen later this year in an historic milestone for the Artemis program. Hardware is being assembled for future Artemis missions at Marshall and Michoud Assembly Facility in conjunction with our partners around the nation. Our Human Landing System team is working hand-in-hand with teams from three companies, virtually, to soon learn which will be the one – or ones – to take humans to the lunar surface. With your work in these areas, Marshall remains crucial for Artemis now and into the new year.

2020 saw the return of humans to space from American soil with the Demo-2 and Crew-1 launches for the Commercial Crew Program. I was proud to witness history as it unfolded, and Marshall is playing a critical role as we establish a new cadence of missions to low-Earth orbit.

And, Marshall's science and technology portfolio continued to blaze a trail into the unexplored regions of our universe this year. Our Earth Science teams achieved groundbreaking results to ensure a brighter tomorrow for people around the world.

And I'm so excited for the work being done – TODAY – on far-reaching technology like the Mars Ascent Vehicle and trail-blazing projects like Solar Cruiser. Our next great science project – the Imaging X-Ray Polarimetry Explorer – will launch later this year, expanding our view of the universe in ways we could never imagine!



Marshall Director Jody Singer.

Expertise at Marshall supporting these initiatives is vast – scouting landing sites on Mars and assisting the agency with identifying science priorities for Artemis III, for example. And Marshall continues to lead the agency in processes that will pay forward to humankind's first journey to deep space, including cryogenic fluid management, and additive manufacturing for the On-Orbit Servicing, Assembly and Manufacturing National Initiative. Marshall has proven we, and our partners, are adapting and ready for many new challenges that our agency, and our world, could face.

On our own campus, we also must apply those lessons about adapting and pushing forward. We prepare to say goodbye to Building 4200, while preserving its history; but we also continue master planning efforts for the Marshall of the future. I look forward to plans for a state-of-the-art lab that we are now prioritizing as we improve our footprint and pursue efficiency.

Through each of these things, and more, I have learned what an incredible team we have here at Marshall and Michoud to rely on. I never dreamed we would learn so much about ourselves, our team, and what we can do when faced with the adversity of this past year. You are getting the job done, supporting the mission, and making incredible progress. I am proud of you.

I invite you to exit 2020 and blast off to 2021 knowing that the ingenuity, passion, hard work, and dedication that brought us through this challenging year will continue to ignite historic achievements in 2021. I am hopeful and excited by what the future holds, and I am honored to be alongside you on the journey.

Jody Singer

JANUARY

SLS Core Stage Completed, Installed in Stennis Test Stand for Green Run

With NASA Deputy Administrator Jim Morhard in attendance, crews rolled out and loaded the first completed core stage for NASA's Space Launch System rocket onto the agency's Pegasus barge at Michoud on Jan. 8. Pegasus ferried the stage to NASA's Stennis Space Center, where the core stage was **lifted and installed into** the B-2 Test Stand on Jan. 22. The 212-foot-tall rocket stage is the largest the agency has ever produced – and tested. Following completion of the comprehensive Green Run test series, the stage will be transported to NASA's Kennedy Space Center for launch.

Celebrating 20 Years of International Space Station Crew Operations

As NASA celebrates 20 years of continuous crew operations on the International Space Station, Marshall is reflecting **on its own contributions** to the orbital research facility. "We helped give the station good bones," said retired NASA engineer Ann McNair, former deputy chief in Marshall's Systems Analysis & Integration Laboratory. That included the massive backbone truss, the Node 1 module later named Unity, the Destiny lab module, and the Joint Quest Airlock, all built by Boeing and tested at Marshall. Center engineers also partnered with Alenia Spazio in Turin, Italy, to test and integrate Node 2 and Node 3, later named Harmony and Tranquility. NASA and its partners assembled the station in orbit via 37 space shuttle flights and four uncrewed Russian launches. To date, more than 3,000 research investigations have been conducted, involving scientists from more than 100 countries.



