## IAF MICROGRAVITY SCIENCES AND PROCESSES SYMPOSIUM (A2)

Science Results from Ground Based Research (4)

Author: Dr. Aaron H. Persad
Massachusetts Institute of Technology (MIT), United States, aaron.persad@utoronto.ca

# EXPERIMENTAL EXAMINATION OF THE THERMODYNAMIC STABLE STATES OF WATER IN A NEAR WEIGHTLESS ENVIRONMENT WHEN CONFINED WITHIN AN ISOLATED AXISYMMETRIC CONTAINER: IMPLICATIONS FOR FUTURE SPACECRAFT DESIGN

## Abstract

The question of how a confined fluid (water) behaves in the near weightless environment is of immense technological relevance for designing spacecraft and life support systems, but not yet fully understood. The importance of this topic was dramatically illustrated on July 16, 2013, when a clogged filter caused nearly 1.5 L of water to coat the inner helmet and face of Italian astronaut Luca Parmitano during his spacewalk from the International Space Station (ISS), leading to terrifying moments of near drowning.

Other studies predicting liquid behaviour in near freefall have typically relied on computational fluid dynamics and Newtonian concepts such as mechanical equilibrium. However, the underlying physics of what causes the water to want to move and settle in certain locations of its container is often masked by complex coupled equations of motions.

Here, we take a different approach and use classical thermodynamics to examine the possible equilibrium states of water sealed in partially-filled glass cylinders. The thermodynamic approach includes a necessary equilibrium condition that is often neglected by Newtonian-based methods—the equality of chemical potentials—and thus leads to some non-intuitive predictions of how water will occupy the cylinders when allowed to reach stable equilibrium in near freefall. Indeed, the apparently strange thermodynamic predictions necessitate experiments to examine the validity of the theory.

These non-intuitive thermodynamic predictions of the equilibrium stability were examined using specially designed glass cylinders containing only pure water and water vapor. The water-filled cylinders were exposed to the near weightless environment of a drop tower (10 seconds of 0g, National Aerospace Laboratory of Japan), of a reduced gravity aircraft (18 seconds of 0g, National Research Council of Canada's Falcon-20), and of the ISS (in progress). The results from the suborbital platforms were striking: the thermodynamic predictions were validated, and new metastable equilibrium states were discovered.

The experimental results provide guidance for new designs of spacecraft fuel tanks and life support systems. The thermodynamic method can also be used on the ground to gain insight into the nanoscale behaviour of water confined within rigid channels, such as in microfluidic devices, or in the kerogen of shale oil/gas industries, i.e. instances where surface forces dominate over gravitational forces in confined geometries.

While this work will provide a high-level view of the thermodynamic theory, the focus will be on experimental work, microgravity results, lessons learned, and future experiments planned to further understand the thermodynamic equilibrium states of confined fluids.