National Aeronautics and Space Administration

Advanced Propulsion Technology and Development

Innovation To Explore

Many advanced propulsion technologies are currently at medium technology readiness level, but opportunities for ground or in-space demonstration are limited. Crossing this technology development "valley of death" affordably is key to bringing these technologies online to serve future exploration needs. For current and near-term propulsion needs, the Center is advancing technologies for cryogenic fluid management (CFM) for in-space propulsion as well as testing new green propellants. For long-term exploration needs, Marshall provides technical risk reduction by advancing a range of technologies to provide affordable, efficient propulsion that enable new mission concepts, including nuclear thermal propulsion, electric propulsion, satellite tethers, and solar sails.

At-A-Glance

Today's in-space propulsion challenges are focused on chemical propulsion, while tomorrow's missions will require advancing the state-of-the-art of propulsion system performance through nonchemical systems. Marshall Space Flight Center has unique experience in many of these areas and the capabilities to rapidly prototype, test, and integrate new propulsion system concepts.

Marshall evaluates a subscale composite cryotank to advance TRL prior to full-scale testing.

Enhancing Today

Marshall's research into CFM includes the storage, fluid distribution, liquid acquisition, and mass gauging of cryogenic propellants. These tasks reduce the development risk and increase the technology readiness of advanced CFM subsystems to store and distribute cryogenic propellants required for long-term exploration missions. CFM utilizes the development of prototype CFM hardware, the creation and use of analytical models to predict sub system performance, and the execution of ground-based tests using liquid oxygen, liquid hydrogen, and methane to demonstrate the performance, applicability, and reliability of CFM subsystems.

Several testbeds support cryogenic propellant storage and transfer research, including the large-scale 10-foot Multi-Purpose Hydrogen Testbed; the 6-foot Cryogenic Test Bed tanks for liquid oxygen damper testing; the 4-foot vibroacoustic tank; and three small-scale stainless steel tanks, one 3-foot and two 18-inch. The tanks can be used for vacuum testing and can run autonomously around the clock.

Marshall is also developing new cryogenic propellant tanks using composite materials, which could provide a substantial mass and cost savings, enabling future missions to reach new destinations. Working with an industry partner, subscale test articles have undergone pressure testing, and a full-scale test article is in development for continued technology development and testing.

The Center also supports the Agency's efforts to develop green propellants for future chemical propulsion systems — propellants less toxic or environmentally hazardous than existing propellants like hydrazine. Working with industry partners, other NASA centers, and interested government agencies, Marshall conducts research and characterization of a variety of candidate propellants to reduce technical risk for ongoing advanced propulsion development efforts and offers testbed capabilities to assess a variety of propellants.

Enabling Tomorrow

Opening the solar system for human exploration will require maturation of nonchemical space propulsion. NASA's current design reference for a human mission to Mars has options for nuclear thermal propulsion and electric propulsion for reaching the destination. In the years leading up to a human planetary mission, these advanced propulsion concepts can also improve robotic precursor missions. Other propulsion technologies, including tethers and solar sails, have applications for both near-Earth and deep space exploration with unmanned spacecraft.

Marshall operates two facilities for nuclear thermal propulsion research and testing. The larger of these, the Nuclear Thermal Rocket Element Environmental Simulator (NTREES), performs realistic non-nuclear testing of various materials for nuclear thermal rocket fuel elements. The NTREES facility is designed to test fuel elements and materials in hot flowing hydrogen, reaching pressures up to 1,000 psi and temperatures of ~5,000 F to simulate space-based nuclear propulsion systems and provide baseline data critical for risk reduction in future propulsion development. The Compact Fuel Element Environmental Test (CFEET), which conducts high-temperature, but not high-pressure, testing, is licensed to test with depleted uranium. By combining our foundational and applied nuclear and materials research and expertise, Marshall provides a unique capability to conduct the entire research process in-house, from design and development of fuel elements to testing.

In the area of advanced fusion research, Marshall is a partner with the University of Alabama at Huntsville's fusion pulse power research project, along with Boeing and the STMD. The research utilizes a donated DOD apparatus originally used for research into nuclear weapon effects. The full assembly weighs almost 50 tons and provides nearly 500,000 joules of energy per pulse.

Electric propulsion research includes unique capabilities in high-power pulse-electric propulsion systems and nuclear fusion propulsion research. Supporting electric propulsion research, Marshall operates a low-thrust vacuum chamber, which also can be used for chemical propulsion research. A recent test successfully simulated a 6-pound thruster using residual propellants from a spent upper stage. As a result, the industry partner can consider adding such thrusters for satellite attitude control or as a means of de-orbiting spent stages. The chamber can test other novel propulsion concepts such as hybrid solid/electric systems.

Marshall has also managed four of NASA's tethered satellite experiments, the Shuttle Tethered Satellite System (TSS-1 and -1R) and the Small Expendable Deployer Systems (SEDS I and SEDS II). Tethers have great potential for raising satellites or deorbiting them at the end of operations by operating as an electric motor with or against Earth's magnetic field. The Center continues to investigate advanced uses for satellites orbiting beyond 70˚ inclination for Earth observation, weather, telecommunications, remote sensing, and planetary exploration.

The Center has been involved in solar sail research from concept to flight. In 2004, Marshall helped test the strength, stiffness and behavior of two competing designs. These led to NanoSail-D and Sunjammer. NanoSail-D, which Marshall managed in 2010, became NASA's first solar sail to achieve orbit. The 100-square-foot polymer sail demonstrated deployment of a compact solar sail boom technology. Marshall now manages Sunjammer, the largest solar sail technology demonstration mission, set for launch in 2014. At nearly 13,000 square feet, it will also demonstrate debris collection and removal from orbit and de-orbit of spent satellites. Potential solar sail missions include polar-stationary Earth observations, heliophysics, NEO reconnaissance, interstellar precursors, orbital debris mitigation and small satellite propulsion.

