



NASA's Marshall Space Flight Center

Supporting America's Exploration of Space, Working to Improve Life on Earth

The unique resources, facilities and expertise at NASA's Marshall Space Flight Center in Huntsville, Ala., are critical to advancing NASA's mission of exploration and discovery. The Marshall Center's engineering capabilities, extensive experience in human spaceflight system development and ability to perform cutting-edge research in Earth and space sciences are vital to the work of the U.S. space program, the long-term economic success of the nation and the quality of life across the planet.

The Marshall Center manages a broad and diverse portfolio of programs and projects. The center leads NASA's development of advanced spacecraft and launch vehicles designed to take human and robotic explorers deeper into the solar system than ever before. The center also manages the Chandra X-ray Observatory; the Discovery, New Frontiers and Lunar Quest programs; the Technology Demonstration Missions program; the Centennial Challenges program; the SERVIR environmental imaging network; and numerous other Earth and space science activities. Marshall also is responsible for science operations aboard the International Space Station. All these endeavors contribute to and sustain Marshall's long history of accomplishment, which includes creating the Saturn V rocket that launched America's astronauts to the moon; Skylab, the world's first space station; Spacelab; the space shuttle's propulsion elements; and development of the Hubble Space Telescope.

The Marshall Center is an experienced developer and integrator of launch systems and a premier developer and integrator of space systems for science and exploration, possessing the engineering capabilities to take hardware from preliminary design to operation in space. The Center's cross-cutting capabilities in science and engineering have led to a key role in managing the next generation of space exploration systems, the heavy-lift Space Launch System.

One of NASA's largest field centers, Marshall employs approximately 6,000 people, including roughly 2,400 civil service and 3,600 contractor employees, and has an annual budget of approximately \$2.5 billion.



Space Launch System Development

The future of space travel is evolving as NASA creates new launch and spaceflight vehicles that will provide the capability for crewed exploration missions beyond low-Earth orbit.

The Marshall Center manages and will deliver the systems needed for the next generation Space Launch System, or SLS — development of which began in earnest in September 2011. The SLS program is developing the nation's next advanced, heavy-lift vehicle — the most powerful rocket ever built. Its design maximizes efficiency and minimizes cost by leveraging investments already made in legacy launch hardware and systems, while also using evolutionary advancements in launch vehicle design.

NASAfacts

The initial launch vehicle configuration will have a lifting capacity of 70 metric tons. The rocket will be evolvable to a 130-metric-ton lift capacity and will be built around a core stage 27.5 feet in diameter, which will share common avionics with its upper stages. It will use a liquid hydrogen and liquid oxygen propulsion system, relying on the space shuttle's RS-25 engine for the core stage and the J-2X engine for the upper stage. Dual, five-segment solid rocket boosters mounted to the sides of the tank will provide added power. The design of the dual boosters on later flights will be determined through competition based on cost, performance and interface requirements.

The Space Launch System will carry NASA's Orion Multi-Purpose Crew Vehicle, cargo, equipment and science experiments to space. It also will provide emergency abort capability, sustain the crew during the space travel and provide safe re-entry from deep space return velocities. Its mission is to provide a safe, affordable and sustainable means of sending explorers on high-value missions to the moon, asteroids and other destinations in the solar system. Additionally, the vehicle will serve as a backup for commercial and international partner transportation services to the International Space Station.

NASA intends to launch the first, full-scale test flight of the Space Launch System by late 2017.

Leading NASA in rocket propulsion technology, Marshall has been launching spacecraft and explorers into space since the beginning of the U.S. space program. From Apollo to space shuttle, the center has played a critical role in transporting people, supplies, and science experiments into low Earth orbit. Engineers at Marshall designed and developed the shuttle main engines, the external fuel tank, and the solid rocket boosters, and continued to advance these key propulsion technologies to maintain the shuttle's safe operation until its retirement in 2011.

