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Fluid Sciences

**The NASA Microgravity Fluid Physics Program – Research Plans for the ISS**

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Building on over four decades of research and technology development related to the behavior of fluids in low gravity environments, the current NASA Microgravity Fluid Physics Program continues the quest for knowledge to further understand and design better fluids systems for use on earth and in space. NASA's Biological and Physical Research Enterprise seeks to exploit the space environment to conduct research supporting human exploration of space (strategic research), research of intrinsic scientific importance and impact (fundamental research), and commercial research. The strategic research thrust will build the vital knowledge base needed to enable NASA's mission to explore the Universe and search for life. There are currently five major research areas in the Microgravity Fluid Physics Program: complex fluids, multiphase flows and phase change, interfacial phenomena, biofluid mechanics, and dynamics and instabilities. Numerous investigations into these areas are being conducted in both ground-based laboratories and facilities and in the flight experiments program. Most of the future NASA-sponsored flight experiments in microgravity fluid physics and transport phenomena will be carried out on the International Space Station (ISS) in the Fluids Integrated Rack (FIR), in the Microgravity Science Glovebox (MSG), in EXPRESS racks, and in other facilities provided by international partners. This paper presents an overview of the near- and long-term visions for NASA's Microgravity Fluid Physics Research Program and brief descriptions of hardware systems planned to enable this research.

Twenty-two Fluid Physics flight investigations are currently planned for the ISS between FY2001 and FY2008. This series of investigations began with the Physics of Colloids in Space (PCS) experiment in FY2001 and will build up to a steady state level of four experiments per year by FY2004. PCS was accommodated in an ISS EXPRESS rack that provided a mounting structure, power, cooling, commanding, and data down linking. Over the next two years, several other colloidal physics light scattering experiments using basically the same hardware will be conducted. Following the PCS series, an experiment to study miscible interface dynamics will be accommodated in the EXPRESS Rack in the DECLIC, a French-developed multi-user facility designed to serve the requirements for a number of different investigations in Fluid Physics and other disciplines. It is also expected that additional Fluid Physics experiments will be conducted in other non-NASA-developed hardware such as the ESA-developed Fluids Science Laboratory.

The FIR is part of the two-rack Fluids and Combustion Facility and will be the major facility dedicated to Fluid Physics experiments over the life of the ISS. Besides power, cooling and data handling capabilities, the FIR will provide common laboratory diagnostic hardware and is being designed to support a wide variety of imaging techniques. The FIR will provide a large volume for experimental hardware, easily reconfigurable diagnostics, and customizable software that will allow accommodations of experiments from other disciplines such as biotechnology. In addition, the design of the FIR infrastructure is such that experiment-unique cameras, light sources and optical hardware can be accommodated through standard interfaces if the FIR diagnostics tools are not sufficient for a particular diagnostic technique. In order to provide a flexible environment that can accommodate the various experimental test cells and the required diagnostics, the FIR provides a large volume for experimental payloads. Within this volume, experiment hardware can be precision-mounted directly to the FIR optics bench and supported with necessary cooling, power, command and data interfaces. The FIR design allows for easy manipulation, installation and removal of FIR hardware by the ISS crew. The FIR can be operated by an ISS crew member through a laptop computer mounted outside of the rack. While the ISS crew will be available for experiment operations, their time will be limited, so the FIR is being designed for both autonomous and remote control operations. Control of the FIR will be primarily through the Telescience Support Center at the Glenn Research Center. The FIR capabilities, combined with multi-user modules and principal investigator (PI)-unique hardware, will allow the FIR to conduct world-class science experiments.

The first multi-user module for the FIR will be the Light Microscopy Module (LMM), a remotely controllable, on-orbit microscope subrack facility. The LMM/FIR combination will allow flexible scheduling and control of physical and biological sciences experiments for about 30 months of on-orbit operation. LMM will meet the needs of fluids, colloidal, and biological experiments with a standard set of science diagnostic equipment to reduce hardware development costs for individual PIs. Key LMM diagnostic capabilities include: video microscopy to observe sample features including basic structures and dynamics, thin film interferometry, laser tweezers for colloidal particle manipulation and patterning, confocal microscopy to provide enhanced three-dimensional visualization of colloidal structures, and spectrophotometry to measure colloidal crystal photonic properties. In addition to using the confocal system, biological experiments can conduct fluorescence imaging by using the fiber-coupled output of a Nd:YAG laser operating at 532 nm or the 437nm line of a mercury arc or appropriate narrow-band filtering of the FIR-provided metal halide white light source.

The second payload on the FIR will be the multi-user, mini-facility Granular Flow Module (GFM). The GFM will utilize services provided by the FIR in addition to GFM-specific systems and diagnostics to study the flow of granular materials (simulated by simple spheres). Anticipated diagnostic capabilities include normal and high-speed video imaging through an optical cover, as well as measurements of the rotational speed, ambient pressure and temperature. In addition to the LMM and GFM multi-user modules, it is anticipated that the FIR will also accommodate a series of individual PI-unique hardware modules.

Finally, the ISS MSG will be utilized to conduct a series of Fluid Physics experiments. The facility provides a double containment sealed laboratory with gloveports with a volume of 260 liters for carrying out crew-interactive experiments. The planned experiments cover a number of topics ranging from a study of the structure of paramagnetic aggregates formed from colloidal emulsions, to boiling experiments, to the study of buoyancy-driven instabilities in single-bubble sonoluminescence, to an ultraviolet-visible-infrared spectrophotometer that complements the measurements made in the LMM. The MSG provides video, power, thermal control, a vacuum vent, analog and digital data downlink, experiment commanding and telemetry, and other services. It was delivered to the ISS in June 2002 and is now operational.

Based on the series of experiments described above, the Microgravity Fluid Physics Program on the ISS is clearly poised to make significant contributions to the store of knowledge for use on earth and future space missions.