NanSail-D served as a proof-of-concept for deployable solar sail technologies.

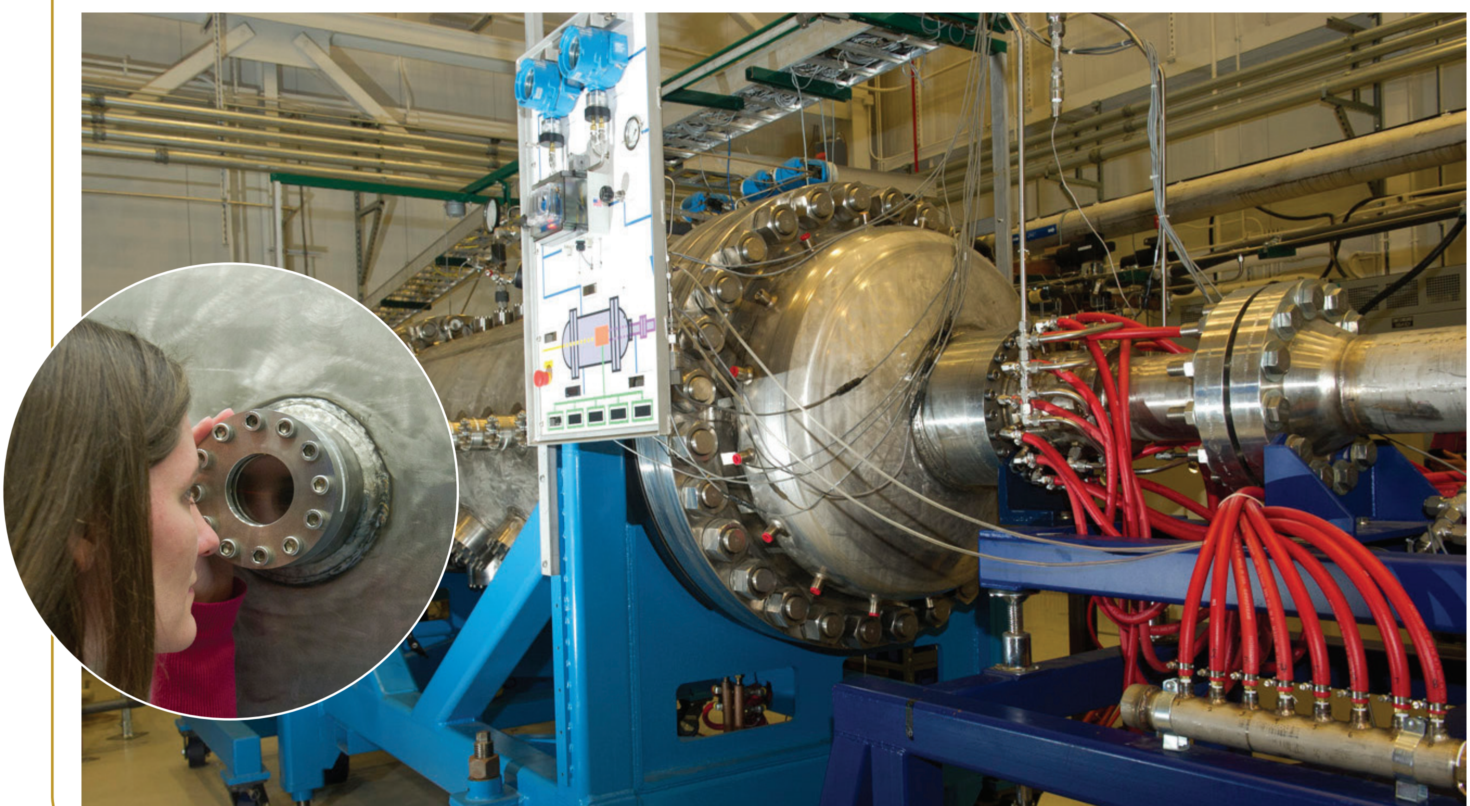
From Nuclear Technology to In-Space Stage

The Nuclear Cryogenic Propulsion Stage project, led by Marshall for the Advanced Exploration Systems program, includes participation by the Department of Energy. The program focuses on crew safety and mission operations in deep space to enable new approaches for rapidly developing prototype systems, demonstrating key capabilities and validating operational concepts for future vehicle development and human missions beyond Earth orbit.

The team is engaged in a three-year project to demonstrate the viability of nuclear propulsion system technologies. The design uses a nuclear reactor to super-heat hydrogen, which expands through a nozzle to generate thrust. A first-generation nuclear cryogenic propulsion system could propel human explorers to Mars more efficiently than conventional spacecraft, reducing crew exposure to harmful space radiation and other effects of long-term space missions. It could also transport heavy cargo and science payloads. Further development and use of a first-generation nuclear system could also provide the foundation for developing extremely advanced propulsion technologies and systems in the future — ones that could take crews even farther into the solar system.

Building on previous successful research and using the NTREES facility, Marshall can safely and thoroughly test simulated nuclear fuel elements of various sizes, providing important test data to reduce technical risk in the design of the Nuclear Cryogenic Propulsion Stage.

NTREES conducts risk-reduction tests on fuel-simulated nuclear fuel elements.



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