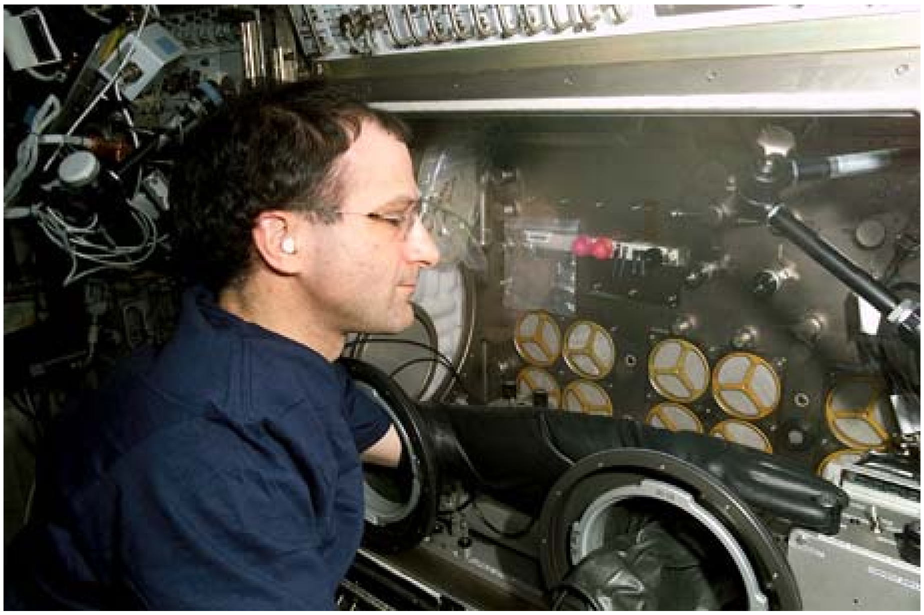
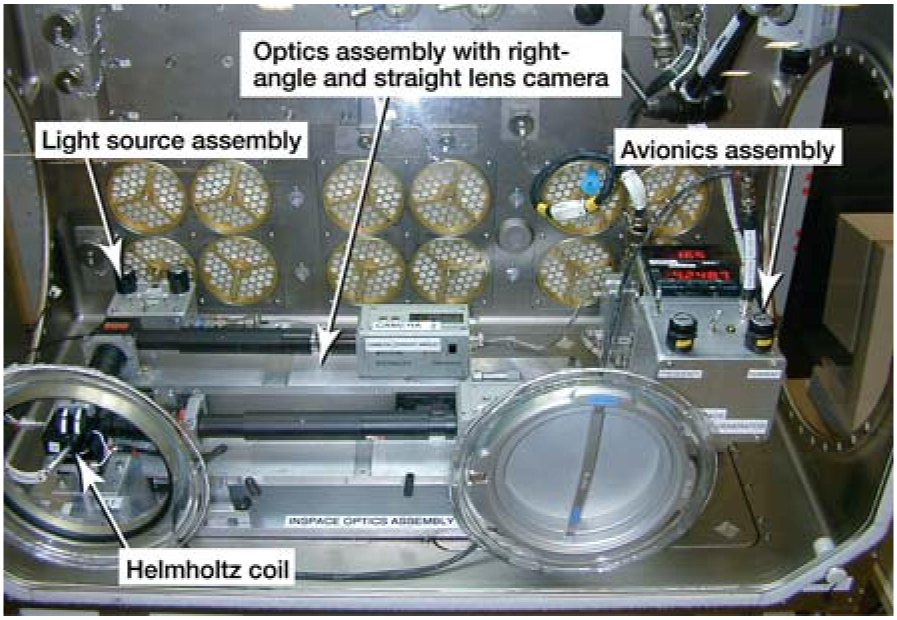
"Smart" Magnetic Fluids Experiment Operated on the International Space Station