National Institute for Rocket Propulsion Systems

Founded in 2011, the National Institute for Rocket Propulsion Systems, or NIRPS, is intended to provide stewardship of our nation's propulsion capabilities, recognizing their vital role in national security, economic competitiveness and the continued exploration of space. The Institute, situated at the Marshall Center, will support the preservation and advancement of government and industry propulsion capabilities to meet current and future aerospace needs for civil and federal agencies.

The Institute will serve as a go-to source for NASA, Federal Aviation Administration, Department of Defense and commercial spaceflight solutions, and will assist with development and operational challenges that may occur as new propulsion systems come online. The Institute will contribute to the success of these ventures by providing each partner organization in need with a full range of design, development, test and evaluation support and technical expertise.

The Institute further will serve in the role of steward and integrator, merging information and industry status with all parties

related to the industrial base and providing policy recommendations to the U.S. government and its agencies.

Retiring Shuttle and Transition

The Marshall Center is responsible for planning, coordination and execution of all transition and retirement activities associated with the Shuttle Propulsion Office, the Ares Projects Office and associated Marshall institutional organizations. This responsibility includes identification and disposition of all requirements and issues associated with strategic capabilities; real and personal property; flight and ground hardware; records and data management; facilities; information technology assets and databases; and associated workforce.

International Space Station Support

The International Space Station — the largest and most complex international scientific project in history — continually orbits the Earth every 90 minutes with a crew of six. The Marshall Center has an important role in developing and sustaining space station hardware and science operations.

The Payload Operations Center at Marshall is NASA's primary space station science command post, coordinating all U.S. scientific and commercial experiments on the station, as well as Earth-to-station science communications — 24 hours a day, every day of the year. The Marshall team also trains station crew members on experiments and ground controllers on monitoring those experiments. It also coordinates the payload activities of NASA's international partners, including the Russian Space Agency, European Space Agency, Japan Aerospace Exploration Agency and Canadian Space Agency. The Payload Operations Center partners with control centers worldwide to plan, synchronize and monitor science activities and optimize the use of valuable on-orbit resources.

As the life of the International Space Station has been extended to 2020 and possibly beyond, Marshall continues to play an important role in station hardware development. Marshall manages development and design of the Environmental Control and Life Support System, which eliminates the need for constant resupply of water and oxygen from Earth.

Marshall also developed and manages Nodes 1, 2 and 3 — modules which interconnect the station's laboratories, living quarters and other facilities — and the Multi-Purpose Logistics Modules, pressurized "moving vans" designed to transfer experiments and supplies to and from the station. The MPLM dubbed "Leonardo" is now a Permanent Multipurpose Module, or PMM. It is permanently attached to the space station to provide more room for supply storage.

A new Earth science observatory rack is providing the International Space Station with an eye in space, helping researchers keep watch over the Earth. The Window Observational Research Facility, or WORF, is helping NASA capture some of the most detailed images and information about our planet ever documented from an orbiting spacecraft. The WORF rack is designed to make the best possible use

of the highest-quality optical science window ever flown on a crewed spacecraft. Meticulously calibrated before its installation, the window has been used by station astronauts since the American Destiny laboratory module became the keystone of space station research facilities in 2011.

Marshall designed and built the Microgravity Science Glovebox, an enclosed experiment facility over 7 feet tall, accessible through airtight “glovedoors,” and delivered a standardized payload rack system for transporting, storing and supporting experiments on the station. The “EXPRESS” Rack — Expedite the Processing of Experiments to the Space Station — enables quick integration of multiple payloads in a streamlined approach.

The most recent rack delivered to the station is the Materials Science Research Rack-1, put into place in 2009 to enable researchers to study a variety of materials in pursuit of new and improved Earth and space applications. The rack allows for the on-orbit study of a variety of materials, including metals, ceramics, semiconductor crystals and glasses. The first processed American sample consisted of an aluminum and silicon alloy that was melted and then directionally solidified. Similar processing of various alloys is typically used to produce commercially important hardware and components such as high temperature turbine blades.

