

**The Development of a Submarine for the Exploration of Titan.** A. López<sup>1</sup>, B Rivera<sup>2</sup>, and J. Colón<sup>2</sup> <sup>1</sup>Arecibo Observatory (STAR Academy) (micoral@outlook.com), <sup>2</sup>Arecibo Observatory (SUAGM) (brivera@naic.edu).

**Introduction:** The concept of a submarine for Saturn's biggest moon, Titan would be an enormous accomplishment for humankind. Is it possible humankind can send a submarine for the exploration of another celestial body besides Earth? Yes, the hypothesis of this research states the development of a submarine for the natural satellite is possible and can be developed with the analysis of research and development of innovating ideas. This research considers the possibilities that such a submarine can actually be constructed. The National Aeronautics Space Administration is in the process of building a submarine for Titan. Still, there are differences between the NASA's submarine and the one being designed in this project [1]. Characteristics such as the efficiency of the submarine, how can the submarine obtains data of the celestial body, and if the submarine is sustainable in the conditions on Titan are analyzed and explained.

The information the submarine is capable of collecting could help in further studying Titan, such as identifying if there could be living organisms. Knowing more of how Titan works as a system, can help us better understand Earth. There is an average amount of information of the natural satellite Titan, obtained from the spacecraft Cassini and the Huygens probe [2]. The data of the probe contributed with the selection of the specific destination in Titan that could be explored, technologies that should be applied, the design of the submarine, and other details.

**Titan:** Due to Titan's dense atmosphere, the moon remained a mystery for a long period of time. The atmosphere's orange organonitrogen kept the surface of Titan a secret. With the Cassini spacecraft and the Huygens probe it was possible to uncover what was under that orange haze. The Cassini-Huygens mission was successfully able to land the Huygens probes on Titan's surface. At the beginning, the probe could only see an orange haze, but then when it was closer to the ground it caught astonishing photos of Titan. In the photos, rock formations that looked like mountains could be seen, and one of the details that caught most attention was the dendritic rain patterns. This dendritic rain patterns made scientist assume there were traces of rivers in Titan. The Huygens data helped create lakes and seas maps, and a global geological map [3]. The geological map was used to decide where it would be the optimal target for our submarine design.

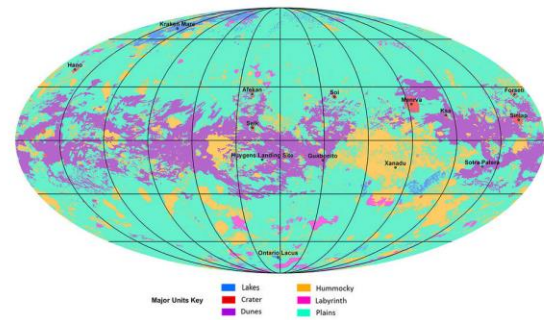


Figure 1: Geological Map of Titan, NASA/JPL-Caltech/ASU

The Kraken Mare is the largest body of liquid in Titan. The Kraken Mare is considered a sea not a river because it is bigger than the Caspian Sea on Earth. It lounges over approximately 1000km towards mid-latitudes. An estimate of the depth appears to be 160 meters, but it may not be the actual depth. The sea covers an area of 154,441 square miles approximately. Kraken Mare appears to have an island called Mayda Insula. The sea can be connected hydrologically to the second largest sea Ligei Mare. The submarine would advance near this island to it with detail. The Sea is divided into three parts, Kraken-1, Kraken-2 and The Throat of the Kraken. The throat of the Kraken Mare is speculated to have currents [4]. Depending on how tides and wind currents move in Kraken, it is plausible the composition or thermal stratification occur. On Titan tidal forces are strong because of Saturn's large gravity, but the tidal forces change to slower periods; this is due to the 15.945 Earth day orbit period. A slower period indicates the resonant tides are improbable, nonetheless, tidal amplitudes have been detected of few of tens of centimeters on the Kraken Mare with the velocity of currents of a few centimeters per second. The exact composition is unknown, but it is known the sea is mostly composed of methane and has ethane, nitriles and higher hydrocarbons [5]. This composition could increase the density, viscosity and dielectric constant. The density of methane is 0.656 kg/m<sup>3</sup> and ethane is 1.36 kg/m<sup>3</sup>. The density of both methane and ethane is approximately 2/3 that of water meaning the viscosity will be similar to water. The submarine will be exploring the Kraken-1 and possibly the Kraken-2 region too. The Throat of the Kraken is an area that submarine most likely will not be exploring. This is because it is speculated that this area contains larger currents and possibly whirlpools. This location would not be optimal for the submarine.

