National Aeronautics and Space Administration

Enceladus Surface Sample Acquisition for In Situ Measurements

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JPL Research and Technology Development Strategic Initiative

Project Objective:

Develop a sampling system for an Enceladus lander mission to acquire and transfer surface samples to in-situ instruments.

- Samples: ten 1cc to 5cc ice samples from top 1 cm
- Material: 40-95% porosity and strength 400 kPa to 12 MPa unconfined compressive strength

Benefits to NASA and JPL:

A future in-situ mission to the surface of Enceladus could be the lowest cost mission to determine if life exists beyond Earth since material from the subsurface ocean, where the presence of hydrothermal activity has been strongly suggested by the Cassini mission, is available on its surface after being ejected by plumes and then settling on the surface. In addition the low radiation environment of Enceladus would not significantly alter the chemical makeup of samples recently deposited on the surface.

This work fills a gap in NASA sampling technology needed for surface sampling in the low gravity (1% Earth-g) environment of Enceladus that is not met by sampling systems developed for microgravity (e.g. comets and asteroids) or higher gravity (e.g. Europa 13%g, Moon 16%g, or Mars 38%g) environments.

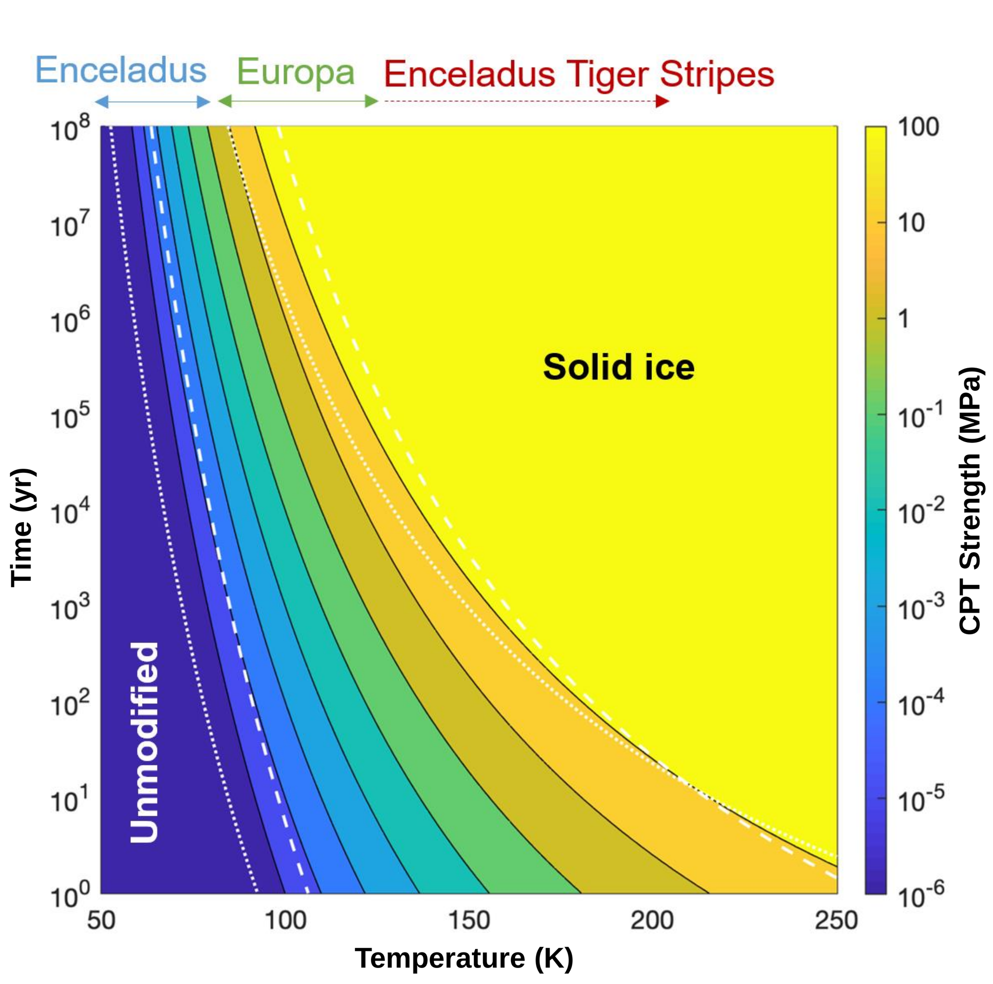

Figure 4. Sintered ice strength evolution model from 1-bar experimental data

FY18/19 Results:

Dual-Rasp Sampling System Development

The novel Dual-Rasp sampling system was developed to meet the unique Enceladus surface sampling needs. Sampling is accomplished with two counter-rotating rasp cutters with teeth that remove material that is thrown up between the cutters and directed by a guide into a sample collection cup (Figure 1). A robotic arm would deploy the tool to the surface. Two versions of sample transfer were developed. A mechanical sample transfer system (Figure 1) has ten sample cups on a carousel attached at the end of the robotic arm. After one 5cc cup is filled, the cup is rotated on the carousel to a volume measurement station where a plunger pushes a lid into the sample cup to measure the sample volume. If there is enough sample, then the tool is docked at the lander deck and the plunger pushes the cup into a science instrument inlet port. Otherwise another sampling attempt could fill the cup further. A pneumatic sample transfer system (Figure 2) uses pneumatics to transfer sample from the collection cup directly to a science instrument inlet port after the tool is docked at the lander deck. A microwave mass flow sensor is being evaluated for sample measurement for this tool version.

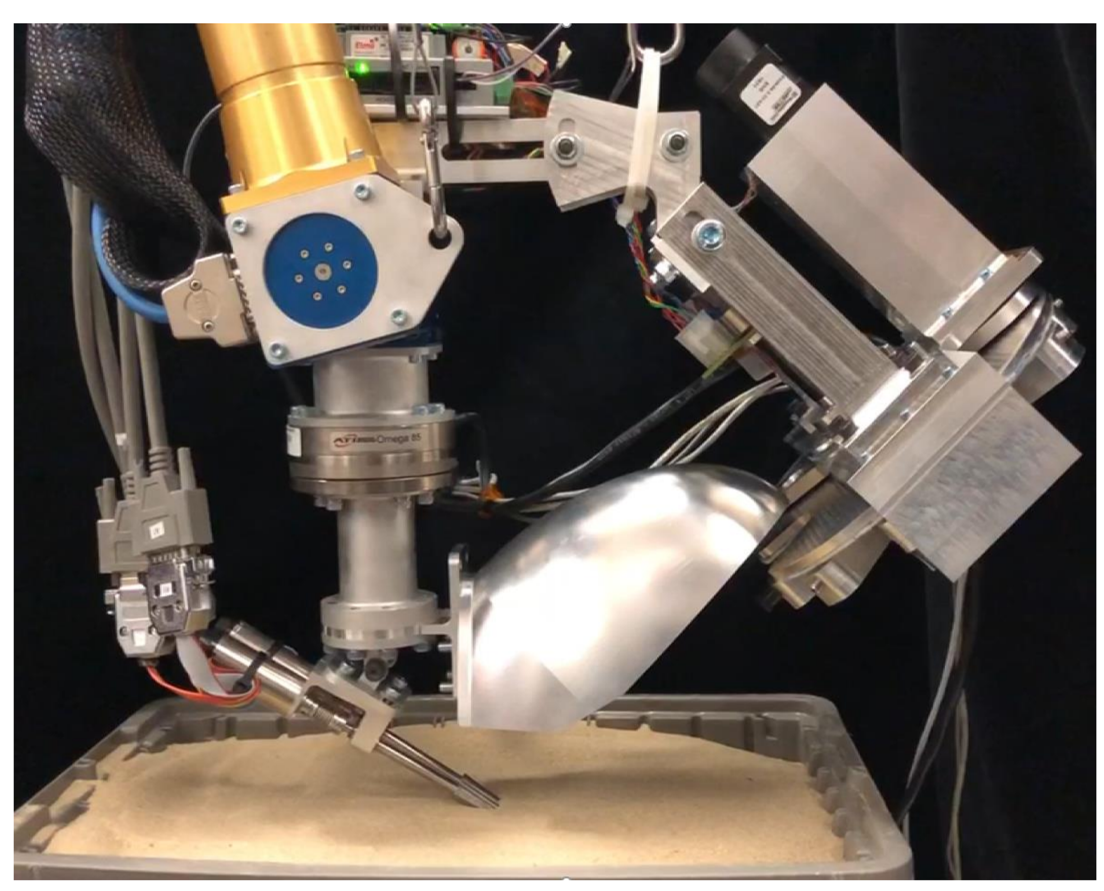

Figure 1. Dual-Rasp with carousel sample transfer

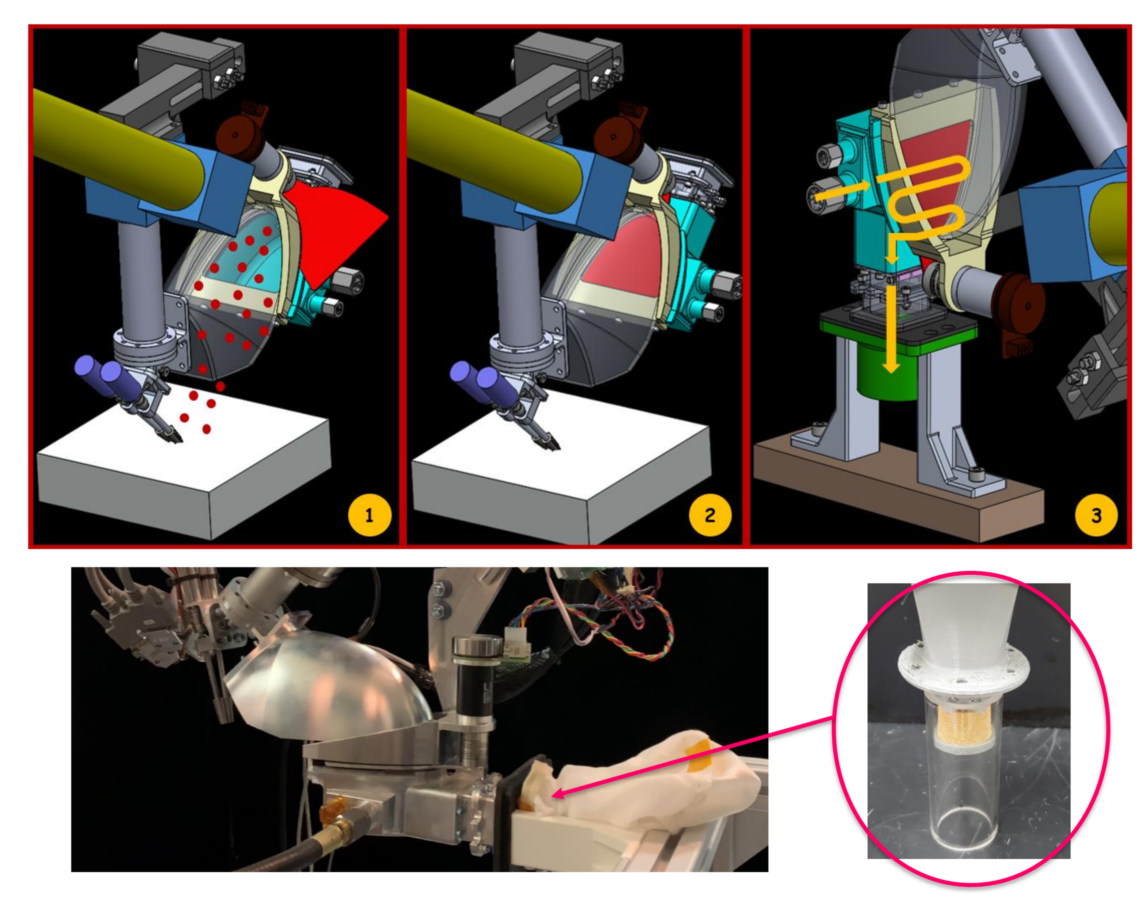

Figure 2. Dual-Rasp with pneumatic sample transfer, concept (top), prototype and science instrument inlet chamber (bottom)

Ice Sintering Modeling and 1-Bar Experimental Characterization

Ice sintering modeling and tests were conducted to determine the potential mechanical properties of the Enceladus surface. Penetration resistance data was periodically collected for 1-10 micron scale ice grains kept at -30ºC, -50ºC, and -80ºC. Sintering of the ice caused growth of the contact regions between grains and mass redistribution, leading to the formation of agglomerate structures and some recrystallization. Combined, these effects resulted in an increase of the penetration resistance of the bulk ice samples, with warmer samples experiencing more modification. Results (Figures 3,4) suggest plume deposits remain weak on Enceladus far from the thermal influence of the Tiger Stripes.