Exploring the Solar System and the Universe

Marshall space scientists are conducting astronomy, astrophysics and heliophysics research into the scientific mysteries of the cosmos, supporting exploration of the solar system and seeking new understanding of the universe beyond.

More than ten years after launch, the world's most powerful X-ray telescope, NASA's Chandra X-ray Observatory, continues to rewrite textbooks with discoveries about our own solar system and images of celestial objects as far as billions of light years away. The Marshall Center was responsible for design, development and construction of NASA's Chandra X-ray Observatory, the world's most powerful X-ray telescope, which was launched in 1999. Marshall continues to manage Chandra operations and science activities.

The X-ray & Cryogenic Facility at Marshall, where both Chandra and the Hubble Space Telescope mirrors were tested for spaceflight, currently is being used to perform cryogenic testing of ultra-precise mirrors for the James Webb Space Telescope, intended to enable high-powered study of the formation of the first stars and galaxies and their evolution.

Marshall solar physicists and engineers continue to design instruments to help us learn more about our sun. Marshall's sounding rocket program seeks to determine the strength and direction of magnetic fields in a region of the sun where the magnetic field has never been measured. Marshall scientists also are developing instrument prototypes for the Solar Probe Plus mission, set to launch in 2018. These instruments will specifically count the most abundant particles in the solar wind — electrons, protons and helium ions — and measure

their properties. The investigation also is designed to sweep up the solar wind in a special receptacle called a Faraday cup, to enable researchers to determine the speed and direction of solar particles.

Marshall also developed scientific instrumentation and manages science operations for the international Hinode mission to study the turbulent surface of the sun. A collaboration among the space agencies of Japan, the United States, the United Kingdom and Europe, Hinode was launched in 2006 to investigate the interaction between the sun's magnetic field and its corona. Marshall scientists collect and analyze data from the Fermi Gamma-ray Burst Monitor, a joint U.S.-German instrument aboard the Gamma-ray Large Area Space Telescope, launched in 2008 to study high-energy gamma rays in deep space.

The Marshall Center also is home to NASA's Discovery, New Frontiers and Lunar Quest programs. The Discovery Program challenges scientists to find innovative ways to unlock the mysteries of the solar system with low-cost, highly focused planetary science investigations. New Frontiers sends cost-effective, mid-sized spacecraft on missions that enhance our understanding of the solar system. The program gives the science community an opportunity to propose full investigations to be conducted as a way to launch exploration missions in the solar system. Examples of program science missions include landing on an asteroid, a flight to investigate Mercury, capturing the essence of a comet and studying the structure of solar energy. Missions are led by NASA's Jet Propulsion Laboratory in Pasadena, Calif.; NASA's Ames Research Center in Moffett Field, Calif.; and Johns Hopkins University in Baltimore, Md. Most recent is the Gravity Recovery and Interior Laboratory, or GRAIL, with launch in September 2011. GRAIL makes detailed measurements of the moon's gravity field, aiding scientific understanding of the moon's structure and dynamics.

NASA's new Lunar Quest Program is a multi-element program consisting of flight missions; sophisticated instruments designed to serve lunar missions of opportunity; and associated research and analysis efforts. The Lunar Quest Program includes the Lunar Reconnaissance Orbiter, which has returned a treasure trove of lunar data and the most detailed map to date of the moon's surface; and the Lunar Atmosphere and Dust Environment Explorer, or LADEE, an upcoming mission to gather detailed information about conditions near the surface and environmental influences on lunar dust. The program includes the Robotic Lander Development Project, which designed, built and is testing a small, smart, versatile robotic lander that could serve as a precursor to sending humans to explore or conduct scientific research on airless bodies across our solar system.

Marshall engineers and scientists have developed a new, small satellite capability with the design, development, test and successful mission operations of the Fast, Affordable Science and Technology Satellite, or FASTSAT, microsatellite. FASTSAT demonstrated the ability to enable governmental, academic and industry researchers to conduct low-cost scientific and

technology experiments on an autonomous satellite in space. The project was a joint activity between NASA and the U.S. Department of Defense Space Test Program, in partnership with the Von Braun Center for Science & Innovation and Dynetics Inc. of Huntsville. Dynetics provided key engineering, manufacturing and ground operations support for the new microsatellite. Thirteen North Alabama firms and the University of Alabama in Huntsville also were part of the project team.

