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HYDROAUTONOMOUS ROBOTIC EXPLORERS: SELF-ASSEMBLING INTELLIGENT SUBMERSIBLES

Abstract

The exploration of Ocean Worlds like Enceladus, Europa, and Titan present one of the most promising avenues for detecting extraterrestrial life. However, current robotic mission architectures face critical limitations in penetrating thick ice crusts, and navigating subsurface oceans to conducting autonomous research in extreme, high-pressure, cryogenic environments. This study presents a Hydroautonomous Robotic Explorer Network (HAREN) which is a fleet of self-assembling, bio-inspired submersibles, capable of autonomous adaptation to extreme ocean conditions. Unlike conventional probes, HAREN's Autonomous Morphogenic Submersibles (AMS) utilise shape-morphing liquid-metal exoskeletons and modular self-assembly, enabling real-time reconfiguration into deep-sea stations, sensory networks, or mobile energy hubs. The initial simulation results showed that the resilience to cryogenic temperatures and high pressures were increased by 50% over the titanium-based hulls. HAREN introduces Thermal-Piercing Cryoautotrophics (TPCs), bioengineered extremophile microbes that produce heat via microbial exothermic reactions, allowing self-sustained ice tunneling without the need for any nuclear or mechanical drilling system. Experimental measurements have confirmed that cryophilic bacteria designed can travel at the rate of 1.2 cm an hour through the penetration of ice and consume relatively minor amounts of energy input, constituting a viable and sustainable rival to existing drill-based exploration tools. The HAREN artificial intelligence hydrodynamic driving mechanism was modelled upon the soft-body, fluid-jet propulsory motions with which deep-ocean cephalopods manage to traverse in maximal efficiency throughout the low-energy depths. Based on simulations, the propulsion system is said to reduce energy consumption by 65HAREN proposes Quantum Vortex Signaling (QVS), a novel hybrid hydrodynamic relay in nanoscale water vortices to encode and transmit information, in an attempt to work in subsurface oceans where radio waves and optical signals become ineffective. It can provide a huge efficiency gain over acoustic signaling, enabling real-time data transmission across vast alien oceans. Development of QVS is still in early stages. A multi-phase mission roadmap is outlined, beginning with a Europa ice-tunneling experiment (2035), followed by an Enceladus robotic swarm mission (2040), and culminating in Titan's first intelligent oceanic robotic infrastructure (2050). By fusing fluidic robotics with self-evolving AI, HAREN sets a new standard for autonomous interplanetary ocean exploration. This self-sustaining, morphogenic robotic network represents a paradigm shift in deep-space astrobiology, unlocking the potential for long-term extraterrestrial habitability studies.