aerospace

The future of aerospace is at NASA Marshall Space Flight Center

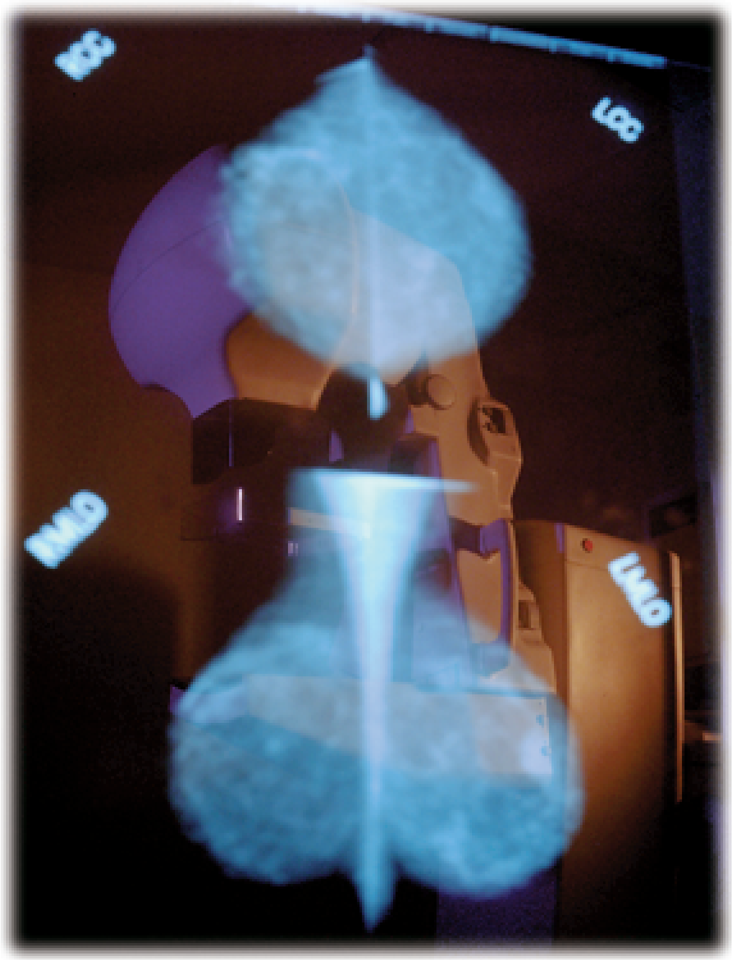
Aerospace technologies we need to reach the stars are the engines to drive America's future.

Aerospace is a high-risk, high-benefit business. Aircraft and spacecraft must perform under extreme environmental conditions. The high potential for damage demands that hardware, materials, electronics, and systems undergo a barrage of testing and analysis before the countdown begins.

Marshall Space Flight Center leads NASA's efforts in space transportation systems development. As such, we have the unique expertise to help ensure the success of your future air and space missions. Over the years, we have acquired the capabilities to design, test, and analyze spacecraft, launch vehicles, payloads, and equipment to improve their efficiency, safety, and performance.

We invite you to partner with Marshall to develop new technologies, learn from our expertise, or to benefit from our comprehensive facilities. This information booklet describes our facilities and capabilities in the following areas:

- *Materials*
- *Electronics*
- *Complex systems*
- *Aircraft and spacecraft.*



From X-Ray Astronomy to Medical Imaging

As a world leader in developing imaging systems for X-ray astronomy, Marshall Space Flight Center is advancing the technology to other applications. In collaboration with the State University of New York–Albany and X-Ray Optical Systems, Inc., Marshall has constructed hard X-ray concentrators using capillary X-ray optics. The capillary optics—formed from a multitude of hollow glass fibers 15 microns in diameter—focus the X rays precisely onto a detector. Long-beam X-ray calibration facilities at Marshall are used to test the optics.

With this expertise, Marshall has formed industry partnerships that have led to two important biomedical spin-off applications:

- **Protein Crystallography**: Micromolecular X-ray crystallography is the primary tool for determining the structure of biological molecules. To achieve brighter, sharper diffraction patterns, researchers are using capillary optics to focus more X rays into a small area of the crystal.
- **Medical X-ray Imaging**: Capillary X-ray optics function as a collimator to reduce scattering, which leads to sharper contrast in medical X-ray images.

This booklet describes other technologies available at Marshall to help you maintain a competitive edge in the global economy.

Marshall's assets can benefit aerospace-related and other industries:

- Astronomy
- Telecommunications
- Aircraft and spacecraft manufacture
- Military
- Navigation systems
- Remote sensing/imaging
- Science and engineering.

MATERIALS

Materials used in aerospace flight are subject to extreme environments, unusual conditions, and stresses. Selecting, manufacturing, and testing the component materials requires a high level of expertise and extensive facilities. We offer both.

Materials Selection

Is a particular material suitable for aerospace flight? The Materials and Processes Technical Information System (MAPTIS) offers several databases with information on the mechanical and physical properties, selection, and verification and control of over 6,000 metals and 24,500 nonmetals.

Material Properties Database

Over 500,000 records contain standard data on material density, mechanical strength, service temperature, and other properties.

Material Selection Database

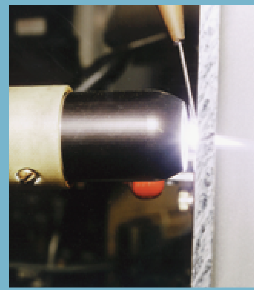
Information indicates the suitability of materials within specific environments.

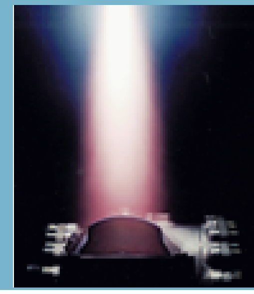
Material Information Databases

Several other databases provide high-level technical detail:

- Long Duration Exposure Facility (LDEF) Database
- Structural Materials Failure Analysis Database
- NASA Materials Environment Data System.







Materials Manufacturing

Marshall uses the most advanced manufacturing processes for materials to support NASA space missions. Several techniques involve the use of robotics, making processes safer, more repeatable, and more reliable. These manufacturing processes are described in greater detail in Marshall's *Manufacturing* book.

Advanced Composites Manufacturing

A diverse range of techniques to make launch vehicles lighter, stronger, and more durable.

Robotic Water Blasting

Stripping and cleaning processes that allow multiple coatings to be removed individually.

Welding

Extensive welding capabilities at the forefront of manufacturing.

High-Speed Machining

A hydraulic-driven spindle with better performance at a lower cost and higher speed than electro-driven spindles.

Thermal Spray Processing

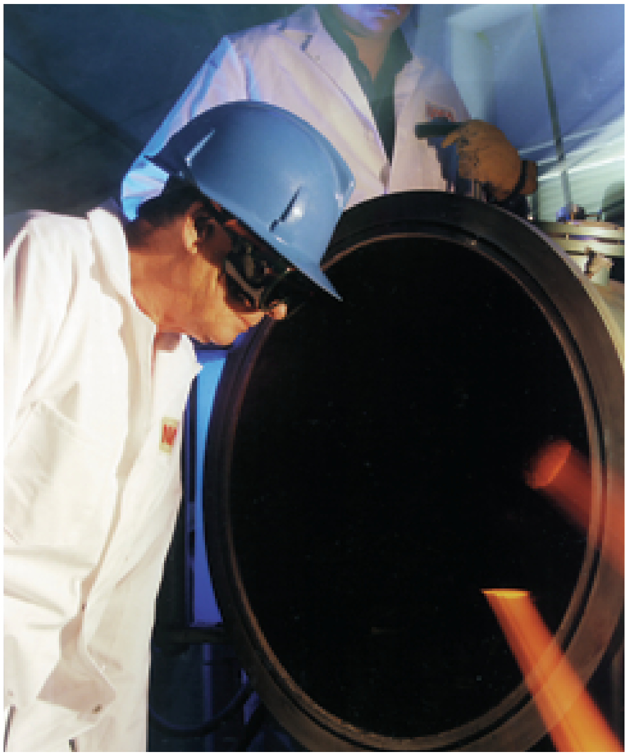
Enables coatings of many different materials to be applied exactly where they are needed.