NanoSail-D is a small satellite technology demonstrator developed by engineers at Marshall in collaboration with NASA's Ames Research Center in Moffett Field, Calif. NanoSail-D demonstrated the capability to eject from FASTSAT and deploy a large solar sail structure from a highly compacted volume without re-contacting the microsatellite. This demonstration can be applied to deploy future communication antennas, satellite deorbit systems, sensor arrays or thin film solar arrays to power spacecraft.

Space optics technologists and researchers at Marshall continue to develop ultra-lightweight optics materials and fabrication technologies, and manage state-of-the-art test facilities for NASA. Our teams are testing advanced optics technologies for future space observatories to replace the Hubble Space Telescope and Chandra Observatory.

Protecting and Improving Life on Earth

Marshall scientists work to improve our quality of life through discoveries in Earth science. Researchers here focus on studying the atmosphere, water vapor, winds, temperatures at different altitudes, lightning and aerosols -- minute particles in the air. Marshall scientists use advanced technologies to observe and understand these aspects of the global climate system to improve agriculture, urban planning, response to severe weather, and water resource management. Earth science researchers use advanced technologies to observe and understand the Earth's global water cycle as it relates to global and regional climate.

A key Earth science project called SERVIR (Spanish for "to serve"), developed and managed for NASA by the Marshall Center, uses a high-tech satellite visualization system to monitor the environment of Central America and other regions. Principally supported by NASA and the U.S. Agency of International Development, SERVIR integrates satellite observations, ground-based data and forecast models to monitor and forecast environmental changes and improve response to natural disasters in Central America, the Caribbean, Africa and the Himalayas. It helps inform science-based decision-making in the areas of climate change, health, agriculture environment, water and weather.

Marshall researchers also manage the NASA Short-term Prediction Research and Transition Center, or SPoRT, which provides real-time NASA satellite data to the National Weather Service to improve forecasting and save lives.

Another way Marshall is using technology to improve life on Earth is through a new initiative called Observing Microwave Emissions for Geospatial Applications, or OMEGA. The

project uses small, special-focus satellites to retrieve global soil moisture data, enabling scientists to analyze the global water cycle and improve weather and flood forecasting. Marshall also is developing the Hurricane Imaging Radiometer, or HIRAD, through a partnership with three universities and the National Oceanic and Atmospheric Administration. The radiometer produces imagery of ocean wind conditions during hurricanes by measuring microwave radiation emitted by the foamy froth whipped up as strong wind swirls across ocean waves.

A key extension of Marshall science endeavors is the National Space Science & Technology Center in Huntsville, where government, industry and academic researchers collaborate on research and education opportunities in the areas of Earth and space science, optics and information technology — and help foster new generations of scientists and engineers. It is the only site in the country that jointly houses NASA and the National Oceanic and Atmospheric Administration's National Weather Service, which partner to understand day-to-day forecast challenges and design customized solutions to protect lives and property from the effects of changes in environment, weather and climate.

Engineering the Future

NASA's diverse suite of flight missions, projects and programs continue to expand humanity's understanding of the universe. It is occasionally not possible, however, to accomplish the goals of a particular mission using currently available technologies. New capabilities and development of innovative new technologies may be needed. Marshall engineers and researchers provide a wide range of advanced technology development efforts to enable and enhance NASA's successful exploration mission. Technology work accomplished by Marshall engineers, scientists and researchers is diverse, ranging from new developments in the areas of space transportation and propulsion to key breakthroughs in space systems and science research.

