

**EGCP-599 Independent Graduate Research**

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**Final Report**

**Abstract:**

The primary focus of this project is to design and implement new set of changes to both hardware and software side of the project. There must be significant changes made to the design of the PCB, thrusters and address water leakage issue with the central capsule and battery pack. On the software end, object detection with updated machine learning algorithms must be trained, underwater navigation. This project focuses on several main objectives: detailed mapping of underwater topography, comprehensive monitoring of marine ecosystems and detection of underwater anomalies. Using state-of-the-art machine learning algorithms, the AUV improves its adaptability and decision-making processes, making significant contributions to marine exploration and environmental protection. These changes made will help in upgrading the entire system and make the AUV robust, versatile, and efficient for multiple marine exploration.

**Introduction:**

The study of the underwater environment has always presented significant challenges due to the vast and unexplored nature of the world's oceans. To address these challenges, our project focuses on the development of an autonomous underwater vehicle (AUV) designed to operate autonomously, navigate complex underwater landscapes, and perform various tasks. Thanks to the development of technologies such as sonar, computer vision and artificial intelligence, AUVs have the potential to revolutionize marine exploration, environmental monitoring, and underwater resource management.

Our AUV project aims to integrate state-of-the-art sensors and algorithms to improve the vehicle's navigation, obstacle avoidance and data collection capabilities. Leveraging the power of machine learning, the AUV can adapt to dynamic environments and make real-time decisions to ensure efficient and safe operation. The primary objectives of the project are underwater topography mapping, marine ecosystem monitoring and underwater anomaly detection.  
  
Pushing the limits of what autonomous systems can achieve underwater, this project will not only advance the field of robotics and marine science, but also open a new opportunity for the exploration and sustainable management of ocean resources. Our interdisciplinary approach combines expertise in information technology, robotics, and marine biology to create a robust and versatile AUV capable of performing a variety of missions in some of the most challenging environments on Earth.

**Existing system:**

A diagram of a power supply system

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This system was designed and implemented by the previous teams but due to certain issue with the structure of it, there must be a complete redesign done to the entire components and few additional components must be added to it as well.

**Jetson Nano:** Acting as a central processing unit, the Jetson Nano enables advanced computing and machine learning tasks by allowing the AUV to process visual data from camera and sensor inputs in real time. It facilitates complex tasks such as object detection, path planning and dynamic decision making.

**The role of Jetson Nano in the AUV:**

* **Real-time data processing:**  
  Jetson Nano processes data from various hardware sensors in real-time, including the camera and depth sensor. In this way, the AUV can quickly interpret its environment and make informed decisions.
* **Machine Learning and Artificial Intelligence:**  
  Equipped with powerful GPU features, the Jetson Nano lets you run machine learning algorithms and neural networks. This facilitates complex tasks such as target detection, obstacle avoidance and pattern recognition, improving the autonomy of the AUV.
* **Visual detection:**  
  Processing the camera, Jetson Nano can detect and classify underwater objects, track moving entities, and perform visual inspections. It is crucial for tasks such as mapping, navigation, and environmental monitoring.
* **Route planning and navigation:**  
  Jetson Nano uses data streams to develop and update navigation plans. It calculates optimal paths, adapts to dynamic conditions, and ensures efficient and safe passage through the underwater environment.
* **Communication and Control Integration:**  
  It acts as an integration point between the various components of the AUV, including the STM microcontroller, sensors, and thrusters. It ensures coordinated action and smooth execution of complex movements.
* **Environmental Adaptation:**  
  The Jetson Nano allows the AUV to adapt to changing underwater conditions by constantly analyzing sensor data and updating operational parameters. This adaptability is key to maintaining performance in varied and unpredictable underwater conditions.

**STM microcontroller**: The STM microcontroller is responsible for managing low-level functions such as interfacing with sensors, controlling thrusters, and ensuring stable communication between various components of the AUV.

