Titan Submarines! *S.R. Oleson[1] , Ralph Lorenz[2], Michael Paul[3], Jason Hartwig[1], Justin Walsh [3]*

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Phase 1 Design: The conceptual design of a submarine for Saturn's moon Titan was a funded NASA's Innovative Advanced Concepts (NIAC) Phase 1 for 2014. The proposal stated the desire to investigate what science a submarine for Titan's liquid hydrocarbon (–180 °C) seas might accomplish and what that submarine might look like. Focusing on a flagship class science system (~100 kg) it was found that a submersible platform can accomplish extensive science both above and below the surface of the Kraken Mare (Figure 1). Submerged science includes mapping using side looking sonar, imaging and spectroscopy of the lakes liquid at all depths, as well as sampling of the lake's bottom and shallow shoreline. While surfaced the submarine will not only sense weather conditions (including the interaction between the liquid and atmosphere) but also image the shoreline, as much as 2 km inland.

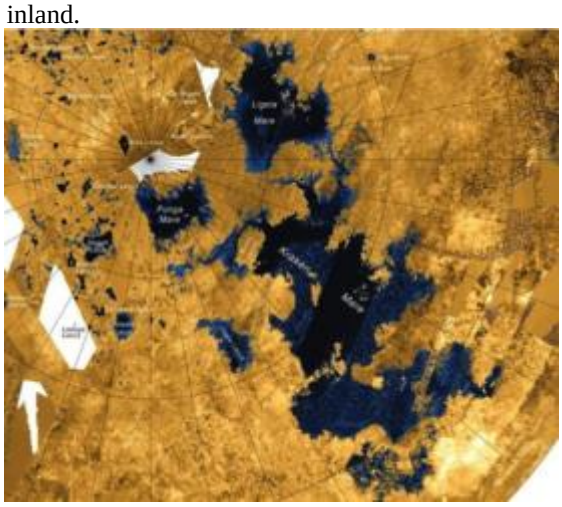

Figure 1—Titan's Seas or Mare in the Northern Hemisphere

This imaging requirement pushed the landing date to Titan's next summer period (~2047) to allow for lighted conditions. Submerged and surfaced investigation are key to understanding both the hydrological cycle of Titan as well as gather hints to how life may have begun on Earth using liquid/sediment/chemical interactions. An estimated 25 Mb of data per day would be generated by the various science packages. Most of the science packages (electronics at least) can be safely kept inside the submarine pressure vessel and warmed by the isotope power system.

The baseline 90 day mission would be to sail submerged and surfaced around and through Kraken Mare investigating the shoreline and inlets to evaluate the sedimentary interaction both on the surface and then below. Depths of Kraken have yet to be sensed (Ligeia to the north is thought to be 200 m (656 ft) deep), but a maximum depth of 1,000 m (3.281 ft) for Kraken Mare was assumed for the design). The sub would spend 20 d at the interface between Kraken Mare and Ligeia Mare for clues to the drainage of liquid methane into the currently predicted predominantly ethane Kraken Mare. During an extended ninety day mission it would transit the throat of Kraken and perform similar explorations in other areas of Kraken Mare. All in all, the submarine could explore over 3,000 km (1,864 mi) in its primary mission at an average speed of 0.3 m/s. The phase I submarine design and some of its attributes are shown in figures 2 and 3.