Aerogel Development

A low-density, porous, nanostructured insulating material that can be used in a variety of aerospace and commercial applications.

Design Support

Marshall offers computer-aided design, engineering, and manufacturing software programs that allow engineers to design, optimize, and verify materials manufacturing processes interactively using three-dimensional computer graphics.

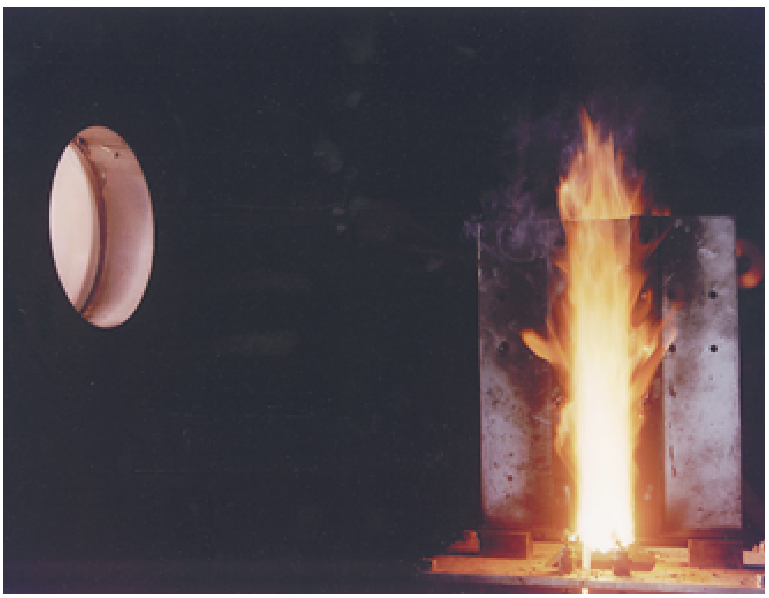


Materials Testing and Analysis

Marshall has the capabilities to conduct the barrage of tests and analyses that hardware and materials must undergo before the countdown begins, ensuring that expensive equipment is not damaged during flight.

Hydrogen Testing

We operate several testing facilities to characterize the performance of materials in hydrogen-rich environments. Customized and standard mechanical tests, including strength, strain to crack, fatigue, creep, shear, compression, and four-point bend, are conducted in extreme environments.



Combustion Research

We have the capabilities to screen your materials for their combustibility and flammability properties and for their performance in oxygen-rich environments. Tests include:

- Upward flame propagation
- Electrical wire insulation flammability
- Simulated panel or major assembly flammability
- Mechanical impact
- Arc tracking
- Frictional heating
- Upward flammability of materials in gaseous oxygen.

High-Heat Flux Testing

We have developed a plasma torch to test how composite materials will perform at temperatures exceeding 5,500 °C. These tests are performed with a nitrogen-argonne plasma torch.

Support Services

Most striking about Marshall's capabilities is the broad range of technologies all available in one place. By providing both standard and hard-to-find technologies to support our materials manufacturing and testing capabilities, Marshall provides a comprehensive array of facilities to meet both aerospace and other industry needs.

Toxic Offgassing

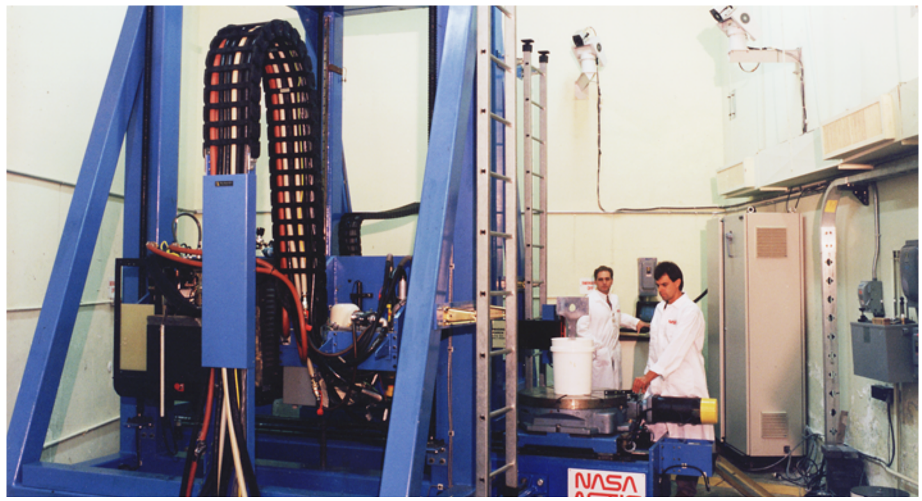
We have developed tests specifically to examine a material's offgas components to ensure the safety of the crew on NASA missions. Samples are analyzed using gas chromatography, mass spectrometry, and other techniques.

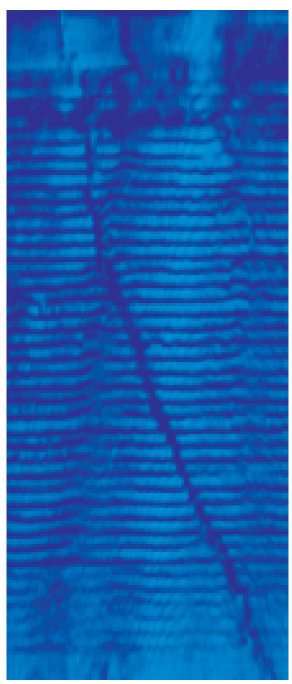
Contamination Detection

The science of contamination detection is advancing, and Marshall is leading the way with our particulate and molecular contamination monitoring. We can perform contamination research in manufacturing, clean room, and simulated space environments. Our contamination detection capabilities are discussed in greater detail in Marshall's *Optics* book.

Materials Contamination Technologies

- Outgassing tests
- Particulate, molecular, and surface contamination monitoring
- Portable Fourier transform infrared spectrometry
- Near infrared surface contamination identification
- Ultraviolet fluorescence surface contamination detection.





Computed Tomography

Marshall's computed tomography capabilities enable the nondestructive evaluation of advanced composite materials, castings, valves, actuators, and turbomachinery.

Failure Analysis

Marshall's Failure Analysis Database provides detailed information on all analyses performed—their results and how problems were solved—for various materials and components both at Marshall and at other NASA centers since the space program began in the 1960s. Plus, we offer a full range of diagnostic equipment and facilities.

Fracture Mechanics

Marshall has the equipment and expertise to test for fatigue, ductile fracture, and nonlinear fracture and to determine how detrimental they may be. Finite element modeling can be used to determine structural integrity and stress loads.

Space Environments Testing

Marshall understands the significance of the space environment on our hardware and can improve space missions by considering those effects. These improvements help lower costs, decrease risk, improve subsystem design and mission operation, and decrease shielding weights.

For example, we maintain extensive thermal vacuum testing capabilities. Items up to 20 ft in diameter can be taken from –290 to 300 °F at pressures down to $1\text{x}10^{-8}$ Torr. Any vehicle ascent rate can be simulated, as can altitudes up to 100,000 ft. Clean room capabilities enable testing of high-precision optical systems. Thermal humidity chambers offer a temperature testing range of –100 to 350 °F and a relative humidity ranging from 5% to 95%. Our other space environments testing capabilities include:

- Neutral thermosphere
- Plasma
- Meteoroids and orbital debris
- Solar environment
- Ionizing radiation
- Geomagnetic field
- Gravitational field.

