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Robotic Exploration of Europa's Subsurface with Autonomous Underwater Vehicle (AUV): A Comprehensive Mission Concept and Design

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Abstract: Next-generation space explorers are keen to identify potential bio signatures on other planets and extraterrestrial bodies. So, we have explored Moon and Mars with scientific landers and rovers which transmitted lots of data for exploration beyond earth's orbit. In this scenario, Europa a moon of Jupiter holds a potential site for biological exploration and detection of bio signatures. In addition, spacecraft have identified that the moon is ejecting water vapor into the surface wherein it could hold all the possible elements to support life under the surface. Going forward, orbiters and landers might produce inaccurate results with spectroscopic analysis and imaging techniques, and it is significant to deploy bots or penetrators into the surface for deep investigation and analysis. Therefore, in this paper, we intend to develop and deploy an AUV (Autonomous Underwater Vehicle) for detecting biological signs and to do numerous biological investigations. Studying Europa's water and its interactions with the moon's icy crust provides valuable insights into the potential habitability of icy worlds and the possibilities for life beyond Earth and that exclusively is the work of our AUV. This project can also help further researches on this moon of Jupiter. The AUV will be deployed into the surface via a lander which will act as a ground command for further operation and data transmission. Further, we have planned to develop a 3D model and simulate its operation in upcoming years. Finally, the objective of this mission might provide useful insights for a future manned exploration missions to Europa considering the complete challenges.

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1. Introduction

Among all the potential candidates in our solar system, Europa drives the attention of space explorers for a possible manned mission in the upcoming decade [1,2]. However, the manned mission is associated with several natural and artificial challenges which could put the life of astronauts at risk [4-6]. Therefore, it is obvious to plan for an unmanned mission and perceive enough knowledge and understanding of Europa's surface and its composite hazards. So, we have planned to explore the surface with a lander and subsurface with an AUV. This paper will provide brief insights about the concept, objective, design study, and mission phases to produce optimal results which might provide an overview and outline for a future manned mission to Europa and other planets as well. The prime objective of this mission is to detect possible bio signatures that could support extraterrestrial life.

2. Overview of Europa

Europa tends to be one of the potential habitats in our solar system where researchers have identified that the surface temperature ranges from 253-394K and the salinity of water ranges from 0.6-1.0 with a relative humidity of 60-100%. In addition, terrestrial simulations have shown that the surface may hold layers of dormant life beneath the surface ice evolving from the ocean [7]. Therefore, this scientific interest inspired us to plan for a

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robotic mission to Europa to explore beyond the impossibility. We will be discussing more on design structures and brief on components in the upcoming section.

3. Design Overview

The figure 2 depicts the typical design of a European Autonomous Underwater Vehicle which is made of Aluminum metal with two-three layers of protective coating for protection from thermal imbalance and surface radiation. The bot is battery-powered and equipped with fundamental sensors such as a gyroscope sensor, Doppler velocity sensor, altimeter, and pressure sensor. In addition to that, we have planned to mount spectrometers (for life detection and analysis) and environmental sensors (for analyzing the environment, temperature, and pressure) for gathering data on the subsurface environment. Further, the bot movement is powered by four thrusters (one at the end of the bot) followed by other components such as ESC, an AI System (for real-time decision and data transmission), and a camera of subsurface imaging [8-10].

Figure 1 Design of Europa's Autonomous Underwater Vehicle (AUV)

3.1. Structural Composition

The AUV's structural framework is primarily constructed from Aluminum due to its favorable strength-to-weight ratio and corrosion-resistant properties. To safeguard against thermal imbalances and surface radiation impacts, the vehicle is shielded with a meticulously designed multi-layer protective coating system.

3.2. Sensor Suite

The Europa's AUV is endowed with a fundamental sensor suite that comprises a gyroscope sensor for orientation determination, a Doppler velocity sensor for precise speed measurement, an altimeter for accurate depth assessment, and a pressure sensor to gauge hydrostatic pressure variations.

3.3. Enhanced Sensing Capabilities

To enhance its capacity for scientific inquiry, the Europa's AUV integrates spectrometers capable of life detection and analysis, enabling the identification of potential biological entities within the underwater domain. Complementary to this, environmental sensors are incorporated to capture pertinent data regarding subsurface conditions encompassing temperature and pressure gradients.

3.4. Propulsion Mechanism

The vehicle's propulsion is accomplished through a quartet of strategically positioned thrusters, with a singular unit situated at the extremity of the vehicle. This configuration provides optimal maneuverability and stability during underwater traversal.

3.5. Ancillary Components

Electronic Speed Controllers (ESCs) are seamlessly integrated into the vehicle's architecture to regulate the power distribution to its thrusters, ensuring precise control over its movements. An AI system is implemented to facilitate real-time decision-making processes and efficient data transmission, enabling adaptive responses to dynamic aquatic conditions. Additionally, a subsurface imaging camera is deployed to capture high-resolution imagery of the underwater environment.

