



# Large-Scale Manufacturing

## *Advancing State-of-the-Art*

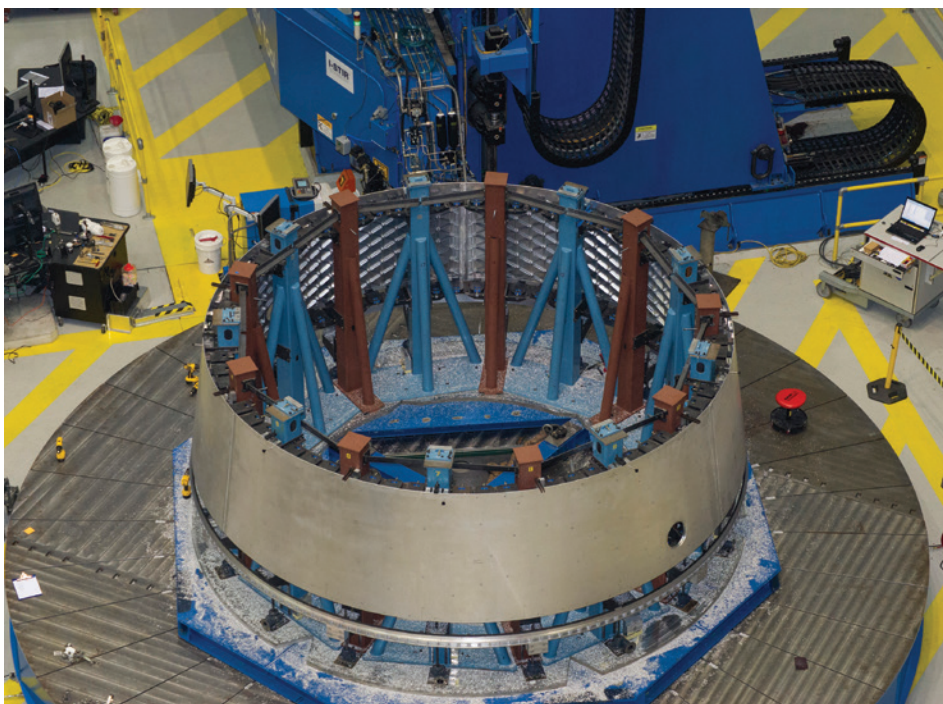
Marshall is a leader in large-scale manufacturing for aerospace, involved in the production of everything from the Redstone rocket to the Saturn V, space shuttle propulsion elements, International Space Station (ISS), and now the Space Launch System (SLS). Marshall has helped “build big” for more than five decades and is uniquely equipped with the expertise and technology to continue leading the development of groundbreaking welding and composite techniques and processes for large-scale manufacturing. The Center also manages the resources and production of tanks, panels, and

other structures at the Michoud Assembly Facility in Louisiana, supporting SLS and other missions and commercial efforts.

The Center conducts path-finding research and development on large-scale manufacturing tools and processes to be implemented by industry partners in production. This reduces risk, decreases costs, and increases mission success — particularly for human space exploration missions, which by their nature demand large-scale structures.

### At-A-Glance

Large, complex space systems — whether launch vehicles, human habitats, or scientific observatories — continually “push the envelope” of large-scale manufacturing capabilities. Marshall Space Flight Center researches, designs, develops, tests and evaluates new processes to be implemented by our contractor partners during production, using both cutting-edge hardware and digital design optimization solutions. Together we are finding new ways to minimize cost and schedule and to enhance the performance of mission elements requiring large-scale manufacturing and production.



Marshall tests manufacturing process and tools for the Orion structural test article to troubleshoot before full-scale production begins.

## Pioneering Techniques for Industry Application

Before embarking on new large-scale manufacturing efforts, Marshall uses digital design tools and models of planned manufacturing facilities to determine any potential logistical difficulties or hardware risks in planned manufacturing flows. By creating digital models of the facilities and tools, the Center can identify potential issues with clearances, handling procedures, or fabrication processes before the facilities are even completed. With the significant costs involved in developing and outfitting large-scale manufacturing facilities, this represents significant reductions in both cost and schedule.

Welding and metals are at the core of manufacturing for space launch vehicles and other large-scale structures. Marshall's team has long pioneered welding techniques and holds many patents, with a specialization in optimizing advanced joining processes, taking them from the laboratory to full-scale flight hardware and structures.

