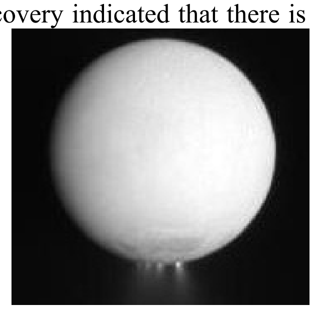
LIFE: Enceladus Sample Return Mission Concept for Searching Evidence of Life. P. Tsou[1], D. E. Brownlee[2], C. P. McKay[3], L. W. Beegle[1], L. Spilker[1], and I. Kanik[1] Jet Propulsion Laboratory, California Institute of Technology (Peter.Tsou@jpl.nasa.gov, 4800 Oak Grove Dr., Pasadena, CA 91109), [2]University of Washington, [3]Ames Research Center

Introduction: One of the most promising targets for the search for life other than Mars in our Solar System is the tiny Saturn moon Enceladus. The Cassini mission to the Saturian system detected an active region on Enceladus where small water particles and gas containing organic materials were being flung into space from a region near the south pole known as the tiger stripes [1]. This discovery indicated that there is very likely a liquid subsurface ocean heated through tidal interactions as Enceladus orbits Saturn [2]. On Earth, whenever there is an energy source, liquid water and organics, there is life; this makes Enceladus one of the prime candidates for a search for life missions [3]. In this presentation, we describe LIFE (Life Investigation For Enceladus) sample return concept from Enceladus in the search for evidence of life.



Cassini Findings: The Cassini Ion Neutral Mass Spectrometer measured the gas composition of the plume to be H_2O (~90%), CO_2 (5%), CO or N_2 (~4%), and CH_4 (~1%) with other organic molecules consisting of C_nH_m (<1%). Subsequent data confirmed the presence of CO rather than N_2 and NH_3 and Ar [4]. Additionally, E-ring ice particle composition has been determined by the Cassini Dust Analyzer and found to contain Na, K and other elements [2]. Currently, Cassini is in the extend mission phase and is expected to continue to study the composition and flux of the plume at least to the year 2017. If life exists on Enceladus, it would revolutionize our understanding of the origin of life throughout the universe and on Earth [3].

Importance of Sample Return: Significant new knowledge of the Moon, comets and the Sun came from the highly in-depth analyses of samples returned by Apollo, STARDUST and Genesis missions, respectively. Samples returned to the laboratory could be independently verified by multiple laboratories using vastly different and independent techniques, capitalizing on the ability of adapting existing or even developing new analysis techniques inconceivable at the time of the mission proposals. Having samples in hand would provide researchers from different disciplines the opportunity to synergistically question and define "life" and to provide more relevant and effective planning for subsequent space explorations for life in these outer planets.

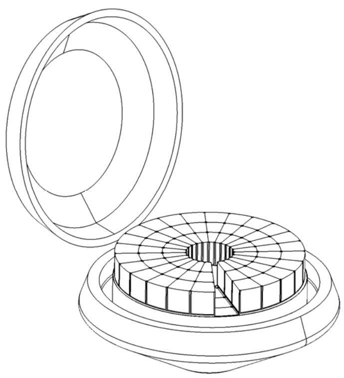
Extraterrestrial Glycine: The recent confirmation of cometary amino acid, glycine (a fundamental building block of proteins) from STARDUST Wild 2 samples [5] showed that an amino acid could be captured and retained in a flyby mission without special preservation techniques. Similarly, nanoSIMS development enabled the isotopic measurements of H, C, and O in STARDUST solid grains to a precision unachievable with comet in situ instrumentation [6]. Given the current sub-femto-mole detections capability with the existing laboratory instruments, the detection limits 20 years from launch promise unprecedented sensitivity approaching the single molecules scale. With these expected improvements, many of the measurements deemed desirable but not attainable today for life detection would then be achievable.

Urgency in Returning Enceladus Samples: The size of the Saturn E ring suggests the Enceladus plume has been in existence for about 3 centuries [7] but without assurance that it would continue in the foreseeable future. If the plume turns off, it would require a very costly and complicated lander to locate and drill for the ocean. All this would deny or delay findings from these samples to benefit future plans for effective missions to Enceladus. Also in order to capitalize on a Jupiter gravity-assist opportunity to reduce both the size of the launch vehicle and the mission duration, LIFE needs be launched by 2019.