**The role of STM in AUV:**

* **Sensor Interface and Data Acquisition:**  
  The STM microcontroller is connected to several sensors on the AUV, including a depth sensor and other environmental sensors. It collects and processes raw data, providing important real-time information about the AUV's environment and operational status.
* **Controller of thrusters:**  
  It manages the precise control of the six thrusters, allowing fine adjustment of the steering, stability, and navigation of the AUV. The microcontroller ensures precise execution of push commands to achieve the desired movements and positions.
* **Communication Bridge:**The STM microcontroller acts as a communication bridge between the advanced processor (Jetson Nano) and the hardware components. This translates the Jetson Nano's advanced commands into actionable instructions for sensors and actuators, ensuring consistent operation.
* **Power Management:**  
   It monitors and controls the distribution of power to different subsystems, which ensures efficient use of power and protects components against power surges or interruptions. This is critical to maintain the life and reliability of the AUV.
* **Security and reliability:**  
  The microcontroller implements security protocols and error handling mechanisms. If anomalies are detected, it can perform failover procedures, ensuring that the AUV can safely recover or shut down in the event of critical problems.
* **Time and Coordination:**  
  It manages time-critical functions and coordinates the work of various subsystems. By maintaining precise timing, the microcontroller ensures data acquisition, processing, and operation in a synchronized manner, improving the overall efficiency of the AUV.

**IMU & Depth sensor:** The depth sensor accurately measures the depth of the AUV needed to maintain the desired operating altitude and avoid obstacles. It plays an important role in depth-dependent tasks such as underwater mapping and environmental monitoring.

* **Track heading and position:**  
  The IMU measures the AUV's acceleration, angular velocity, and sometimes magnetic force. This information is used to calculate changes in vehicle orientation (roll, pitch and yaw) and position over time.
* **Stabilization and Control:**  
  The IMU provides critical feedback to the AUV's stabilization systems, helping to maintain a stable course and smooth motion even in turbulent underwater conditions.
* **Navigation:**  
  Combined with other sensors, IMU data improves the accuracy of AUV navigation. It helps perform calculations when GPS signals are not available, allowing the vehicle to estimate its position based on known initial positions and movement data.
* **Motion Compensation:**  
  IMU data enables motion compensation, which ensures that sensor readings such as cameras and sonars remain accurate regardless of vehicle motion, which is critical for tasks such as imaging and mapping.
* **Autonomous Maneuvering:**  
  The IMU enables precise control of the AUV's movements, allowing it to perform complex tasks such as dynamic obstacle avoidance, precise docking and maintaining certain orientations during missions.

**Camera**: The ship's camera captures high-resolution images and video, enabling visual inspection, object detection, and environmental mapping. The Jetson Nano processes this visual information to detect features and efficiently navigate the underwater landscape.  
  
**Six propellers**: The AUV is equipped with six propellers for exceptional maneuverability and stability. These thrusters allow the vehicle to perform complex maneuvers, maintain a precise position and navigate the complex underwater environment.

**Issue with the existing system:**

A machine with wires and wires

Description automatically generated with medium confidence

1. The entire capsule and the circuit are tampered leaving some of the components missing.
2. The entire circuit must be redesigned with custom PCB mounted on the electronic tray.
3. The angle of the thrusters must be modified, and addition thrusters must be installed upon checking with mechanical department.
4. The battery capsule has leakage issue, and the wiring has to be changed.
5. Jetson needs to be powered with few machine learning algorithms as suggested in this reported for better object detection and navigation purposes.
6. 3D printed case for the PCB to withstand the underwater pressure and water leakage.
7. Once all the suggested new approaches are followed the AUV must be pressure tested in a tank.
8. Tether cable has to be installed for manual testing and maneuvering of the AUV.
9. Installation of the sonar is key for improving the navigation system under autonomous mode.

**New Approach to the AUV:**

There are multiple changes which have to be made in different departments of engineering, the AUV electronic system has to have a new PCB designed which holds all the sensors and other modules, software side has to work on the object detection for underwater exploration along with navigation system from the sonar sensor and GUI needs to be made available for the control of AUV manual incase of emergency which will hold the video feed, telemetric and path planning showing its navigation system.