Marshall, Michoud Leaders Share Wisdom, Challenges

What does it take to manage a team at Marshall and Michoud? What additional challenges did leaders face while guiding their teams in the midst of a global pandemic? Throughout 2020, managers **shared their insights** on those topics and more in the monthly Take 5 profile series. The Star profiled leaders from the Office of the Chief Information Officer, Human Exploration Development & Operations Office, Engineering Directorate, Office of Center Operations, Office of the Chief Financial Officer, Mars Ascent Vehicle project, Commercial Crew Program, Office of Diversity and Equal Opportunity, Science and Technology Office, and Office of Procurement.



FEBRUARY

Chandra Spots Record-breaking Black Hole Explosion

NASA's Chandra X-ray Observatory **detected the biggest explosion** in the universe from 390 million light-years away. Originating in the Ophiuchus galaxy cluster, researchers believe the unrivaled outburst was from a supermassive black hole at the center of the cluster. Although black holes are famous for pulling material toward them, they often expel extraordinary amounts of material and energy when matter falling toward the black hole is redirected into jets, or beams, that blast outward into space and slam into any surrounding material. The record-breaking eruption was discovered using X-ray data from Chandra and the European Space Agency's XMM-Newton observatory, as well as radio data from the Murchison Widefield Array in Australia and the Giant Metrewave Radio Telescope in India. Marshall manages the Chandra program.



Marshall Celebrates Contributions by Diverse Workforce

Each year, Marshall celebrates the diversity of its team – people of all ages, backgrounds, ethnicities, and orientations who design, build, and test the rockets, engines, technologies, and science hardware that help expand humanity's reach into the cosmos. During Black History Month in February, Marshall turned its commemorative spotlight on its workforce alums **from historically Black colleges and universities**. Their impact is plainly evident at Marshall, where more than one in four civil service employees who identify as a minority are graduates of an HBCU or minority-serving institution. NASA works to engage and inspire underrepresented populations through a wide variety of education initiatives, internships, and other activities and added inclusion as a core value this year. Marshall's diversity events are organized by the Office of Diversity and Equal Opportunity.

Marshall, NASA Leaders Address Proposed FY2021 Agency Budget

Marshall Director Jody Singer joined Steve Jurczyk, NASA associate administrator, to answer questions from Marshall team members **during a town hall** Feb. 10. Singer and Jurczyk addressed President Donald Trump's proposed fiscal year 2021 NASA budget, which called for \$25.2 billion for the agency -- a figure that included \$2.3 billion for the Space Launch System, and \$3.4 billion for the development of a human landing system. Marshall manages the SLS and Human Landing System programs. "The budget aligns with our leadership in human spaceflight," Singer said. "We are setting the path to go forward and I'm very proud of the work we do. We are providing the resources necessary to deliver on HLS and the SLS."

Moon Thrusters Withstand Over 60 Hot Fire Tests

NASA and Frontier Aerospace of Simi Valley, California, completed approximately **60 hot fire engine tests** on two lunar lander thruster prototypes March 16. The thruster is being developed by Frontier Aerospace as part of a project led and managed by Marshall. Future Artemis program lunar landers could use next-generation thrusters to enter lunar orbit and descend to the surface. Before the engines make the trip to the Moon, helping deliver new science instruments and technology demonstrations, they're being tested on Earth. The tests occurred over the course of 10 days and took place in a vacuum chamber at Moog-ISP in Niagara Falls, New York, that simulates the environment of space.

Marshall Moved to Mandatory Telework in Response to COVID-19

In an effort to limit the spread of COVID-19, Marshall initiated **mandatory telework status** March 13. All agency centers and facilities entered Stage 3 of NASA's Response Framework, requiring employees who are able to telework to do so until further notice. Access to centers and facilities was restricted to mission-essential personnel – those working key mission functions or safeguarding security and property. Marshall leadership encouraged employees to protect themselves and others and follow guidance from the Centers for Disease Control and Prevention and the agency's chief health and medical officer, JD Polk. "As always, the protection and care of our NASA team is the top priority and critical to the success of our mission," NASA Associate Administrator Steve Jurczyk wrote in an email to the workforce.

