EPSC Abstracts
Vol. 11, EPSC2017-157-1, 2017
European Planetary Science Congress 2017

OCEANUS: A New Frontiers mission concept to study Titan's potential habitability

C. Sotin (1), A. Hayes (2), M. Malaska (1), M. Mastrogiuseppe (3), E. Mazarico (4), J. Soderblom (5), P. Tortora (6), M. Trainer (4), E. Turtle (7) and the OCEANUS Science Team
(1) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA (Christophe.Sotin@jpl.nasa.gov), (2) Department of Astronomy, Cornell University, Ithaca, NY 14853, USA, (3) Sapienza Universita Di Roma, Roma, Italy, (4) Goddard Space Flight Center, Greenbelt, MD, USA, (5) MIT, Boston, MA, USA, (6) Dipartimento di Ingegneria Industriale, Università di Bologna, Forlì, Italy, (7) Johns Hopkins Applied Physics Lab, Laurel, MD, USA.

Abstract

Oceanus is a proposed Titan orbiter that would characterize Titan's habitability globally. It would decipher organic photochemistry in the atmosphere, observe the transport pathways of organics on the surface, locate near-surface liquid water and evaluate its longevity, and discern processes that may transport organics into the ocean. It would carry a multistage mass spectrometer, an IR camera that sees through Titan's atmosphere, and a radar altimeter. It would spend two years in Saturn's orbit with 20 Titan flybys followed by two years in a circular polar orbit around Titan.

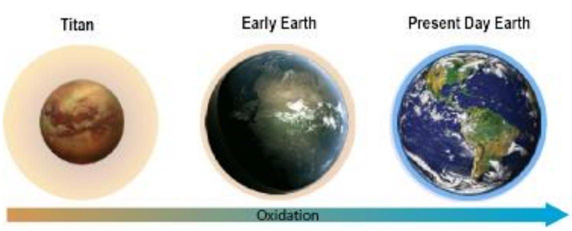

Figure 1: Oceanus would determine the details and mechanisms of the organic chemical pathways on Titan and would teach us about the fundamental chemical processes that can occur on potentially life-bearing "pale orange dots."

1. Introduction

The Decadal Survey describes Titan as the most accessible location in the solar system for studying planetary organic chemistry, including prebiotic and potentially exotic biochemistries [1]. It's an Ocean World with a methane-rich reducing atmosphere, similar to early Earth's [e.g.,2,3]. On Earth, synthesis of complex organics from methane may have created an orange hazy layer. Before Earth was a 'pale blue dot' (Fig. 1), it may have been a 'pale orange dot' like Titan [4]. On Earth, methane-producing organisms evolved early, and the atmosphere remained reducing for about a billion years after the origin of life. If other worlds follow Earth's path, 'pale orange dots' may be widespread in the universe. By studying Titan, Oceanus would provide insight into the chemistry, geology, and geophysics of exoplanets with reducing atmospheres [5].

2. Proposed Science goals and objectives

Oceanus would follow the organics from their synthesis in the upper atmosphere to their hydrolysis in subsurface water reservoirs. With its four science goals, Oceanus would address the two objectives stated in the New Frontiers AO for Titan: (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. Science Goal 1 reveals the workings of organic chemistry in the upper atmosphere and whether biologically relevant elements (oxygen) and repeating subunits (e.g., HCN) are incorporated into large organic molecules. Science Goal 2 investigates how organics are transported across the surface, where they have accumulated, and where processed organic materials have been eroded. Science Goal 3 examines impact craters and candidate cryovolcanic features to determine whether organics have been in contact with near-surface liquid water, or where water deposits, such as ice dikes and sills, were emplaced in organic sediments in the subsurface. Science Goal

4 determines if pathways exist for the transport of surface organics to the subsurface ocean. It studies Titan's tectonic history; detects crustal thickness, thermal properties, and mass distribution; and answers whether Titan's ocean is in contact with the rocky core.

These science goals lead to eleven science objectives which can be addressed by a payload of three instruments and the gravity investigation.

3. Instruments

The proposed payload is composed of three instruments. The first instrument is a multistage quadrupole ion-trap mass spectrometer with mass range of 2-1000 Da (10x higher range than Cassini, and 100x higher sensitivity). It would inventory organic molecules in Titan's atmosphere at multiple altitudes down to 750 km. Oceanus would provide a unique data set of organic molecules built in an environment common to a number of planets in the solar system and beyond.

The second instrument is a camera tailored for Titan. The Cassini mission has demonstrated that Titan's surface can be observed in seven infrared atmospheric windows [6]. The Oceanus camera can see through the atmosphere in three colors (1.3, 2.0, and 5 μm). Oceanus has the capability to image half of Titan's surface at <70 m resolution (Fig.2), including at least eight fluvial networks, four basins, three craters, three cryovolcanic regions, and five tectonic features.

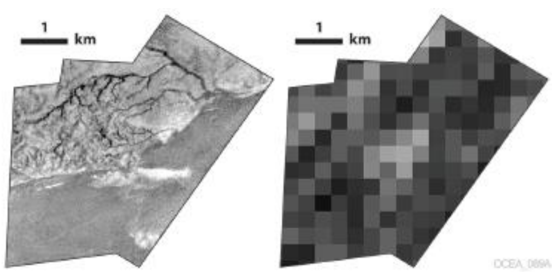

Figure 2: **(Left)** Oceanus would image up to 50% of Titan at $\leqslant$70-m resolution, similar to the DISR mosaic acquired over <0.002% of the surface during the Huygens descent (~100-m resolution). (**Right**) Cassini SAR image of the same area at ~1-km resolution. Cassini SAR mapped less than 50% of Titan.

The third instrument is an X-Band radar altimeter with 1-m vertical resolution. Combined with gravity science, it would measure tidal deformation, crustal thickness and viscosity, lateral density variations, and other interior properties to learn whether the ocean is in direct contact with the silicate core. Oceanus would provide a global coverage with 1-m vertical resolution and spatial posting of <100 km at the equator

Oceanus would be launched in 2024, with a 10-year cruise. The spacecraft would spend two years orbiting Saturn with 18 science flybys of Titan as close as 750 km followed by another two years in a 1500-km circular, 5-hr polar orbit. In its first day orbiting Titan, Oceanus would spend more time close to Titan than Cassini has with 127 targeted flybys in 13 years.

4. Summary and Conclusions

Oceanus would answer fundamental questions about organic synthesis in planetary atmospheres. In situ observation of Titan's complex photochemistry is key to understanding the evolution of other worlds with atmospheric methane photolysis, including ice giants, Pluto, early Earth, early Mars, and exoplanets. Oceanus would investigate the transport of organic material on Titan's surface, characterizing the myriad processes that affect surface evolution on sedimentary worlds. Revealing Titan's interior structure and the properties of its crust and internal ocean would reframe our understanding of the construction and habitability of ocean worlds.

Acknowledgements

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

References

[1] Squyres et al., (2011) The National Academies Press. [2] Ueno et al., (2006) Nature, 440, 516–519 [3] Trainer et al. (2004) Astrobiology, 4, 409-419 [4] Trainer et al. (2006) Proceedings of the National Academy of Sciences, 103, 18035–18042. [5] Arney et al. (2016) Astrobiology, 16, 873-899 [6] Sotin C. et al. (2005) Nature, 435, 786-789.