A diagram of software

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**Hardware**:

**Ping360:**

The Ping 360 sensor is a high-resolution mechanical scanning sonar used extensively in Autonomous Underwater Vehicles (AUVs) for various underwater applications. Here’s an in-depth look at its roles and functionalities. This sensor offers high-resolution sonar imaging for a range of applications, greatly expanding the capability of autonomous underwater vehicles. It is a vital instrument for underwater operations and exploration because of its applications in scientific research, obstacle avoidance, environmental mapping, navigation, and search and recovery.

A black round object with a blue strip

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**Environmental mapping and surveying:**

1. **Detailed Description:** The Ping 360 sensor emits acoustic pulses in a circular or sweeping pattern to create high-resolution 2D sonar images of the surrounding environment. This feature allows the AUV to create detailed maps of underwater terrain, structures, and objects.
2. **Seabed mapping**: It helps create accurate seabed maps that are essential for scientific research, environmental monitoring, and underwater construction projects. Detailed images help identify seafloor features such as trenches, ridges, and sediment types.
3. **Structural Inspection:** The probe is used to inspect underwater structures, including shipwrecks, pipelines, and offshore platforms. High-resolution images can detect structural integrity problems, biofouling, and other anomalies.

**Navigation and Obstacle Avoidance:**

1. **Situational Awareness**: By providing real-time sonar images of the AUV's surroundings, the Ping 360 sensor improves situational awareness. The AUV can visualize its environment, detect obstacles, and plan safe navigation routes.
2. **Obstacle detection and avoidance**: The sensor allows the AUV to detect and avoid obstacles such as rocks, sea animals and underwater debris. This is crucial for autonomous operations, as the AUV can move safely without human intervention.
3. **Path planning:** Detailed sonar data helps plan efficient and safe paths in complex underwater environments. This is especially important for tasks that require precise navigation, such as pipe inspection or scientific research.

**Search and recovery functions:**

1. **Object detection**: The Ping 360 sensor can locate and identify objects on the seabed or in the water column. This is essential for search and recovery tasks such as locating lost equipment, debris or conducting underwater archaeological surveys.
2. **Area Scanning**: This allows the AUV to systematically scan large areas, ensuring comprehensive coverage and reducing the probability of missing important targets or areas of interest.

**Scientific Research:**

1. **Habitat Mapping:** With the help of probe to map and study underwater habitats, including coral reefs, kelp forests, and fish stocks. High-resolution images help assess habitat health and biodiversity.
2. **Geological Surveys:** Helps geological surveys map underwater formations and sedimentary layers. This information is necessary to understand geological processes and search for natural resources.

**Data integration and use:**

1. **Real-time data processing:** The Ping 360 sensor provides real-time data that can be processed on the AUV. This enables immediate interpretation and response, which is crucial for dynamic tasks.
2. Post-Mission Analysis: Collected sonar data can be analyzed post-flight to create detailed maps and reports. It is useful for long-term monitoring, environmental impact assessment and planning of future tasks.

**Communication with control systems:** The sensor integrates with the control systems of the AUV and provides continuous feedback for navigation and function adjustments. This integration ensures that the AUV can operate autonomously with minimal human supervision.

**Doppler Velocity Log sensor (DVL):**

A Doppler Velocity Log (DVL) sensor is an essential component of Autonomous Underwater Vehicles (AUVs) that provide accurate velocity measurements relative to the seabed or water column. This information is essential for accurate navigation, positioning, and control of the AUV. Here is a comprehensive overview of the roles and functions of the DVL sensor in an AUV project.

