# Onboard Mission Management and Machine Learning Integration for Small Resident Underwater Vehicles

Abubakar Aliyu BADAWI
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ROBOTICS

## INTRODUCTION

- Subsea intervention and inspection are essential for maintaining and operating underwater infrastructure, focusing on tasks such as examining pipeline integrity and assessing subsea structures.
- Developing advanced architectures for onboard mission management in small resident underwater vehicles enhances their ability to perform these critical tasks autonomously, reducing the need for human intervention and increasing operational safety.
- Advancements in autonomous technology, including AI and machine learning, are transforming these vehicles into highly capable, independent agents that can perform complex tasks without direct human control.

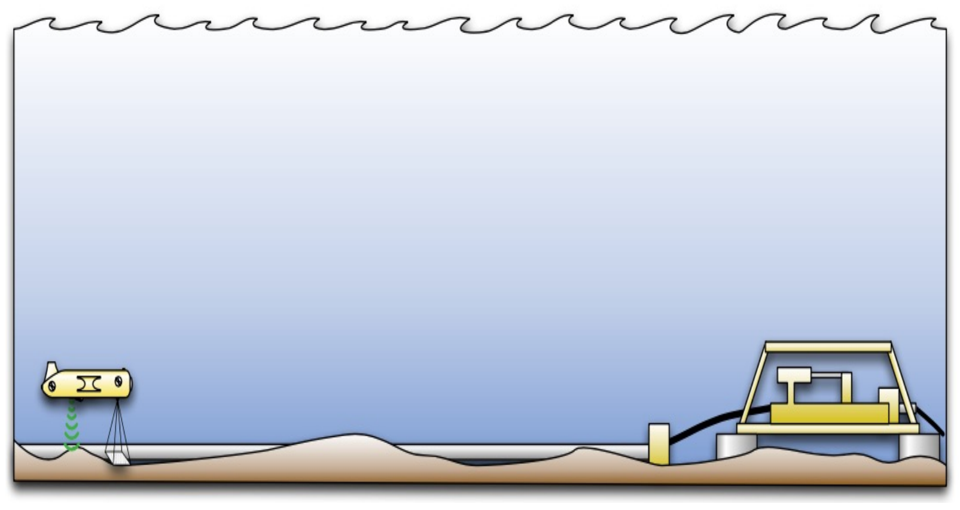


**Fig 1:** A subsea residence AUV

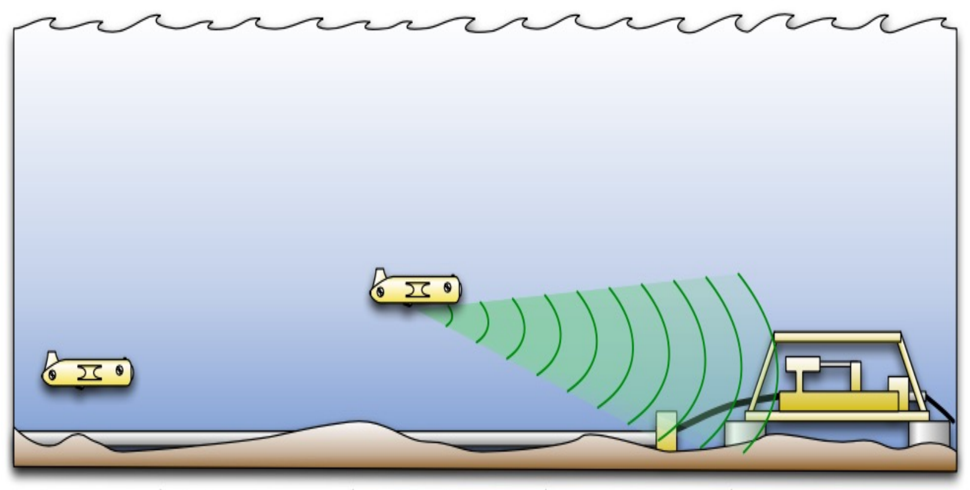


**Fig 2:** A subsea residence AUV localizing

## MOTIVATION

- Autonomy in subsea environments minimizes the need for human intervention by employing advanced machine learning algorithms in small resident underwater vehicles (AUVs and ROVs), improving the precision and efficiency of tasks such as inspections and repairs, thereby reducing human risk.
- Machine learning significantly boosts decision-making capabilities in autonomous underwater operations, enabling these vehicles to rapidly and accurately address issues like structural integrity and environmental monitoring, which prevents potential hazards and decreases operational downtime.