Analytical and General Chemistry

Marshall has all the equipment you need to perform standard as well as mission-specific chemical analyses:

- Spectral photometers
- Fourier transform infrared spectrometers
- Plasma, emission, and mass spectrometers
- Alloy analyzers
- Gas chromotographers
- X-ray fluorescence instruments.

Environment Protection

Marshall is leading NASA's effort to develop environmentally friendly adhesives, degreasers, dewaxers, fuels, paints and paint strippers, primers, insulation, flushing and cleaning agents, precision-cleaning materials, blowing agents, brazing alloys, and propulsion fuels. Marshall thus has developed extensive expertise in testing the environmental impact of various materials and processes.

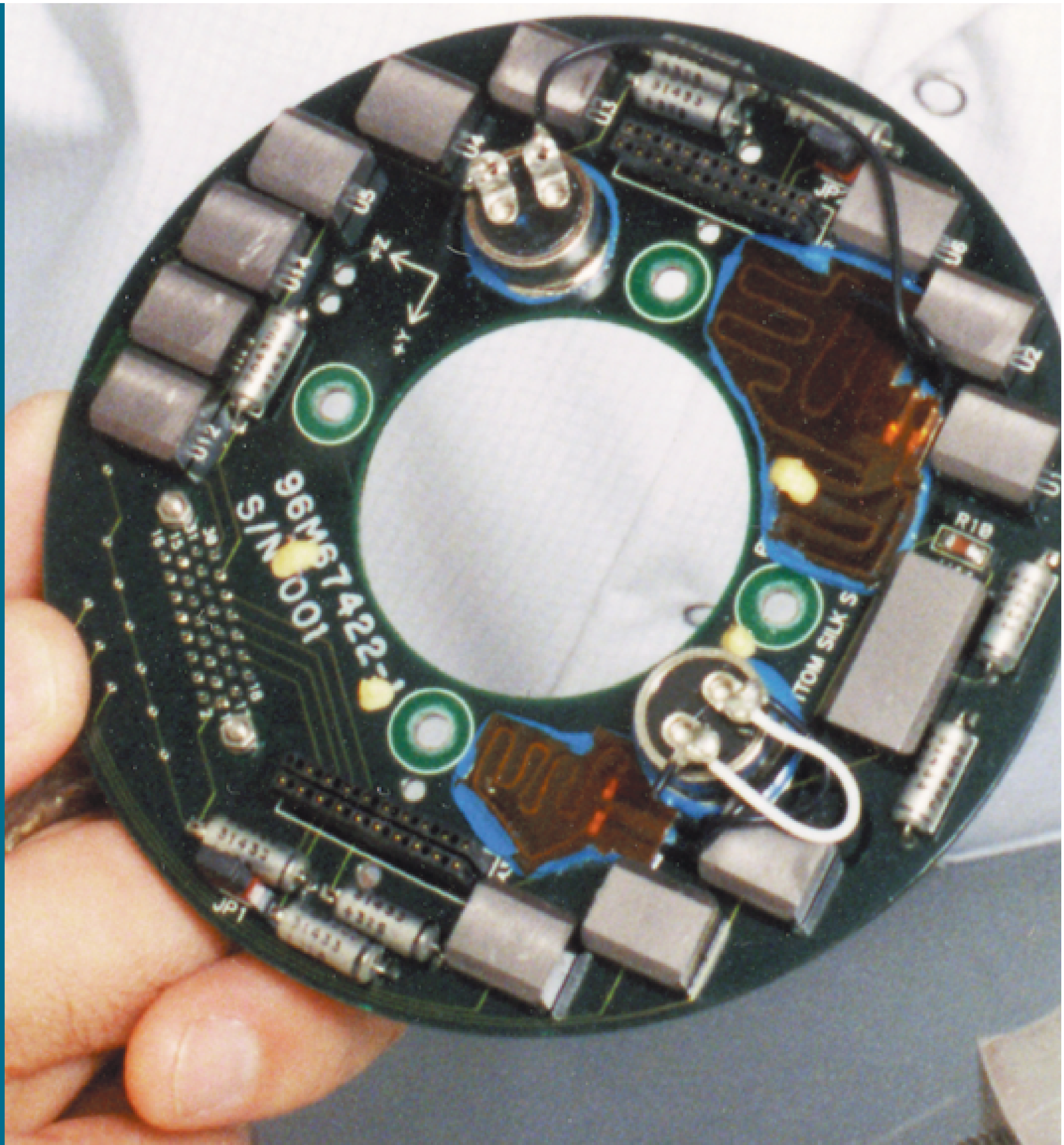
Virtual Reality at Marshall

Operations such as welding in space can be difficult and dangerous, but simulating microgravity for crew training can be expensive, physically demanding, and of limited duration. That's why Marshall has incorporated the latest technology—virtual reality (VR)—into its space operations development, design, and training activities.

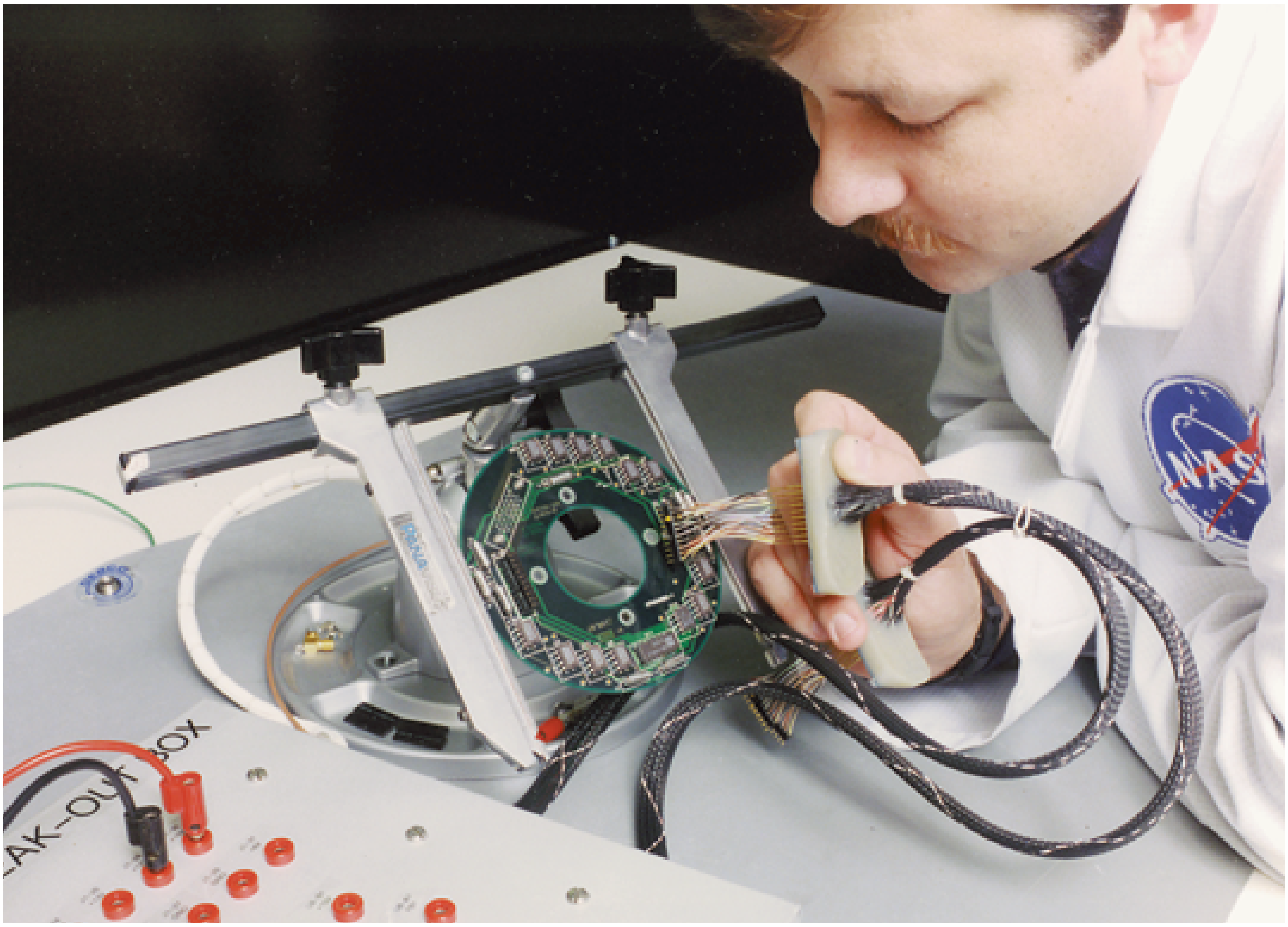
In addition to developing a space welding trainer, Marshall has explored using VR to introduce crew to Spacelab's revised stowage configuration prior to mission. This same capability has been used to create "virtual cadavers" for medical anatomy training. Human engineering and payload training using VR will be a major part of the design and development of the International Space Station.

