CRYOGENIC ICES UNDER VACUUM: PRELIMINARY TESTS RELATED TO SAMPLING MATERIAL ON EUROPA'S SURFACE. D. F. Berisford[1], J. Foster[1], M. J. Poston[1], K. P. Hand[1], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109, daniel.berisford@jpl.nasa.gov.

Introduction: We have performed a set of low-cost experiments to demonstrate the behavior of cutting tools applied to cryogenic ices in rough vacuum conditions, for application to sampling of ice-covered ocean moons such as Europa, Enceladus, and Titan. This work will feed forward into tool and sample acquisition system development efforts for surface sampling systems of landed payloads on these worlds.

Experimental Setup: Using COTS components, we have assembled a small vacuum chamber with mechanical and electrical feedthroughs to allow transmission of tool motion and instrumentation signals. Figures 1 and 2 show the experiment setup. The chamber is a modified aluminum Shattervac 5-gallon chamber from Best Value Vacs [1] with a polycarbonate lid.

The mechanical feedthrough is comprised of a linear sliding dynamic seal using a spring-loaded PTFE shaft seal for the linear motion. The rotary motion feedthrough is a dynamic O-ring type, and mounts atop the linear sliding tube. This allows the tool motor to be located outside of the vacuum chamber. A 90° bevel gear assembly mounted inside the chamber changes the shaft angle to allow the use of saw blades. Without this adapter, drill-type tools can be used in place of saws.

Instrumentation inside the chamber consists of four thermocouples used to measure ice temperature at several depths. These thermocouples can also serve to measure bevel gear case or shaft temperature. Also mounted inside the chamber is a COTS webcam, modified for vacuum operation.

Freezing and Cutting Cryogenic Ice: To freeze the ice sample, we fill the open chamber with water to an approximate desired depth, with a maximum of 20 cm. This water can contain desired impurities likely to be found in Europan ice [2, 3]. We then assemble the chamber and draw rough vacuum to de-gas the liquid. We then immerse the chamber in an external liquid nitrogen bath, of depth at least that of the water sample inside the chamber. When the liquid is fully frozen and the desired sample temperature is achieved, we begin the cutting test. This method can generate bulk samples of ice at temperatures below 100K in approximately two hours. However, the ice often contains unpredictable cracks, as the growth rate and grain size are not controlled.

Figure 3 shows an image of the setup during a saw-blade cutting test. For this test, the ice is made from water saturated with $MgSO_4$.

Preliminary Results: To date, tests have been performed using pure water, $MgSO_4$- saturated water, and Earth ocean water ices. In all cases qualitative cutting performance using several COTS saw blades indicate the ability to cut cryogenic ices rapidly, compared to rock or concrete analogs. Testing with catchment cups inside the chamber indicate the ability to collect >1cc of sample volume in under one minute in all cases.

Future tests will refine the apparatus, and add quantitative measurement capability for tool reaction forces and cutting power/ energy to evaluate tool cutting performance. These tests provide qualitative early insight

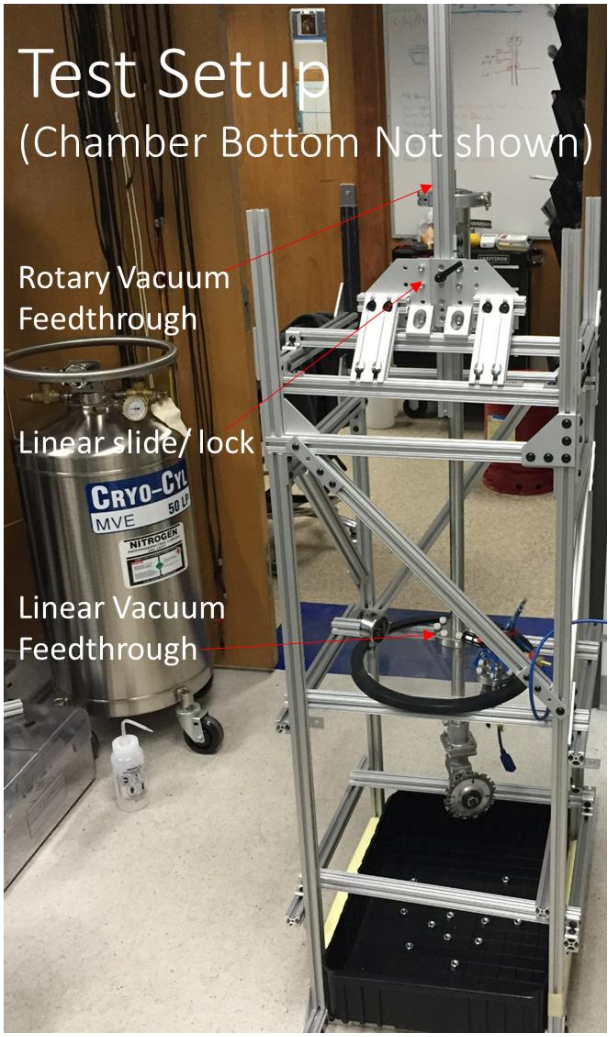

Figure 1. Experimental Setup showing overall structure. The vacuum chamber wall is removed for clarity here.

as to the behavior of cryogenic ices in response to cutting tool application under vacuum.

