Hypervelocity Capture and Analysis of Simulated Plume Materials of Enceladus

Principal Investigator: Isik Kanik (322)

Co-Is: . Bryana Henderson (322), Steven Jones (353), Amanda Stockton (Georgia Tech), Thomas Orlando (Georgia Tech)

Program: SURP

Jet Propulsion Laboratory
California Institute of Technology

Assigned Presentation # RPC-095

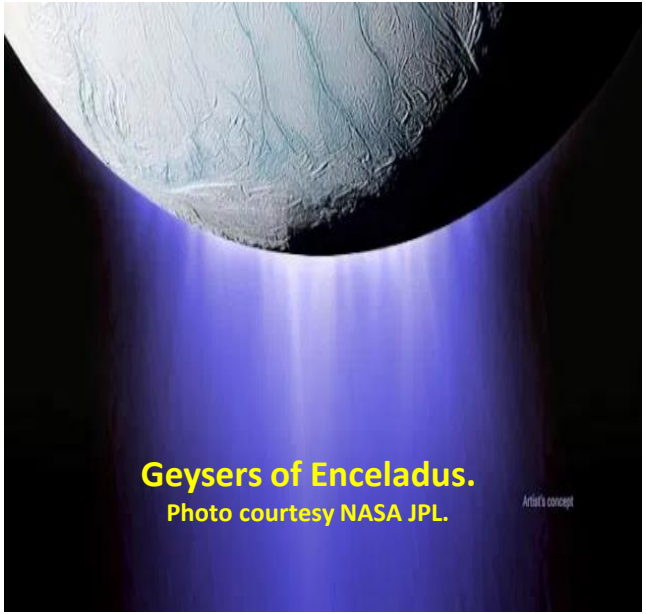
Abstract

A better understanding of biosignature survivability in captured material at flyby velocities from the Enceladus plume is critical for future mission design studies. Typical sample capture velocities of spacecraft flying through the Enceladus plume are several km/s, resulting in extremely high shock pressures experienced by the sampled material. These conditions could result in degradation of captured organics or partial racemization of any chiral molecules potentially present. Our objective of this investigation was to **determine the extent of molecular degradation and racemization of potential organic molecular biomarkers in simulated Enceladus plume capture conditions.** In order to accomplish our objectives, we utilized a strategic, collaborative partnership with Georgia Institute of Technology (GIT) and JPL to carry out this investigation.

Problem Description

a) **Why Enceladus Plume Sampling and Analysis Strategies:** One of Saturn's moons, Enceladus, has become a highly attractive target for astrobiology studies due to cryovolcanism occurring at the southern region and a subsurface liquid water ocean. Because of this, a flyby mission to capture plume ejecta is a highly viable approach to analyze Enceladus samples *in situ* or via sample return. The sample capture velocities of spacecraft flying through the Enceladus plume are several km/s, resulting in extremely high shock pressures experienced by the sampled material. These conditions could result in degradation of organics or partial racemization of any chiral molecules present. **With this in mind, a better understanding of biosignature survivability in captured material at flyby velocities from the Enceladus plume is critical for future mission design studies.**

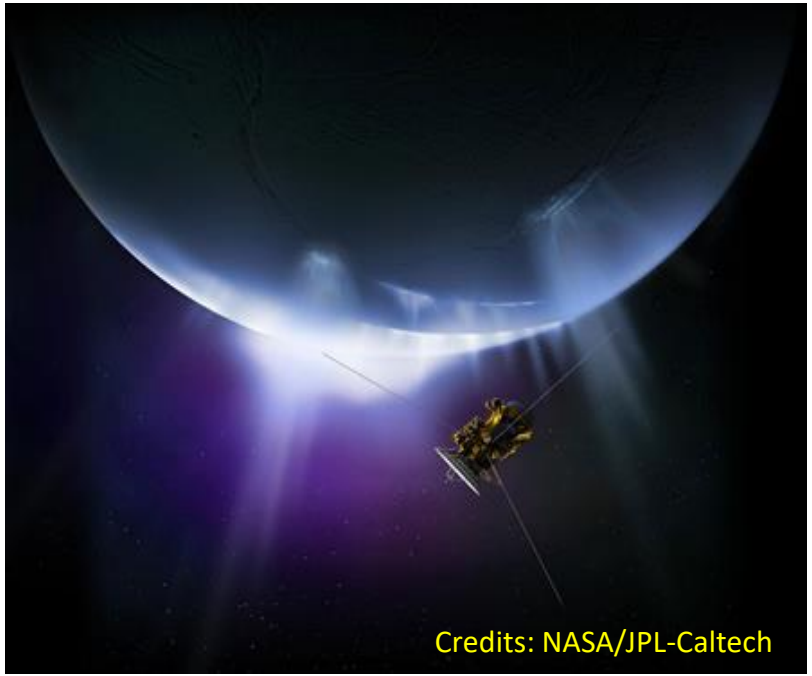
b) **Our Approach:** In order to determine the extent of molecular degradation and racemization of potential organic molecular biomarkers in simulated Enceladus plume capture conditions, we planned to perform hypervelocity (up to 4 km/s) impact experiments with ice grain projectiles through laser induced thermal expansion process utilizing our **Laser-Induced Projectile Impact Testing** (**LIPIT**) system developed at GIT.