4. Description on Components & Payloads

- ***Pressure sensor:*** The pressure sensor is to measure the ocean pressure to prevent the bot from diving deeper into the ocean based on pressure variance. It will help prevent the bot to penetrate a deeper and more uncontrollable environment where it can lose all control over its operation.
- ***Gyroscope sensor:*** It helps the bot to adjust and stabilize its orientation despite ocean turbulence and other external effects.
- ***Altimeter:*** The altimeter is intended for localization, finding the altitude relative to the bot position.
- ***Gyroscope sensor and Doppler velocity Sensor:*** The sensors are for maintaining stability during navigation and directional changes. And the Doppler velocity sensor is to measure the velocity of the bot in the European ocean.
- ***Ultra-Sonic Sound Sensors and Emitters:*** These sensors will be used for oceanic communication in terms of transmitting and receiving data from the lander.
- ***Thrusters:*** We have mounted four electric-powered thrusters for bot movement where the motor control is driven by ESC
- ***ORC Camera:*** The camera is intended to use the crack detection algorithm that can be processed by the AI and find abnormalities and scientific investigation, wherein the camera is protected by a glass gasket.
- ***Battery:*** The bot is powered by durable lithium-ion batteries for longer survival and uninterrupted exploration.

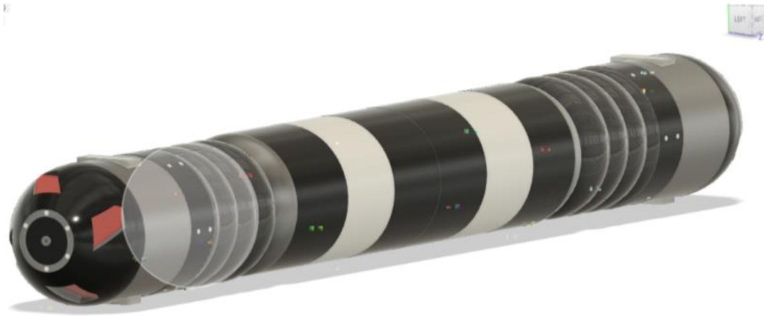

Figure 2 Typical Design of European Autonomous Underwater Vehicle

5. Working Mechanism

A lander integrated with AUV will land on the European surface at the targeted landing site (determined by the space explorers) followed by the deployment of the AUV into the European ocean after a complex drilling process performed by the lander's robotic arm. Further, the bot will penetrate the ocean where the dynamic movement is powered by electric thrusters. Following, the bot will conduct all the scientific investigations predetermined by the ground**.**

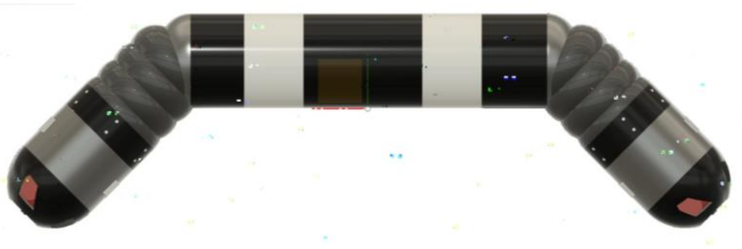

Figure 3 Isometric View of AUV

6. Scientific Objectives of the Mission

We have planned to accomplish the following mission objectives as part of Robotic Europa's exploration. Some of them are as follows:

- Image the European ocean and transit back to Earth.
- Detect for potential bio signatures and evidence of past life.
- Detect European Ocean environment from all aspects.
- Collect water samples and return to earth for ground investigation and analysis

7. Conclusion

Based on the scientific interest and feasibility of a possible unmanned mission to Mars and other extraterrestrial bodies, we have provided an effective way to explore the subsurface of Europa with an autonomous underwater vehicle. Considering the challenges and mission perspective, we presented design and specifications of the European Autonomous Underwater Vehicle underscore its comprehensive approach to underwater exploration. By amalgamating robust structural elements, an array of sophisticated sensors, enhanced analytical tools, and cutting-edge propulsion and AI systems, the EAUV is poised to contribute significantly to the scientific comprehension of submerged environments.

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9. Biography

Rithanya is an up-and-coming researcher in the fields of space exploration and biotechnology. Currently interning at Acceleron Aerospace, she has shown an unwavering passion for her work and a drive to succeed. Rithanya is particularly interested in the intersection between space research and biotechnology, and hopes to make groundbreaking discoveries in this area. In 2022, Rithanya won the Autonomous Underwater Vehicle Content held nationally in India, showcasing her impressive problem-solving skills and technical abilities. Her dedication to her work has earned her accolades and recognition in the scientific community, and she is now looking for opportunities to continue her research and publish her findings in academic journals. Rithanya's innovative ideas and tireless work ethic make her a rising star in the field of space research and biotechnology, and she is sure to make significant contributions to these fields in the years to come.

10. Acknowledgement

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11. Conflict of Interest

The author have no conflict of interest to report.

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