## BACKGROUND

Resident autonomous underwater vehicles (AUVs) equipped with advanced docking and wireless charging capabilities enable prolonged and continuous subsea operations, significantly enhancing the effectiveness of underwater infrastructure inspections and monitoring.

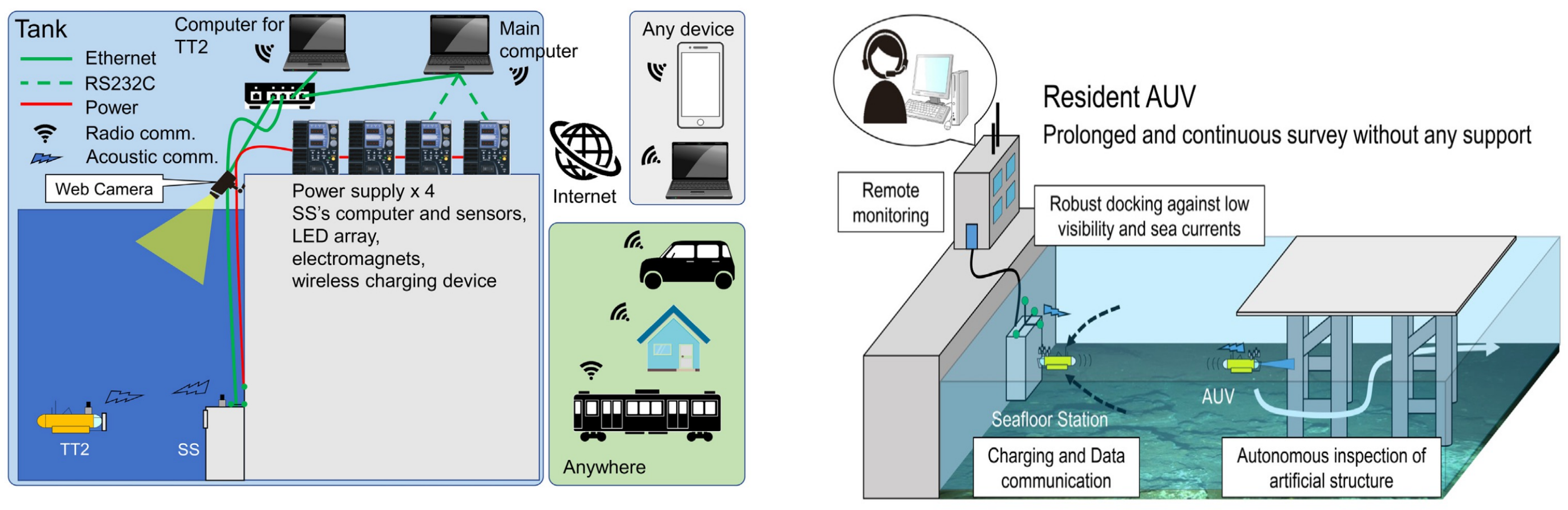


**Fig 3:** Resident AUV for inspecting underwater infrastructures.

- In [1] Mintchev et al. present a novel docking system for small-scale underwater robots, addressing the challenge of recharging and data transfer during long missions through submerged docking stations.
- In [2], Campos et al. detail the implementation of low-cost embedded systems to enable autonomous hover operations in small underwater vehicles, utilizing visual systems for real-time positional feedback which allows for precise stability and manoeuvrability in complex environments.
- In [3], Wang et al. describe a hovering control strategy for underwater vehicles using cascade PID controllers that effectively manage the complex dynamics of underwater environments, enhancing the vehicle's ability to maintain a fixed position with high precision.
- In [4] Bao et al. highlighted the advantages of Hardware-in-the-Loop (HIL) simulations in AUV control system development, demonstrating cost-effectiveness and risk reduction by enabling thorough system tests before deployment
- In [5] Okereke et al. emphasize the role of machine learning techniques in enhancing local path planning for autonomous underwater vehicles (AUVs), focusing on real-time navigation and obstacle avoidance in dynamic and unknown environments