Marshall Team Members Listen Close, Learn About Interior of Mars

NASA's InSight Mars lander completed its first Earth year on the Red Planet, and **scientists listened closely** as Mars revealed a few of its secrets. Using InSight's three primary instruments, scientists and mission managers detected multiple marsquakes, determined the magnetic field around the lander is 10 times stronger than indicated by Mars orbiters, and even determined the size and intensity of a dust devil that passed within 22 yards of the lander. While one instrument proved difficult to put in place, the team was able to learn more about soil properties on Mars that otherwise would not have been learned. InSight is part of NASA's Discovery Program, which is managed by Marshall.

APRIL

Marshall Ground, Marine Teams Integral to Moving SLS Rocket

As NASA prepares for the launch of Artemis I, the inaugural mission of the agency's Artemis program, one Marshall team will be there every step of the way: the aptly nicknamed "SLS Move Team." The Ground and Marine Transportation teams ensure all flight hardware for NASA's Space Launch System core stage is safely and efficiently transported from the site where it was manufactured to various test facilities and – ultimately – to its future launch site. The teams spend months meticulously planning and developing detailed transportation move procedures for test and flight hardware alike.

Spinoff 2020: Marshall Inventions Improve Life on Earth

NASA's 44th annual issue of Spinoff contained **seven Marshall technologies** that improve life on Earth. Marshall-developed materials are used in a new humidity sensor that uses nanotechnology and nontoxic ingredients, and new mobile device and medication cases that use space blanket material. Marshall technologists also helped develop a pressure vessel to improve transportation of liquid fuels. Engineers from NASA and Virgin Orbit of Long Beach, California, helped develop innovative combustion chambers for the LauncherOne rocket. Knowledge of liquid rocket engine development – gained from working with NASA – helps countries use coal in a greener way. Bastion Technologies, a Houston-based Marshall contractor, developed a new device to shear and seal an oil well's drill pipe. Marshall makes licenses for the Generalized Fluid System Simulation Program software available to business and educational institutions.

NASA Selects Companies to Develop Human Landing System

On April 30, NASA **announced three companies** to design and develop human landing systems for the agency's Artemis program. Blue Origin of Kent, Washington; Dynetics, a Leidos company of Huntsville; and SpaceX of Hawthorne, California, each proposed unique lander designs -- one of which will deliver the first woman and next man to the lunar surface by 2024. With this development, NASA is on track -- for the first time in history -- for sustainable human exploration of the Moon. "When I say this is historic," NASA Administrator Jim Bridenstine said, "I mean that in 2020, Congress gave us a bipartisan budget including funding for a human landing system -- something we as an agency and as a country have not had since 1972."



MAY

Last of Vital, Versatile Science EXPRESS Racks arrives at International Space Station

Among the cargo delivered in May to the International Space Station was the 11th and final NASA “EXpedite the PROcessing of Experiments to the Space Station” multipurpose payload shelving unit, or EXPRESS Rack. These permanent fixtures support a variety of experiments, each providing power, protective storage, cooling and heating, communications, and easy transport for up to 10 small payloads. Since installation of the first rack in 2001, NASA has logged more than 85 total years of combined rack operating hours. NASA’s Johnson Space Center funded the racks, while Boeing and Marshall engineers jointly developed, built, and tested them at Marshall in the late 1990s. EXPRESS Rack experiments continue to be monitored around the clock from Marshall’s Payload Operations Integration Center.

Marshall Contributes to Historic Test Flight of SpaceX Crew Dragon

On May 30, for the first time in history, NASA astronauts launched from American soil in a commercially built and operated American crew spacecraft. Known as NASA’s SpaceX Demo-2, the mission was an end-to-end test flight to validate the SpaceX crew transportation system, including launch, in-orbit, docking, and landing operations. A team at Marshall’s Huntsville Operations Support Center joined NASA and SpaceX teams in monitoring the launch. Working with SpaceX, teams improved the safety and reliability of the Merlin engines, stage propulsion, Draco and SuperDraco thrusters, life support system, the abort and flight termination systems, structures, materials and processes, fracture control, and integrated performance analyses.