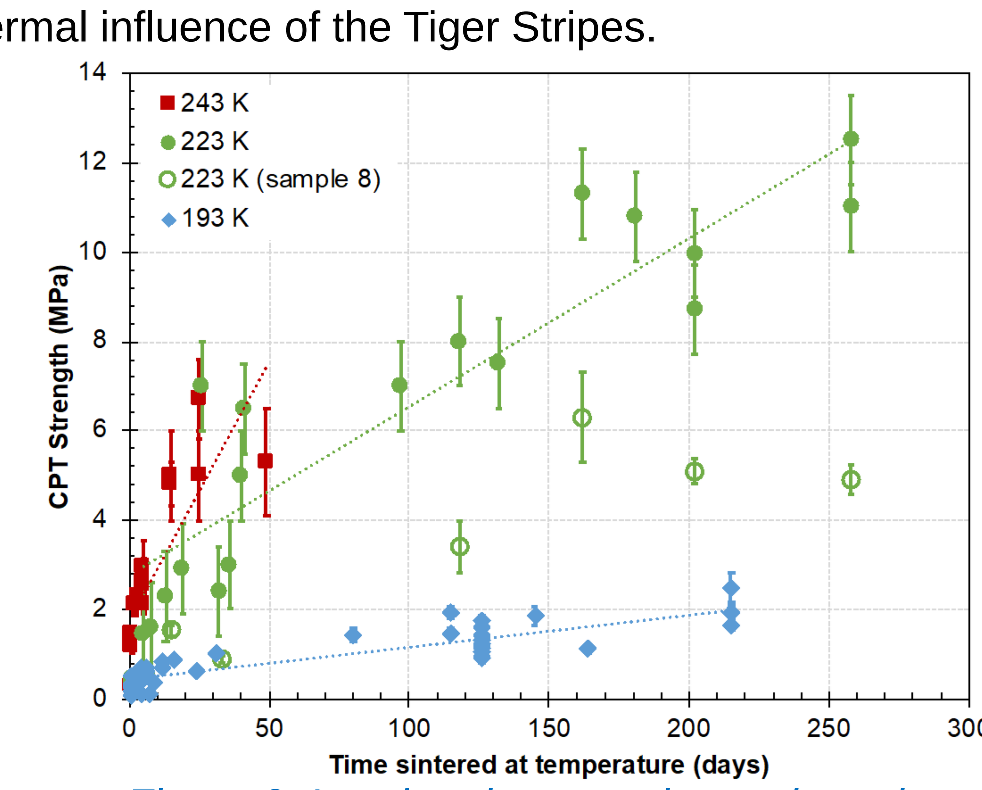

Figure 3. Ice sintering experimental results

Icy Bodies Simulation (IBoS) Chamber

The IBoS chamber was designed (Figure 5) and fabricated for use in generating and evolving icy body materials including to represent the Enceladus surface. Micron-scale particles will be produced and subject to Enceladus thermal and vacuum conditions and the evolving mechanical properties will be measured.

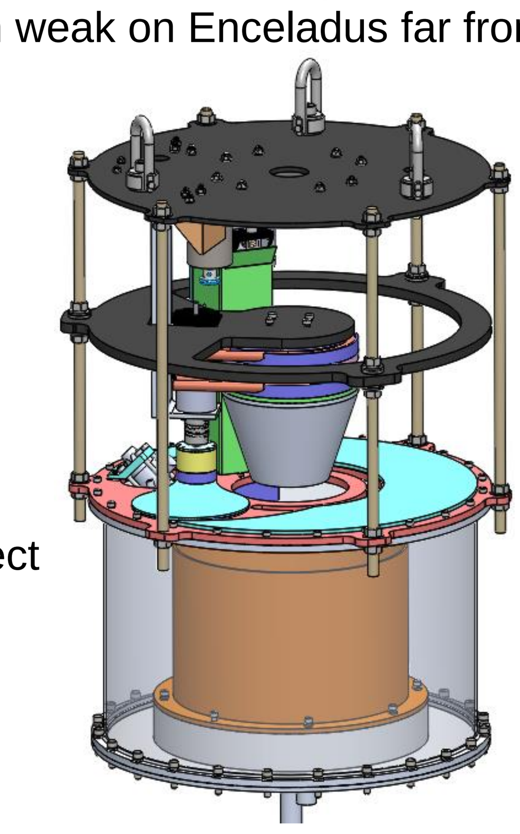

Figure 5. IBoS chamber design

Publications:

- Choukroun, M., Phelps, E.S., Molaro, J.L., Hodyss, R., Mitchell, K.L, "**Sintering of Fine-grained Porous Water Ice: Preliminary Investigation of Microstructure and Strength Evolution.**" American Geophysical Union poster, December 2018.
- Molaro, J.L., Choukroun, M., Phillips, C.B., Phelps, E.S., Hodyss, R., Mitchell, K.L., Lora, J.M., and Meirion-Griffith, G., (2019). "**The Microstructural Evolution of Water Ice in the Solar System Through Sintering**", Journal of Geophysical Research (Planets). 124, 243-277.
- Badescu, M., Backes, P., Moreland, S., Brinkman, A., Riccobono, D., Dotson, M., Csomay-Shanklin, N., Ubellacker, S., Molaro, J.L., Choukroun, M., Genta, G., "**Sampling Tool Concepts for Enceladus Lander In-situ Analysis.**" IEEE Aerospace Conference, March 2-9, 2019 Big Sky, Montana.
- Genta, G., Riccobono, D., Moreland, S., Backes, P., "**Modeling of Low Gravity Sampling and Sample Transfer Systems for Enceladus Surface Acquisition**". Proceedings of the Turin Academy of Sciences, 2020, In Press.

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Poster No. RPC-230