1 Introduction

1.1 Purpose

The technological environment of science exploration and military operations is leaning more and more towards autonomous vehicles, whether it be on land, in the air, or underwater. From an engineering perspective, Autonomous Underwater Vehicles (AUV) present unique challenges on many fronts. The environment they operate in is an extremely hazardous one given varying ocean temperatures and currents, significant barometric pressures, numerous flora and fauna capable of immobilizing or incapacitating robotic systems, and any sort of long range command systems would require a tether. The systems being developed by Ocean’s Seven are immediately applicable to AUV development and can be extended to improve all forms of autonomous vehicles.

1.2 Scope

Product development will include a backplane to provide a level of modularity and upgradability that will allow for rapid testing of prototype components and replacement of obsolete or failed parts; a power distribution system to efficiently convert the single DC voltage, provided by the LiPo batteries to the array of required voltages and current capacities; and a control system that will maintain awareness of acceleration, velocity, and position vectors and take input from the CPU in the form of desired velocity vector, then perform the appropriate calculations and motor array manipulation.

1.3 Definitions, Acronyms, Abbreviations

AUV: Autonomous Underwater Vehicle. A type of vehicle designed to operate in an underwater environment without input from a human operator.

Backplane: The main power distribution and communication board designed to be modular to allow for rapid testing and replacement of sub components, including power conversion circuits, controls system boards, etc.

Control Boards: The combined motor and motion controlling modules responsible for accurately orienting the AUV and determining pathing.

The Customer: CU Robotics Club

DVL: Doppler Velocity Logger. A bottom tracking sonar device that records velocity and relative position based on Doppler shifts in sonar signals reflected from the sea floor.

ESC: Electronic Speed Controller. A motor controller unit that takes in a PWM signal and outputs a three phase analog voltage to manipulate motor velocity.

IMU: Inertial Measurement Unit: A sensor array consisting of an accelerometer, gyroscope, and magnetometer. Provides accurate data on translational acceleration, rotational acceleration, and magnetic field strength.

LiPo: Lithium Polymer batteries, the primary power source for the AUV.

Motor Array: Eight, three phase, brushless DC motors positioned around the axes of the AUV enabling three degrees of translational freedom and three degrees of rotational freedom.

1.4 References

1.5 Overview

The following sections outline the specific requirements from the customer pertaining to the needs of provided hardware and informational requirements of the different components.

2 Overall Discription

2.1 Product Perspective

The product is divided into three components: the backplane, power system, and the control boards. The backplane unifies power distribution paths and communication buses throughout the AUV, providing simplified integration and upgrading of major components in the AUV. The power system will consist of multiple buck and or boost circuits to facilitate efficient conversion of the single voltage level DC input from the LiPos to multiple DC voltage and current capacity requirements of the electrical components of the AUV. The control board is responsible for taking in information from multiple sensors then manipulating the motor array to maintain relative orientation, and take a desired direction and velocity as input then maneuver appropriately to achieve the desired outcome.

2.1.1 System Interfaces

A waterproof connection is required to transfer main power from the LiPos to the backplane. The AUV backplane must interface with waterproof connectors in order to facilitate communication and power transfer from within the main hull to external enclosures such as the DVL and the motors. The backplane will interface with additional electrical components outside the scope of this proposal.

Power Systems will interface directly with the backplane and all other devices will draw power from the backplane

The Control Boards must interface with the IMU’s, DVL, ESC’s, and CPU through the backplane in order to sense and change the AUV’s orientation and velocity.

2.1.2 User Interfaces

Kill Switch: An externally accessible mechanical switch to disconnect power to all moving parts, including the motor array and any pneumatic devices used for object manipulation.

Location and Orientation Data: Transmitted from the control boards to the CPU via a data bus on the backplane for decision making.

2.1.3 Software Interfaces

The AUV controller must interface with the CPU’s mission control software which gives desired orientation and velocity information to the controller.

2.2 Product Functions

2.2.1 Essential Functions

· User shut down actuator power in hardware (kill-switch) from outside the main hull

· Power Supply monitors power usage. Unit powers down if abnormal power usage occurs

· Power Supply distributes stable power to electronic components

· Controls system keeps unit underwater during operation

· Controls system allows unit to move in all 6 degrees of freedom so that it can change velocity and orientation as needed.

· Controls system outputs logs of current orientation

· Controls system outputs logs of current velocity

· Controls system outputs logs of estimated position

· Controls system samples orientation data from IMU’s

· Controls system samples velocity and position data from DVL

· Controls system accepts velocity change commands from CPU

· Controls system accepts orientation change commands from CPU

· Controls system outputs PWM signals to ESC’s in order to control motors

· Backplane facilitates power transfer to electronic components

· Backplane facilitates communication of electronic components via a bus



2.2.2 Desired Functions

2.2.3

· User shut down actuator power in software

· User hot-swaps power switch between batteries and benchtop power supply

· CPU supplies predefined mission functions which the controls system schedules

2.2.4 Extension Functions

· Power Supply manages power efficiently for extended run time

· User powers on/off main CPU in hardware from outside the main hull

2.3 User Characteristics

2.3.1

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| --- | --- |
| Users | Robosub Team |
| Required Knowledge | The user will have explicit knowledge of the system and be able to recreate and debug problems from the documentation |
| Responsibilities | -The user will control software that drives the control system  -The user will be responsible for ensure connection outside of the backplane  -The user will physically install the product into the AUV  -The user will be responsible for charging batteries |
| Success Criteria | The user defines success as having power delivered from the power supply to the electronic components via the backplane, communication with key components via the backplane, and a well-controlled AUV |
| Disability Accommodation | Installation will not have disability accommodations. Once installed the system should operate autonomously. |
| Language Challenges | Documentation will require knowledge of English. After installation the system should operate independently. |