Area High School Students Build Lockers for Trip to Space Station

As part of NASA’s Demo-2 mission, astronauts Doug Hurley and Bob Behnken brought with them to the International Space Station four lockers built by high school students from North Alabama and around the country. The locker contents included space suit components and exercise harnesses. Part of NASA’s HUNCH – High school students United with NASA to Create Hardware – Program, each locker is comprised of approximately 280 components, including 41 parts machined by the students, and more than 200 rivets, fasteners, and bearings. The pieces are manufactured to the tight tolerances required of any piece of hardware making the journey to the space station. Each student and instructor signs the lockers and the astronauts take pictures with the lockers in orbit – a memento for the builders.

NASA Completes Space Launch System Structural Testing Campaign

Marshall engineers **completed the structural testing campaign** for the agency's Space Launch System rocket by testing the liquid oxygen structural test article to its point of failure June 24. Water gushed from the propellant tank at Marshall's Test Stand 4697 as hydraulic cylinders in the test stand applied millions of pounds of crippling force from all sides. The liquid oxygen tank failed in the weld location and at the approximate load levels engineers expected, proving flight readiness and providing critical data for the tank's designers. The successful completion of the SLS structural qualification testing at Marshall wrapped up the largest test campaign at the center since tests conducted for the Space Shuttle Program more than 30 years ago.

Marshall Resumes Authorized Mission-Critical On-site Work

As Marshall entered week 12 of mandatory telework to mitigate the spread of COVID-19, the center's leadership refined an in-depth, phased strategy for **returning to on-site work**. The decision was made in consultation with occupational safety, labor representation, and management of both government employees and contractors to identify potential risks and required mitigation precautions. The Space Launch System core stage production activities carefully recommenced at Michoud. At Marshall, progress resumed for several SLS components -- including the liquid oxygen tank structural testing, launch vehicle stage adapter updates, facility cleaning and preparations, and several facilities were cleaned and prepared for work to resume. Progress on the Imaging X-ray Polarimetry Explorer picked up, as well.

Mission Success is in Our Hands

The Star spotlighted how **eight Marshall team members** made meaningful connections between their jobs and the safety and success of NASA and Marshall missions. The Mission Success Is in Our Hands initiative is a centerwide campaign led by Marshall's Safety and Mission Assurance Directorate and partner Jacobs Engineering of Huntsville that promotes and strengthens the center's focus on mission, hardware, and crew safety.

Marshall Teams Load Artemis I Hardware on Barge for Trip to Kennedy

Marshall teams moved the Artemis I **launch vehicle stage adapter** for NASA's Space Launch System rocket onto the agency's Pegasus barge July 17. The adapter is a cone-shaped piece of hardware that connects the deep space rocket's core stage and interim cryogenic propulsion stage. While the larger stages of the SLS rocket are manufactured at other NASA facilities, the LVSA is produced exclusively at Marshall by Teledyne Brown Engineering in Huntsville. The hardware was the final piece of Artemis I rocket hardware built at Marshall to be delivered to Kennedy. It arrived at Kennedy on July 29, shortly before the launch of NASA's Mars Perseverance rover.



#Celebrating 60 Years of Marshall Space Flight Center

On July 1, 1960, the technical and administrative core of the Army Ballistic Missile Agency became NASA's Marshall Space Flight Center. The transfer of this experienced group provided the young agency with a solid foundation. Sixty years of historic leaps and strides later, Marshall celebrated its milestone anniversary with a look back at some of its **most iconic accomplishments**. "I could not be more proud to be part of the history Marshall has made," Marshall Director Jody Singer said. "The world has witnessed us achieve 60 consecutive years of discovery, exploration, and victories for all of humankind. Celebrating these achievements reminds us of all the groundbreaking history still to come from the Marshall team."

Mars 2020 Perseverance Rover Begins Journey to Jezero Crater

NASA's **Mars 2020 Perseverance rover mission** launched July 30 to the Red Planet. The rover's primary mission is to seek out signs of past microscopic life on Mars, explore the diverse geology of its landing site, Jezero Crater, and demonstrate technologies that will pave the way for future robotic and human exploration. Marshall planetary scientist Caleb Fassett was instrumental in helping NASA identify Jezero as the optimal landing site for Mars 2020. Built and managed by NASA's Jet Propulsion Laboratory, Perseverance is set to land on Mars on Feb. 18, 2021. Mars 2020 is part of America's larger Moon to Mars endeavor, which includes long-duration lunar missions that will prepare human explorers to visit the Red Planet for the first time.

