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The Titan Mare Explorer Mission (TiME): A Discovery mission to a Titan sea

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Abstract

The Titan Mare Explorer (TiME) is a Discovery class mission to Titan, and would be the first in situ exploration of an extraterrestrial sea. The mission is one of three recently chosen by NASA for a Phase A study; one mission will be downselected for launch in the summer of 2012. TiME is a lake lander, which would float on the surface of a sea, performing chemical, meteorological and visual observations.

1. Introduction

Prior to the Cassini-Huygens mission to the Saturn system, oceans of liquid hydrocarbons were hypothesized to cover much of the surface of Titan (e.g., 1). Initial data from Cassini-Huygens instead found the equatorial and mid-latitude regions to be relatively dry, characterized by riverbeds and "seas" of dunes (e.g., 2, 3). The discovery of more than 400 lakes and seas in Cassini radar data [4, 5] ranging in size up to 100,000 km^2 [5] confirmed the expectation that liquid hydrocarbons exist on the surface of Titan. A wide range of evidence shows that the largest of these are liquid bodies [6, 7]. The lakes and seas provide the first evidence for an active condensable-liquid cycle on another planetary body. The Titan Mare Explorer (TiME) is a Discovery-class mission, cost-capped at $425 million, which would constrain Titan's active methane cycle as well as its potentially interesting prebiotic organic chemistry by providing in situ measurements from the surface of a Titan sea.

Titan's lakes and seas are hypothesized to fill through rainfall and/or intersection with the subsurface liquid hydrocarbon table, and are likely hold some combination of liquid methane and liquid ethane. Titan's seas probably contain dissolved amounts of many other compounds, including admixtures of nitrogen and organic species, as the seas are a sink for the products of photolysis in the atmosphere. The methane cycle on Titan is dominated by precipitation in polar regions and evaporation in equatorial regions, allowing the seas to persist near the North and South Poles [8].

The stability of lakes and seas on Titan is dependent upon the abundance of methane in the atmosphere-surface system, as well as liquid methane in the subsurface. Ethane, under Titan surface conditions, is a dominant product of methane stratospheric photochemistry, and its presence in the seas would increase their stability against evaporation [9]. The methane/ethane ratio in the lakes is unknown and is not likely to be definitively determined with current data, but ethane has been identified in Ontario Lacus [6], late winter tropospheric clouds (which must be largely methane) have been identified above the lakes region [10], and methane and ethane were detected by the Huygens probe after landing [11]. Determining the methane/ethane ratio is critical to constraining the significance of the sources of methane on Titan. In addition to likely seasonal changes in lake composition and depth [10, 12], Titan's lakes and seas may take part in longer-term pole-pole transport forced by the changing astronomical configuration of the seasons, similar to the manner in which the glacial cycles of Earth and Mars are forced by Croll-

After the Cassini mission, many aspects of the lakes and seas of Titan will remain unknown or poorly understood, including their composition, physical properties, depths, and shoreline characteristics, all critical to understanding Titan's active methane cycle. Titan's lakes and seas are also an important astrobiological target. It cannot be ruled out that further chemistry may take place on the surface, yielding prebiotic molecules impossible to form in the gas phase. The only way to understand Titan's methane cycle, its climate, and its prebiotic chemistry are through in-situ chemical analysis and observations.

2. Mission Description

The primary target for the TiME mission is Ligeia Mare (78°N, 250°W), one of the largest seas on Titan with a surface area of ~100,000 km^2. Kraken Mare, to the south of Ligeia, is a potential backup target. TiME science objectives are: 1) measure the sea chemistry to determine their role as a source and sink of methane and its chemical products, 2) measure the sea depth to help constrain organic inventory, 3) constrain marine processes including sea circulation and the nature of the sea surface, 4) determine sea surface meteorology, and 5) constrain prebiotic chemistry in the sea. TiME instruments include a mass spectrometer, a physical properties and meteorology package, and imaging systems. The science objectives of TiME are directly responsive to goals from the 2003 and 2010 Solar System Decadal Surveys [14, 15], including understanding volatiles and organics in the solar system, through TiME measurements of organics on another planetary object, and understanding planetary processes, through TiME's first in situ measurements of a liquid cycle beyond Earth.

We plan a launch date of January 2016, with an arrival in 2023. Both Earth and sun remain above the horizon for the three-month minimum lifetime of the mission, during which TiME collects and transmits data from the sea surface. A launch date for TiME before 2020 is enabling; launching after that date would result in an arrival during northern winter on Titan, after the sun and Earth have set, making direct to Earth transmission infeasible, and minimizing science observations of the sea surface, atmospheric phenomena, and shorelines.

The TiME Discovery mission would test the Advanced Stirling Radioisotope Generators (ASRGs) Its high heritage instruments, simple surface operations, government-furnished launch and power systems, and relatively benign entry, descent and landing conditions make a lake lander mission to Titan achievable as a Discovery-class mission.

3. Summary and Conclusions

TiME would provide the first in situ exploration of an extraterrestrial sea and the first in situ measurements of an active liquid cycle beyond Earth. By directly sampling the sea liquids, it would aid in understanding the limits of life in the solar system. TiME would return data from Titan by 2023, capturing critical science well in advance of future flagship class missions. The Phase A study for the TiME mission will be completed in April, 2012, with NASA downselecting one of the three Phase A Discovery mission concepts for implementation in the summer of 2012.

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