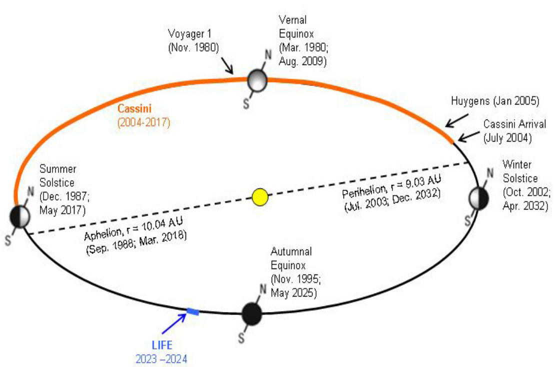
E Ring Samples: E Ring samples would not be as pristine as the samples that are in the geysers; however, this would be offset by the ability to collect orders of magnitude amount more material from the E Ring increasing their analysis value. Since the proposed trajectory would cross the E-ring multiple times, E ring samples of various ages would also provide historical information on the nature of degradation of organics at 10 AU.

Science from LIFE: Of the theories for the origin of life on Earth or Mars [8], three could apply to Enceladus: 1) origin in an organic-rich liquid water mixture, 2) origin in the redox gradient of a submarine hydrothermal vent, and 3) panspermia. Each of these theories could be tested with a direct analysis of plume material [3].

*Sample Return Science***:** The primary science objective of the proposed LIFE mission would then be to capture, preserve, and return samples from the Enceladus plume as shown below in an artist's concept, the Saturn E ring and upper Titan atmospheric samples. The secondary science objective of LIFE would be to perform improved in situ measurements complimentary to Cassini's observations of both Enceladus and Titan with increased mass range and sensitivity. The Titan upper atmosphere samples would offer a detailed understanding of the complex organic chemistry and its processing by the 10 AU environment. LIFE would build upon the successful STARDUST sampling approach [9] and make significant augmentations to the sample collector to accommodate volatile samples by including a descoped continuous deposition collector to trap volatiles. Specifically, LIFE would augment the STARDUST success of capturing volatiles by 1) potentially reducing the sample capture speed to as low as 2 km/s, 2) reducing the aerogel entry density by a factor of 5, 3) maintaining sample temperatures well below the sample ambient temperature (~230K), and 4) operating an active volatiles trapping and sealing deposition collector. The trajectory for LIFE would enable multiple flybys and multiple samplings of the Enceladus jets, each at different altitudes and E-ring material of different ages. Since we want to perform multiple samplings, a rotating collector able to expose one sector at a time as shown on the right would be considered.



In situ Science: In situ measurements would provide valuable context for the collected samples. In situ measurements would capture instantaneous portions of volatiles that escape capture or degrade after capture. LIFE would arrive in the Fall and could determine the seasonal variability of the Enceladus jets and Titan atmosphere. Rapid imaging of the jets in multiple flybys would help characterize the dynamics of jetting events.



COST: The most cost-effective and low-risk approach is to adapt as much as possible from the STARDUST mission, which performed on-schedule and under-cost [10]. LIFE's next NASA flight opportunity would be either the 2012 Discovery or the subsequent 2014 New Frontiers Mission.

The 2010 Discovery AO set a cost cap of $425 million along with a basic launch vehicle and up to NASA furnished two Advanced Sterling Radioisotope Generators (ASRG). In a favorable scenario, LIFE could fit within a 2012 Discovery Program cost cap. The 2010 New Frontiers cost cap was $625 million but there would be a need to procure two ASRGs as power sources without a technology infusion subsidy by a Discovery mission. Missing the Jupiter gravity assist in 2014 would cause an increase in the launch vehicle capability and additional operations cost for longer mission duration.

Cost for any large endeavor is highly dependent on the project managing mindset and must include deliberate and careful implementation of rigorous cost control with objectives equal in vigor to any science and engineering requirements. Whether the proposed mission would be implemented as a Discovery or as a New Frontier flight, staying within the project cost caps would require this concerted discipline. If the "design to cost" mindset practiced in STARDUST is vigorously applied to LIFE, another on-cost and on-schedule replication could result.

Summary: LIFE presents a low-cost flyby concept for a sample return mission to Enceladus, a body with high astrobiological potential. There is ample evidence that liquid water exists under ice coverage, in the form of active geyser regions in the "tiger stripes" area of the southern Enceladus hemisphere. Therefore, it is of utmost importance to return samples from Enceladus' plume to Earth for comprehensive analyses by multidisciplinary scientists and sophisticated ground laboratories. Then life in the outer planets could be defined with the nature of its current or past life markers so that some of the theories for the origin of life on Earth could be applied to Enceladus. <u>A mission opportunity such as LIFE proposes is extremely rare: it offers comparable Flagship science but at a low flyby sample return cost.</u>

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