Technologies engineered at Marshall to support space transportation projects include the ability to use ionic liquids or microwave energy to extract — from in-situ resources found on other solar system bodies — critical liquids and gases that may be used for fuels or for life-support; the ability to automatically monitor sensors across a space vehicle and autonomously diagnose and troubleshoot issues; and the use of carbon nanotubes in development of high efficiency spacecraft radiators. Propulsion-related technology research includes development of a sophisticated cryogenic fuel tank using composite materials; and in-space propulsion technology research into alternative propulsion systems such as electrodynamic tether propulsion, solar sails and nuclear-based propulsion systems.

New engineering breakthroughs supporting space systems research and development at Marshall include autonomous mobile systems used for crewed and uncrewed exploration tasks; air and water revitalization systems providing environmental life support; avionics and processors hardened to withstand deep-space environments and radiation during long missions; robotic lander capabilities; cryogenic fluid management, storage, and transfer; and new advances to protect

human beings from the debilitating rigors of space travel. Science research at Marshall is supported by technology development studies in X-ray interferometry and telescope mirror development; space weather analysis, characterization and event prediction; advanced instrument and sensor development; and more comprehensive evaluation and definition of the space environment itself.

In support of these individual technology development efforts, the Marshall Center hosts a pair of technology program offices on behalf of NASA's Space Technology Program: the Centennial Challenges program and the Technology Demonstration Missions program.

Centennial Challenges

Centennial Challenges, NASA's technology prize competition program, was introduced in 2005 to honor the centennial of powered flight. In keeping with the spirit of the Wright Brothers and other American innovators who paved the way to space, the program encourages the participation of independent inventors — small businesses, student groups and individuals — who work without government support. NASA challenges these independent inventors to generate innovative solutions for technical problems of interest to NASA and the nation, and provides them with the opportunity to stimulate or create new business ventures.

The Marshall Center manages the program for the agency. Challenges are conducted through unfunded Space Act Agreement partnerships between NASA and nonprofit Allied Organizations. While NASA provides the prize purse for the competitions, each Allied Organization is responsible for planning and conducting the challenge. Prize challenges may require participants to deliver prototypes that perform according to certain standards; create new methods of solving old technical problems; or accomplish feats that involve the development of new technology or the unprecedented application of existing technology.

Technology Demonstration Missions

The Technology Demonstration Missions program exists to mature revolutionary, crosscutting technologies to flight readiness status through projects that perform relevant environment testing. Once a technology has been proven in the laboratory environment, the program allows an opportunity to “bridge the gap” from laboratory to flight — providing an opportunity for system-level technology solutions to operate in a realistic space environment, where they will gain operational heritage and reduce risks to future missions by eliminating the need to fly unproven technology solutions.

Marshall team members participated in the development of the Space Technology Roadmaps, a set of 15 documents that chart the development of multiple technology areas. These roadmaps will help NASA identify new technology development opportunities, enable planners to integrate new and innovative technologies into future flight programs, and prioritize the agency's future technology development investments.

Engineers and technologists at the Marshall Center deliver highly skilled, crosscutting engineering services — the backbone to mission success — in support of Marshall programs and projects across the center and NASA. Their work serves both the current and near-term planned agency missions and far-flung efforts still on the drawing board, awaiting the necessary development and maturation to support NASA's future exploration goals.

The center's capabilities include integrated modeling and simulation; developing, testing and integrating launch vehicle systems; developing propulsion systems and components; developing propellant management, storage and delivery systems; and designing automated rendezvous and capture systems. With these capabilities, Marshall is poised to support a broad range of space programs.

Marshall Center researchers and engineers develop products for science investigations, conduct verification and integration of state-of-the-art spacecraft and vehicle systems and research and develop propulsion elements for space transportation systems. They provide research, technology and engineering support in materials, processes and products to be used in space exploration and manufacturing; and perform materials diagnostics and failure analysis for NASA and other customers. They manage the functions, resources, services and facilities necessary for simulation of aerospace environments and flight-like conditions; perform research, development, qualification and acceptance testing of flight and non-flight aerospace hardware; analyze and develop requirements for flight and ground systems; and manage ground and flight operations, including day-to-day science operations on the International Space Station.