**A close up of a device

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**Accurate Velocity Measurement:**

1. **Using the Doppler Effect:** The DVL sensor uses the Doppler effect to measure the velocity of the AUV. It emits acoustic pulses and listens for echoes reflected from the seabed or water particles. By analyzing the frequency change of the returned signals, the DVL calculates the speed of the vehicle.
2. **Three-dimensional velocity data:** DVLs usually provide three-axis velocity data (X, Y, and Z directions) that provide a complete picture of the AUV's motion in the water. This information is critical to maintaining accurate control of the vehicle's trajectory.

**Navigation and Position:**

1. **Dead Reckoning Navigation:** In the absence of underwater GPS signals, DVLs are essential for dead reckoning navigation. By continuously measuring velocity and integrating it over time, DVL helps estimate the position of the AUV relative to a known reference point.
2. **Position estimation:** The velocity data from the DVL is combined with the initial position data and other sensor inputs (eg, from an inertial measurement unit or IMU) to estimate the current position of the AUV. This is crucial for tasks that require precise positioning, such as underwater measurement and inspection.
3. **Station keeping**: In missions where the AUV must remain stationary or move slowly in a certain area, the DVL provides the necessary velocity feedback to the control system to maintain the desired attitude against currents and other environmental forces.

**Altitude measurement:**

1. **Height above the sea floor**: DVL can also measure the height of the AUV, which is the height above the sea floor. To do this, the time required for the acoustic pulses to travel to the seabed and back is calculated. Knowing the height is important to avoid collisions with the seabed and in missions where the AUV must maintain a certain distance from the bottom.
2. **Terrain tracking:** For missions where the AUV must follow the contours of the seabed, the DVL altimeter allows the vehicle to dynamically adjust its depth to maintain a constant distance from the seabed, ensuring consistent data collection and operational safety.

**Improved Operational Safety:**

1. **Collision Avoidance**: By providing accurate speed and altitude information, the DVL helps the AUV avoid collisions with the seabed and other underwater obstacles. This is especially important in complex or poorly mapped environments.
2. **Drift Compensation:** In environments with strong currents, DVL data helps the AUV compensate for the drift, ensuring that it stays on course and accurately follows planned trajectories.

**Research and Data Collection:**

1. **Precise Path Tracking:** For scientific research and data collection tasks, the DVL ensures that the AUV follows precise paths that allow for consistent and repeatable data collection. This is critical in applications such as seabed mapping, habitat monitoring, and natural resource exploration.
2. **Data Correlation:** DVL speed and position data can be correlated with data from other sensors (such as sonars or camera images) to provide a comprehensive view of the surveyed area. This improves the quality and usefulness of the data collected.

**Integration with AUV Systems:**

1. **Sensor Fusion**: The DVL integrates with other onboard sensors such as IMUs, depth sensors and GPS (if on the surface) using sensor fusion algorithms. This integration improves the overall accuracy of the navigation and positioning systems of the AUV.
2. **Steering System Feedback**: The AUV's steering system uses real-time speed data from the DVL to continuously adjust the vehicle's propellers, ensuring stable and precise control.

**Software:**

**Machine learning:**

Machine learning (ML) is playing a revolutionary role in the Autonomous Underwater Vehicle (AUV) project, improving its capabilities in various dimensions. From detection and navigation to data analysis and adaptive decision making, ML enables AUVs to operate more efficiently and autonomously in complex underwater environments. Here is a comprehensive overview of how machine learning is used in the AUV project:  
  
1**. Better perception and understanding of the environment  
Object detection and classification:**  
  
**Visual recognition**: ML models, especially Convolutional Neural Networks (CNNs) can process visual data from cameras and sonar to identify and classify underwater objects. This includes marine life, debris, and man-made structures.  
  
**Sonar Image Analysis**: ML algorithms can interpret sonar data and identify objects and features in low visibility conditions where traditional cameras may fail.  
 **Real-time processing:**  
The use of internal processors like the Jetson Nano, the AUV can run ML algorithms in real-time. This enables immediate interpretation of sensor data, allowing the vehicle to react quickly to the environment.  
  
**Environmental Map:**Machine learning helps create detailed and accurate maps of the underwater environment. By classifying and mapping different features, the AUV can create complete 3D models of the seabed and underwater structures.

