A NEW FACILITY TO MEASURE THERMAL PROPERTIES OF ULTRAVOLATILE ICES (N₂, CH₄ AND CO) IN THE OUTER SOLAR SYSTEM. M. Suda¹, A. Emran², and V. Chevrier³, ¹University of Arkansas, Arkansas Center for Space and Planetary Science, Fayetteville, AR 72701 , ²NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA, ³University of Arkansas, Arkansas Center for Space and Planetary Science, Fayetteville, AR 72701 (suda@uark.edu)

Introduction: Ices such as N₂, CH₄, and CO are abundant in the outer solar system, these three ices also cover much of the surface of Pluto [1]. As the temperatures in the outer solar system are extremely low, N₂, CH₄, and CO act as volatile ices, sublimating and condensing throughout the Pluto year [2]. This process can give Pluto a tenuous atmosphere at times during its orbit, resulting in volatile transport and changing geomorphology [2]. One of the most important parameters for determining surface temperatures and subsequent volatile transport is the Thermal inertia (TI). Thermal inertia is the property of a material that describes how quickly it responds to changes in temperature (warming or cooling). Precise values for the thermal inertia of N₂, CH₄, and CO ices, and their potential mixtures, at outer solar system temperatures and pressures are not currently available, making understanding how these surface ices affect the global geography and surface-atmosphere interactions difficult [2].

Therefore, at the University of Arkansas we have developed a new simulation chamber for the study of icy bodies in the outer solar system. While the W.M. Keck Laboratory for Space and Planetary Simulations already hosts a Pluto Simulation Chamber [3], the Outer Solar System Astrophysics Lab (OSSAL) chamber is different in that it can produce larger samples of ice for experimentation. The current Pluto Simulation Chamber deposits ice samples in a 1-dimensional sheet on the cold tip, while the new OSSAL chamber can produce cubic volumes of ice for analysis. Additionally, many components have been built off of and improved upon from the original Pluto Simulation Chamber, including but not limited to, the cold tip, cryocooler, and vacuum pumps.

Outer Solar System Conditions: While the planned future of the OSSAL chamber is to be used to study various icy bodies in the outer solar system including Kuiper Belt Objects (KBOs) and Trans-Neptunian Objects (TNOs), currently it is being used to analyze thermal properties of Pluto’s or KBO’s surface volatile ices. The average temperature of Pluto’s surface is 38 K and with an average pressure of 10 microbars [3]. We plan to use extremely low pressures analogous to that of Pluto’s surface (microbar range) and temperatures ranging from 20 K to 60 K in our upcoming experimental protocol.

Methodology: In order to measure the thermal properties of our samples, and ultimately determine their TI values, we will use the dual-probe heat-pulse (DPHP) method [4]. In this method, a probe with two stainless steel needles are inserted into the sample, one heater needle and one sensor needle. The heater needle produces a short heat pulse while the sensor needle records changes in temperature across a set period of time. Using this data, we can estimate values such as thermal inertia, thermal conductivity, and volumetric heat capacity.

Figure 1: Current state of the Outer Solar System Astrophysics Lab chamber at the University of Arkansas. Pictured ports include Super Bee pressure gauge, thermocouples, a viewing port, the Dual Probe, vacuum outlet, and gas inlet.
Figure 2: Schematic of the Outer Solar System Astrophysics Lab chamber

Dimensions and Materials: The OSSAL chamber is a solid stainless steel cylinder 51 cm tall with a 20.5 cm diameter. Along the sides it has eight 2.75” CF feed thru flanges, 4 of which are currently in use with the other 4 for future instruments. Installed currently is a Super Bee pressure gauge, a feed thru for the vacuum, a feed thru for gas intake, and a wire connecting the dual probe to a LabView controller that feeds data to the computer for analysis. The new Outer Solar System Astrophysics Lab chamber has many similar components to our already existing Pluto Simulation Chamber, but with some notable upgrades:

Cooling. The OSSAL chamber utilizes a copper cold tip for cooling of the sample container, with a helium cryocooler. The cooler is a Sumitomo Cryogenics F-70 helium refrigerator system, with which the copper cold tip can reach temperatures as low as 15 K. The cryocooler uses liquid helium and water to reach these extreme temperatures.

Pressure. The OSSAL chamber is depressurized using both a roughing pump and turbo pump. Using both pumps, the inside of the chamber can reach pressures as low as ~10 microbars to simulate outer solar system conditions.

Data Collection. Heat pulses from the heater wire as well as data recording are performed using a Campbell Scientific CR6 Datalogger. Initial sample temperature, pulse time, and sample temperature change over time are all recorded into the lab computer via the Datalogger.

Sample Container. The sample container is a 2” by 2” by 2” brass cube containing a 1 cubic inch sample, with insertions point for a gas inlet and outlet on the back wall, two holes for the dual probe on the top, and a window drilled with stainless steel bolts in the front for visual inspection of the sample. The plexiglass window was installed in the first version of the sample holder, with a plan to use stronger material, as well as a material transparent to infrared radiation (quartz or sapphire) in subsequent versions, enabling us to perform FTIR or Raman spectroscopy for further analysis.

Figure 3: Version 1 of the OSSAL sample container. In view is the window, with gas inlet and outlet on the back wall. The top holds a divot for insertion of the dual probe.

Conclusion: Once completed, the OSSAL chamber will be capable of a multitude of experimental protocols, and can be customized as needed using the four free CF ports. In the future, the chamber and sample container will continue to be upgraded to produce data and results that will further our understanding of the outer reaches of our Solar System.