AUGUST

Motor Test Helps Evaluate New SLS Materials

On Aug. 6, a 22-second hot fire test in the [East Test Area at Marshall](#) helped NASA and Northrop Grumman Corp. of Promontory, Utah – the Space Launch System solid rocket booster prime contractor – evaluate a new nozzle material for the boosters. Material changes are evaluated in phases from subscale to full-scale tests, and the test was a significant step in that process. Using a 24-inch-diameter, 20-foot-long subscale test motor that burned nearly 1,800 pounds of propellant and produced 23,000 pounds of thrust, the team collected data to help verify use of the solvent on future SLS flights beyond Artemis III. Engineers also collected information about the material’s behavior during booster assembly.

Two From Marshall Inducted into NASA’s Inventors Hall of Fame

NASA’s [top inventors](#) now have their own digital temple of achievement: the agency’s online Inventors Hall of Fame. Among the inaugural 2020 inductees were Marshall’s David Howard and William “Neill” Myers. Howard, who holds 20 U.S. patents, has spent his career designing, developing, building, and testing signal conditioning and electronic control systems that play a critical role in NASA’s human and robotic missions, including on the International Space Station and NASA’s Lightning Imaging Sensor. Myers’ work revolved around the mechanical facets, resulting in a Marshall-record 27 patents. Favoring simple and elegant, yet creative, solutions, he used his prowess to design and develop spacecraft and propulsion technologies. Many of his technologies became important spinoffs, including a knee brace celebrated at the White House in 1997.

NASA Announces Winners of Student Launch, Rover Challenge

While in-person activities in Huntsville were canceled for both NASA’s [Student Launch](#) and [Human Exploration Rover Challenge](#) Artemis Student Challenges due to the COVID-19 pandemic, the hard work of the teams was still celebrated and recognized. On July 23, a virtual awards ceremony honored the Student Launch winners, including overall winner Vanderbilt University of Nashville, Tennessee, which claimed top honors for the seventh time in the last eight years. On Aug. 21, winners of the Human Exploration Rover Challenge were celebrated in a virtual awards ceremony. Eight categories were awarded, including the American Institute of Aeronautics and Astronautics’ Neil Armstrong Best Design Award. Escambia High School in Pensacola, Florida, won the high school division. Middle Tennessee State University – Team 2 of Murfreesboro won the college division.

NASA Conducts Space Launch System Booster Test for Future Artemis Missions

As NASA began assembling the boosters of NASA's Space Launch System rocket for the first Artemis mission to the Moon, teams in Utah on Sept. 2 conducted the first full-scale, full-duration **booster hot fire test** for flights beyond Artemis III. For a little over two minutes – the same amount of time that the boosters power the SLS rocket during liftoff and flight – the five-segment flight support booster fired into the Utah desert, producing more than 3.5 million pounds of thrust. Engineers are using data from the test to evaluate the motor's performance as well as potential new materials and processes to improve SLS rocket boosters for missions following the initial Artemis Moon landing.

Marshall Wins Sixth SBA Cup

NASA honored Marshall on Sept. 30 with the **Small Business Administrator's Cup** for managing the agency's most effective small business program. It was the center's sixth Administrator's Cup awarded since 2008. The annual award recognizes the NASA center with the best innovative practices that promote small business participation in various agency initiatives, and honors significant contributions to NASA's small business programs by the winning center's senior management, procurement office, and program and technical personnel. Marshall has earned the prize more often than any other NASA center. The award was presented virtually to Marshall Director Jody Singer and Marshall small business specialist David Brock by NASA Associate Administrator Steve Jurczyk and Glenn Delgado, associate administrator of NASA's Office of Small Business Programs, as part of Marshall's 14th annual Industry & Advocate Awards ceremony.