References: [1] http://www.bestvaluevacs.com. [2] Carlson, R. W., et al. (2009) Europa, University of Arizona Press, Tucson (2009): 283-327. [3] Hand K. P. and Carlson R. W. (2015) *Geophys. Res. Lttrs*., 42, 3174-3178.

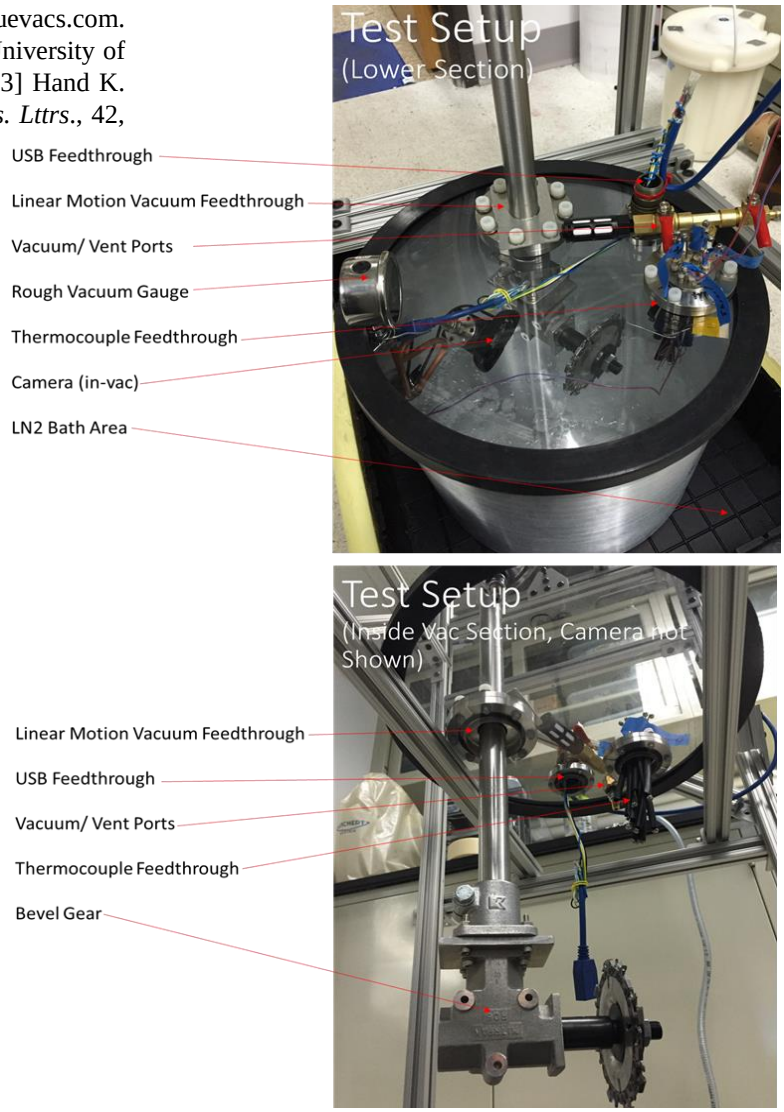

Figure 2. Test Setup photos showing chamber lid (top), and chamber internal parts (bottom - chamber wall removed, view looking upward)

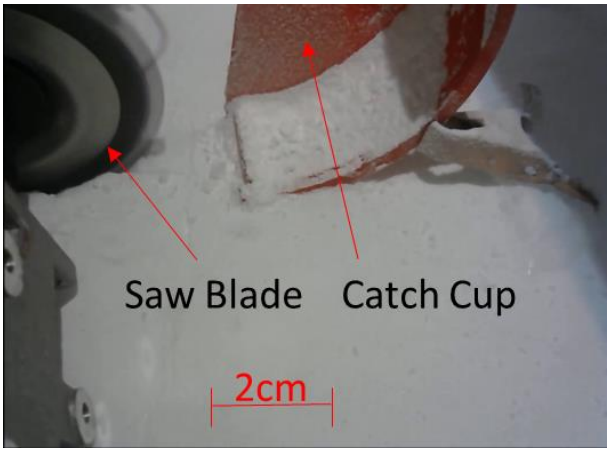

Figure 3: In-Vacuum camera image during cutting of MgSO4- saturated water ice at 90K