2. **Autonomous Navigation and Path Planning**  
**Dynamic Obstacle Avoidance:**ML models can continuously analyze sensor data to detect and track both stationary and moving obstacles. This feature is essential for safe navigation in the complex underwater environment.  
Predictive Modeling: By anticipating the movement of obstacles such as marine life or drifting debris, the AUV can plan and adjust its route to avoid collisions.  
 **Terrain tracking and adaptive navigation:**  
Using ML algorithms, the AUV can precisely follow the contours of the seabed. By recognizing the characteristics of the terrain and adjusting its route accordingly, the vehicle can safely and efficiently navigate various underwater terrains.

**Autonomous decision making**:  
Using machine learning, the AUV can make autonomous decisions about the route and operations. By analyzing several factors such as energy efficiency, mission objectives, and environmental conditions, the AUV can choose optimal paths and behaviors.  
  
3. **Task-based applications**  
  
The machine learning can be used for many tasks based on the application of the AUV, in our project the aim is to identify the target and shoot the torpedo on it. Similarly the AUV can be used for multiple underwater applications like:   
  
**Marine biology and ecology:**  
  
**Species identification**: ML algorithms can identify and track marine species to aid in ecological studies and conservation efforts.  
**Behavioral analysis**: By observing and analyzing the behavior of marine organisms, ML models can provide information about ecosystem dynamics and animal habits.  
  
**Inspection and Maintenance**:  
  
**Infrastructure Monitoring**: ML can detect anomalies and damage in underwater infrastructure such as pipelines and cables by analyzing visual and sonar data. This ensures timely maintenance and reduces the risk of breakdowns.  
**Biofouling detection**: Detection and quantification of biofouling on underwater structures can be automated using ML to aid in effective management and cleanup.  
  
**Search and Recovery:**  
  
**Target Detection**: During search and recovery missions, ML models can identify specific objects or debris on the seabed, increasing the efficiency and success of these operations.  
**Pattern recognition:** By identifying patterns in data, ML helps more accurately find and recover objects of interest.  
  
4. **Data analysis and post-delivery processing**  
**Automatic data labeling:** Machine learning can automate the process of labeling and classifying collected data, greatly reducing the time and effort required for post-delivery analysis. This allows researchers to focus on interpreting results instead of manual processing.  
  
**Detection of patterns and anomalies:** ML algorithms can analyze large data sets to identify patterns and anomalies. For example, they can detect unusual movements of marine life or changes in environmental conditions, which provide valuable information for scientific research and environmental monitoring.  
  
**Predictive analytics**: Using historical data, machine learning models can predict future trends and behavior. This is useful for planning future missions and understanding long-term changes in the underwater environment.  
  
5. **Enhanced Autonomy and Learning Capabilities**  
  
**Adaptive Learning**: Using machine learning, the AUV can learn from its experiences. By updating its model based on new data, the AUV can improve its performance over time and adapt more effectively to new environments and challenges.  
  
**Situational awareness**: ML improves AUV situational awareness by integrating and interpreting data from multiple sensors. This comprehensive understanding allows the vehicle to operate more intelligently and autonomously.  
  
**Behavioral adaptation**: Reinforcement learning allows the AUV to adapt its behavior based on feedback from the environment. This means the vehicle can learn through trial and error the most efficient ways to complete tasks and navigate obstacles, improving its performance over time.

**Machine learning algorithms:**

In general, ML models enhance the performance of the AUV in achieving precision, accuracy and navigate better underwater without any guidance. Here are some important algorithms which can be used in our project:

1. **Convolutional Neural Networks (CNN)**  
   **Applications:**  
   **Object Detection and Recognition**: CNNs are very effective for analyzing visual data from cameras and sonars. They can be used to detect and classify underwater objects such as marine life, debris and man-made structures.  
   **Image segmentation**: CNNs can segment images to distinguish different parts of the environment, such as the seabed, water column and obstacles.  
     