2.4 Design Constraints

2.4.1 Backplane Constraints

· Backplane must fit within main hull dimension

o W <= x.x”

o L <= x.x”

· Backplane must interface with waterproof connectors

2.4.2 Control System Constraints

· Control system must interact with a predefined CPU software system provided by the customer

· Control system must interact with ESC’s provided by the customer

· Control system must interact with sensors provided by the customer, or interact with sensors easily acquirable by the customer

2.4.3 Power Constraints

· Customer requires power over Ethernet for certain components

2.5 Assumptions and Dependencies

2.5.1 Main hull provided by the customer must be built before full interfacing can be completed

2.5.2 Controls system is dependent on sensors being available and in working condition

2.5.3 Controls system is dependent on CPU input provided by customer

2.5.4 Waterproof connectors provided by customer must be properly spliced and arranged in the main hull

2.5.5 Controls system is dependent on motor placement which is to be determined based off the main hull design.

2.5.6 Power requirements are dependent on electronic components provided by customer and subject to change

2.5.7 Testing is dependent on access to a large body of water. Typically this will be the CU Rec Center pool which must be open and available.

3 Specific Requirements

3.1 Marketing Requirements

3.1.1 Accurately maneuver the AUV through the mission

3.1.2 Maintain stable orientations and trajectories

3.1.3 Externally actuated mechanical kill switch removing power from moving components

3.1.4 Maintain power to all AUV electronics during normal operations.

3.1.5 Facilitate communication between electronic components

3.1.6 Whole system operation time greater than or equal to 25 minutes

3.1.7 Fit within the watertight enclosures on the main chassis without obstructing airflow

3.1.8 Include appropriate safety mechanisms (hardware,software) to avoid operating conditions that are unsafe to the system or bystanders

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| Marketing Requirements | Engineering Requirements | Justification |
| 7 | The system must be no wider than x.x (<6) in., no longer than x.x in. and no taller than x.x in. | The watertight enclosures will be 6” diameter acrylic tubes and all components must fit within. |
| 3,4 | Power traces for all moving components must be isolated from all digital electronics | Activating the kill switch should only disable moving components and not digital. |
| 1 | The system must be able to adjust the vehicle's orientation and velocity to within x.x° and x.x m/s | The AUV will be travelling over distances up to 100 yards and must arrive at an objective within an observational distance.    The AUV must be able to move through designated areas as small as 4’x8’ |
| 4,6 | The system must deliver more than x.xA and y.yV for a minimum of 25 minutes, without replacing batteries | The competition constraints give no more than 25 minutes for running the course. |
| 5 | The system must have a communication bus using xxx standard to facilitate data transfer between electronic components | Multiple components in the AUV will require sending and receiving data. Implementing a single communication standard reduces the number of data buses required on the backplane. |
| 3,8 | The motor power traces must be switchable by means kill switch. | In order to prevent injury all motors must be disabled in the event the kill switch is activated. This must work even when power to the vehicle is lost. |
| 8 | The power system should shut down in the continuous current draw exceeds x.xA or the LiPo batteries falls below x.xV | LiPo batteries are very dangerous when operated outside of their normal ranges. |

4 Use Cases

4.1 UC1: System Power Up

4.1.1 Scope

· The scope for this use case is under normal operations.

4.1.2 Level

· The level of this use case is a function.

4.1.3 Primary Actor

· The primary actor is the user.

4.1.4 Stakeholders/Interests

· *User* – Needs to be remotely powered on and determine initial conditions to begin operations on specified challenges.

· *RoboSub team* – Needs to tether in and power on the sub after placing it in the pool’s starting area.

4.1.5 Preconditions

· The UAV is off and positioned in the appropriate area of operations.

4.1.6 Main Success Scenario

3. RoboSub team places the UAV in the pool.

4. RoboSub team powers on the UAV via tethered cable and laptop.

5. CPU undergoes boot sequence.

6. CPU determines initial position, relative to the starting gate.

7. UAV powers motors and moves toward starting gate.

4.1.7 Extensions

4.2 UC2: Normal Operation

4.2.1 Scope

· The scope for this use case is under normal operations.

4.2.2 Level

· The level of this use case is a function.

4.2.3 Primary Actor

· The primary actor is the user.

4.2.4 Stakeholders/Interests

· *User –* Needs to navigate using the control system

· *RoboSub team –* N/A

4.2.5 Preconditions

· The UAV is powered on and has oriented itself relative to the starting gate.

4.2.6 Main Success Scenario

1. AUV begins mission control

2. Control system begins recording data from sensors to determine orientation set current position

3. Control system begins accepting commands from CPU in order to manipulate motor array

4. Control system adjust PWM outputs on motors to adjust orientation and velocity

5. Control system relays current orientation and velocity to CPU

4.3 UC3: Active Kill Switch

4.3.1 Scope

The scope for this use case is when the sub has been killed due to a diver or an operator activating the kill switch.

4.3.2 Level

The level of this use case is a function.

4.3.3 Primary Actor

The primary actor is the user

4.3.4 Stakeholders/Intersts

User - Diver/Team member wishes to cease vehicle movements in a run reset or emergency

AUV - Wishes to maintain data integrity, digital electronics functionality

4.3.5 Preconditions

The AUV is powered on and the Kill switch has been activated

4.3.6 Main Success Scenario

1. The power system shuts down power to all moving parts.
   1. The power system continues to provide power to all additional components
2. Controls system continues to monitor positional data from the AUV
3. The AUV is positioned at run start by the diver.
4. Kill switch is disabled by the diver
5. Controls system initiates system log restart.

Success Guarantees