OCEANUS: A NEW FRONTIERS MISSION CONCEPT TO STUDY TITAN'S HABITABILITY

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Introduction: The New Frontiers 4 AO includes the Ocean Worlds Titan and Enceladus. For Titan, the science goals are (i) Understand the organic and methanogenic cycle on Titan, especially as it relates to prebiotic chemistry; and (ii) Investigate the subsurface ocean and/or liquid reservoirs, particularly their evolution and possible interaction with the surface. The *Oceanus* mission concept would addresses these two science goals plus other important science questions defined by the 2011 Decadal Survey [1].

Cassini/Huygens has demonstrated that Titan is an organic world of two oceans: surface hydrocarbon seas [2,3] that cover part of the north polar region and a subsurface deep water ocean [4] that decouples the outer ice crust from an inner core likely composed of hydrated silicates [5]. *Oceanus* is a Titan orbiter that would follow up on these amazing discoveries and assess Titan's habitability by following the organics and examining the atmospheric photochemistry, surface organic transport and methane cycle history, and potential for transport of surface organics to the deep subsurface ocean.

Titan's reduced nitrogen-rich atmosphere is an organic factory [6] where complex organic molecules are produced by a series of reactions starting from the photolysis of methane [7,8]. Titan's 90-95 K surface temperature and 1.5 bar surface pressure permits methane to condense out of the atmosphere and flow as a liquid on the surface. As a result, Titan's methane-based hydrologic system produces a rich set of geologic features (river networks, alluvial fans, polar lakes/seas, etc.) that mimic Earth with its water cycle. Understanding this rich geomorphology is limited by *Cassini's* kilometer-scale imaging resolution. *Oceanus* would take advantage of being in Titan orbit to acquire 25 m/pixel images of Titan's diverse surface [9].

Laboratory studies have shown that exposure of simulated Titan organics to water generates prebiotic molecules such as amino acids and nucleobases [10, 11]. *Oceanus* would investigate Titan's interior properties to determine if the ice shell is convecting, and image candidates for cryovolcanic, impact, and tectonic processes that could facilitate exchange with the interior and exposure of surface organics with liquid water.

Science Questions and Investigations: The discoveries of *Cassini/Huygens* raise several questions related to Titan's astrobiological potential: What are the synthesis pathways and compositions of the heavy organic molecules produced in Titan's atmosphere? How much oxygen is incorporated into these upper-atmosphere complex organics? Are there places on the surface or in the subsurface where this organic material may have been in contact with liquid water (e.g., impact melt pools, cryovolcanic flows)? How thick is the ice shell and is it convecting? Answers to these questions aid the assessment of Titan's habitability and the organic chemistry of early Earth, which had a more reduced atmosphere at the time life emerged [12].

Oceanus would address these questions with three high-heritage instruments: a mass spectrometer (high–resolution *in situ* measurements of the organic material over a large mass range and at different altitudes), an infrared camera (high signal/noise images of Titan's surface at 1500 km altitude at 1.3, 2, and 5 µm), and a radar altimeter (global topography and measurements of tidal deformation). All of these measurements improve on *Cassini* by orders of magnitude.

Chemistry: The mass spectrometer investigation would determine (i) the processes at work to form the heavy molecules, and (ii) the amount of oxygenated functional groups incorporated into atmospheric organics, and (iii) the multi-stage MS fragmentations pattern of large molecules providing information on their likely composition and how they were synthesized.

Geology: Titan's wide variety of geologic features would be targeted with an order of magnitude better spatial resolution, SNR, and topographic measurements.

Geophysics: Transport from the surface to the potentially convecting interior would greatly increase the habitability of the subsurface ocean, by supplying the building blocks for life to a water-rich environment. Using radar altimetery, gravity science tracking experiments, and stereo imaging, *Oceanus* would determine how thick and rigid the ice crust is, its deformation history, and whether it is convecting.

Acknowledgments: This work has been performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract to NASA.

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