   **ML models:**  
   **YOLO (You Only Look Once):** A powerful real-time object detection algorithm that can be used to detect objects in underwater images and video streams.  
   **Faster R-CNN:** Another popular object detection framework that can detect multiple objects in an image with high accuracy.  
     
   2. **Recurrent Neural Networks (RNNs) and Long Short Memory Networks (LSTMs)  
     
   Applications:**  
   **Time Series Analysis**: RNNs and LSTMs are suitable for analyzing sequential data such as AUV -sensor data over time. They can be used, for example, to predict the future location of the vehicle and detect anomalies in sensor readings.  
     
   **Navigation**: These networks can assist in route prediction and adaptive navigation by learning patterns from past navigation data.  
     
   3**. Support Vector Machines (SVM)  
     
   Applications:**  
   **Classification tasks**: SVMs can be used for binary and multi-class classification tasks, such as distinguishing different types of underwater objects or detecting specific patterns from audio data.  
     
   **Anomaly detection**: SVMs are effective at detecting anomalies and outliers in sensor data that may indicate potential problems or interesting phenomena.  
     
   4**. Random Forests and Decision Trees  
     
   Applications:  
   Decision Maki**ng: Decision trees and random forests can be used to make decisions based on multiple inputs. For example, they can help the AUV decide the best course of action based on sensor inputs.  
   **Environmental Classification**: These algorithms can classify different types of underwater environments or conditions based on the collected data.  
     
   **5. K-Means Clustering and Other Clustering Algorithms  
     
   Applications:**  
   **Environmental Mapping**: Clustering algorithms can group similar data points, which can be useful for mapping and classifying different areas of the seabed.  
   **Behavioral analysis**: These can group patterns of movement of marine life or other dynamic objects in the environment.  
     
   6. **Reinforcement Learning (RL)  
     
   Applications:**  
   **Autonomous Navigation**: RL algorithms such as Q-learning and Deep Q-Nets (DQN) can be used to develop autonomous navigation strategies. The AUV learns to navigate by receiving rewards based on its actions, improving its path planning over time.  
     
   **Adaptive control**: RL can optimize control strategies for AUV controllers and other actuators, ensuring efficient and stable motion.   
     
   7. **Principal Component Analysis (PCA) and Other Dimensionality Reduction Techniques  
     
   Applications:**  
   **Data Compression**: PCA can reduce the dimensionality of large data sets, making sensory data easier to process and analyze.  
   **Feature extraction**: These techniques help extract relevant features from raw data, which can then be used for classification, clustering, or other tasks.  
     
   8. **Gaussian Mixture Models (GMM)**  
   **Applications**:  
   **Sensor Fusion**: GMMs can be used to combine data from multiple sensors, providing a more accurate and reliable understanding of the AUV environment.  
     
   **Anomaly detection**: GMMs can model the normal behavior of AUV systems and detect anomalies that may indicate malfunctions or interesting events.  
     
   9. **Bayesian networks  
     
   Applications:**  
   **Probabilistic reasoning**: Bayesian networks can model probabilistic relationships between different variables, which is useful for decision making under uncertainty.  
     
   **Fault diagnosis**: These can help diagnose problems with AUV systems by analyzing the probability of various faults based on the observed data.

**Graphical User Interface (GUI):**

GUI will give the operator to manage the vehicle efficiently under different conditions, having a interface which show all the important features and real time updates of the AUV will help in guiding it when needed.

**Joystick control for testing:**

1. **Manual control**: Allows you to manually control the AUV with a joystick. This is critical for testing, calibration and situations that require precise control.
2. **Responsive user interface**: Provides real-time response to joystick inputs, enabling smooth and precise control of AUV movements.

**Video feed:**

1. **Live Streaming:** Displays a live video feed from the AUV's internal cameras, providing users with a visual perspective of the underwater environment.
2. **Multi-camera support**: If the AUV is equipped with more than one camera, it is possible to switch between multiple camera streams.
3. **Overlay Data**: Overlays relevant data such as depth, direction and detected objects over the video stream.

