Department of Aerospace Engineering Sciences
Senior Projects – ASEN 4018

KRAKEN

Project Definition Document (PDD)

Document History

Release	Date	Description	Name
Draft	09/06/2007	Initial Draft (Sections 1-3 complete)	Geoffrey Lake
Initial	09/13/2007	Initial release	Peter Klein

Approval

Title	Name	Signature	Date
Customer			
Advisor #1			
Advisor #2			
CC			

Project Definition Document

Aerospace Senior Projects (ASEN 4018 & 4028)

1.0 Information

1.1 Project Title

KRAKEN (Tentative) – Kinetically Roving Autonomously Kontrolled Electro-Nautic is a fully autonomous submarine capable of translation in three dimensions and rotation about the yaw axis under feedback control to demonstrate the usefulness of vortex ring technology against current design ideologies.

1.2 Project Customers

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2.0 Background and Context

In the current drive of marine exploration, autonomous underwater vehicles (AUVs) are becoming increasingly important. It is critical for AUVs to be able to operate in a variety of conditions efficiently and effectively. These AUVs can be used for exploration, excavation, and for military operations. Particularly, AUVs are capable of accessing marine environments that traditionally cannot easily be accessed by other means, such as deep sea caves and areas under polar ice caps. However, as the marine environment is complex and varied, it is essential that the design of AUVs allows for them to be able to operate in extreme conditions and be adaptable to the required tasks.

Hydrodynamic design of autonomous underwater vehicles is often driven by a few competing fronts: (i) rapid and efficient deployment to the work-zone and (ii) low-speed maneuvering during the docking procedure and for operations at the work-zone. Rapid deployment necessitates a streamlined body of revolution (e.g. torpedo-shape design) for fast cruising with minimal energy. Examples of AUVs with this design include WHOI's REMUS, MIT's Odyssey, and Ocean Voyager II from Florida Atlantic University. However, since the trajectory of these types of vehicles is adjusted using control surfaces, the magnitude of the available control force is proportional to the vehicle's speed. Consequently, these vehicles are difficult to maneuver at low-speeds and in tight spaces. Such vehicles also cannot enter a precise hovering mode.

On the other hand, low-speed maneuvering and better control is often achieved by a box design where the low-drag design is sacrificed by adding multiple thrusters at different locations and directions. WHOI's ABE[3] and SeaBED and Stanford's OTTER[2] are among AUVs in this category. In this case, precise maneuvering can be achieved at the cost of increased drag and the need for an alternate technique to transport the vehicle from the offshore base or an escort ship to the work-zone. In an effort to resolve this trade-off, the use of compact vortex ring thrusters (VRTs) for low-speed maneuvering or locomotion of small AUVs has been applied. The propulsion scheme suggested here is loosely inspired by the propulsion of cephalopods and jellyfish.

VRTs have been used effectively for the low-speed maneuvering of small torpedo shaped underwater vehicles[1]. The torpedo shape allows for high-speed, long-distance travel while the vortex ring thrusters, placed in a particular formation, allow for accurate low-speed maneuvering. This was demonstrated by the CALAMAR-E senior project team in 2005-2006, which used vortex ring thrusters for low speed maneuvering successfully for the first time. By applying vortex ring thrusters to an underwater vehicle, a design can be produced to effectively navigate through a course and complete a set of objectives. In order to test the vehicle's ability to sense its environment and act accordingly, it must be tested using a practice course. One of these tests is the Association for Unmanned Vehicle Systems International's (AUVSI) Student Autonomous Underwater Vehicle competition.

The AUVSI competition challenges student-built AUV designs to autonomously navigate a course and complete a set of objectives. These objectives are designed to simulate common tasks required by AUVs, such as a recognizing a pipeline and following it, docking with an object, and surfacing in a confined area. This competition will be the guiding drive for this AUV design. This will be the first time that a vortex ring thruster design will be entered into the competition as well as an initial attempt to automate an underwater vehicle with vortex ring thrusters. The prototype of the vortex ring thrusters used on this vehicle will be designed and tested by Mike Krieg [5].