## STATE OF THE ART

### 1- DOCKING SYSTEM

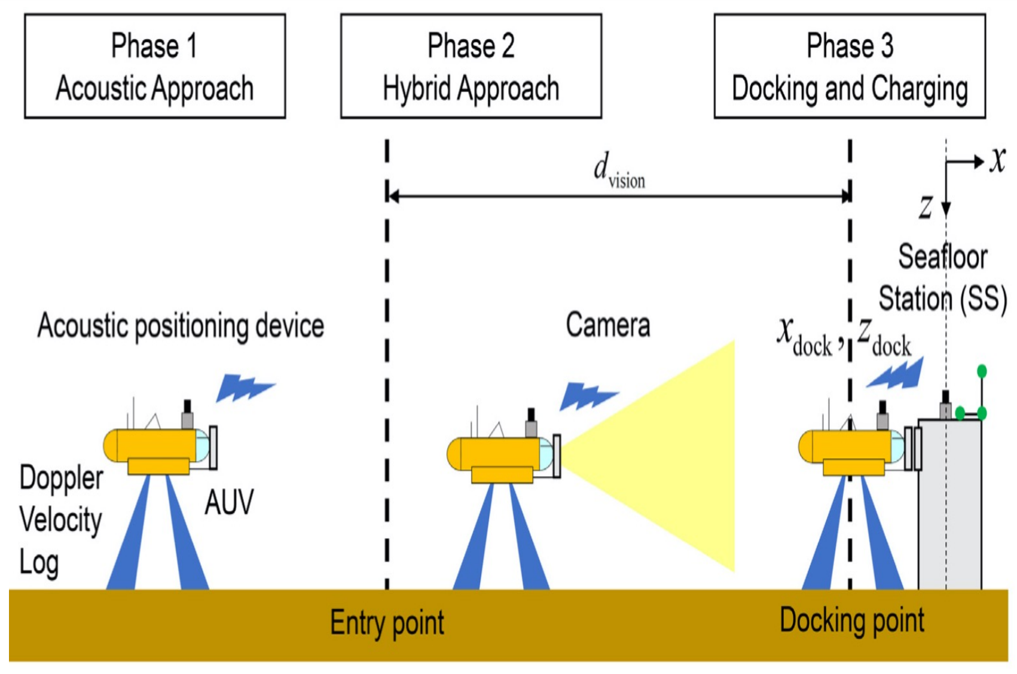


**Fig 5:** Resident AUV for inspecting underwater infrastructures.

### 2 - ACOUSTIC POSITIONING SYSTEM

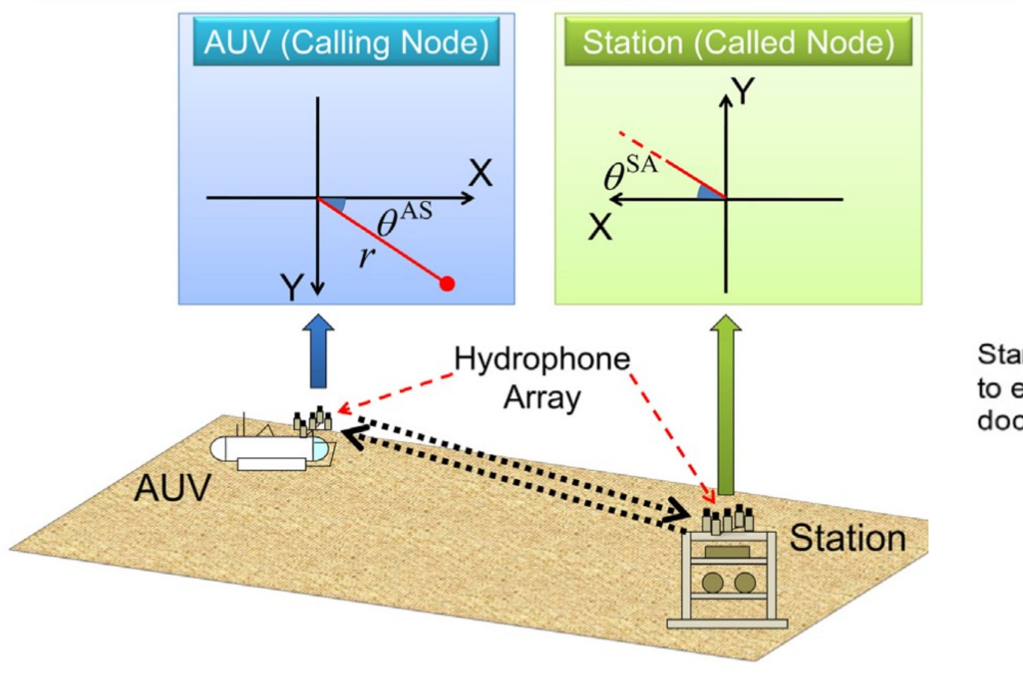


**Fig 6:** Mutual acoustic positioning based on the SS

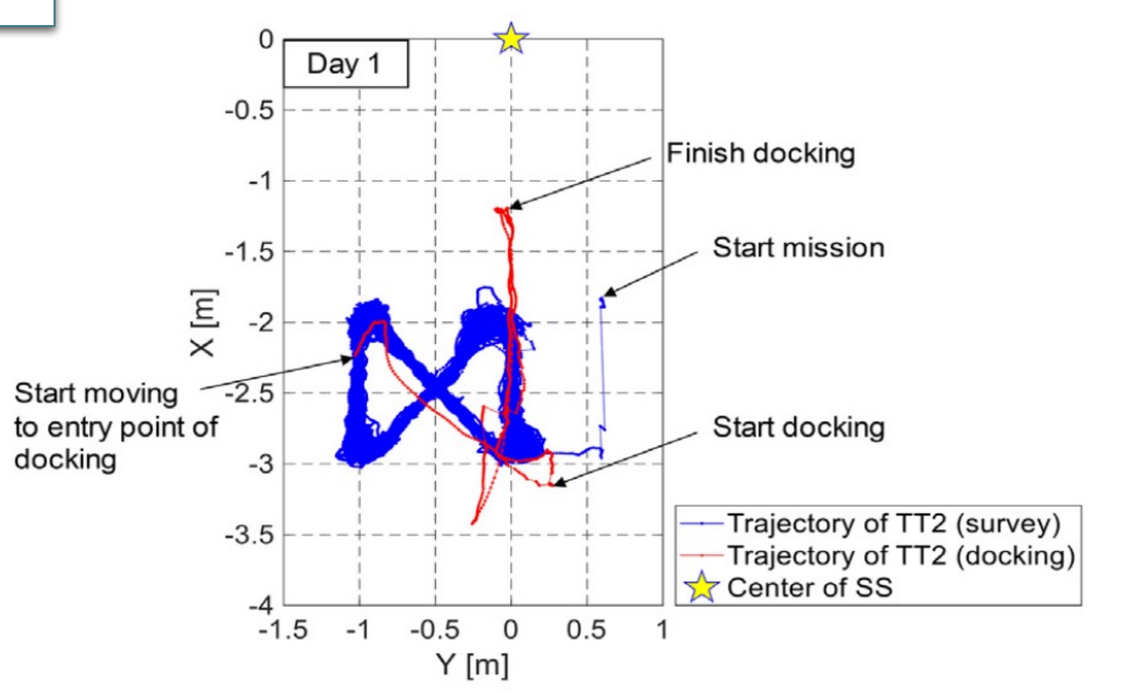


**Fig 7:** Horizontal trajectory of TT2

- **Docking System**: In [6] the AUV uses both acoustic and visual positioning for effective docking at a seafloor station, designed to withstand low visibility and strong currents.
- **Acoustic Positioning System**: The authors in [6] used an advanced acoustic system that helps the AUV accurately locate its position relative to the docking station from a distance, crucial for initial docking stages.
- **Trajectory Management**: In [6] again highlights a strategy for managing the AUV's navigation path, optimizing real-time adjustments for successful docking in changing sea conditions.
- **Hovering Control System:** In [2] the control system for the underwater vehicle achieves stable hovering by integrating cascade PID controllers across multiple loops (horizontal position, depth, and yaw) with velocity controllers for surge, sway, heave, and yaw, effectively managing the vehicle's position and orientation in challenging underwater environments.
- **Path Planning:** The authors in [5] uses machine learning to integrate sensing data into a supervised learning model that predicts class labels for path planning, which informs the cost calculations in the planning stage for optimal path determination and subsequent actuation.