To benefit this technology development effort and other research and program/project work across NASA, the Marshall Center will deepen and expand its focus on value-added partnerships across government, industry and academia. A new organization at the center will be responsible for undertaking new work building upon the center's 50 years of knowledge, experience and specialized facilities. It will work closely with administrators, strategic planners, managers and teams across the center and its partner organizations to develop long-term center plans, focus Marshall's capabilities to propose and compete for new work, and evaluate new opportunities to ensure these efforts support the center's core capabilities.

Michoud Assembly Facility

The Marshall Center also manages the Michoud Assembly Facility in New Orleans, one of the world's largest manufacturing facilities, with 832 acres of infrastructure and more than 2,500 employees on-site. For nearly 40 years, Michoud workers manufactured and built the Space Shuttle Program's external tank. Now workers are positioning Michoud to play a key role in NASA's heavy-lift launch vehicle and other next-generation exploration efforts.

Providing Real-world Solutions

Over the decades, thousands of life-saving, life-improving technologies and applications have been derived from NASA and Marshall research and exploration missions: advanced breast cancer imaging systems, heart pumps, biohazard detectors, water filtration systems and LASIK eye surgery to correct vision are just a few innovations.

NASA's Innovative Partnerships Program, managed at the Marshall Center, works with industry partners to spinoff space technology and adapt it for new, innovative applications across the medical, communications, safety and transportation industries, among others. One innovative technology funded by the program, for example, has led to new medical breakthroughs in mitigating the painful side effects of chemotherapy and radiation treatment. Originally developed for plant growth experiments on space shuttle missions, a far red/near infrared light-emitting diode treatment was given to cancer patients undergoing bone marrow or stem cell transplants during a two-year trial. The treatment, known as High Emissivity Aluminiferous Luminescent Substrate, or HEALS, demonstrated a 96 percent chance that it decreased or diminished patients' pain. FDA premarket approval of devices using the treatment technology are under way.

Leveraging Marshall's unique capability to blend science and engineering, the center's Small Business Innovation Research Program and Small Business Technology Transfer Program have contributed to technologies that make possible affordable drinking water throughout the world; improved wound healing and chronic pain alleviation for soldiers and civilians; and provided artificial intelligence-based technology to improve tutoring programs.

Education Initiatives

The Marshall Center leads and participates in numerous NASA education projects and activities to engage and inspire the next generation of explorers.

Marshall organizes the annual NASA Great Moonbuggy Race, a competition inspired by the Apollo-era lunar rovers. Since its start in 1994, the race has challenged more than 7,500 high school and college students worldwide to design, build and race human-powered moonbuggies on simulated lunar terrain. Marshall also leads the annual NASA Student Launch Projects rocketry challenge, founded in 2001. Since then, more than 1,500 American students from middle schools, high schools, college and universities have designed, built and launched working rockets, complete with scientific payloads.

These and other initiatives, geared toward both students and educators, enable K-12 and college students to apply their learning to science and engineering projects, and help them gain relevant experience, critical skills and capabilities needed to achieve NASA's continuing space exploration missions.

More About NASA

With its rich history of unique scientific and technological achievements in human spaceflight, aeronautics, science and space applications, NASA inspires new generations of Americans to ask questions and search for answers as the nation blazes new trails through space. The agency's knowledge and experience accelerates innovation with a return on investment that includes further opportunities for exploration, a better understanding of our solar system and improvements to everyday life on Earth.

The Marshall Center pursues NASA's mission by partnering with and supporting the work of the other NASA field centers. The Marshall Center also works closely with the U.S. Department of Defense, the Department of Energy, the National Oceanic and Atmospheric Administration and other government agencies, and with leading academic institutions and industry partners around the world.

For more information about the Marshall Center, visit:
<http://www.nasa.gov/centers/marshall/>

National Aeronautics and Space Administration

George C. Marshall Space Flight Center

Huntsville, AL 35812

www.nasa.gov/marshall