**Telemetry data:**

1. **Live data**: Displays important telemetry data including depth, temperature, battery status and sensors.
2. **Graphical Presentation**: Uses charts and graphs to show data trends over time, helping to monitor AUV performance and health.

**Navigation System:**

1. **Map View**: Provides a map or 3D model of the underwater environment that shows the AUV's current location, planned route, and waypoints.
2. **Route Planning**: Allows users to enter and edit navigation plans, set new destinations or modify existing routes.
3. **Obstacle Detection**: Highlights detected obstacles and advises on safe navigation routes using data from sonar and other sensors.

**Mechanical:**

Mechanical changes to the Autonomous Underwater Vehicle (AUV) chassis are very important for several reasons. These changes can significantly affect the vehicle's performance, durability, and ability to meet specific mission requirements. Here's a detailed look at why mechanical changes is important:  
  
1. **Hydrodynamics and Performance  
Improved Hydrodynamics:**  
  
**Drag Reduction**: Mechanical changes to optimize the shape of an AUV can reduce hydrodynamic drag, allowing the vehicle to move more. . effectively through water. A simplified frame reduces energy consumption and increases working range.  
**Speed ​​and maneuverability:** The hydrodynamically optimized design improves the AUV's speed and maneuverability, which is important for missions that require fast navigation and precise movements.  
  
**Depth Capability**: Strengthening the hull to withstand high pressures at greater depths allows the AUV to operate in deeper underwater environments, expanding its range of applications.  
  
2. **Payload and sensor integration  
Modular structure:**  
  
**Flexibility**: the modular section design of AUV allows easy integration and exchange of different payloads and sensors. This adaptability is critical for mission-specific configurations.  
**Space Optimization**: Mechanical modifications can optimize the internal space to accommodate more or larger sensors, improving the data collection capabilities of the AUV.

3. **Stability and Control  
Buoyancy and Ballast:**  
  
**Neutral Buoyancy**: Adjusting the buoyancy of the AUV to achieve neutral buoyancy is essential for stable and efficient underwater operation. The right ballast systems help maintain the desired depth and direction.  
**Center of gravity:** Changing the internal layout to optimize the center of gravity improves stability and handling, especially in complex movements.  
  
4. **Thermal Management  
Heat Removal:**  
  
**Cooling Systems**: Incorporating efficient cooling systems into the mechanical design ensures that the ship's electronic and power systems remain at their operating temperature, preventing overheating and potential damage.  
  
5. **Application-Specific Adaptations  
Custom Features:**  
  
**Special Tools and Attachments**: Mechanical modifications may include the addition of special tools, robotic arms, or other accessories required for specific tasks such as sampling, inspection, or repair. work

**Modifications in Thrusters:**

The existing AUV has 6 thrusters which are placed on the side panel of the main chassis. Adding two more thrusters will help in boosting the performance of the AUV. It helps in many aspects but there are certain downsides of increasing the number of thrusters which has to be addressed by an expert from mechanical department.

**Improved maneuverability**

1. **Fine-tuned Control**: Additional thrusters can improve control of the AUV's movements, allowing for more precise movements, which is especially useful in complex or cluttered environments.
2. **Multi-directional movement**: With more thrusters, the AUV can achieve better maneuverability in multiple directions, improving its ability to navigate in confined spaces, move stably and perform complex tasks such as inspections or sampling.

**Increased Redundancy:**

1. **Safety**: Additional thrusters increase propulsion system redundancy. If one or more thrusters fail, the AUV can still maintain maneuverability and complete its mission, increasing overall reliability and safety.
2. **Fault tolerance**: For critical operations, redundant thrusters ensure that the AUV can handle partial system failures without significantly affecting its performance.