The friction stir process developed by The Welding Institute has been advanced at Marshall, which began using it in the 1990s with difficult aluminum lithium alloys while building the ISS. Marshall invented a retractable pin tool for friction stir welding, developed a self-reacting friction stir process, matured friction pull plug welding, developed techniques for other alloys, and established engineering requirements and design data used throughout the aerospace industry. Today, the Center uses

tools and techniques for ultrasonic stir welding and thermal stir welding, a derivative of the friction stir process used with nickel-based and titanium alloys or high-temperature steels. These processes may dramatically reduce the size and cost of weld technology and be suitable for in-space welding. The method was demonstrated in welding the Orion Stage Adapters and Multi-Purpose Crew Vehicle simulator.

Marshall also specializes in the use of composite materials for launch vehicles and space structures. The Center has developed a variety of composite articles for propulsion systems and launch vehicles, including cryogenic tanks, test panels, rocket motor cases and fairings. Recent activities include work with commercial partners to develop and test composite cryogenic hydrogen tanks. Switching from metallic to composite tanks could result in a dramatic reduction in mass, greatly increasing the performance of future space systems, including the SLS.

With the recent addition of an automated fiber placement robot, Marshall can construct large, lightweight composite components and, using the Center's facilities, test the structure's characteristics. This robotic equipment offers high speed precision for composite manufacturing that equals lower cost and faster production.

Marshall and Michoud Assembly Facility equipment has been used to manufacture components for the next-generation lightweight tank program and a number of launch vehicle programs, including the X-38. Marshall is also working with the NASA Engineering and Safety Center (NESC) to develop and test Composite Overwrap Pressure Vessels and was involved in the NESC study of a full-scale Composite Crew Module as a light-weight alternative to the Orion Multi-Purpose Crew Vehicle design.



Marshall evaluated a Composite Crew Module as a much lighter alternative to the baseline Orion design.

## Sustaining Engineering Support for Large-Scale Production

Marshall's facilities are often used to provide sustaining engineering support to full production facilities by troubleshooting problems that arise during manufacturing at the Michoud Assembly Facility or in private industry. Commercial partners have also used the Center's facilities, which include the same advanced welding, composite, and other tools used at Michoud, while waiting for delivery or installation of their own equipment. Marshall's team has been called upon for failure analysis of Army Apache, Blackhawk, Chinook and other helicopter parts, as well as to help solve problems for other centers, government agencies and industry.

## Comprehensive Large-Scale Manufacturing and Testing Facilities

The Center offers a full suite of support capabilities for large-scale manufacturing, including on-site inspection and non-destructive evaluation expertise and technology, including Structured Light Scanning, photogrammetry, microscopy, spectroscopy, and chemical analysis.

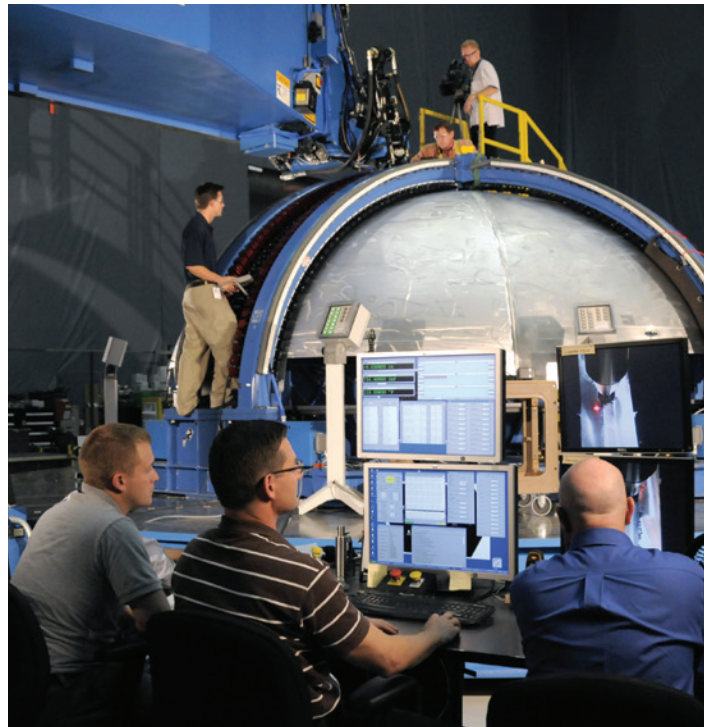
Marshall's experienced team is complemented by the Center's unique collection of tools and technology. There is a broad range of advanced welding, composite and assembly equipment, including seven friction stir welding systems; plug welding and fusion welding systems; four-axis filament winding machines; tape laying machinery; and more. In addition, the Center offers some rare and unique capabilities including:

### Welding

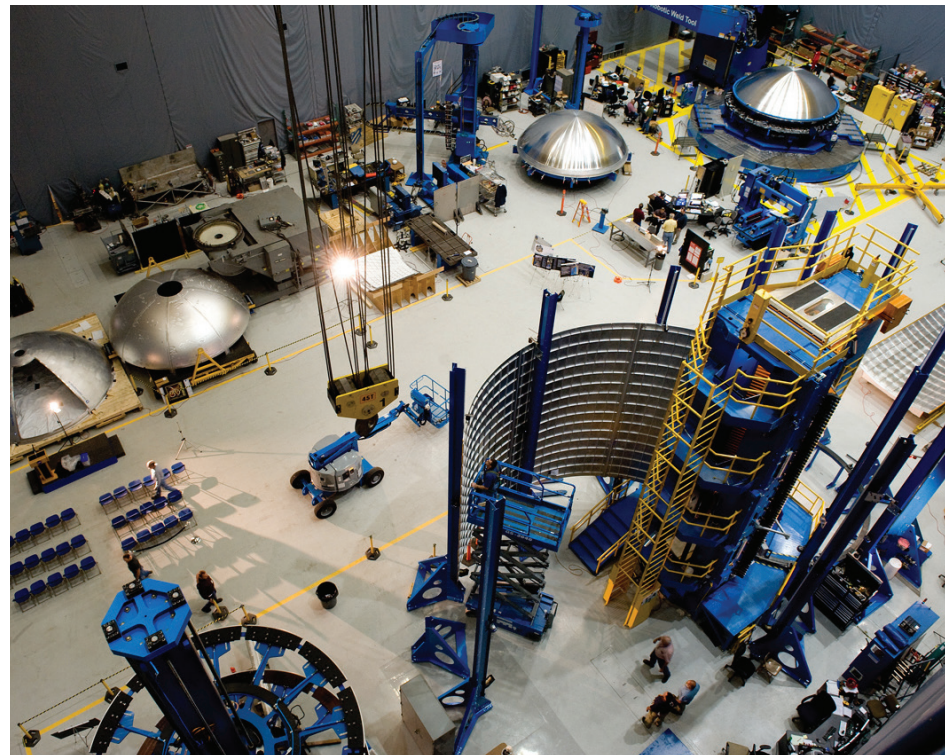
- Large Robotic Weld tool, with a 30-foot-diameter turntable, capable of complex-curvature weldments to 36 feet in diameter and 22.5 feet tall
- A pair of Vertical Weld Tool 1, capable of welding up to 20 feet tall with a range of diameters from 8 feet to 40 feet
- Vertical Weld Tool 2, can weld up to 25 feet tall with a range of diameters from 10 feet to 40 feet
- Vertical Assembly Tool for welding 18-foot-diameter circumferential joints
- Three unique panel weld systems in support of weld development
- Two Friction Plug Weld systems
- Thermal Stir Weld system for welding high-strength alloys

### Composites

- 18 x 20-foot autoclave with 2-ton hoist
- 9 x 12-foot autoclave
- 4 x 6-foot autoclave
- Curing ovens ranging from 2 x 2-foot to 20 x 60-foot
- 5,000-square-foot clean room and other clean rooms and work areas
- 400-square-foot airlock with 2-ton hoist



Marshall's Robotic Weld Tool can handle the complex curvatures needed for launch vehicle fuel tank domes.