### 3 - HOVERING CONTROL SYSTEM

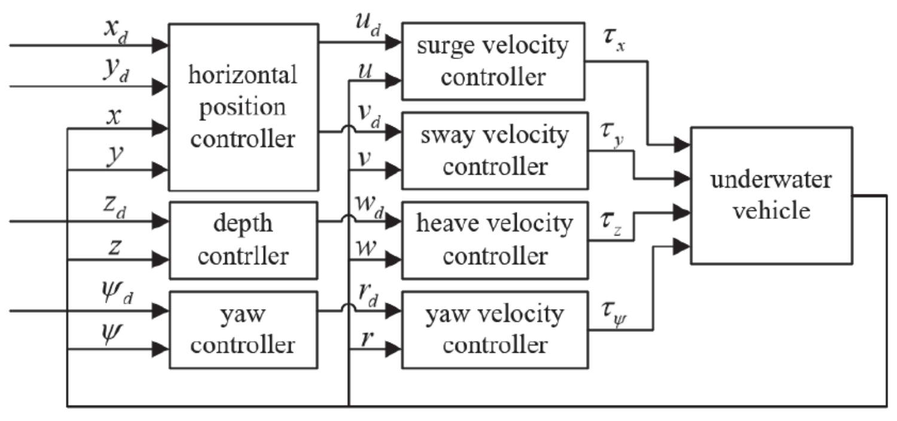


**Fig 8:** Block-diagram of hovering control system.

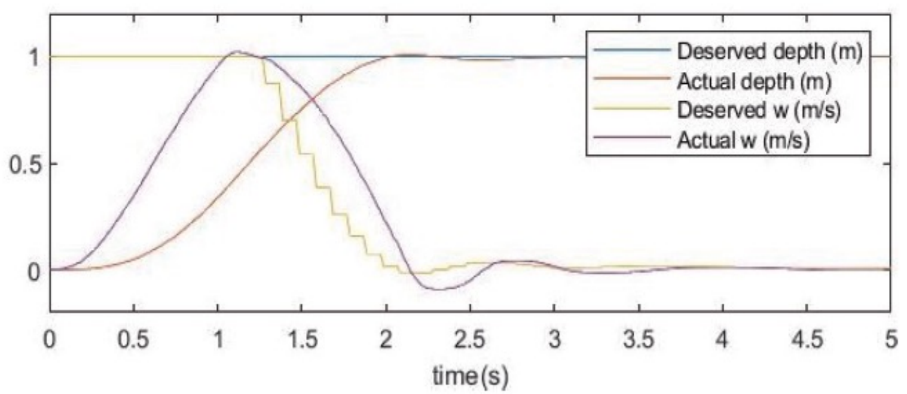


**Fig 9:** Response curve in heave

### 4 - PATH PLANNING

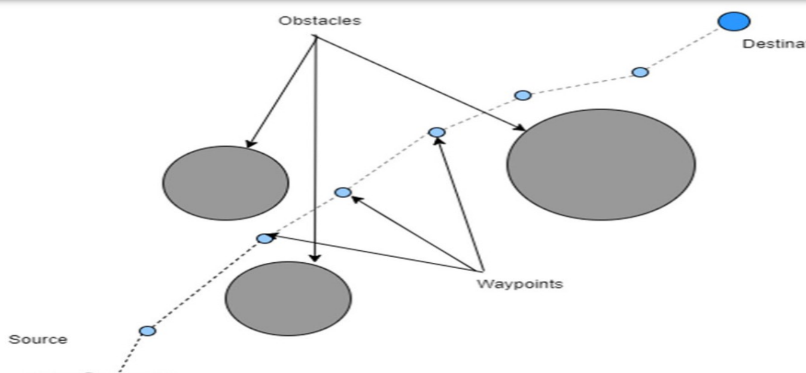


**Fig 10:** A typical path planning a path for AUV

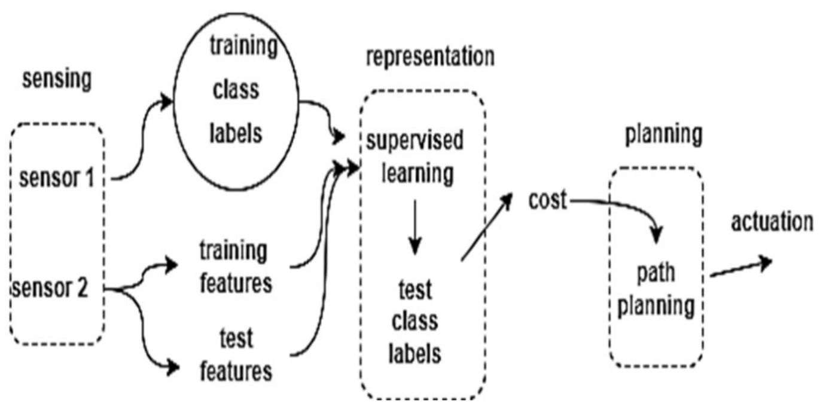
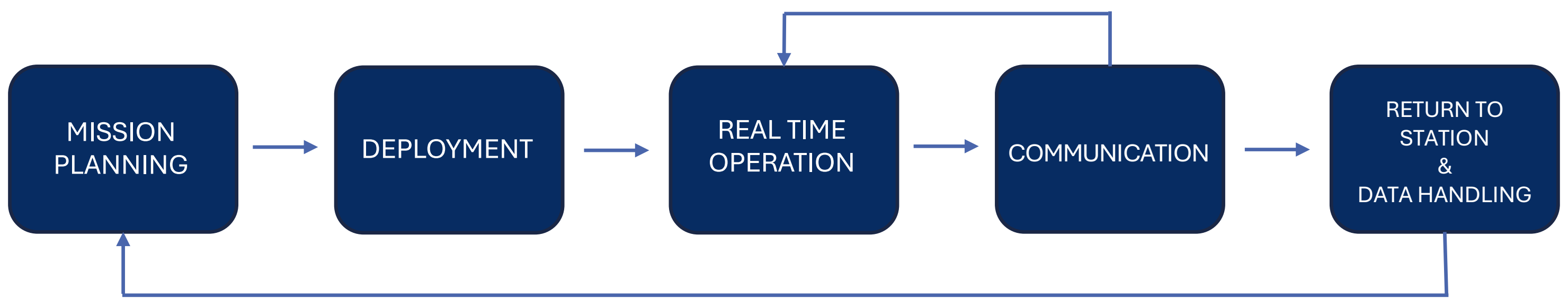


**Fig 11:** A typical path planning for AUV using supervised learning

## EXPECTED THESIS CONTRIBUTIONS

- Building on the embedded system work by Campos et al. [2], I will develop architectures for enhance on-board mission management in resident underwater vehicles, focusing on enhancing autonomy through integration of real-time computational feedback and advance control strategies.
- Building upon the work of Okereke et al. [5] on AI-enhanced path planning, I will evaluate and enhance machine learning algorithms against traditional control methods to improve decision-making and adaptability in complex underwater navigation tasks.
- Drawing on Bao et al.'s work [4], I will implement and refine hardware-in-the-loop simulations within the UNDINA project's framework to validate the effectiveness and robustness of newly developed control systems for small hovering underwater vehicles.



MISSION PLANNING → DEPLOYMENT → REAL TIME OPERATION → COMMUNICATION → RETURN TO STATION & DATA HANDLING

**Fig 12:** PROPOSED ONBOARD MISSION MANAGEMENT ARCHITECTURE

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