3.0 Goal

The goal of the KRAKEN project is to design, develop, test, and verify a fully autonomous, low volume, low mass submersible with high endurance and maneuverability. This vehicle will implement vortex ring thruster (VRT) technology and will be used by the customer to compare the performance of this bio-inspired propulsion system against conventional methods. The technology will be validated by completing a mission similar to that which is required of vehicles at the student autonomous underwater vehicle (AUV) competition held by the Association for Unmanned Vehicle Systems International (AUVSI).

4.0 Objectives

The main objective of this project is the delivery of a lightweight autonomous submersible capable of three-dimensional translation and yawing for a to be determined (TBD) customer mission. Ideally, this vehicle shall compete in the AUVSI AUV competition; therefore, the Senior Projects mission tasks shall be based off of competition tasks. For the first crucial mission task, the vehicle must pass through an underwater gate. After this, any of the remaining tasks can be accomplished in any order; bonus points are given for extra time remaining. Tasks include “docking with” (bumping) a buoy, following a pipeline, dropping a marker into a box, homing in on an acoustic pinger, and surfacing over the pinger in a specified area. Several AUV competition requirements shall also be used as a baseline; these include weight and volume, full automation, and safety. Being able to complete all competition tasks is too difficult, so select tasks will be chosen.

The development of a submarine capable of rapid forward motion through conventional propulsion methods and low-speed lateral maneuverability and reorientation by using VRTs is significant project objective. Minimum project success entails building a vehicle capable of using VRTs as the primary method of lateral motion.

Autonomy is a crucial mission objective. For this project, autonomy refers to the vehicle’s ability to accomplish the predetermined mission without human interaction. This entails an environmental sensing system, a motion control system, and a mission control system. At a minimum, the environmental sensing system shall consist of image recognition. The objective of the motion control system is for actuator control. This is needed to ensure that the vehicle can move to the desired location as efficiently and quickly as possible. The last automation objective is the development of a mission control system. The mission control system is used for the identification, the prioritization, and the accomplishment of mission tasks. Minimum autonomous mission success is defined by running successful tests of these systems.

The image recognition system of the vehicle will be used to determine relative location and orientation of two different objects. The two objects are an orange pipeline and a black box surrounded by a white border (preliminary ideas). In a real-world mission, the image recognition system would be used to help the vehicle operate autonomously. In this case, it could help the vehicle find and inspect a pipeline, and drop a sensor at a desired location. Using the image recognition system to detect simple objects will provide a proof of concept of the interaction between autonomy and image recognition.

5.0 Functional Block Diagram

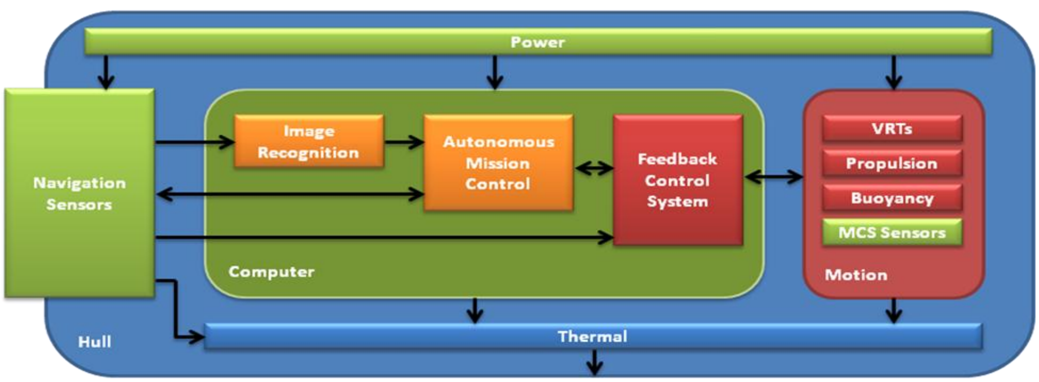

Figure 1: functional block diagram

This functional block diagram in figure 1 above shows the relationships between the various subsystems of the AUV. Green blocks represent the electronics system, blue blocks represent the structures system, orange blocks represent the navigation system, and the red blocks represent the MCS system. All systems will be developed by the team.