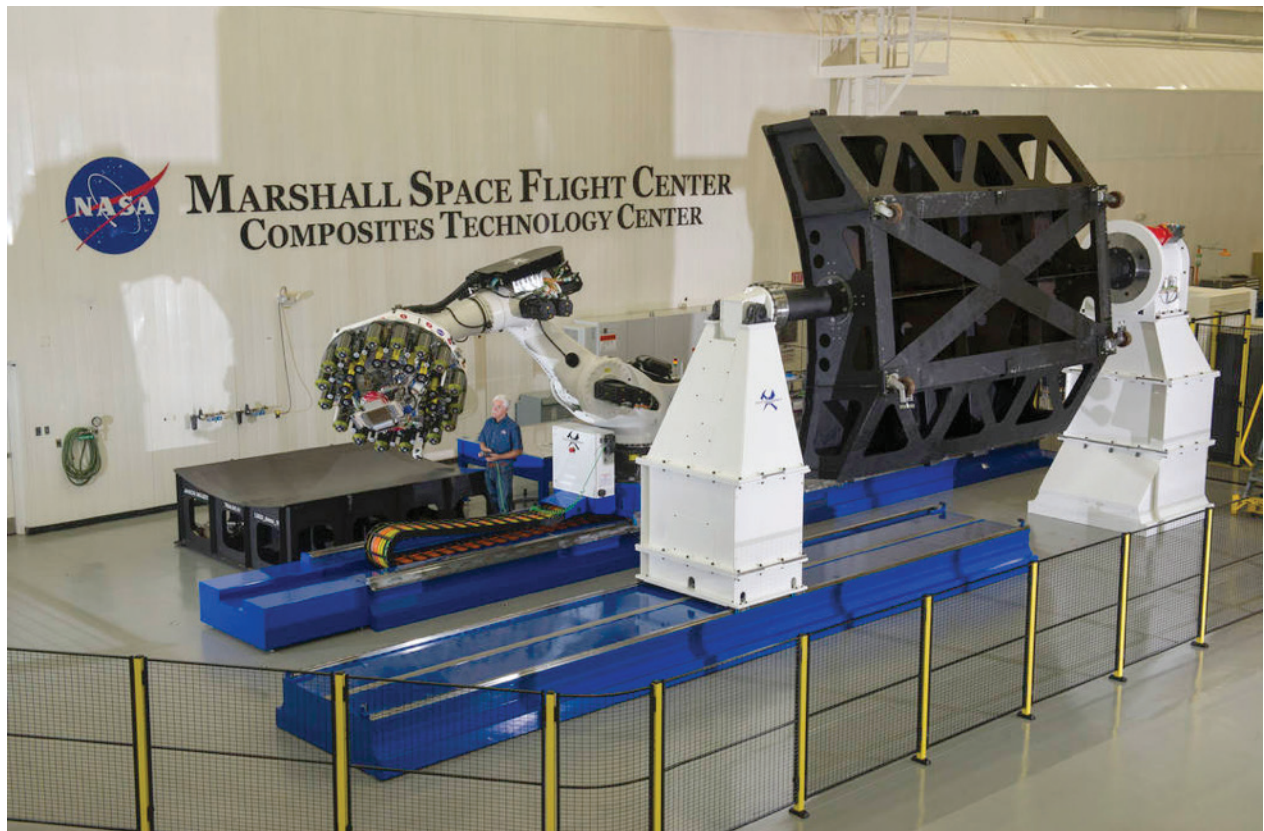


Advanced welding tools are used at Marshall to reduce project risk before flight hardware begins production.

## Exploring Composite Materials for Space Systems

Lightweight composites have the potential to increase the amount of payload that can be carried by a rocket along with lowering its total production cost. NASA is conducting composites manufacturing technology development and demonstration projects to determine whether composites can be part of the evolved Space Launch System and other exploration spacecraft, such as landers, rovers, and habitats. A new robot at Marshall can create composite materials out of carbon-fiber strands an order of magnitude faster than the older systems that will allow for the development of new construction techniques to make advanced composite materials cheaper. The large structures built by the robot will be tested in nearby Marshall structural test stands where spaceflight conditions can be simulated.

To make large composite structures, the robot travels on a track, and a head at the end of its 21-foot robot arm articulates in multiple directions. The head can hold up to 16 spools of carbon fibers that look like pieces of tape and are as thin as human hairs. The robot places the fibers onto a tooling surface in precise patterns to form different large structures of varying shapes and sizes. In what looks like an elaborate dance, the tooling surface holds the piece on a rotisserie-like system on a parallel track next to the robot. The robot head can be changed for different projects, which makes the system flexible and usable for various types of manufacturing.



This new robotic fiber placement tool can drastically reduce the cost and improve the quality of large space structures.

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