Marshall's VR facilities complement our other aerospace capabilities to let you move easily from component design to testing and redesign to production—all in the same place.

ELECTRONICS



The integrity and functionality of a spacecraft's electrical power systems, avionics equipment, and other electronic parts is crucial to the success of a mission. Marshall has developed the capabilities to design and test high-performance energy, avionics, and electronics systems and components. Our expertise and laboratories offer multiple benefits that will ensure your mission's future success.



Electrical Power

Marshall's power electronics experts have experience with everything from fractional wattage power supplies to the multikilowatt power systems that deliver primary power to orbiting spacecraft.

Power Conditioning Design

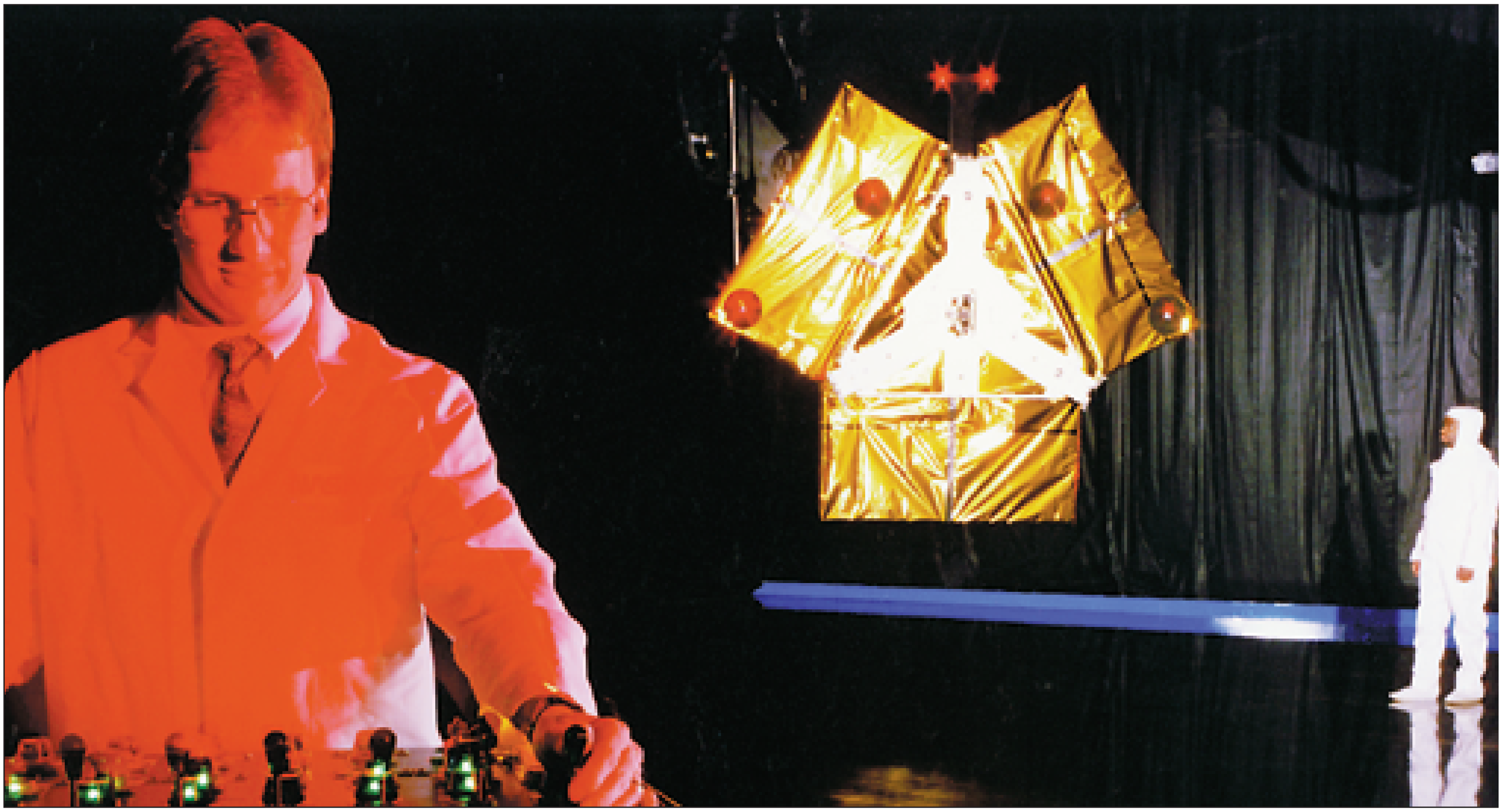
Marshall has thermal test chambers, core winders, and other specialized power conversion test equipment needed to design all types of power conditioning systems:

- Solar array power
- Peak power tracking
- Constant power supplies
- Battery protection/reconditioning electronics
- Furnace controllers
- Experimental power supplies
- Supercapacitors.

Energy Conversion and Storage

From solar arrays to batteries, Marshall has the design, development, and testing equipment to ensure your missions have an adequate power supply:

- Spectrolab
- Large-area pulsed solar simulator
- Temperature-coefficient-characterization analyzers
- Battery chargers
- Load banks
- Data acquisition equipment.



Avionics System Simulation

The electronics that control the guidance, navigation, and control of space hardware must be in perfect working order to ensure a successful mission. Marshall has the capabilities to conduct simulations to predict and analyze launch, orbital, and contact activities. This includes the ability to assemble six-degrees-of-freedom targets.

Navigational Simulations

Global positioning system (GPS) receivers with satellite constellation simulation and a differential GPS landing system enable simulations for navigational purposes.

Flat Floor Facility

This facility can be used to conduct rendezvous and docking simulations to assist in-ground design of payloads to account for the effects of microgravity. Scene generation and imaging can simulate total darkness or full sunlight.

