OCEANUS: A NEW FRONTIERS ORBITER TO STUDY TITAN'S POTENTIAL HABITABILITY C. Sotin[1], A. Hayes[2], M. Malaska[1], F. Nimmo[3], M. Trainer[4], M. Mastrogiuseppe[5], J. Soderblom[6], P. Tortora[7], J. Hofgartner[1], O. Aharonson[8], J. W. Barnes[9], R. Hodyss[1], L. Iess[5], R. Kirk[10], P.Lavvas[11], R. Lorenz[12], J.I. Lunine[2], E. Mazarico[4], A. McEwen[13], C. Neish[14], C. Nixon, E. Turtle[12], V. Vuitton[15], R. Yelle[13]. [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA. [2]Department of Astronomy, Cornell University, Ithaca, NY 14853, USA. [3]Department of Earth and Planetary Science, University of California at Santa Cruz, USA. [4]NASA Goddard Space Flight Center, Greenbelt, MD, USA. [5]Sapienza Universita Di Roma, Roma, Italy. [6]MIT, Boston, MA, USA. [7]University Bologna, Italy. [8]Tel Aviv University, Israel. [9]Department of Physics, University of Idaho, Engineering-Physics Building, Moscow, ID 83844, USA. [10]U.S. Geological Survey, Astrogeology Science Center, Flagstaff AZ 86001, USA. [11]Groupe de Spectrométrie Moléculaire et Atmosphérique UMR CNRS 7331, Université de Reims Champagne Ardenne. [12]Applied Physics Laboratory, John Hopkins University, USA. [13]Department of Planetary Sciences, University of Arizona, Tucson, AZ 85721, USA. [14]Planetary Science Institute, Tucson, AZ 85719, USA. [15]Université Grenoble Alpes, CNRS, IPAG, F-38000 Grenoble, France (Christophe.sotin@jpl.nasa.gov).

Introduction: Cassini has demonstrated that Titan is an organic world of two oceans: surface hydrocarbon seas [1,2] that cover part of the north polar region and a deep water ocean [3] that decouples the outer ice crust from an inner core likely composed of hydrated silicates [4]. Oceanus is an orbiter that would follow up on Cassini's amazing discoveries and assess Titan's habitability by following the organics through the methanologic cycle and assessing exchange processes between the atmosphere, surface, and subsurface.

Titan's reduced nitrogen-rich atmosphere operates as an organic factory [5] where heavy organic molecules are produced by a series of reations starting by the photolysis of methane [6,7]. These organics coat Titan's surface and are moved around through a complex source-to-sink sediment transport system analogous to surface processes here on Earth. Titan's 90-95 K surface temperature at 1.5 bar surface pressure permit methane and ethane to condense out of the atmosphere and flow as liquids on the surface. As a result, Titan's methane-based hydrologic system produces a rich set of geologic features (dunes, river networks, polar lakes/seas, etc.) that mimic Eath's water cycle. Cassini's observations of this rich geomorphology is hindered by kilometer-scale resolution. Oceanus will take advantage of a narrow atmospheric window at 5 µm to acquire 25 m/pixel (< 100 m resolution) images of Titan diverse surface [8].

The presence of ^{40}Ar, a product of the decay of ^{40}K contained in the silicate core, and methane whose origin is still controversial (primordial methane trapped in the interior or methane being a byproduct of the hydration of Titan's silicate fraction) argue for exchange processes between the interior and the atmosphere. Like we see here on Earth, these processes will be chronicled in the interaction between geological features on Titan's surface. Oceanus will investigate specific features identified by Cassini as potential candidates for cryvolcanism, impact, and tectonic processes that could facilitate exhance with the interior.

The New Frontiers 4 AO includes the theme "Ocean Worlds (Titan and/or Enceladus)" focused on the search for signs of extant life and/or characterizing the potential habitability of Titan and/or Enceladus. The Titan's science objectives 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. Oceanus not only addresses these two science objectives but would also be responsive to a large number of the important science questions defined by the 2013 Decadal Survey.

Science questions and investigations: The discoveries of the Cassini missions have triggered several questions related to Titan's potential habitability. What is the composition of the heavy organic molecules produced in Titan's atmosphere? Are they prebiotic molecules? How much oxygen is incorporated into these molecules. As they fall on the surface and are subject to Titan's sediment transport system, which includes both fluvial and aeolian processes, are there places in the subsurface or surface where this organic material may have been in contact with liquid water (e.g., impact melt pools, cryovolcanic flows)? Where is the ethane, a main product of the photolysis of methane, trapped? How thick is the crust? Is it convecting and therefore releasing internal heat very efficiently? Answers to those questions will not only inform on Titan's potential habitability but will also shed light on the organic chemistry that occurred on early Earth when Earth had a more reduced atmosphere at the time life emerged [REF].