**Design:** One of the most important elements to analyze is the material of the submarine, since most of the other branches of the design rely on this fact. The overall idea of the submarine's composition is that it will have three layers. The first layer will be composed of a material that will resist the  $-179^{\circ}\text{C}$ . This material will be located at the outer part of the submarine. The second layer an insulator. The third layer located in the inside of the submarine will be a material that will let the heat escape slowly and maintain a specific amount of heat inside. Each of the materials selected complies with a specific purpose. The outer part layer made of a material resistant to temperature  $-179^{\circ}\text{C}$  will help the submarine be able to resist Titan's conditions. The second layer is an insulator which will have a function of not allowing the cold temperature of Titan affect inside of the submarine. The third layer will be the material that will allow the heat to escape slowly because if the heat inside the submarine escapes fast it will make the methane boil thus making bubbles creating difficulties for the submarine.

**Technologies:** The various types of technology, such as sensors and other instruments will help identify and acquire important data such as the depth and chemistry of the Kraken Mare, more information about the tides, seasons, geological information of Titan and furthermore. The most asked questions such as can there be a carbon-based life form or can the exploration of the Kraken Mare hold clues to how life originated on our planet, technologies inserted in the submarine may answer questions like those.

**Engine:** The nuclear engine produces internal combustion which is one of the characteristics that makes it suitable for the submarine. The nuclear fusion engine consists of a primary circuit and a secondary circuit. The primary circuit consist of a reactor, a coolant pump, pressurizer and a steam generator. In the reactor the nuclear fusion is happening in, the reactor connects to the pressurizer and the main coolant pump. Eventually, the tubes pass through the steam generator. In the steam generator, there will be water so steam can be formed and go to the secondary circuit. When the steam is in the secondary circuit in will be directed into two paths. The first path of steam will pass through a throttle, eventually powering the main turbine. The main turbine will be connected to a clutch that will also be connected to an electrical propulsion motor. The electrical propulsion motor will be attached to a reduction gearing and a thrust block. The second path that the steam takes leads to powering a turbo generator, the turbo generator powers cable with electricity. The electricity cables run thru the motor generator to the main condenser then the electrical propulsion motor it will also be directed to a battery and eventually the cable also leads to the primary

circuit where it connects to the main coolant pump and the pressurizer. The engine will also have a cooling system so the temperature of the whole submarine can be the same. Approximately the engine should be able to function for seven years.

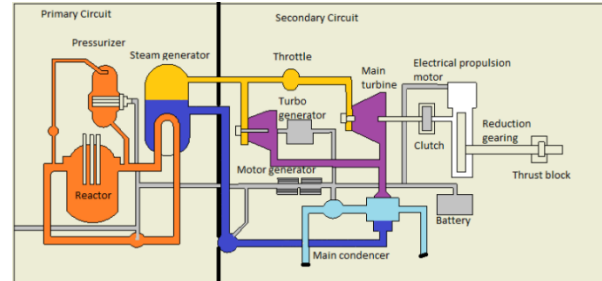


Figure 1: Nuclear Fusion Engine Design

**Conclusion:** The development of a submarine for Titan can be possible. Research helped construct this project part by part, making it possible to hypothetically visit Titan and complete a mission acquiring important data of the natural satellite. With this project we could successfully collect new data of Titan, making great scientific discoveries. The results this submarine design could be the building blocks of more complex studies and designs.

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