6.0 System Operational Timeline (Concept of Operations)

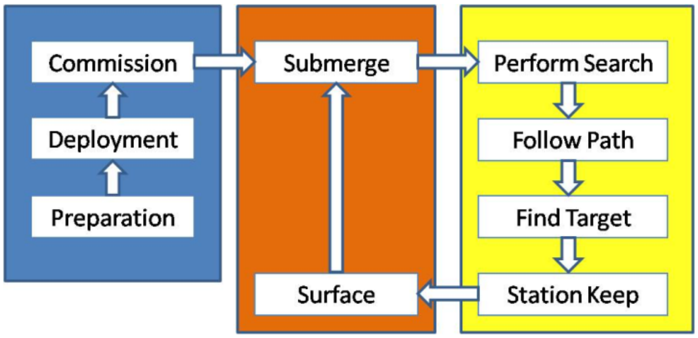

Figure 2: Concept of Operations

Figure 2 shows the current concept of operations. The vehicle will be prepared on the dock by the team and then deployed into the water slung on a crane. Once the vehicle has been commissioned, it will submerge and search for the pre-defined shapes. Upon finding and identifying one shape the vehicle will follow a path based on orientation information to a target object. The vehicle will then station-keep under small disturbances, and then surface.

7.0 Project Requirements (0.PRJ)

7.1 Level 0 project requirement (0.PRJ.1)

7.1.1 The vehicle shall not exceed a maximum dry weight of 84 pounds (38 kg).

7.1.2 Lightweight vehicles enable greater numbers to be deployed, while requiring fewer operators to prepare and handle. The AUVSI competition deducts points for masses over 84 lbs. to a maximum of 140lbs.

7.1.3 Customer requirement

7.1.4 (Inspection) The vehicle will be weighed in air while dry.

7.2 Level 0 project requirement (0.PRJ.2)

7.2.1 The vehicle shall have an image recognition system capable of providing location and orientation of TBD unique objects relative to the vehicle.

7.2.2 Recognizing distinct objects by color and shape are critical to search missions, the type of work AUVs are most suited for. The AUVSI competition therefore arranges tasks to exercise this type of technology and its usefulness. In addition, a vehicle must be able to locate the object and its orientation relative to the vehicle for documentation purposes.

7.2.3 Customer requirement

7.2.4 (Test) To verify accurate object detection, live tests will be conducted.

7.3 Level 0 project requirement (0.PRJ.3)

7.3.1 The vehicle shall be capable of forward motion and ascent/descent.

7.3.2 The vehicle must be able to move between various points in the water, and point at a fixed heading or location. The vehicle must propel itself in forward, rearward, lateral, and vertical directions as well as creating a torque for yawing rotation.

7.3.3 Customer requirement

7.3.4 (Demonstration) The propulsion system will be tested in a body of water to verify required velocities are achieved.

7.4 Level 0 project requirement (0.PRJ.4)

7.4.1 The vehicle shall be capable of operating autonomously.

7.4.2 The vehicle shall contain an onboard processor with the capability of providing controlling signals to the other subsystems in order to complete the mission.

7.4.3 Customer requirement

7.4.4 (Test / Demonstration) Simulate inputs and outputs in dry run and test system in pool.

7.5 Level 0 project requirement (0.PRJ.5)

7.5.1 The vehicle shall be capable of integrating Vortex Ring Thruster (VRT) technology to translate laterally and rotate about the yaw axis.