Relevance to NASA and JPL:

The LIPIT technique has a much higher throughput and a versatile technique capable of various types of particle (grains, ice covered grains and ice grains) acceleration than current alternatives, while still affording linear velocity distributions and low cost. The results of this work will provide a significant advancement in our understanding of the biomarker capture process and survivability and will provide highly valuable information for future astrobiology missions designed for Enceladus.

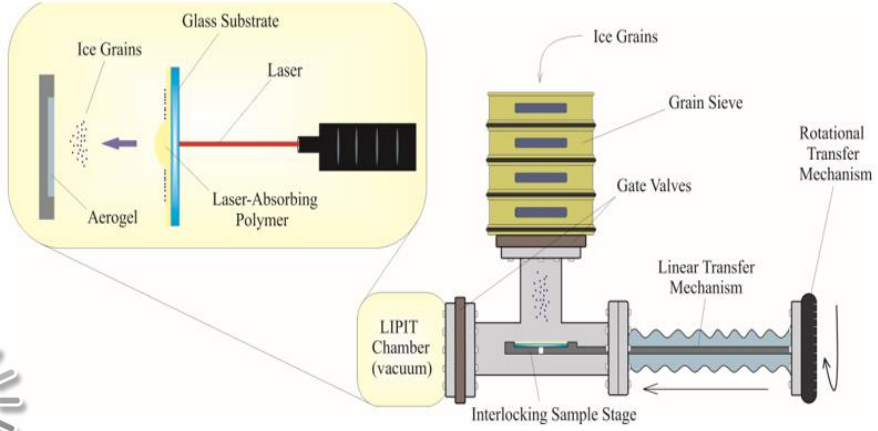
The significance of this effort is that it would represent a first step for a better understanding of hypervelocity (up to 4 km/s) impact on ice grains in capturing plume materials from Enceladus' plume in a potential *in situ* sampling or cryogenic sample return mission scenario.



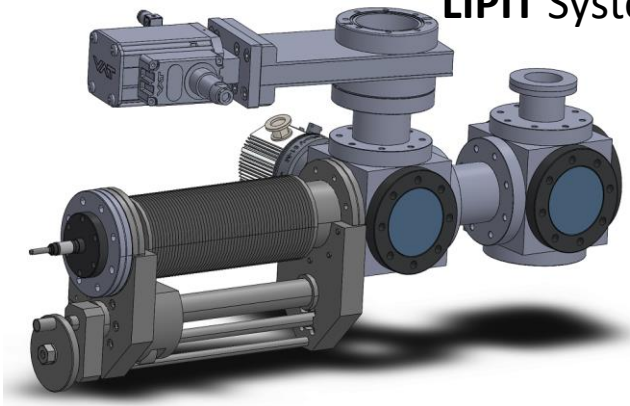
Organic compounds such as amino acids may be captured in a flyby mission to Enceladus in a way such that key chemical biosignatures are preserved.

Why LIPIT?

Recently developed hypervelocity acceleration technologies, while able to obtain high velocities, are unable to examine chiral modifications resulting from hypervelocity impact. Our Laser Induced Particle Impact Testing (LIPIT) method [1], would circumvent this issue, providing chiral analysis in addition to molecular degradation. LIPIT is also a highly versatile hypervelocity acceleration technique relative to other impact techniques since it is capable of simulating various sample capture scenarios during flyby by utilizing different capture media and grain sizes. We can accelerate grains, ice covered grains and ice grains using the same apparatus.



