SIMULATING THE MOON'S GRAVITY ON EARTH USING MAGNETIC LEVITATION *

Donald Strayer, Yuanming Liu, Charles Hays, Richard Kidd, and Ulf E. Israelsson Jet Propulsion Laboratory, California Institute of Technology Pasadena, California, U.S.A. 91109-8099

* This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

We will present a description of a facility that is currently under construction at JPL to simulate the Moon's gravity. It is a laboratory-based variable-gravity testbed that will be used to study fluid and biological systems in simulated gravity levels other than Earth's gravity, such as those on Mars (0.39g), the Moon (0.16g), Europa (~g/7), or in space (0g). This facility represents an example of using Physics and Quantum Technology to achieve technological advantage to support NASA`s new vision for human and robotic exploration.

The centerpiece of the facility is a superconducting gradient magnet with a rather large room-temperature bore. The magnet generates magnetic body forces acting on a body or fluid to counter or enhance Earth's gravity, achieving simulated gravity levels tunable from 0 g to several g.

The magnet will be constructed using Nb_3Sn for the inner coils and NbTi for the outer coils. The magnet will be immersed in 2.2K liquid helium, and will be operated in the persistent mode; liquid helium top-ups occur once each 10 days without interrupting the magnet's function. Because of this unique operation mode of superconducting magnets, one can operate the magnet for a long period of time (months) without recharging, making long-duration experiments possible without consuming enormous amounts of electricity and liquid helium. The magnet will be capable of producing more than 14.5 $Tesla^2/cm$ in the product of field and field gradient, generating a magnetic force strong enough to levitate (cancel Earth's gravity force upon) water and most biological materials. The large room-temperature bore (6.6 cm, or 2.6 inches) permits us to study sizable fluid samples of common fluids, and to observe biological systems at or near room temperature at many gravity levels, and to observe cryogenic fluids at reduced temperature in a cryostat insert.

With this versatile facility, we shall focus on two areas of research in fluid systems. First, we shall study heat and mass transfer as a function of gravity in Rayleigh-Bénard thermal convection; Marangoni convection; gas-liquid two-phase systems; binary fluids; and fluids in confined media such as microchannels, aerogels, and granular materials (such as soil and sand). These studies will provide us understanding on how these fundamental physical phenomena are affected by the gravity levels and will lead us to understand the ways that fluid technologies will behave on other planets.

Second, based on the knowledge gained, we shall test and optimize the designs of flight thermal fluid devices that are to be used in the life-support fluid systems and resource utilization systems for human and robotic explorations and colonization of other planets and moons. By operating scale models of fluid devices in our levitation magnet, we shall study the performance of the following devices at reduced gravity levels: heat exchangers, liquefiers, refrigerators, heat pumps, evaporators, sublimators, and two-phase flow loops. Optimization of these devices for the intended gravity environment will help us to achieve best performance, thus reducing the devices' mass and power consumption, very precious commodities for space exploration.

Other than fluid systems, the facility will be open to investigators to study how biological systems behave under the gravity of other planets and the Moon. The ability to easily alter effective gravity levels will facilitate looking for thresholds on effects of reduced gravity.

The facility is expected to be operational in about a year, fully equipped with electronic instrumentation, visualization optics, and data acquisition systems. We are also considering establishing support systems for small animals to be tested at reduced gravity levels.