TITAN SUBMERSIBLE EXPLORER –THE CASE FOR SUBSURFACE SAMPLING OF TITANIAN LAKES.

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Abstract: Discoveries from the Cassini–Huygens mission, supported by NASA and ESA, indicate that a number of large liquid hydrocarbon lakes exist in the polar regions of Titan. These findings are significant as they present the first evidence for an "open" stable body of liquid anywhere other than earth. The largest of these, Lake Kraken Mare, covers approximately 40,000 square miles.

The possible existence of an inner water ocean, which could seep into the base of the lake through cryovolcanism, and the search for life and pre-biotic materials, suggest that some of the most interesting chemistry could occur at the bottom of the lake. If the lake is not well mixed by turnover or other mechanism, then a study of these reaction products will require the acquisition of samples from the depths of the lake.

The decadal survey[i] identifies a number of questions specifically relating to Titan's organic rich environment.

- What are the chemistry, distribution, and cycling of organic materials on Titan?
- Is Titan internally active, producing water-rich environments with potential habitability?
- What are the current state and the history of Titan's surface?
- What drives the meteorology of Titan?
- Has there been climate change on Titan?
- Could Titan support life forms that do not require liquid water?

NASA's planetary missions have focused on the search for water – a direction that excludes the possibility that life can arise in the absence of water and by extension, excludes the surface of Titan. Although a consensus on an encompassing definition for life has yet be agreed on, one of the suggested key criteria is the concept that all life requires expenditure of energy in metabolism[ii],[iii],[iv],[v]; hence a more encompassing philosophy than the "search for water" is to "follow the energy"[vi]. The acquisition of chemical energy to support life has become so widely established in microbial ecology that it is recognized that if the substrates of any chemical reaction that yields energy on Earth are available then a microbe has likely evolved to exploit it[vii]. Lakes at Titan[viii] and oceans on Europa represent an enormous chemical source of energy. Correspondingly Titan and Europa contain many sources of electron donors and acceptors, trace complex organics, methane, ethane, benzene, hydrogen cyanide, carbon dioxide, hydrogen, ammonia, and potentially crustal releases of metals and sulfides that could readily be combined in a variety of energy yielding metabolisms . Gradients in these electron donors and acceptors that may drive chemoautotrophic metabolisms are quite likely to exist within Titan's methane/ethane lakes and within the Europan ocean.

All chemoautotrophic metabolisms drive electron donors and acceptors out of chemical equilibrium via assimilation and waste production thus novel distributions of these compounds are key evidence of life (i.e., organic compound pattern recognition via chromatographic separation). Further, the vast majority of autotrophic metabolisms on Earth discriminate against the heavy isotopes in a mass dependent manner that is unique from photolytic driven fractionation and the equilibrium distribution of isotopes that results abiologically. Classical examples on Earth include discriminations evident during photosynthesis, nitrification, denitrification, sulfate reduction, sulfide oxidation, methane oxidation and methanogenesis . Novel isotope fractionations associated with energy yielding reactions are thus recognized as a key approach for the recognition of life[iii],[vi], [vii] . and the exploration of complex organic chemistries. Thus organic pattern recognition in conjunction with stable isotope analysis has become one of the key means to identify the presence of particular metabolic pathways.

A team of Scientists and Engineers, led by Southwest Research Institute (SwRI), performed a study as part of an Internal Research and Development Program (IR&D) to look at how it might be possible to sample and analyze material from the bottom of the lake.). The researchers believe a submersible explorer will help maximize the value of a Titan Saturn System Mission. The study evaluates the feasibility of a submersible explorer concept and addresses, at a high level, the primary design challenges that must be overcome for this concept to progress to a detailed design level. They include thermal, structural, buoyancy control, power, instrumentation, communication, mass distribution and risk mitigation topics.

The Titan Submersible Explorer (TSE) is a simple concept that has been designed to maximize science return from a harsh environment. The mission can be viewed as comprising three phases; aeroentry, lake surface analysis and lake subsurface analysis. To minimize the effect of any possible failure, data is returned to the orbiter at each phase before commencing the next phase. See Figure 1 for in-situ mission operations.

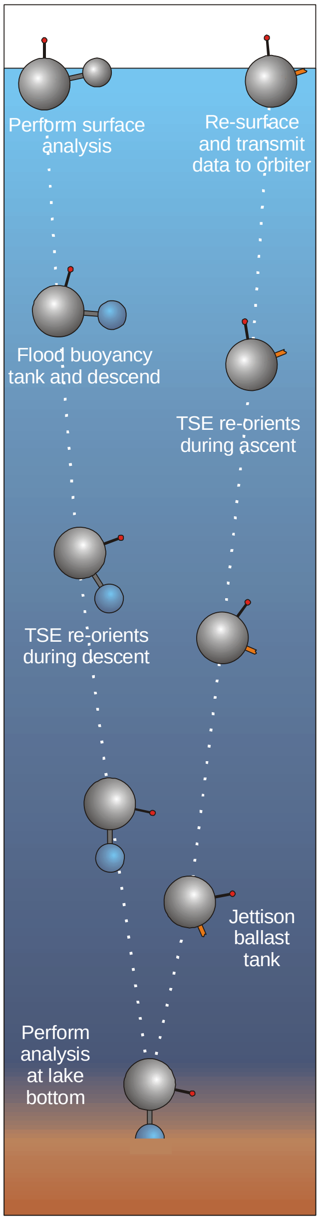

Figure 1.

Similar to the Huygens probe, the TSE will be targeted and released by a delivery spacecraft, to enter Titan's atmosphere and descend into Kraken Mare or one of the larger lakes. The battery powered TSE is tasked with five primary objectives:

1. To study the high latitude atmosphere by mass spectrometry during the decent phase to the lake,
2. Once on the lake surface, to evaluate the surface chemistry and lake depth using sonar measurements,
3. To evaluate chemistry at the bottom of the lake,
4. To analyzed a sample of lake bottom sediment,
5. To monitor tidal changes over two Titanian days.

Three instrument systems will be carried within the TSE. The Temperature, PResure and Motion (TPM) package, The Acoustics Package (AP), and the Mass Spectrometer and Inlet system (MSI)

The TSE offers a low risk approach to providing significant data return for use in answering the scientific questions posed about Titan in the decadal survey. TSE provides significant data return from a location that is widely accepted to be significant to the evolution of Titan. With additional mass the TSE mission could accommodate additional science programs to study the polar atmosphere on descent and also to study the composition of the lake sediment.

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