LIPIT System Set-up

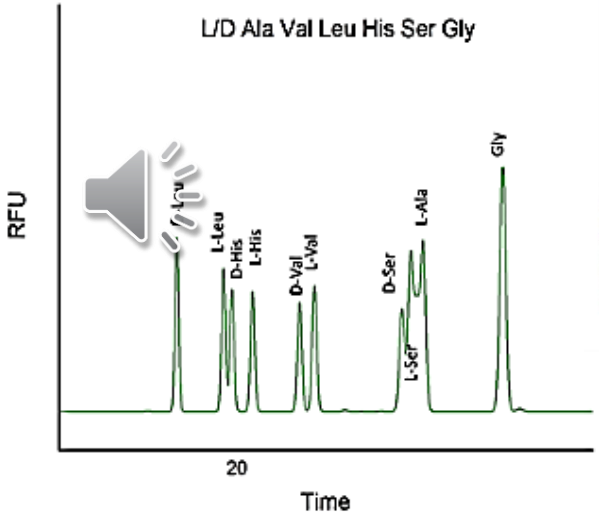


Results

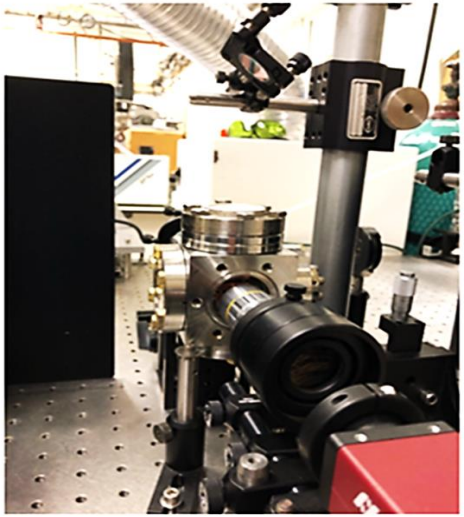
A. Engineering Design of the high-vacuum LIPIT system was successfully completed at GIT

B. Preliminary LIPIT experiments at ambient pressures were successfully completed at GIT:

- Successfully accelerated, imaged mid-flight, and captured silica spheres on indium foil.
- We then tried to capture frozen brine grains on indium foil. However, our preliminary results are inconclusive.
- A chiral CE-LIF method was developed (see figure) for post-impact organic analysis. (Manuscript is in preparation).

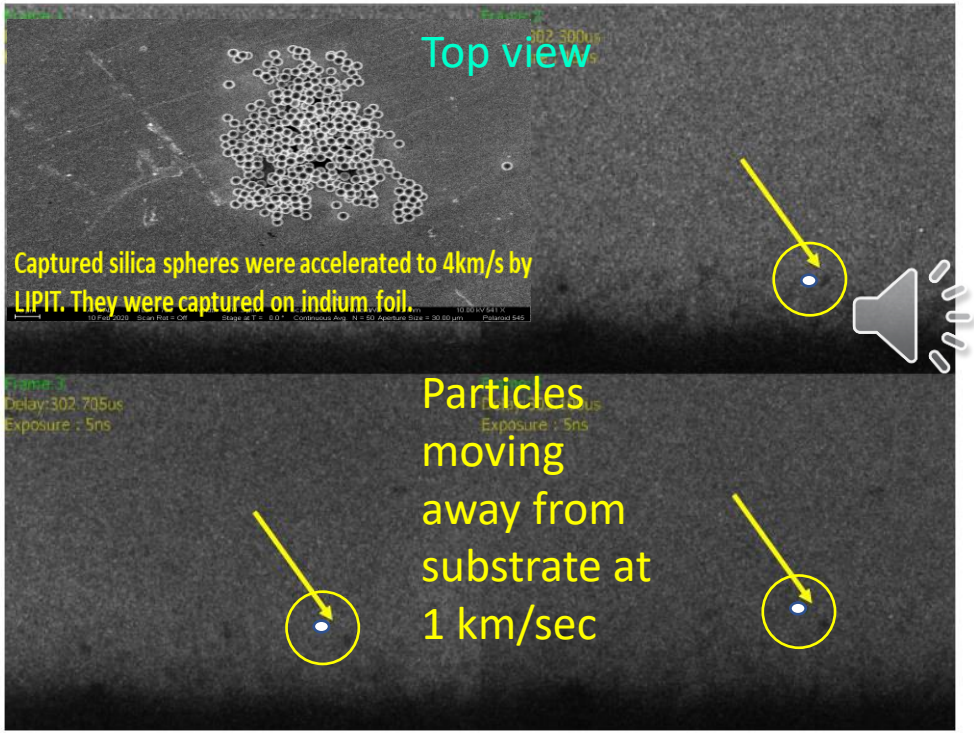


GIT Ph.D. student K. Marshall Seaton has been able to separate L and D amino acids



Enceladus **LIPIT** system

Results



- We recently measured velocity distribution of particles with a fast frame grabbing camera incorporated into the LIPIT system.
- We expect to get up to 5 km/sec accelerations after further optimization with control of the grain size, with multiple or single particle impact studies.

Measuring particle velocities

References

[1] Lee, J.-H., D. Veysset, J.P. Singer, M. Retsch, G. Saini, T. Pezeril, K.A. Nelson, and E.L. Thomas, *High strain rate deformation of layered nanocomposites.* Nature communications, 2012. **3**: p. 1164.

Publications:

Analysis of Amino Acids by Capillary Electrophoresis with Laser-Induced Fluorescence Using Carboxyfluorescein Succinimidyl Ester: Chiral and Achiral Separation Optimization (In preparation, 2020).