7.5.2 This means that the vehicle must have the necessary input/output capabilities, power availability, hull volume, sealability, and sensing capabilities.

7.5.3 Customer requirement

7.5.4 (Inspection / Demonstration) The customer will provide the necessary integration requirements to be verified.

7.6 Level 0 project requirement (0.PRJ.6)

7.6.1 The vehicle shall be safe, in and out of water, for both operators and spectators.

7.6.2 This requirement is needed to ensure that operators and testers are not injured by the submarine because testing and mission requirements dictate that operators shall be in the proximity of the submarine.

7.6.3 AUVSI Standards

7.6.4 (Inspection / Demonstration) This shall be verified through satisfactory completion of sub-system requirements being met.

7.7 Level 0 project requirement (0.PRJ.7)

7.7.1 The assembled vehicle shall fit within a box of 1.83m x .91m x .91m.

7.7.2 This requirement comes from two drivers. First, the competition requires that the vehicle fit within this volume. Second, the vehicle must be easily transportable because there will be a variety of testing facilities and locations.

7.7.3 AUVSI Standards

7.7.4 (Inspection) The vehicle will be measured and all components must fit within the required volume.

7.8 Level 0 project requirement (0.PRJ.8)

7.8.1 The vehicle shall be capable of continuous full operation for 15 minutes while submerged.

7.8.2 2007 AUVSI rules shall be used as guidelines. Currently these guidelines include a 15 minute time-frame, an audible pinger below a high-point value surfacing area, a visually recognizable path to follow, and a underwater docking buoy.

7.8.3 AUVSI Standards

7.8.4 (Test) This shall be verified through simulated missions. Endurance shall be tested in an underwater test.

7.9 Level 0 project requirement (0.PRJ.9)

7.9.1 The vehicle's power source shall be dock serviceable.

7.9.2 AUVs must be deployed rapidly from docks, or ships to pursue scientific and military missions at low cost. The vehicle must therefore be serviceable in a short amount of time near an aqueous environment.

7.9.3 N/A

7.9.4 (Demonstration) To verify, the project will demonstrate the removal and replacement of the power plant in a simulated mission.

8.0 Top Level System Requirements (0.SYS)

8.1 Level 0 system requirement (0.NAV.1.1)

8.1.1 The Image Recognition system shall be able to provide object identification, orientation, and direction relative to the vehicle at a TBD rate.

8.1.2 Customer requirements state that the vehicle must identify objects (Project Requirement 7-2). In order to accurately utilize this information, these characteristics are needed.

8.1.3 0.PROJ.2

8.1.4 (Demonstration) Test image recognition system with objects in pool.

8.2 Level 0 system requirement (0.NAV.1.2)

8.2.1 The Image Recognition system shall be capable of operation in a TBD range of refractive indices.

8.2.2 Water in which AUVs must operate is generally not clear, and in order to be able to operate in varied environments, the image recognition system must be able to recognize objects at distances in excess of 10 feet in a TBD range of refractive indices.

8.2.3 0.PROJ.2

8.2.4 (Test) Video evidence from test in lake or through a filter simulating degraded water quality.

8.3 Level 0 system requirement (0.NAV.2.1)

8.3.1 The autonomy system shall accept inputs from sensors, determine necessary tasks based on mission plan, and provide directional instructions to the MCS.

8.3.2 This will work toward fulfilling the project level requirement 7-4 which requires the vehicle to be autonomous. Autonomy is important for AUVs because remote control is difficult underwater (radio signals).

8.3.3 0.PROJ.4

8.3.4 (Test) Wet and dry run testing to verify the proper transfer of data to and from the autonomy system.

8.4 Level 0 system requirement (0.NAV.3.1)

8.4.1 The autonomy system shall process health and status information from sensors within the vehicle and address any problems as they arise.

8.4.2 This is related to the project requirement 7-7 which states that the vehicle must be safe. The system will primarily focus on preventing hardware failure due to leaking or overheating.