Future Rocket Engines May Include Large-Scale 3D Printing

Additive manufacturing, or 3D printing, experts from NASA, industry, and academia are pioneering methods to print rocket engine parts that could power journeys into deep space. NASA's **Rapid Analysis and Manufacturing Propulsion Technology** project is advancing an additive manufacturing technique called blown powder directed energy deposition to 3D-print rocket engine parts using metal powder and lasers, potentially reducing the production cost and time of large, complex engine components. The RAMPT team produced one of the largest NASA-printed nozzles, measuring 40 inches in diameter and standing 38 inches tall, with fully integrated cooling channels. Fabrication occurred in record time – just 30 days compared with nearly one year using traditional welding methods – and completion occurred a year earlier than scheduled due to the technology advancing rapidly.

OCTOBER

Marshall Master Plan Supports Workforce, Future Missions

The **Marshall Master Plan**, developed in 2003 and revised periodically by engineers in Marshall's Office of Center Operations, serves as a road map to the development and sustainment of facilities, structures, utilities, roads, and land to support operations critical to NASA's mission. It identifies aging buildings to be vacated and deactivated to make way for new, efficient facilities that will equip Marshall for the future. Building 4200, pictured here and previously intended to be demolished in 2030, is set to be deactivated in fall 2021 in the wake of newly detected exterior structural issues. Marshall also will deactivate Building 4487 to prioritize construction of a new science and avionics laboratory beginning in fiscal year 2024. The master planning team aligns its stewardship of center facilities with NASA's strategic plan.

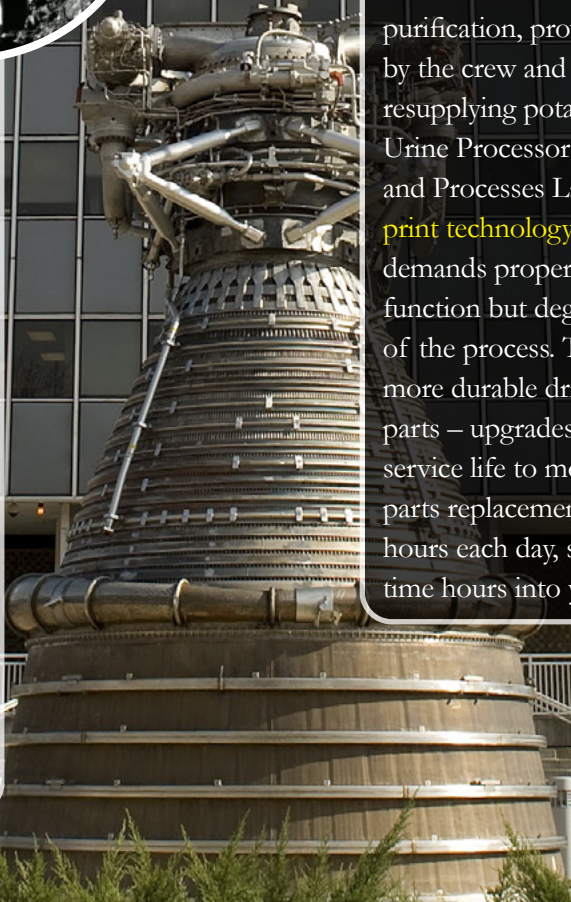


OSIRIS-REx Collects Significant Amount of Asteroid

On Oct. 20, NASA's "Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer" spacecraft, or OSIRIS-REx, **collected rocks and dust** from the surface of an asteroid – an unprecedented NASA milestone. The ancient asteroid, Bennu, offered scientists a window into the early solar system as it was first taking shape billions of years ago and flinging ingredients that could have helped seed life on Earth. The craft's Touch and Go Sample Acquisition Mechanism, intended to obtain 2 ounces of material, successfully captured much more than that, stowing it in the spacecraft's Sample Return Capsule for the journey home. NASA's Goddard Space Flight Center manages mission operations for OSIRIS-REx, the third mission in NASA's New Frontiers Program. Marshall manages New Frontiers for NASA's Science Mission Directorate.

