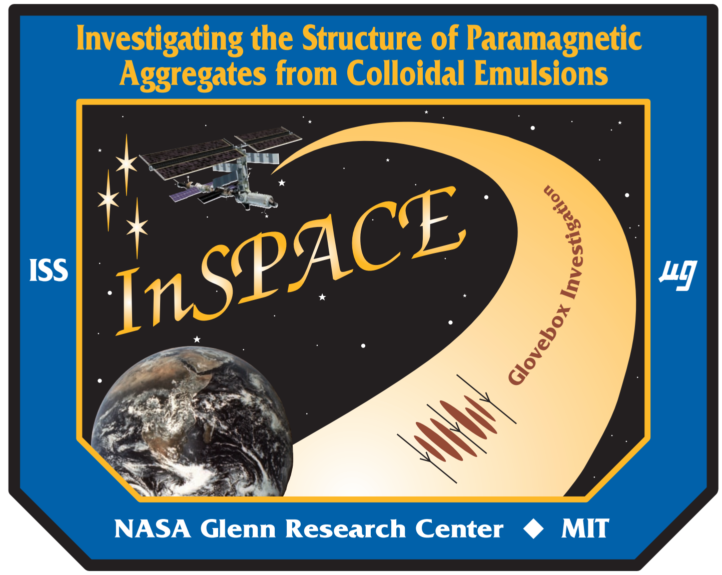
National Aeronautics and Space Administration

Glenn Research Center
Cleveland, Ohio

Investigating the Structure of Paramagnetic Aggregates From Colloidal Emulsions (InSPACE)

Overview

InSPACE is a microgravity fluid physics experiment that will be performed on the International Space Station (ISS). The purpose of this investigation is to obtain fundamental data of the complex properties of an exciting class of smart materials termed magnetorheological (MR) fluids. MR fluids are suspensions of small (micron-sized) superparamagnetic particles in a nonmagnetic medium. These controllable fluids can quickly transition into a nearly solidlike state when exposed to a magnetic field and return to their original liquid state when the magnetic field is removed. Their relative stiffness can be controlled by controlling the strength of the magnetic field. Due to the rapid-response interface that they provide between mechanical components and electronic controls, MR fluids can be used to improve or develop new brake systems, seat suspensions, robotics, clutches, airplane landing gear, and vibration damping systems.



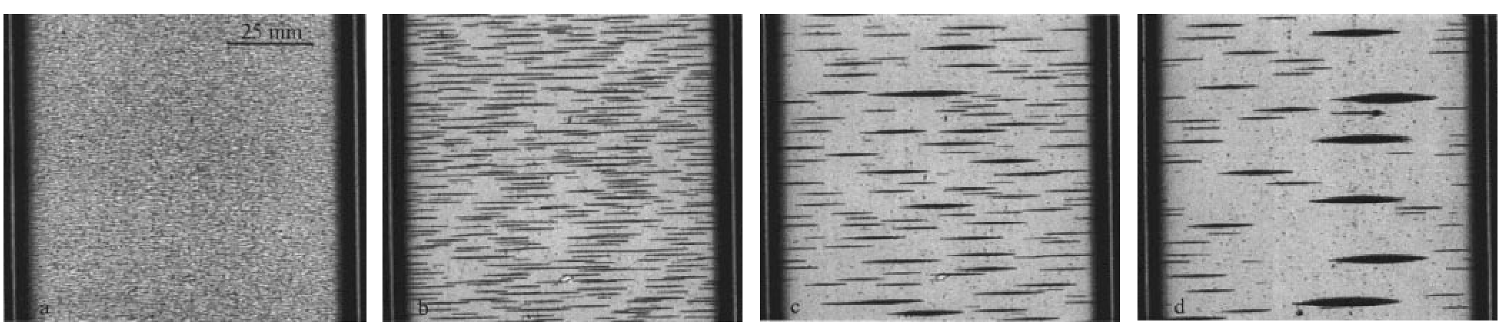
Science Background and Objectives

The purpose of this investigation is to obtain fundamental data of the complex properties of MR fluids. Specifically, the goal of InSPACE is to determine the true three-dimensional low-energy (equilibrium) structure of an MR emulsion in a pulsed magnetic field. The microstructure of MR fluids plays a significant role in determining their bulk rheological properties. InSPACE will conduct a microscopic video study of the MR fluid in a pulsed magnetic field to determine the effect of varying magnetic field, pulse frequency, and particle size on the equilibrium microstructures.