8.4.3 0.PROJ.4; 0.PROJ.6

8.4.4 (Test) Run simulated system failures (eg. leak, overheating detection) while monitoring virtual outputs to verify proper response from the autonomy system.

8.5 Level 0 system requirement (0.MCS.1.1)

8.5.1 Vehicle shall be capable of TBD forward $(+u)$ velocity.

8.5.2 To complete the mission tasks, forward motion is required.

8.5.3 0.PROJ.3

8.5.4 (Test) The velocity shall be verified by measuring the maximum velocity. Instrumentation can be integrated in the event performance is not as expected.

8.6 Level 0 system requirement (0.MCS.1.2)

8.6.1 Vehicle shall be capable of a TBD rearward (-*u)* velocity.

8.6.2 The vehicle must move in the rearward direction whenever the shortest and best path to the target is directly behind it.

8.6.3 0.PROJ.3

8.6.4 (Test) The velocity shall be verified by measuring the maximum velocity. Instrumentation can be integrated in the event performance is not as expected.

8.7 Level 0 system requirement (0.MCS.1.3)

8.7.1 Vehicle shall be capable of TBD lateral (+*v/-v)* velocity using VRTs.

8.7.2 To complete the competition tasks, a slow lateral direction velocity is required.

8.7.3 0.PROJ.5

8.7.4 (Test) The velocity shall be verified by timing the vehicle over a preset distance while submerged. Instrumentation can be integrated in the event performance is not as expected.

8.8 Level 0 system requirement (0.MCS.1.4)

8.8.1 Vehicle shall be capable of TBD ascent/descent (+*w* /-*w)* velocity.

8.8.2 One of the main mission requirements is that the vehicle rises to the surface within in a predefined area.

8.8.3 0.PROJ.3

8.8.4 (Test) The velocity shall be verified by timing the vehicle over a preset distance while submerged. Instrumentation can be integrated in the event performance is not as expected.

8.9 Level 0 system requirement (0.MCS.1.5)

8.9.1 Vehicle shall be capable of a TBD yaw (+r/-r) rate using VRTs.

8.9.2 Yaw rotation is the primary method of changing direction in low speed maneuvers.

8.9.3 0.PROJ.5

8.9.4 (Test) By measuring the time it takes to move a preset angle in an underwater environment, this velocity shall be verified.

8.10 Level 0 system requirement (0.MCS.2.1)

8.10.1 The vehicle shall be made positively buoyant in the event of power loss to the vehicle.

8.10.2 The vehicle needs to be safe for operators around the vehicle in the testing water as well as must be easy to recover in the event of system failure.

8.10.3 0.PROJ.6

8.10.4 (Demonstration) Activate kill switch and observe positive buoyancy behavior.

8.11 Level 0 system requirement (0.MCS.3.1)

8.11.1 The vehicle shall have shrouds on any external moving parts such as propellers.

8.11.2 The vehicle needs to be safe for operators around the vehicle in the testing water.

8.11.3 0.PROJ.6

8.11.4 (Inspection) Inspect all external moving parts and their shrouds before operation.

8.12 Level 0 system requirement (0.MCS.4.1)

8.12.1 The motion control hardware shall be capable of operating continuously for 15 minutes.

8.12.2 In order for the vehicle to operate for 15 minutes the motion control hardware must be capable of operating for the same time limit.

8.12.3 0.PROJ.8

8.12.4 (Test) Test each hardware component of the motion control system individually while the vehicle is submerged and held fixed for 15 minutes.

8.13 Level 0 system requirement (0.ELC.1.1)

8.13.1 The vehicle’s computer shall have no less than TBD I/O ports.

8.13.2 This requirement is needed to interface with the NAV and MCS systems.

8.13.3 0.PROJ.4

8.13.4 (Inspection) Inspect I/O ports before integration.