Other Avionics Facilities

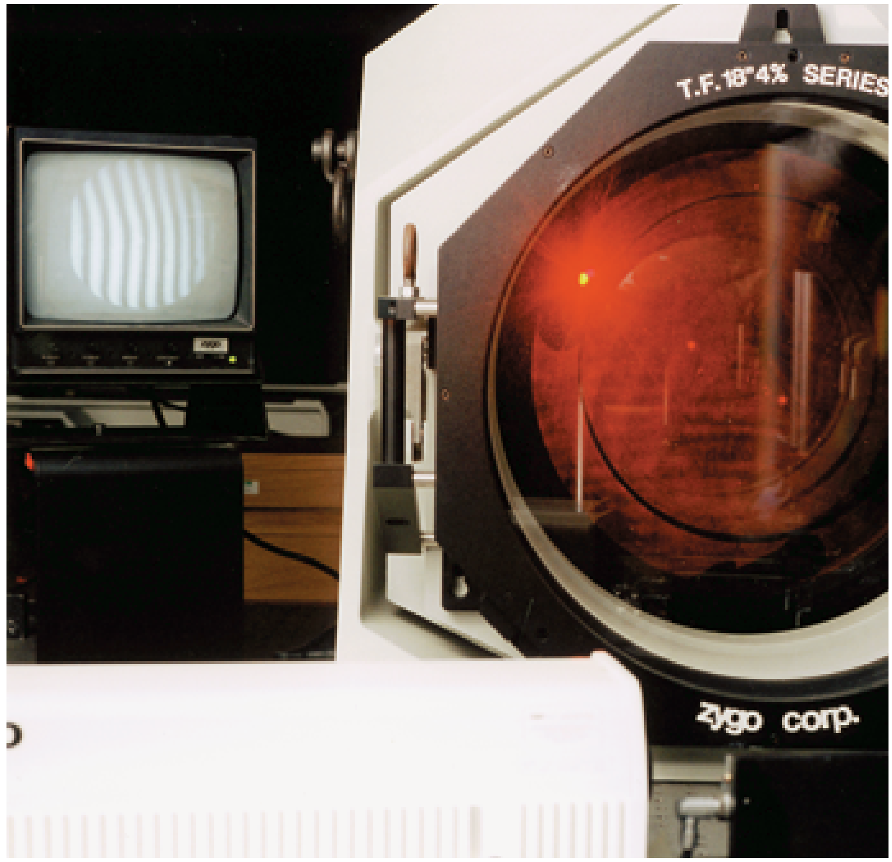
Marshall has extensive avionics laboratories and facilities:

- Contact Dynamics Test Facility/Mechanisms Test Bed
- Earth-to-Orbit Simulation Laboratory
- Image Motion Compensation Systems Integration Test Facility
- Integrated Engineering System
- Orbital Servicer Simulator
- Avionics System Test Bed
- Microgravity Robotics Laboratory
- Remote Manipulator System
- Space Shuttle Main Engine Hardware Simulation Lab
- Virtual Research Center.

Electronic Parts

Marshall's experts have a broad knowledge base for determining which parts are appropriate for particular space missions:

- Capacitors
- Circuit breakers
- Connectors and connector accessories
- Crystals and crystal oscillators
- Diodes
- Fiber optics
- Filters
- Fuses
- Hybrid devices
- Inductors
- Magnetics
- Microcircuits
- Relays
- Resistors
- Switches
- Thermistors
- Transformers
- Transistors
- Wire and cable.



Advanced Design and Testing

The two main goals of Marshall's electronics design program are to increase reliability and decrease costs and design time. Marshall offers an integrated design system, high-end simulation capabilities, software and hardware models, hardware description languages, and synthesis technology. In addition, our laboratories have all the equipment needed to conduct the required tests of solar cells and electronic parts, including failure analysis.

Evaluation

Is an electronic part suitable for space travel? Marshall's engineers have extensive experience evaluating electronic parts for NASA missions. Using military and industry standards, engineering manuals and drawings, technical articles, and test/screening data, our experts can assess whether an electrical component will perform properly in space.

Electromagnetic Interference Testing

Aerospace equipment is exposed to electromagnetic interference in space and on the launch pad. It is essential to understand the electromagnetic environments your products may experience and how they will perform. Marshall offers a permanent shielded enclosure as well as a portable tent to test aerospace vehicles and equipment.

Capabilities

- Power levels provided by radio frequency power filters:
  - 208/120 VAC 3 PH 60 Hz
  - 28 VDC and 120 VDC
- Capable of testing units demanding up to 28 VDC 200 A and 120 VDC 50 A.

COMPLEX SYSTEMS

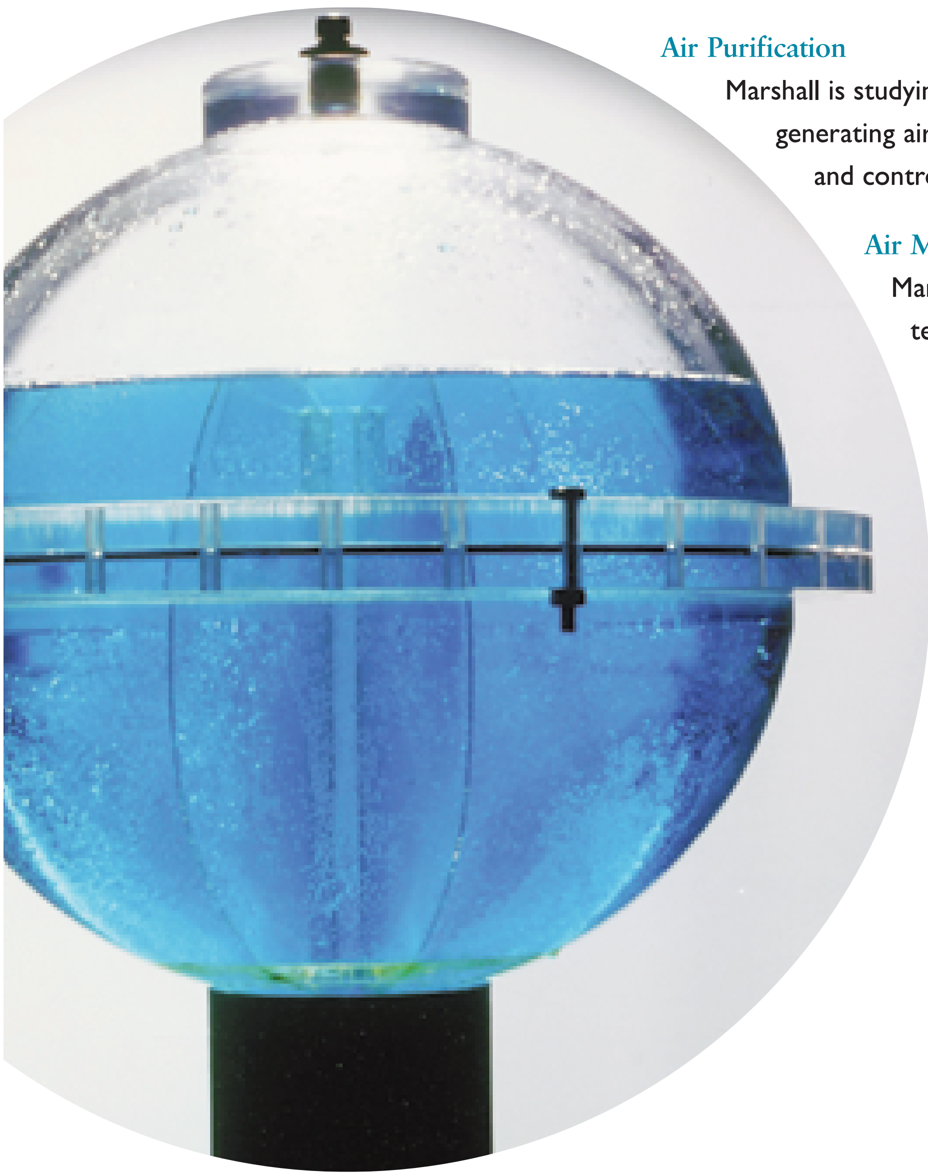
Accomplishing the goals of a space mission is directly linked to the performance of the antenna, water and air purification, and X-ray astronomy systems involved. Marshall has the extensive equipment and expertise to understand the mechanics and dynamics of these complex systems.