**Improved Stability:**

1. **Pitch and Yaw control**: Additional thrusters can improve the AUV's ability to control pitch, pitch, and roll. This is crucial for maintaining stability in rough waters or when performing tasks that require a stable position.
2. **Counterforce**: Additional thrusters can help resist external forces such as currents, improving the AUV's ability to hold its position or follow a precise path.

**Better performance in difficult conditions**:

1. **Fast operations**: More thrusters can increase the overall thrust of an AUV, allowing it to operate at higher speeds when needed, such as rescue operations or time-sensitive missions.
2. **Heavy Payload**: If the AUV needs to carry a heavier load or additional equipment, additional thrusters can provide the thrust needed to maintain performance and maneuverability.

**Considerations and trade-offs:**

1. **Power consumption**:

* **Increased power requirement**: More control thrusters consume more power, which can shorten the AUV's operating time if the power supply is not increased accordingly.
* **Battery Life**: The need for additional power sources or larger batteries can increase the weight and size of the AUV, which can affect its design and buoyancy.

1. **Complexity and Cost**:

* **Design Complexity**: Integrating additional thrusters into an existing design can be difficult and may require significant changes to the AUV's structure and control systems.
* **Cost**: Adding additional thrusters increases the total cost of the AUV, including the cost of the thrusters themselves, additional power systems and conversion procedures.

1. **Hydrodynamic Effect**:

* **Increased Drag**: More thrust can increase hydrodynamic drag, which can reduce the AUV's efficiency. This requires careful planning to balance the benefits of additional thrust with increased drag.
* **Design Optimization:** It is very important to ensure that the additional thrusters do not adversely affect the streamlined shape and hydrodynamic performance of the AUV.

1. **Control System Complexity**:

* **Complex Algorithms**: Managing more thrusters requires more complex control algorithms to ensure smooth and coordinated operation, which can complicate AUV software development.
* **Integration Issues:** Proper integration of additional thrusters into the existing control system is essential to avoid disturbances such as vibration or unintended movements.

**Summarize**:

There must be significant changes made to the AUV considering all the departments of engineering coming together to alter the existing model which has multiple issues starting from running the thruster motors, battery leakage issue, poop circuit design and lack of machine learning implementation. This legacy project has to be pitched to other students of mechanical and computer science department to gather some insights on how to proceed with the new approach. To summarize, for the AUV to start and perform specific tasks these changes must be made:   
  
**Proposed alterations:**   
1. **Integration of Machine Learning:**  
The introduction of machine learning algorithms such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) have greatly improved the perception, navigation, and navigation of the AUV. decision-making capabilities - to make possibilities. These algorithms enable real-time target detection, environment mapping and adaptive navigation, improving vehicle autonomy and operational efficiency.

**2. Improved propulsion and control:**  
Adding additional thrusters and optimizing their angles improved the maneuverability, stability, and fault tolerance of the AUV. The improved propeller assembly ensures precise movements, better controllability in dynamic underwater environments and better redundancy for safer operation.

**3. Sophisticated Sensor Suite:**  
The integration of the Ping 360 sonar and the Doppler Velocity Log (DVL) sensor improved the situational awareness and navigation accuracy of the AUV. Ping 360 provides high-resolution imaging for obstacle detection, while DVL provides accurate speed and position tracking essential for complex missions.

**4. User-friendly interface:**  
The development of a complete graphical user interface with joystick control, real-time video feed, telemetry display and navigation system made the AUV more user-friendly. This user interface facilitates manual testing, real-time monitoring, and effective mission planning, ensuring that users can effectively control the vehicle in a variety of scenarios.

**5. Mechanical Improvements**:  
Mechanical changes such as improved hydrodynamics, material selection and modular design improved the performance, durability, and adaptability of the AUV. These modifications ensure that the AUV can operate effectively in harsh underwater environments and perform mission-specific tasks with ease.

**6. Telemetry and data management:**  
Inclusion of advanced telemetry systems and data analysis tools ensures real-time tracking and post-shipment data processing. This feature is critical to mission success because it allows instant customization and in-depth analysis of the collected data.