8.14 Level 0 system requirement (0.ELC.1.2)

8.14.1 The vehicle computer shall be replaceable and bootable in a TBD time.

8.14.2 Hardware reset is necessary for any computing system. This is required to facilitate dock servicing of the vehicle.

8.14.3 0.PROJ.9

8.14.4 (Demonstration) Perform a computer reboot within the TBD time.

8.15 Level 0 system requirement (0.ELC.1.3)

8.15.1 The computer shall be able to be powered by a non-vehicular power source.

8.15.2 When the computer is removed from the vehicle, external power will be required to avoid removal of extra parts (batteries).

8.15.3 N/A

8.15.4 (Demonstration)

8.16 Level 0 system requirement (0.ELC.1.4)

8.16.1 The computer shall be network accessible.

8.16.2 The computer must be a network accessible so that at any point in its operation, human operators can see vehicle parameters. This will be needed for the non autonomy mode used in testing.

8.16.3 N/A

8.16.4 (Demonstration)

8.17 Level 0 system requirement (0.ELC.2.1)

8.17.1 The electronics system shall provide TBD power for any combination of 2 VRTs to run simultaneously.

8.17.2 The VRTs operate in pairs for rotation and lateral translation and therefore any combination of 2 VRTs must be capable of running simultaneously.

8.17.3 0.PROJ.9

8.17.4 (Test) Integrate 2 VRTs and test operation while monitoring power input.

8.18 Level 0 system requirement (0.ELC.2.2)

8.18.1 The vehicle open circuit voltage shall not exceed 60VDC.

8.18.2 This is a derivative of safety and general power usage requirements. It is also derived from AUVSI safety standards.

8.18.3 0.PROJ.6

8.18.4 (Test) Battery voltage measurement

8.19 Level 0 system requirement (0.ELC.2.3)

8.19.1 The vehicle shall have a "kill-all" switch which disconnects power to all systems.

8.19.2 This is a safety requirement to meet AUVSI standards.

8.19.3 0.PROJ.6

8.19.4 (Demonstration)

8.20 Level 0 system requirement (0.ELC.3.1)

8.20.1 The power source shall be able to provide power for a minimum of 15 minutes under full operation.

8.20.2 To demonstrate the VRTs, the vehicle should run for no less than 15 min.

8.20.3 0.PROJ.8

8.20.4 (Test)

8.21 Level 0 system requirement (0.ELC.3.2)

8.21.1 The vehicle's power source shall be replaceable in a TBD time.

8.21.2 Batteries cannot be charged in an enclosed area (ie., the vehicle). This is required to facilitate dock servicing of the vehicle.

8.21.3 0.PROJ.9

8.21.4 (Demonstration)

8.22 Level 0 system requirement (0.STR.1.1)

8.22.1 The structure shall dissipate heat so that all components remain within their TBD temperature limits during continuous operation, both in and out of the water.

8.22.2 It will be necessary to test the vehicle for long periods of time, both in the water and out. For this reason it will be important that the vehicle does not damage any internal components due to overheating.

8.22.3 This requirement relates to the structural system.

8.22.4 (Test) The internal temperature of the vehicle will be monitored at several key locations during extended runs.

8.23 Level 0 system requirement (0.STR.2.1)

8.23.1 The structure shall be capable of submerging to a TBD depth for 15min without damage or leaks.

8.23.2 It is important both for buoyancy control and mission survivability that the vehicle does not take on water or crush at depth.

8.23.3 This requirement relates to the structural system.

8.23.4 (Test) The vehicle shall be submerged at the TBD depth, then analyzed for leaks.

8.24 Level 0 system requirement (0.STR.3.1)

8.24.1 All propellers shall have shrouds that extend 2 inches from the front and back of propeller or be covered with grates.

8.24.2 This requirement is for the safety of individuals within the vicinity of the submarine.

8.24.3 This requirement relates to the MCS.

8.24.4 (Inspection) The vehicle will be inspected to meet safety criteria.

