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Titan Submarine : AUV Design for Cryogenic Extraterrestrial Seas of Hydrocarbons

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Saturn's moon Titan has three seas, apparently composed predominantly of liquid methane, near its north pole. The largest of these, Ligeia Mare and Kraken Mare, span about 400km and 1000km respectively, and are linked by a narrow strait. Radar measurements from the Cassini spacecraft (currently in orbit around Saturn) show that Ligeia at least is 160m deep, Kraken perhaps deeper. Titan has a nitrogen atmosphere somewhat denser than Earth's, and gravity about the same as the Earth's moon, and its surface temperature is about 92K ; the seas are liquid under conditions rather similar to those of liquified natural gas (LNG) a commodity with familiar engineering properties. We report a NASA Innovative Advanced Concepts (NIAC) study into a submersible vehicle able to explore these seas, to survey shoreline geomorphology, investigate air-sea exchange processes, measure composition to evaluate stratification and mixing, and map the seabed.

The Titan environment poses unique thermal management and buoyancy control challenges (the temperature-dependent solubility of nitrogen in methane leads to the requirement to isolate displacement gas from liquid in buoyancy control tanks, and may result in some effervescence due to the heat dissipation into the liquid from the vehicle's radioisotope power supply, a potential noise source for sonar systems). The vehicle must also be delivered from the air, either by parachute extraction from or controlled ditching of a slender entry system, and must communicate its results back to Earth. Nominally the latter function is achieved with a large dorsal phased-array antenna, operated while surfaced, but solutions using an orbiting relay spacecraft and even communication while submerged, are being examined. While these aspects seem fantastical, in many respects the structural, propulsion and navigation/autonomy challenges of such a vehicle are little different from terrestrial autonomous underwater vehicles.

We discuss the results of the study to date, which brought together power/propulsion/space systems expertise from NASA Glenn Research Center, with hydrodynamics, propulsion and operations from the Penn State Applied Research Lab, and the latest Titan understanding from the JHU Applied Physics Lab.