Marshall Engineers Solve International Space Station Recycling Challenge

The distillation system for the International Space Station's urine processor assembly delivers reclaimed wastewater for filtration and purification, providing 90% of the water needed by the crew and reducing costs associated with resupplying potable water from Earth. Marshall's Urine Processor Assembly team and Materials and Processes Laboratory engineers **used 3D print technology** to upgrade the belt drive, which demands proper contact and tension to function but degrades due to the steam and heat of the process. The Marshall team printed a more durable drive pulley and redesigned other parts – upgrades expected to extend the unit's service life to more than 4,300 hours without parts replacement. The unit operates just a few hours each day, stretching those anticipated lifetime hours into years.



Marshall Team Enables Increased Science Return From Space Station Astronauts

On Nov. 16, the largest long-duration International Space Station expedition took its first orbit when the Crew-1 mission docked to the outpost and joined the Expedition 64 mission. The **Payload Operations Integration Center** at Marshall, which manages all of the experiments on the space station, was ready to support the record science capability enabled by the large crew. During missions with three crew members on the space station, 40-50 hours of science can be performed each week, while a seven-astronaut crew can perform 80-100 hours. In addition to timeline integration and management, the team at Marshall helps resolve any issues that arise during an experiment, having worked with the experiments' scientists from the time each investigation is selected to fly.

Artemis I Space Launch System Booster Stacking Shapes Up

NASA's Space Launch System rocket began to take shape inside the Vertical Assembly Building at Kennedy in November. Engineers lowered the **first of 10 segments** into place on the mobile launcher Nov. 21. The aft assemblies, which house the system that controls 70% of the steering during the rocket's initial ascent, are the first pieces of hardware to be placed on the mobile launcher. Each SLS booster consists of five segments. When fully assembled, each rocket booster will be about the length of a football field.

Centennial Challenges Launches Two New Challenges in 2020

The Centennial Challenges program, managed at Marshall, launched two new lunar-focused challenges in 2020. These new competitions incentivize garage inventors, entrepreneurs, and university students alike to advance technology for long-duration space exploration. The **Break the Ice Lunar Challenge**, the first Centennial Challenge to be led by Marshall, offers a \$500,000 prize purse for Phase 1 and seeks innovative solutions for excavating icy regolith at the lunar South Pole. The **Watts on the Moon Challenge**, featuring a \$500,000 prize purse for Phase 1, invites teams to create novel solutions for distributing, managing, and storing power on the Moon.

NASA Selects Solar Cruiser to Demonstrate Solar Sail Propulsion

NASA selected **Solar Cruiser** – a SmallSat mission led by principal investigator Les Johnson of Marshall – to share a ride to space in 2025 with the Interstellar Mapping and Acceleration Probe. Consisting of a nearly 18,000-square-foot solar sail, Solar Cruiser will demonstrate the ability to use solar radiation as a propulsion system. Such a system could provide access to new orbits enabling high-value science, including SmallSat observations from deep space, out of the ecliptic plane, and in stationary orbits in Earth's geo-tail. By positioning a monitoring spacecraft closer to the Sun, space weather scientists hope to obtain more advanced warnings of solar storms headed to Earth.

NASA Completes Design Review of SLS Exploration Upper Stage

The Exploration Upper Stage, or EUS, for NASA's Space Launch System rocket passed its **critical design review** Dec. 18. The assessment certifies the EUS meets critical design requirements to withstand deep space environments and, when completed, will ensure astronaut safety. The EUS will be used for future flights of the SLS rocket beyond Artemis III. Boeing, the prime contractor for the EUS as well as the core stage, will manufacture and assemble the upper stage at Michoud.

NASA Makes Progress on Green Run Testing, Future Core Stages

December marked several milestones for NASA's Space Launch System Program. Technicians refined procedures for test operations before successfully completing propellant loading during the seventh of eight Green Run tests – a **full wet dress rehearsal** – Dec. 20. The wet dress rehearsal test involves loading and draining the stage's two immense propellant tanks of thousands of gallons of cryogenic propellants. Following data analysis of a successful wet dress rehearsal test, teams will prepare for the final test of the Green Run series: the SLS hot fire. As technicians at Stennis progress through Green Run testing for Artemis I, technicians at Michoud are simultaneously manufacturing core stages for Artemis II and Artemis III.