8.25 Level 0 system requirement (0.STR.4.1)

8.25.1 The vehicle shall have a TBD mass allocation for the VRTs.

8.25.2 The vehicle must be able to carry the VRTs within its structure for low speed maneuvering purposes.

8.25.3 0.PROJ.6 and customer requirement

8.25.4 (Test) The VRTs will be massed individually. This mass is included in the overall mass budget.

8.26 Level 0 system requirement (0.STR.4.2)

8.26.1 The vehicle shall have a TBD volume allocation and TBD dimensions for VRT integration.

8.26.2 The vehicle must be able to carry the VRTs within its structure for low speed maneuvering.

8.26.3 0.PROJ.6 and customer requirement

8.26.4 (Test) The VRT allocation will be dimensioned according to manufacturer specifications.

8.27 Level 0 system requirement (0.STR.4.3)

8.27.1 The vehicle shall have four thruster interface ports at TBD locations for the VRTs to fit.

8.27.2 The ports will allow easy installation and removal of VRTs in their completely assembled form.

8.27.3 0.PROJ.6 and customer requirement

8.27.4 (Demonstration) The integration of the VRTs into the ports on the vehicle shall be demonstrated.

9.0 Minimum Requirements for Success

To achieve a successful mission the project must prove ability of the AUV's autonomous mode. This is defined as accepting an input (Image Recognition), determining necessary outputs (Autonomy), and providing those outputs to actuators capable of performing the desired motion (VRTs).

9.1 Level 0 project requirement (0.PRJ.2)

9.1.1 The vehicle shall have an image recognition system capable of providing location and orientation relative to the vehicle of TBD unique objects.

9.2 Level 0 project requirement (0.PRJ.4)

9.2.1 The vehicle shall be capable of operating autonomously.

9.3 Level 0 project requirement (0.PRJ.5)

9.3.1 The vehicle shall be capable of integrating Vortex Ring Thruster (VRT) technology to translate laterally and rotate about the yaw axis.

10.0 Deliverables

10.1 Deliverable #1 (0.DEL.1)

10.1.1 The senior projects team will deliver an autonomous underwater vehicle capable of integrating the Vortex Ring Thrusters to the customer.

10.2 Deliverable #2 (0.DEL.2)

10.2.1 The senior projects team will deliver all documentation related to the design, construction, and maintenance of the autonomous underwater vehicle to the customer.

10.3 Deliverable #3 (0.DEL.3)

10.3.1 The senior projects team will deliver all code run on the autonomous underwater vehicle to the customer.

10.4 Deliverable #4 (0.DEL.4)

10.4.1 The senior projects team will deliver all documentation related to the code run on the autonomous underwater vehicle to the customer.

11.0 Technical Risk

11.1 Hull Sealing (0.RSK.1)

11.1.1 It is difficult to create an underwater vehicle that does not leak. As depth increases, water pressure also increases, and leaking will get worse. Proper sealing is essential for the success of this project.

11.1.2 The previous CU design (CALAMAR-E) had a very successful sealing system, and it may be possible to borrow and improve on their techniques.

11.2 Hydrodynamic Modeling, Control System, and Autonomy (0.RSK.2)

11.2.1 One of the major requirements of the project is to design an autonomous vehicle. Controlling an autonomous vehicle requires a good theoretical model of the vehicle's characteristics, and this type of model is not yet available for the VRTs.

11.2.2 The group has several people with extensive experience in programming and some experience with control systems, which are both essential skills for overcoming this technical risk.

11.3 Environmental Sensing (0.RSK.3)

11.3.1 An autonomous vehicle must have a high level of environmental awareness. This project will have image recognition, which must be developed by the team since existing technology would be too expensive to procure with our current budget.

11.3.2 Work has been done on both of these systems last semester and over the summer with promising results. Also, the team is working to acquire additional funds from company sponsors that could allow us to purchase off-the-shelf systems if necessary.