Oceanus will address these questions with three high-heritage instruments that will address the potential habitability of Titan: an infrared camera that would acquire 25 m pixel size images of Titan's surface at 1500 km altitude, a radar altimeter that would provide a global topography and measurements of the time-dependent deformation of Titan's surface, and a mass spectrometer capable of chareacterizing the processes that build the heavy molecules fabricated in Titan's upper atmosphere as well as determining their building blocks. In addition, information on the gravity field would be obtained from the Doppler shift of the microwave carrier used in the radio link to the ground.

Three investigations cover the needs to address Titan's potential habitability: organic geochemistry, geology and geophysics. With imaging and greatly improved measurements of static and time-dependent gravity and topography measurements, Oceanus would determine how thick and rigid the crust is, its deformation history and whether it is convecting. Transport from the surface to the interior would greatly increase the habitability of the subsurface ocean, by supplying the building blocks for life to a water-rich environment. The mass spectrometer will perform high–resolution in situ measurements of the organic material over a large mass range and at different altitudes. It will provide the information required to determine (i) the processes at work to form the heavy molecules, (ii) the functional group pattern of large molecules providing information on their composition. Some of these molecules are known to be important for biochemical processes on Earth, such as amino acids and nucleobases. Titan displays a large variety of geological features that can be revisited selectively with a high resolution infrared camera. Exploring these features with an order of magnitude increase in spatial resolution and SNR will allow Oceanus to "Explore and understand the processes common to Earth that occur on another body, including the nature of Titan's climate and weather and their time evolution, its geologic processes, the origin of its unique atmosphere, and analogies between its methane cycle and Earth water cycle" (Decadal Survey, 2013). The process interactions observed between geomorphologic features on Titan chronicle the history of its landscape evolution and elucidate the transport of organics between the subsurface, surface, and atmosphere.

Conclusion: Titan is a moon that resembles a planet with active processes at work. The Cassini mission has demonstrated that organics and water, two of the major ingredients for habitability, are present. By following the organics and the water, the Oceanus orbiter will characterize Titan's potential habitability.

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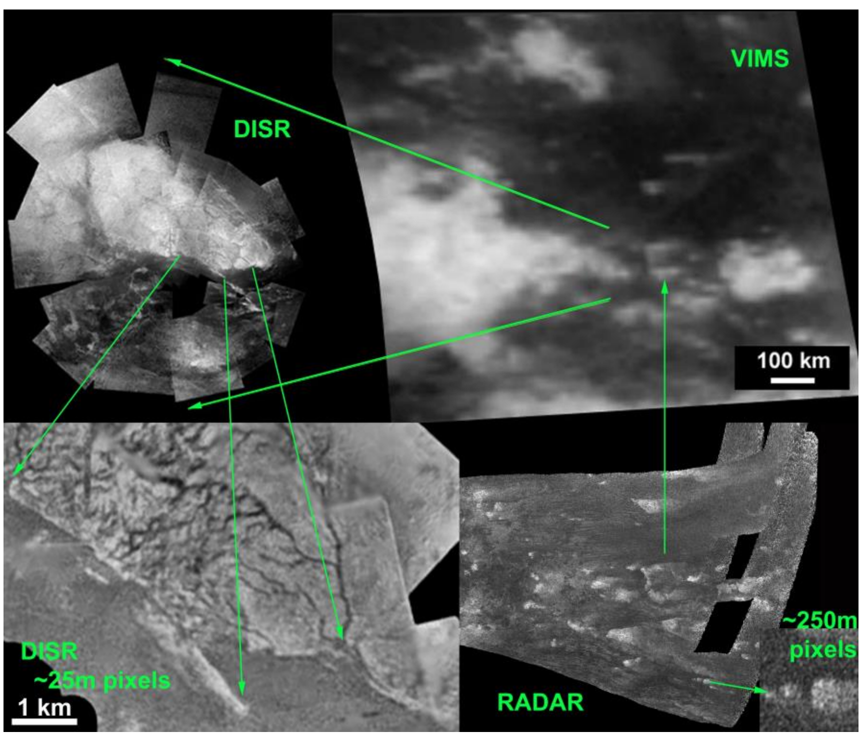

Fig.1 : A 25 m pixel scale image provides details at the level of the images acquire by the Huygens probe a few kilometers above Titan's surface. Features such as streams that are observed in the 25 m Huygens images are unseen in the 250 m RADAR images.