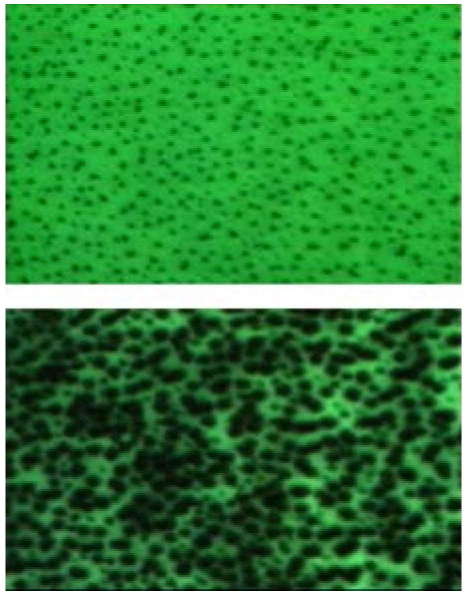
ISS Expedition Six Science Officer Don Petit operating the InSPACE investigation in the Microgravity Science Glovebox onboard the ISS.

InSPACE is a microgravity fluid physics experiment that was operated on the International Space Station (ISS) in the Microgravity Science Glovebox from late March 2003 through early July 2003. (InSPACE is an acronym for Investigating the Structure of Paramagnetic Aggregates From Colloidal Emulsions.) The purpose of the experiment is to obtain fundamental data of the complex properties of an exciting class of smart materials termed magnetorheological (MR) fluids. MR fluids are suspensions, or colloids, comprised of small (micrometer-sized) superparamagnetic particles in a nonmagnetic medium. Colloids are suspensions of very small particles suspended in a liquid. (Examples of other colloids are blood, milk, and paint.) These controllable fluids can quickly transition into a nearly solid state when exposed to a magnetic field and return to their original liquid state when the magnetic field is removed. Controlling the strength of the magnetic field can control the relative stiffness of these fluids. MR fluids can be used to improve or develop new seat suspensions, robotics, clutches, airplane landing gear, and vibration damping systems. The principal investigator for InSPACE is Professor Alice P. Gast of the Massachusetts Institute of Technology (MIT). The InSPACE hardware was developed at the NASA Glenn Research Center.



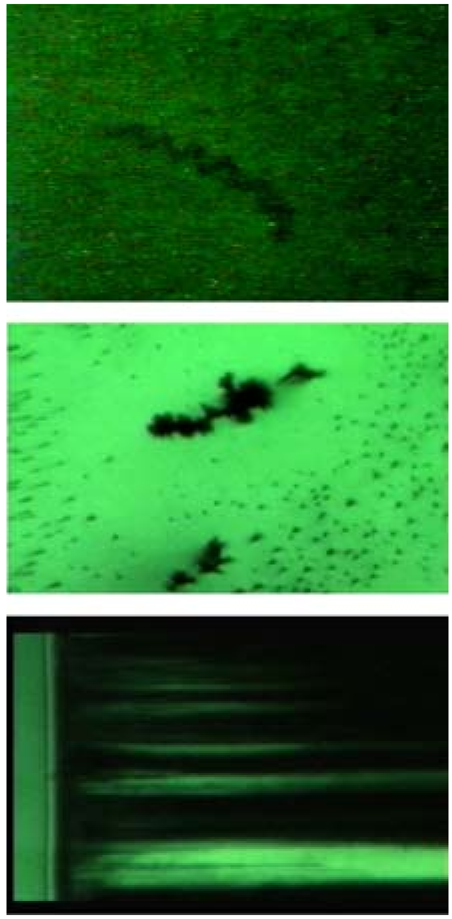
InSPACE experiment hardware mounted in the Microgravity Science Glovebox onboard the ISS. The hardware consists of the following components: a Helmholtz coil assembly that produces a uniform magnetic field in the sample mounted in the center of the coil, an MR fluid sample contained in a precision rectangular borosilicate glass vial (50-mm-long by 1-mm internal square), an avionics assembly that provides the capability for selecting a specified electrical current and frequency to produce the desired pulsed magnetic field inside the coil assembly, a light box assembly that illuminates the experiment so that it can be viewed, and an optics assembly that includes two video cameras for imaging the experiment from straight-on and right-angle views during the test runs.