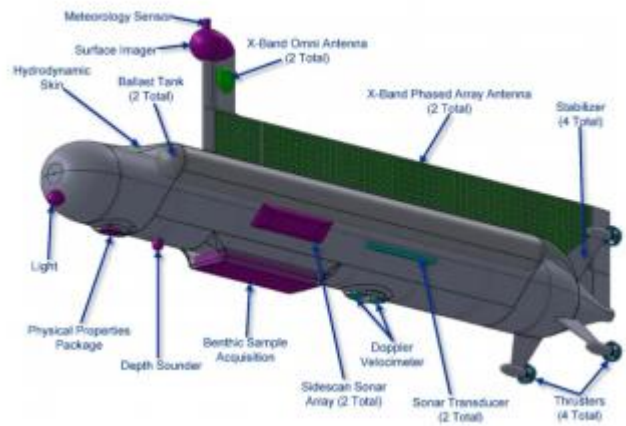

Figure 2—Phase I Titan Submarine – Standalone – External

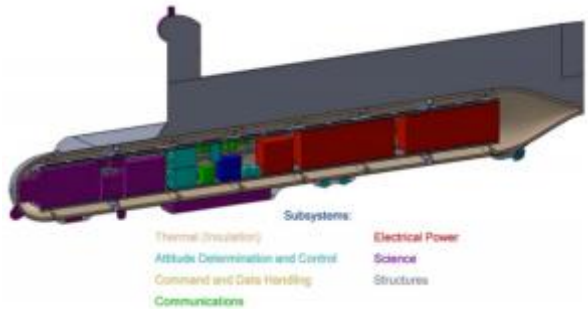

Figure 3—Phase I Titan Submarine – Internal

Phase 2 Designs: A Two year phase II was awarded the team in 2015. Phase II is currently at a half-way point with good results on modeling and testing of Titan Sea mixtures, saturations, and efferevescence which will have great impact on Sub design. The first of two Phase II designs was completed, this time focusing on Ligea Mare and assuming deployment and communications/navigation support from an orbiter. The use of an orbiter allows for earlier arrival, slower transit speeds and most strikingly communications from the bottom of the sea – removing the need for surfacing to communicate. The conceptual design is shown in figures 4-7. It includes the same suite of instruments for sea and sea bed chemical analyses, surface and subsurface imaging, and surface weather sensing.

Current results, plans for phase II completion and steps beyond phase II will be discussed.

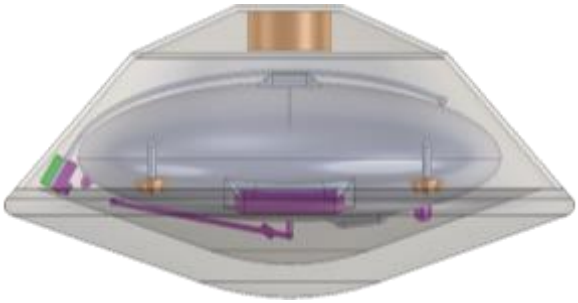

Figure 4. Phase II Orbiter Supported 'Titan Turtle' Submarine in Huygens sized Aeroshell

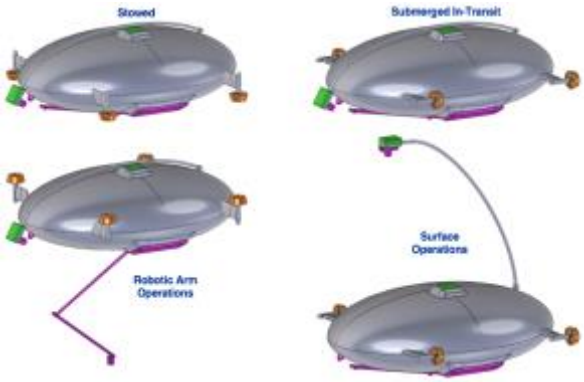

Figure 5. Phase II Orbiter Supported 'Titan Turtle' Submarine in various operational phases

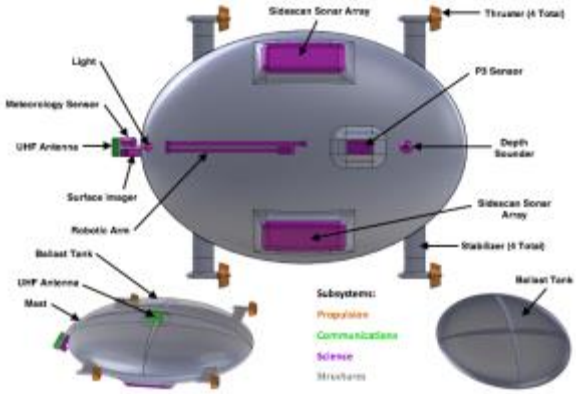

Figure 6. 'Titan Turtle' Submarine External Components

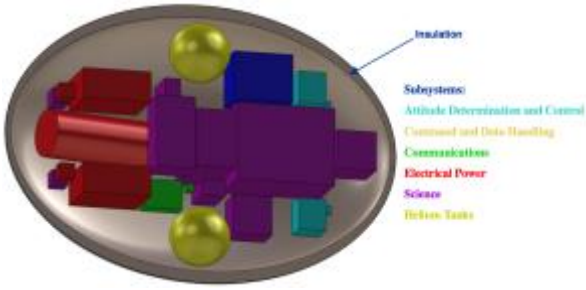

Figure 7. 'Titan Turtle' Submarine Internal Components

References: Oleson, SR, Lorenz, RD, Paul, MV, NASA/TM-2015-218831 Phase I Final Report: Titan Submarined