

# Interface Configuration Experiments (ICE) Explore the Effects of Microgravity on Fluids



*Top (or left): ICE flight hardware ("exotic" vessels) for USML-1. Bottom (or right): ICE flight cells for USML-2: proboscis (three) and wedge vessels (one).*

The Interface Configuration Experiment (ICE) is actually a series of experiments that explore the striking behavior of liquid-vapor interfaces (i.e., fluid surfaces) in a low-gravity environment under which major shifts in liquid position can arise from small changes in container shape or contact angle. Although these experiments are designed to test current mathematical theory, there are numerous practical applications that could result from these studies. When designing fluid management systems for space-based operations, it is important to be able to predict the locations and configurations that fluids will assume in containers under low-gravity conditions. The increased ability to predict, and hence control, fluid interfaces is vital to systems and/or processes where capillary forces play a significant role both in space and on the Earth. Some of these applications are in general coating processes (paints, pesticides, printing, etc.), fluid transport in porous media (ground water flows, oil recovery, etc.), liquid propellant systems in space (liquid fuel and oxygen), capillary-pumped loops and heat pipes, and space-based life-support systems.

In space, almost every fluid system is affected, if not dominated, by capillarity. Knowledge of the liquid-vapor interface behavior, and in particular the interface shape from which any analysis must begin, is required as a foundation to predict how these fluids will react in microgravity and on Earth. With such knowledge, system designs can be optimized, thereby decreasing costs and complexity, while increasing performance and reliability. ICE has increased, and will continue to increase this knowledge, as it probes the specific peculiarities of current theory upon which our current understanding of these effects is based.

Several versions of ICE were conducted in NASA Lewis Research Center's drop towers and on the space shuttle during the first and second United States Microgravity Laboratory missions (USML-1 and USML-2). Additional tests are planned for the space shuttle and for the Russian Mir space station. These studies will focus on interfacial problems concerning surface existence, uniqueness, configuration, stability, and flow characteristics.

Results to date have clearly demonstrated the need for experimental data regarding the behavior of large-scale capillary surfaces in containers of irregular cross-section. For example, ICE on USML-1 revealed the existence of a globally stable, asymmetric interface configuration in a rotationally symmetric container. For many applications, the possibility of encountering such surfaces must be considered because they may be detrimental to the operation of a system in space. A result from the USML-2 mission revealed that fluid locations after long-duration exposures (days) to low gravity can be significantly different than for short durations (hours). This fact raises concerns both for designers of space systems and for scientists in that true equilibrium for certain capillary surfaces may take days, even weeks, to be achieved.

These experiments were conceived and developed by Paul Concus of Lawrence Berkeley Laboratory and the University of California at Berkeley, Robert Finn of Stanford University, and Mark Weislogel of the NASA Lewis Research Center in Cleveland, Ohio. The hardware was designed and b