

Titan submarines: a state-of-the-art review of their development

*Based on the works of Hartwig, Lorenz and Oleson, as well as NASA papers

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Introduction

- Titan, the largest moon of Saturn, has methane-ethane lakes at its poles
- The lakes were only investigated from Voyager 1 and the Cassini probe
- Submarines were suggested to investigate

Mission Design

- Explore Kraken 1
- Investigate the Kraken-Ligeia throat
- Reach Kraken 2 using the throat, if possible
- 1 year duration

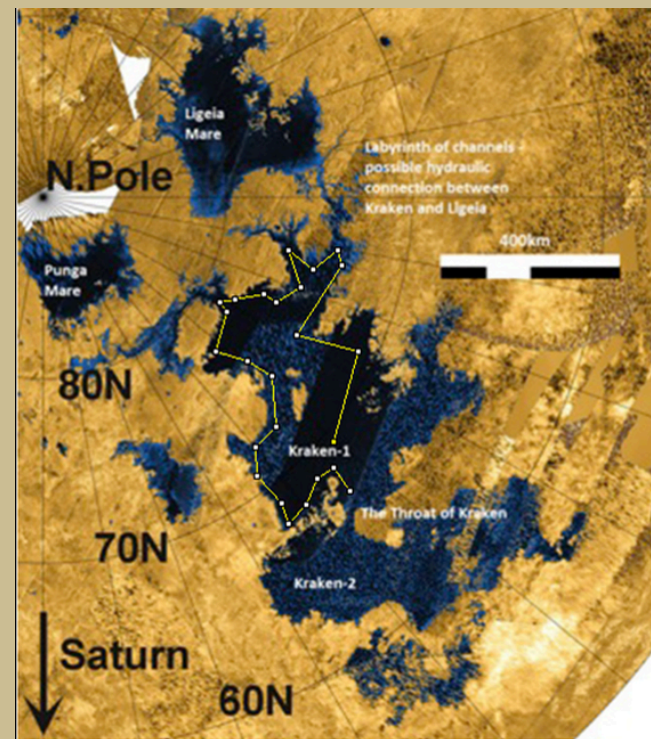


Fig 1. Phase 1 of the mission

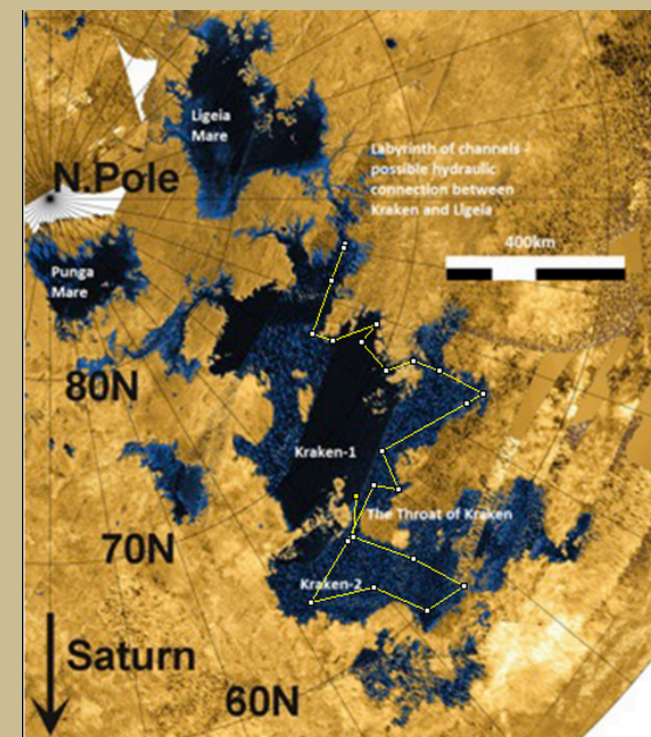


Fig 2. Phase 2 of the mission

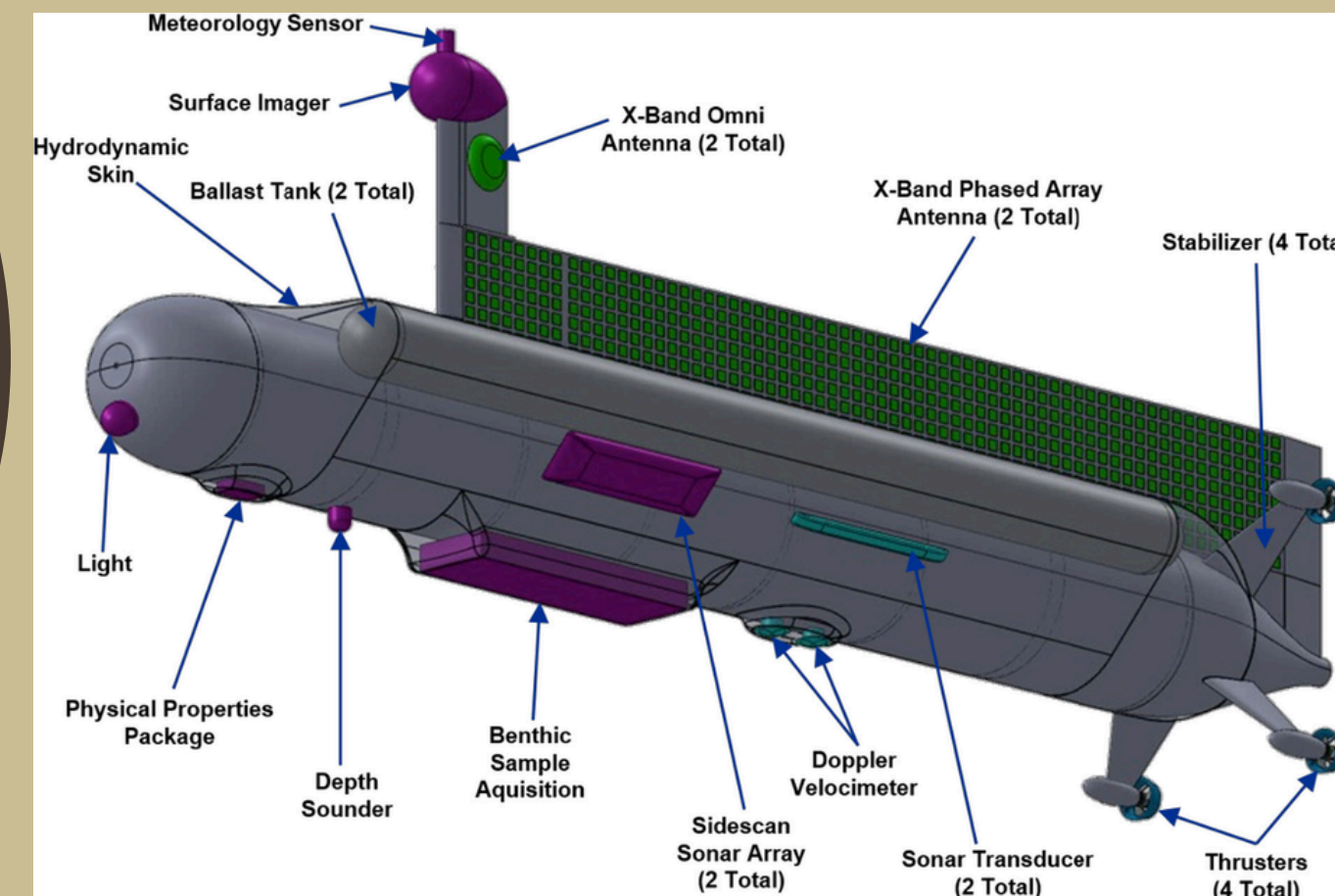


Fig 3. Titan submarine design

Submarine design

- X-ray phase array antenna maintains constant contact with Earth
- Sonars and Doppler velocimeters
- Sample acquisition
- Ballast tanks
- Thermal
- Electrical Power
- Attitude Control
- Command and Data handling
- Science