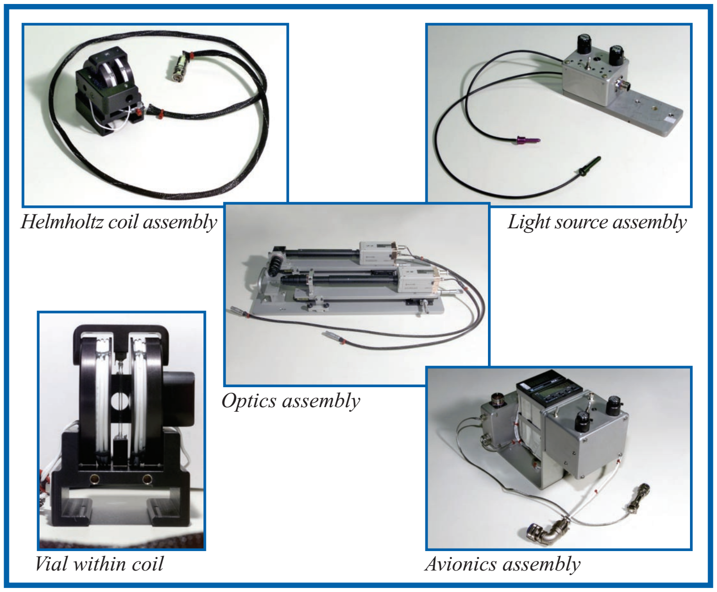
On Earth, gravity causes sedimentation, which means heavier groups of particles sink while lighter ones remain suspended. The low-gravity environment that is provided on the space station facility will eliminate the effects of sedimentation, which otherwise become significant for these relatively large aggregate structures. A pulsed magnetic field will be used to mimic the forces applied to these fluids in real applications, such as vibration damping systems. A pulsed field also tends to produce intricate thick structures with different properties than structures produced by a constant magnetic field. InSPACE will provide fundamental data characterizing the structures formed in MR fluids. These results may be utilized to enhance applications on Earth and provide an early understanding of the behavior of MR fluids in microgravity so as to aid in the development of highly technical experiments.

Experiment Operations

The majority of the InSPACE hardware was launched to the ISS on Flight UF–2/STS–111 (June 5, 2002). The MR samples were launched on Flight 11A/STS–113 (November 23, 2002). Experiment operations by the ISS astronaut crew are scheduled to occur during ISS Expedition Six and Seven in the Microgravity Science Glovebox (MSG) that is located in the U.S. Destiny Laboratory Module. The MSG includes an enclosed work volume that provides power and interfaces for data and video that can be downlinked to the science team while the experiment is operating.



Structure evolution in an MR fluid over time while an alternating magnetic field is applied. The far left image shows the fluid after 1 second of exposure to a high-frequency-pulsed magnetic field. The suspended particles form a strong network. The images to the right show the fluid after 3 minutes, 15 minutes, and 1 hour of exposure. The particles have formed aggregates that offer little structural support and are in the lowest energy state.



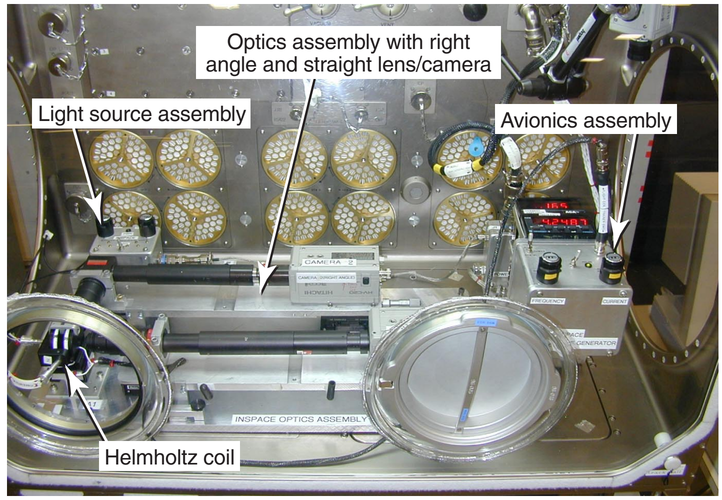
InSPACE hardware components.

Before the flight, three primary Helmholtz coil assemblies (electromagnets that produce a uniform magnetic field) and three spares, each with a small precision rectangular borosilicate glass vial, 50 millimeters long by 1 millimeter internal square, were outfitted with the MR fluid. Each fluid sample is composed of small, magnetizable particles of uniform size suspended in an aqueous medium. The particle sizes are different in each of the three primary coil assemblies. The crew will install a coil onto an optics assembly that includes two cameras for imaging the samples from a straight-on and right-angle view during test runs. The cameras will focus on a very small area of the vial, only 0.3 millimeters across. A backlighting system will be used to illuminate the samples.

The astronaut will set a specified electrical current and frequency on an avionics assembly that will produce a pulsed magnetic field inside the coil. This magnetic field will cause the particles in the fluid to group together, or aggregate, and form microstructures inside the fluid.

An InSPACE coil assembly is shown being installed in position for testing. The assembly holds a small vial which contains magnetorheological fluid.

For a period of about 1 to 2 hours, the cameras will record the microstructures. This video will be distributed to the scientists at Massachusetts Institute of Technology and to the Telescience Center at NASA's Glenn Research Center in Cleveland, Ohio, where scientists and engineers will observe the microstructures as they form and change. The video recorded onboard the ISS will be returned to Earth for more in-depth analysis. Nine tests will be performed for each coil for a total of 27 experiment runs.



InSPACE experiment hardware mounted in the MSG engineering unit during ground testing.

Benefits

This is the first time this experiment has been conducted in space. It will provide fundamental data on the way the particles and aggregate structures in the fluid respond to a pulsed external magnetic field in a microgravity environment. When these fluids are used in braking systems and for other electromechanical devices, they are often exposed to such fields that affect their operations.

The data from the experiment can be used to test theoretical models of the structure of suspensions of small particles in applied fields. By understanding the complex properties of these fluids and learning the way the particles interact, scientists can develop more sophisticated methods for controlling these fluids and using them in a variety of devices.

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For more information on microgravity research, visit http://microgravity.grc.nasa.gov/

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