Water and Air Purification Systems

As work on the International Space Station progresses, Marshall has advanced water and air purification systems to ensure the health and safety of on-board astronauts. These systems are smaller, lighter, and more efficient than previous technologies and can be used in Earth-based applications. Marshall's Environmental Control and Life Support Facility can test individual components or integrated systems.

Water Purification

Marshall uses commercially available components to perform ion exchange and adsorption to regenerate hygiene or brackish water into usable—even potable—water. Systems can purify and store up to 150 pounds of water.



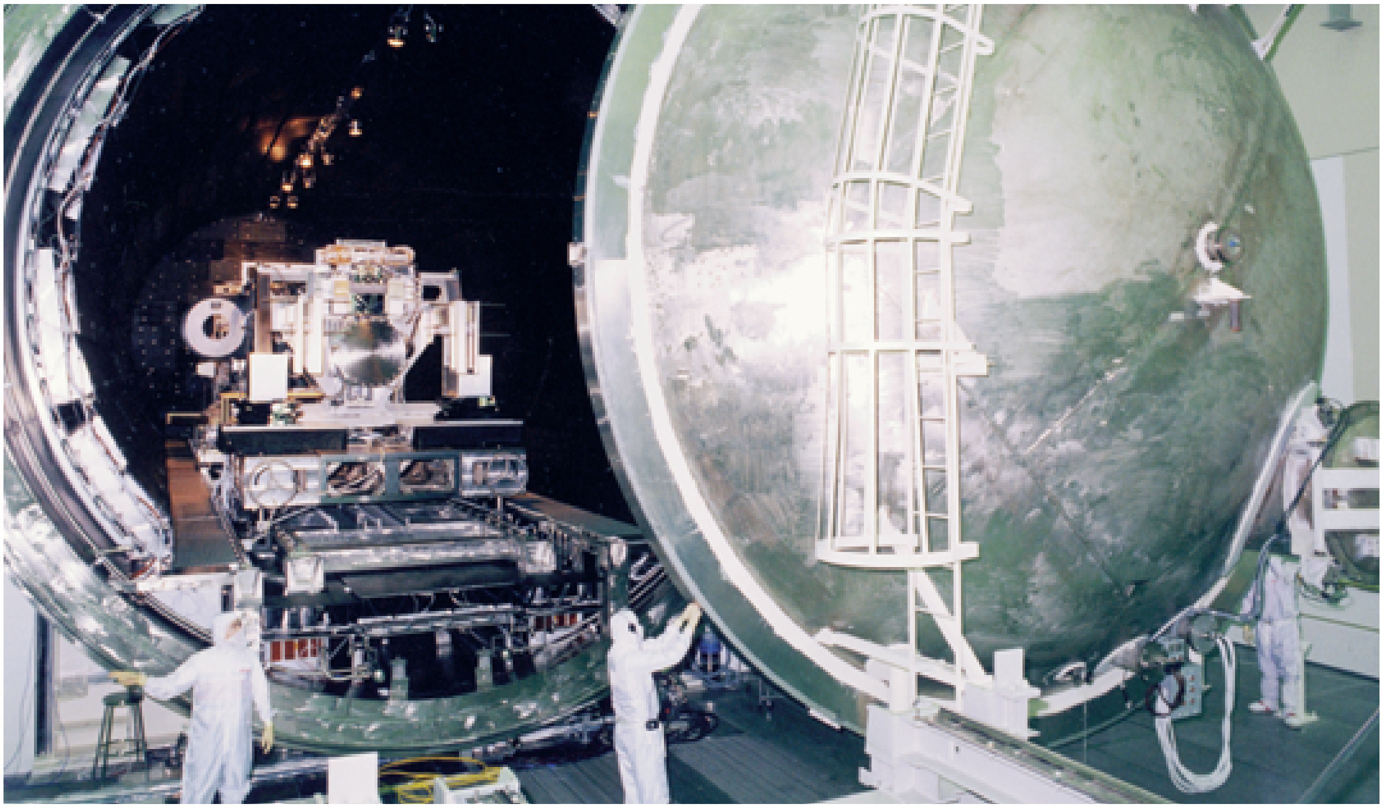
Air Purification

Marshall is studying purification and filtration techniques for generating air from wastewater, removing carbon dioxide, and controlling trace contaminants.

Air Monitoring

Marshall is also focusing on techniques and technologies to monitor and control industrial emissions, including water vapor, carbon dioxide, and trace contaminants. Test chambers can control various parameters:

- Humidity
- Temperature
- Pressure
- Nitrogen levels
- Oxygen levels.



X-ray Astronomy

To ensure that telescopes and other observation equipment will perform properly, Marshall has developed the capabilities to simulate the X rays emitted from distant celestial objects. Our X-ray Calibration Facility—the largest of its kind in the world—has extensive equipment for testing and calibrating observatory technologies.

X-Ray Generators

Marshall offers four X-ray source combinations that are capable of producing a well-calibrated parallel beam of X rays over a 1,700-ft optical path with the following range of energies:

Electron impact point source:	0.1–10.0 keV
Penning gas discharge source:	95–500 eV
Rotating anode source (6–40 kV, 10–450 mA) combined with:	
High-resolution erect field spectrometer:	0.09–1.5 keV
Double crystal monochromator:	1.0–10.0 keV

Each source can be accurately and quickly positioned on the optical axis. An X-ray filter chamber with up to 62 filters also is available.

X-Ray Focal Plane Detectors

A system of focal plane detectors is available for X-ray optical testing. The system contains thin-window proportional counters and a solid-state detector with precisely positioned pinholes and slits. We also offer a multichannel, plate-based high-speed camera.

Vacuum Chamber

Our optically clean, thermally controlled vacuum chamber can accommodate Shuttle-sized payloads in its 60 x 20 ft test area. Cryogenic and turbomolecular pumps allow vacuum pressures below 5×10^{-7} Torr. The chamber is equipped with cryogenic shrouds and heat shields with a thermal control range of –180 to 160 °F. The chamber includes a vibration-isolated test bench and precision five-degree-of-freedom positioners for optical testing. The chamber opens into a 6,000 ft^2, class 1,000+ clean room. Precision handling systems are provided for experiment assembly. Emergency generators and uninterruptable power supplies support the facility.

Antennas

Marshall's radio frequency (RF) facilities can be used to measure impedance, insertion loss, isolation, frequency, power, and antenna radiation distribution patterns accurately.

Half-Mile Range

Two 90-foot test towers simulate free-space conditions for antenna radiation patterns from 2 to 60 GHz.

400-Foot Range

A mobile transit tower provides for adjustable range length for antenna radiation patterns from 100 MHz to 60 GHz.

Anechoic Chamber

This 120-ft tapered chamber can be used to test models or devices up to 12 ft in diameter to verify scale-model antenna patterns and measure antenna free-space patterns from 200 MHz to 40 GHz.

Radar/Command/Microwave Laboratory

Available for design, development, testing, and analysis of RF communication systems, this lab can be used to measure several characteristics:

- Power
- Sensitivity
- Modulation
- Bandwidth
- Spectral qualities
- Voltage standing-wave ratio
- Impedance.

AIRCRAFT &

SPACECRAFT

The two most fundamental elements of successful air and space travel are the vehicle's structural and flow dynamics. Vehicles require structural integrity. The aerodynamic forces, moments, and loads affecting them can make or break an aerospace endeavor. Our staff are experts in structural and mechanical design and in developing aerodynamic and thermodynamic launch, space, and entry vehicles and propulsion systems.