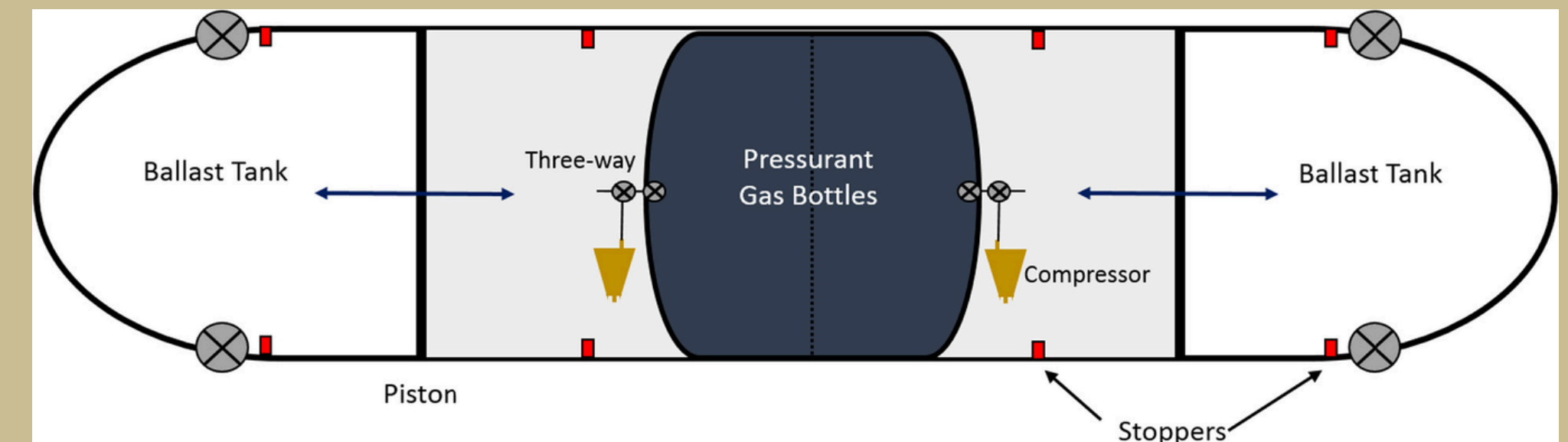


Fig 5. Ballast system

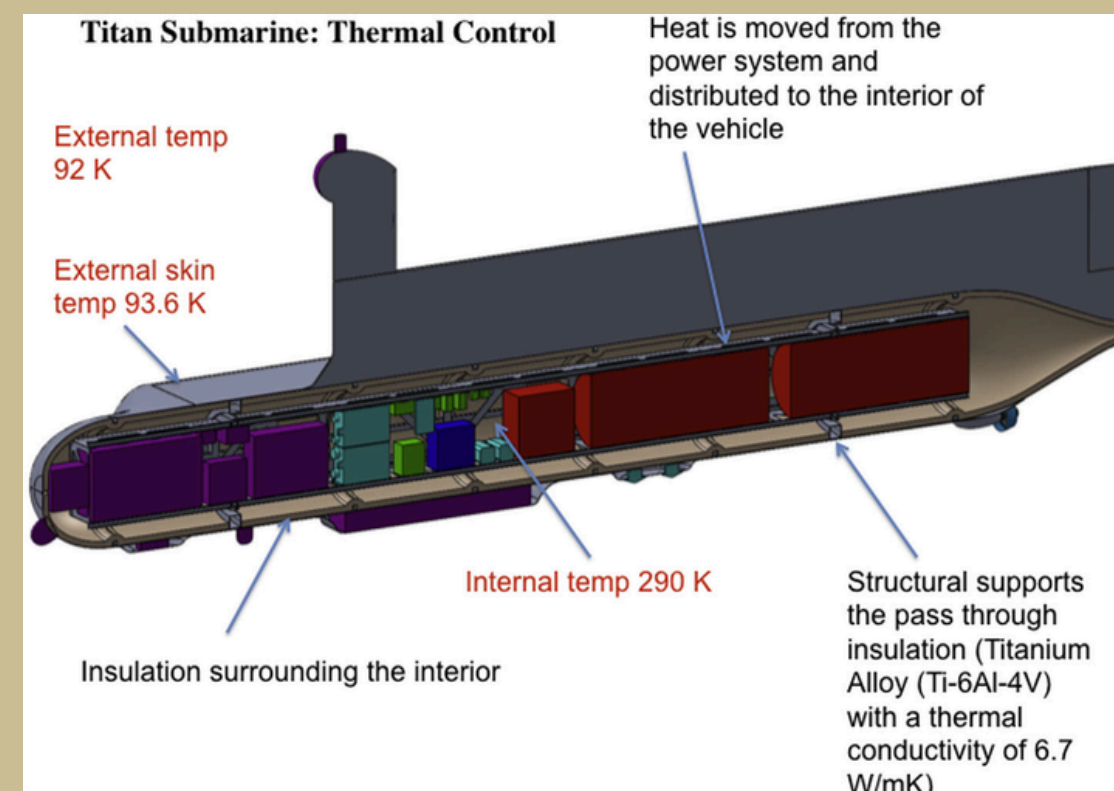


Fig 4. Thermal management

Thermal management

- Stirling radioisotope generators (SRGs) provide power - 842W max
- Waste heat provided by SRG - 3800W
- Operating temperature ~290 - 310K (17-37 C)
- Liquid methane and ethane at 92K (-181 C)

Issues:

- Bubble generation
- Vaporization of nitrogen from the lakes
- Different densities

Ballast system

- Three-way vents
- Piston-based ballast tanks
- Two gases were considered: N2 and Ne

Issues with both gasses:

- Need for compressors to recover and store the pressurant for the ascent stage.
- Need for cryogenic rated components (valves, compressors, piston, etc.).
- Need for mechanical separation between the ballast liquid/-pressurant interface. Pressure control is complicated due to nitrogen gas dissolved in the liquid portion of the ballast tank.
- Leakage will occur across the mechanical separator (piston) over time, with continued usage.

N2

- Exists in-situ on Titan (no need for pressurant)
- Gradual leakage is of no concern
- Nitrogen cannot be compressed isothermally, so heat needs to be supplied

Ne

- Neon remains as a gas during all phases of the mission, simplifying pressure control.
- Gradual leakage across the mechanical interface