11.4 Testing Facilities (0.RSK.4)

11.4.1 Much of the testing for this project must take place in the water. This requires constant and reliable access to pool facilities. Other student groups have higher priority for access to on-campus facilities, and it can be difficult to schedule time at other pools.

11.4.2 The team has developed a good relationship with the facility managers on campus. Also, there are several other pools in the area that can possibly be used if on campus facilities are unavailable.

11.5 Buoyancy (0.RSK.5)

11.5.1 This project will require an effective buoyancy system to actively control the depth of the vehicle. Previous CU vehicles have not used active buoyancy, so there are not a lot of resources available to the team in this area

11.5.2 Technical papers of other competition vehicles are available and the buoyancy methods used in those may be adaptable to this project

12.0 Anticipated Engineering Expertise

Anticipated Engineering Expertise	
Technical Area	**Description of Need**
Hydrodynamics	Hydrodynamic modeling of hull drag, control surfaces, appendages
Structures	Hull structure, watertight seals
Control Systems	Control of Motion Actuators, modeling of control systems
Thermodynamics	Cooling of Electronics, Sensors, Motors
Materials	Hull material, part material, corrosion protection
Propulsion	Propeller, Vortex Ring Generators, Buoyancy Control
Software Design	Control, Image Recognition, Sensor, Artificial Intelligence Software
Data Acquisition	Environmental Sensors (Image Recognition, Acoustics)
Electronics Design	Sensor Integration, Power Conditioning
Electronics Fabrication	Sensor Integration, Power Conditioning
Mechanical Design	Propeller, Hull shape, Motor Integration, space allocation
Mechanical Fabrication	Hull, Motor Integration, Buoyancy control system, Electronics racks

13.0 Resources

13.1 Facilities

In addition to the aerospace department facilities available to all senior project teams (such as the electronics lab and the machine shop), this team requires special facilities due to the aquatic nature of the project. In particular, pool facilities are essential for the testing phase. The team has been allowed to use the Carlson pool on previous occasions, as is likely to be able to use it in the future. Other on-campus pools include a dive well in the Recreation Center that has a maximum depth of 14 ft and the Claire Small pool, but the team has not yet secured access to either of these pools. The project will also have access to the Microfluidics laboratory courtesy of Professor Mohseni. This lab contains a 700 gallon tank in which some testing could be performed.

13.2 Additional Advisors

One particular area of expertise that the team is lacking is hydrodynamics. The control system for the vehicle to be autonomous requires a precise hydrodynamic model. Unfortunately, team members primarily have experience with aerodynamics, which can not be used to accurately model performance in water.

Additional experience in sealing the vehicle for underwater use is critical for success. The previous generations of submarines have indicated that this area must be carefully planned for and implemented.

13.3 Funds

In addition to the $4000 provided by the aerospace department to fund this project, the team has actively working to secure other sources of funds. In particular, two proposals have been submitted to UROP, which would increase our funding by $6000. Also, contact has been made with several companies including Lockheed Martin and National Instruments regarding possible sponsorship of the team. Such sponsorships could provide funds or discounts on parts for the vehicle.

Current cost budget puts the total budget at about $10,000. Bulk costs come from the processing components (CPU, etc.) and the sensor suites. Donations or loaned components could significantly reduce the project cost.

Obtaining additional funds would allow the project to use more reliable commercial off the shelf systems, but is not critical to the project.

14.0 Acknowledgements

14.1 Customer contacts

Michael Krieg is primarily responsible for designing, manufacturing, and testing a prototype of the VRTs that will be used on the vehicle. As a result, he helped design and approved the requirements of the VRTs and their integration.

14.2 Faculty members

The PAB has given their inputs to the PDD.

14.3 Graduate Students

Michael Krieg and Craig Turansky have given their opinions and recommendations on requirement writing.

15.0 References

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