Structural Dynamics

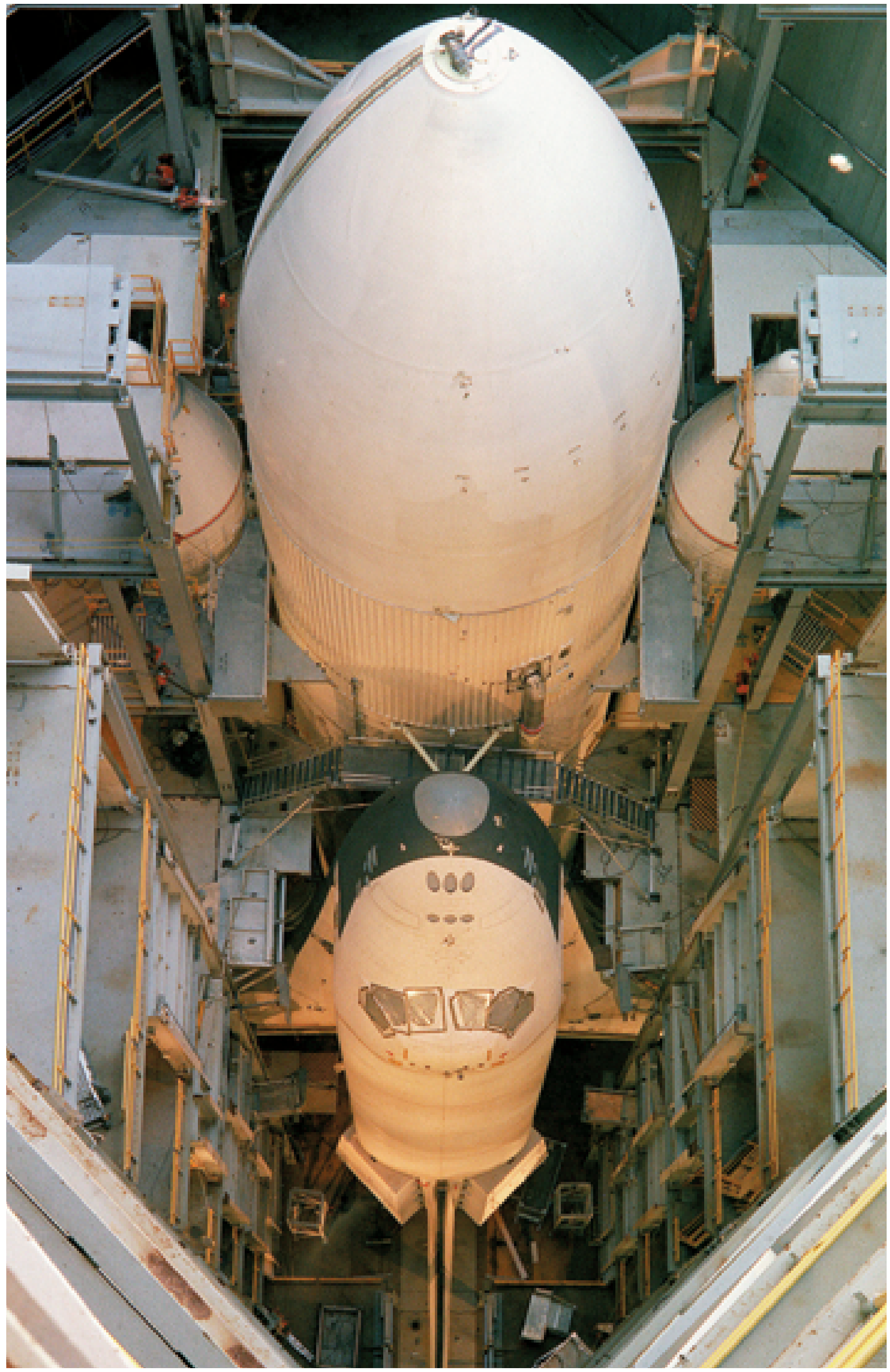
Marshall's structural dynamics facilities function as an interactive combination of analysis, simulation, synthesis, design, and testing for aerospace systems.

Vibration and Vibroacoustic Testing

Marshall uses electrodynamic exciters and air modulators to simulate flight conditions in determining mechanical properties. When coupled with our comprehensive design and analysis capabilities, these tests can be performed early in the system development process, greatly enhancing the ruggedness and life cycle of equipment, instrumentation, components, and structures.

Capabilities

- Eight electrodynamic exciters
- Five amplifiers
- Reverberation chamber
- Progressive wave tube
- Anechoic chamber



Pyrotechnics

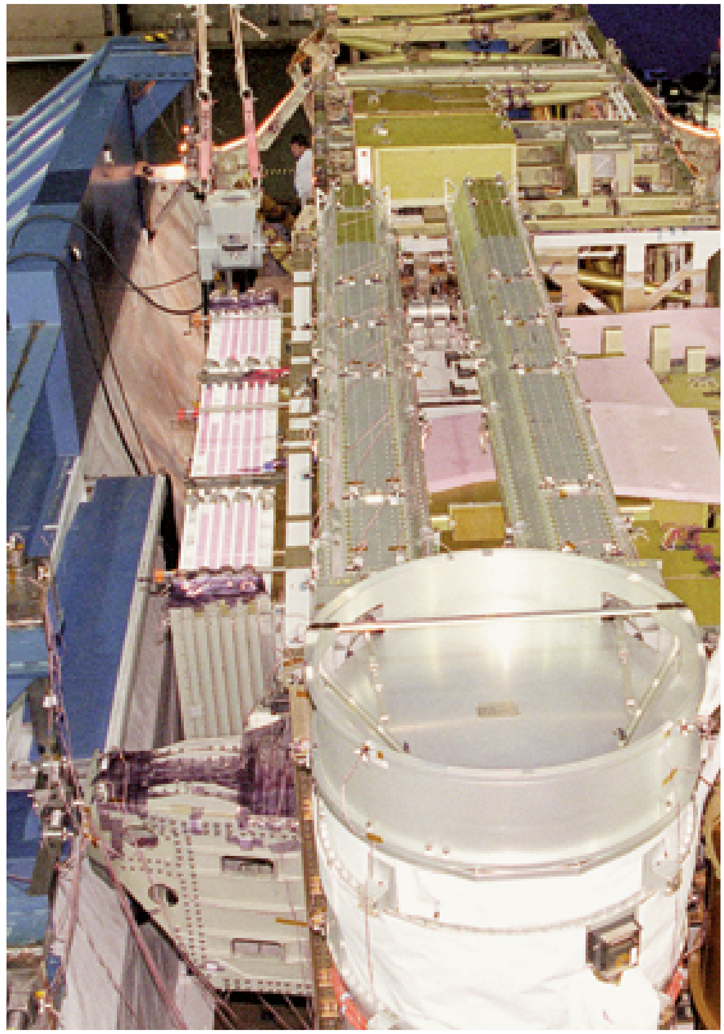
Every spacecraft has countless exploding bolts, state separations, air tools, and systems that undergo pyrotechnic shock. Marshall's Pyrotechnic Shock Test Facility can generate dynamic transients with explosive materials for shock levels of up to 30,000 g and 10 kHz. These testing and analysis capabilities can help improve the design of aerospace components by measuring damage, degradation, and loss of performance integrity. In addition, we have extensive expertise in designing pyrotechnic systems for aerospace and other applications.