The InSPACE samples were delivered to the ISS in November 2002, on the Space Shuttle Endeavour, on Space Station Utilization Flight UF-2/STS113. Operations began on March 31, 2003, with the processing of three different particle size samples at multiple test parameters. This investigation focused on determining the structural organization of MR colloidal aggregates when exposed to a pulsing magnetic field. On Earth, the aggregates take the shape of footballs with spiky tips. This characteristic shape may be influenced by the pull of gravity, which causes most particles initially suspended in the fluid to sediment, (i.e., settle and collect at the bottom of the cell). In the absence of sedimentation effects on the ISS, the behavior and shape of these MR aggregate structures are dominated exclusively by magnetic and surface tension forces. The microscopic detail of these structures was imaged under two orthogonal camera views. The video was downlinked to the InSPACE team at Glenn's Telescience Support Center and to MIT and also recorded onboard the ISS on videotapes that will be brought back to the ground by the space shuttles. The study examined the effect on the structure formation by varying the magnetic field strength and pulse frequency, and particle size. Fundamental data that characterized the structure formation were obtained.



Early-stage structure generation. Top: Array of chain structures seen on end during steady magnetic field conditions (straight-on view looks in on the magnetic field lines); 0.66-µm particles at H = 1816 A/m (magnetic field). Bottom: The chain structures start to diffuse right after the magnetic field starts pulsing, but they will reorganize over time into a smaller number of large aggregates (straight-on view); 0.66-µm particles at H = 1816 A/m at 20 Hz.

InSPACE completed its last planned test run on July 2, 2003. Operations occurred on 21 days over approximately a 3-month period. Forty-one test points were completed during 26 test runs. During the initial testing, the procedures followed by the crew were modified to maximize the observation of some unexpected and interesting aggregate behavior. As a result Dr. Gast has reported on the formation of aggregate shapes that are more extended and diverse than those observed on the ground. Sheets of magnetic material folded over in a labyrinth pattern and large columnar aggregates with complex interfaces with the surrounding fluid are examples of the interesting structures that have been observed on the ISS. In light of these early findings, the understanding of the fundamental properties of MR fluids on the basis of ground-based observations may need to be reconsidered.



Late-stage structure development. Top: Labyrinth structure formed from the folding over of a two-dimensional sheet of magnetic particles (straight-on view); 0.66-µm particles at H = 1816 A/m (magnetic field) at 5 Hz. Center: Large aggregates forming complex interfaces with the surrounding fluid (straight-on view); 0.66-µm particles at H = 2082 A/m at 15 Hz. Bottom: Columnar aggregate structures imaged across the magnetic field (right-angle view); 0.66-µm particles at H = 2082 A/m at 20 Hz.

The experiments on the ISS have provided a vast amount of video data for analysis. While this analysis is ongoing, plans are being made for additional experimental runs. For this purpose, additional hardware and cells containing samples of different magnetic particles and sizes are being fabricated for a future launch to the ISS. The InSPACE hardware will remain on orbit until this testing is completed.

Reference

1. Promislow, J.H.E.; and Gast, A.P.: Magnetorheological Fluid Structure in a Pulsed Magnetic Field. Langmuir, vol. 12, no. 17, 1996, pp. 4095-4102.

Find out more about this research:
Glenn's Microgravity Science Division at http://microgravity.grc.nasa.gov/
Microgravity Science Glovebox at
http://spaceresearch.nasa.gov/research_projects/ros/msg.html

ISS research overview at http://spaceresearch.nasa.gov/research_projects/ros/ros.html
InSPACE at http://exploration.grc.nasa.gov/inspace/
Dr. Alice P. Gast at MIT at http://web.mit.edu/cheme/people/faculty/gast.html
Amazing Magnetic Fluids (Science@NASA article) at
http://science.nasa.gov/headlines/y2002/23aug_MRfluids.htm?list47209

Glenn contacts: Dr. Juan H. Agui, 216-433-5409, Juan.H.Agui@nasa.gov ; and Jack F. Lekan, 216-433-3459, John.F.Lekan@nasa.gov
Authors: Dr. Juan H. Agui and Jack F. Lekan
Headquarters program office: OBPR
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