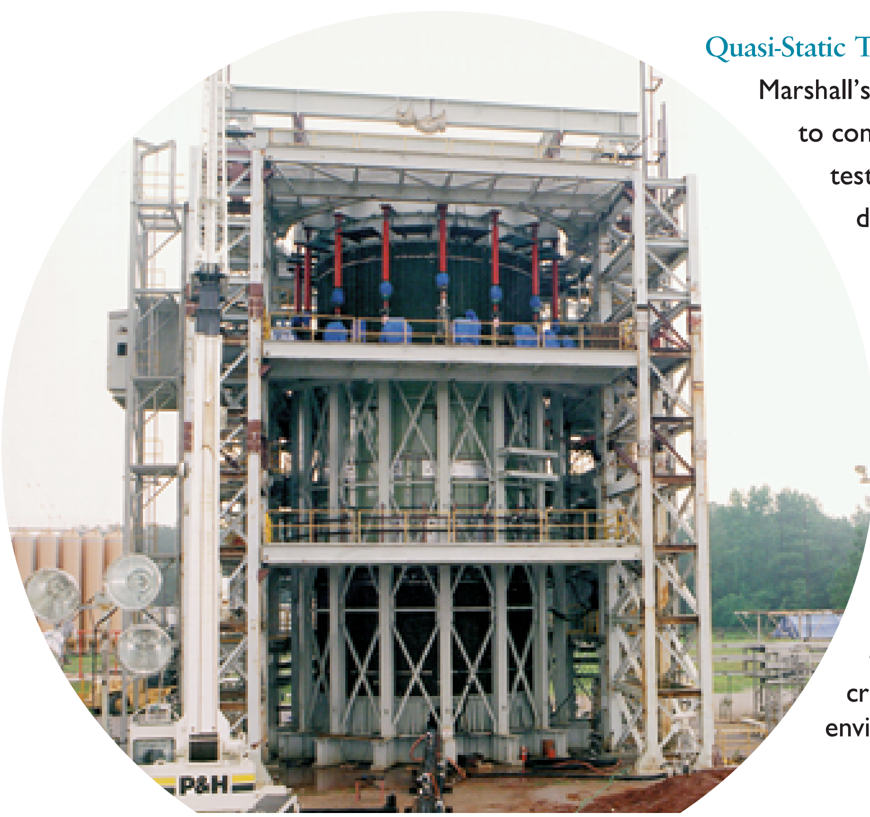
Modal Testing

To verify the design and integrity of aerospace structures and payloads, Marshall offers extensive modal testing equipment and facilities. As with the vibration test facilities, our modal testing capabilities provide extra benefits when coupled with Marshall's structural dynamic software analysis capabilities.

Capabilities

- 16 modal shakers
- Impact hammers
- 30 ft^3 class 100,000 clean room
- A laser holography modal lab
- Three test beds for large space structures





Quasi-Static Testing

Marshall's quasi-static testing facilities can be used to conduct full-scale reaction load and hydraulic testing of large structures—up to 60 ft in diameter—and components/ systems, including struts, brackets, plates, and panels.

Capabilities

- Compression loads up to 33 million lbs
- Tension loads up to 3 million lbs
- Pressure measurement
- Contourable photoelastic coatings for strain and temperature testing
- Hazardous testing in pressurized, cryogenic, liquid hydrogen, and nitrogen environments.

Flow Dynamics

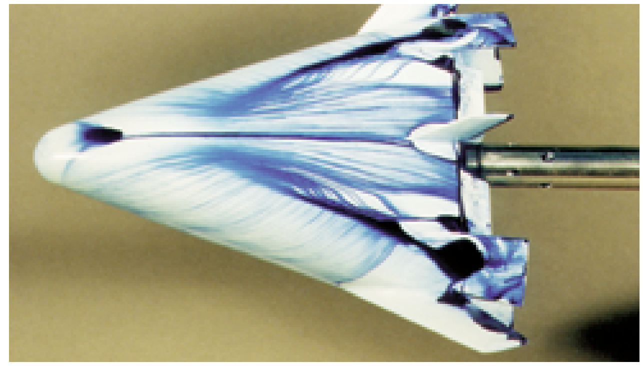
It is essential to understand how fluid dynamics and thermal environments affect aircraft and spacecraft. In addition to our testing facilities for studying flow dynamics, Marshall has the capabilities for complex path flow visualization. This gives engineers a realistic picture of what's going on in their complex machines, such as injectors, manifolds, and turbomachinery.

Aerodynamics

- 14-inch Trisonic Wind Tunnel—An intermittent blowdown tunnel with two interchangeable test sections:
  - Transonic section: Wind speeds of Mach 0.20–1.96
  - Supersonic section: Wind speeds of Mach 2.75–5.00.

Water Flow

- Liquid/Solid/Hybrid Rocket Engine Water Flow Facility—Used to test complex internal flow interactions such as circumferential flow around submerged nozzles. Transparent acrylic models allow flow visualization.
- Water Flow Pump Test Facility—Used to test full-scale models of liquid rocket engine pumps with the following specifications:
  - Horsepower: 350 HP
  - Flow: Up to 5,000 gal/min
  - Inlet pressure: Down to 4 lb/sq in absolute
  - Discharge pressure: Up to 350 lb/sq in absolute.
- Water Flow Inducer Test Facility—Used to test low head-rise liquid rocket engine pump components, such as inducers with the following specifications:
  - Flow: Up to 2,000 gal/min
  - Inlet pressure: Down to 4 lb/sq in absolute
  - Discharge pressure: Up to 150 lb/sq in absolute.



Air Flow

- Nozzle Test Facility—A high-tech facility for testing rocket engine nozzles:
  - Flow: Up to 8 lbm/s, with piping for up to 50 lbm/s
  - Pressure: 25 to 350 psia
  - Back pressure: Down to 0.05 psia
  - Temperature: Up to 350 °F
  - Exit diameter: 10-in maximum.
- Liquid Rocket Engine Air Flow Facility—Used to simulate liquid rocket engine hot gas ducts and manifolds to measure their environment and performance. Operates from a 420-psi gauge storage vessel.
- Solid Rocket Motor Air Flow Facility—Used to investigate the effects on internal flow fields due to gimbaling submerged nozzles, slot/port interactions, and other flow disturbances. Operates from a 1,900-psi gauge storage vessel.
- Air Flow Turbine Test Facility—Used to obtain experimental data and scientific studies of gas turbines. Capable of controlling inlet total temperature and pressure, pressure ratio, delta pressure across the turbine rig, and turbine revolutions per minute.

Heat Flow

- Thermal protection systems
- Thermal model development
- Active and passive thermal control systems
- Vehicle thermostructural systems
- Cryogenic systems
- Infrared thermography
- Hydraulic modeling
- Finite element modeling
- Solid modeling
- Thermal transient analysis.

Advanced Propulsion at Marshall

Marshall's comprehensive propulsion laboratories, equipment, and experience complement the other aerospace capabilities described. The Propulsion Laboratory is dedicated to researching, developing, engineering, testing, and evaluating propulsion systems for launch and space vehicles and associated equipment.

Testing Capabilities

- High vacuum testing
- Liquid hydrogen and oxygen testing
- Hot gas facility
- Hydrogen cold flow facility
- Advanced engine test facility
- Static test stands.

Propulsion Expertise

- Liquid rocket engines
- Solid and hybrid motors
- Combustion devices
- High-pressure and cryogenic propellants
- Nozzle insulation, case insulation, fuel cartridge inhibitors, and propellant grains.

These capabilities and expertise are described in greater detail in Marshall's *Propulsion* book.

Technology Transfer at NASA Marshall Space Flight Center

This information package has been assembled as part of NASA Marshall Space Flight Center's technology transfer program. The primary goal of the technology transfer process at Marshall is to encourage broader utilization of Marshall-developed technologies and unique combination of facilities in the U.S. industrial community.

We invite you to contact Marshall to discuss possible partnership opportunities and availability of facilities.

NP-1998-10-75-MSFC