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A Student Design, Develop, Test & Deploy Project: Perseus II - Development of an Unmanned Marine System for an Underwater Unexploded Ordnance Mission

Mr. Michael DeLorme, Stevens Institute of Technology (SES)

Mr. Michael DeLorme Mr. DeLorme has 11 years of professional experience as a Research Associate/Engineer at Stevens; Davidson Laboratory, DHS National Center for Secure and Resilient Maritime Commerce (CSR), and Systems Engineering Research Center. Research concentrations include experimental marine hydrodynamics, unmanned marine vehicles, the implementation of hydro-acoustics for the detection of marine vehicles, and the coordination of complex, multidisciplinary, systems engineering focused student design and development projects.

Michael Giglia
Ethan Hayon
Joseph Huyett
Donald Montemarano
Mark Siembab

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Abstract

A multi-disciplinary team of 5 undergraduate students from Stevens Institute of Technology took part in a project where they were challenged by the Rapid Reaction Technology Office (RRTO) of the Assistant Secretary of Defense with the design, development, and functional demonstration of an unmanned marine system (UMS) with the intended mission of searching for, locating, and collecting information on objects that are potentially unexploded ordnance (UXO) underwater.

The multi-disciplinary student team was comprised of mechanical engineering, naval engineering, and computer science students. The problem statement they received was simple and purposefully generalized, "… assemble an Unmanned Underwater Vehicle (UUV), Remotely Operated Vehicle (ROV), Autonomous Underwater Vehicle (AUV), or Unmanned Surface Vessel (USV) in a relatively short period of time that is capable of searching for, locating, and collecting information on objects that are potentially unexploded ordnance (UXO)." The students had two semesters and a budget of $15,000 to go from this statement to a field demonstration of their solution in Key West, FL.

This project's multi-disciplinary nature, broadly defined real world problem, engaged and thoughtful sponsor, and unique advising requirement produced student outcomes that cover most if not all of the ABET student outcomes criteria. This paper will cover the project from concept to final successful demonstration including; team forming, academic advising, mission planning, project planning, research, development, fabrication, sensor development, sensor integration, testing, demonstration, reporting, assessment and student outcomes.

Background

The US Government defines "unexploded ordnance" as military munitions that:

(A) have been primed, fused, armed, or otherwise prepared for action;

(B) have been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material; and

(C) remain unexploded, whether by malfunction, design, or any other cause.[1]

There are estimates of hundreds of million pounds of unexploded ordnance (UXO) sitting underwater around the world and tens of millions in US waterways. These UXO are not going away and the problem is not relegated to deep ocean waters. Many of the UXO that cause the greatest concern are near, or in some cases onshore in coastal areas, estuaries, rivers and lakes.

Couple this with the fact that a large percentage of the world and US population live near coastal areas and we can clearly see why underwater UXO is a problem that needs to be addressed. Underwater UXO ranging from WWII mines to small arms munitions have been found by; swimmers, divers, fishermen, and people strolling the beach. Coastal erosion and storms tend to aggravate the problem as items that were once buried are unearthed leading to more sightings.

Military installations and former military installations are prone to UXO of all type but the underwater UXO present particular challenges owing to the complexities of localization and identification of UXO underwater and the challenges of underwater operations in general. A possible underwater UXO sighting scenario might involve a recreational diver reporting what she believes may be an old missile or bomb to the local authorities. The typical local first responders are not prepared to handle this situation. The responsibility for the incident response will often fall on military experts and frequently military divers. This is a dangerous task and whether the sighting is real, or as may be the case a false alarm, it is costly.

One group with a particular interest and experience in the underwater UXO problem is the US Naval Facilities Engineering Command (NAVFAC). When NAVFAC's problem was presented to the Office of the Secretary of Defense, Rapid Reaction Technology Office (RRTO) the RRTO developed an innovative program aimed at addressing this problem. The Rapid Reaction Technology Office created Perseus II; a government program to enlist undergraduate students to design unmanned marine systems (UMS) to help solve the underwater UXO problem. With support from the Applied Research Laboratory (ARL) at Pennsylvania State University, the RRTO enlisted five schools: Florida Atlantic University (FAU), Florida Keys Community College (FKCC) , North Carolina Agricultural and Technical State University (NC A&T), Georgia Institute of Technology (GT), and Stevens Institute of Technology (Stevens) to assign teams of undergraduate students to tackle the problem of underwater UXOs. A primary goal of Perseus was to gain insight and fresh ideas from the students who would have an outsider's perspective on the problem, and be unencumbered by institutional preconceptions about how to solve the problem.

The outcomes of the Perseus II project are not only the technical output of the student's work. The project had additional goals of enhancing STEM education and interesting high performing students in technologies related to unmanned systems. With respect to all three primary goals the project was a success. All of the student teams had varying degrees of technical success. The educational benefits of project based learning are well established and the apparent enthusiasm of the students clearly indicated a strong interest was either developed or fostered through their involvement in Perseus II.

From this point forward this paper will focus on the project from the perspective of the Stevens Institute of Technology team.

Project Definition

Perseus II was defined by the sponsor as a "student design, build, and demonstrate project to provide an Unmanned Marine System capable of locating potential unexploded ordnance (UXO) or discarded sea mines." The scope of those three tasks; designing, building, & demonstrating and unmanned marine system are challenging in and of themselves. Combining these challenges with the mission related requirements of "locating, localizing, providing precise object identity, armed/safe condition, material condition of the object, and identification of potential attachment points for recovery" the project became far more complex requiring multiple sensors, sensor integration, underwater geolocation, and research into a topics that are not typically covered at the undergraduate level.

Team Formation

At Stevens the project began with the assembly of the undergraduate student team. Given the complexity and nature of the project a subset of engineering disciplines were identified and the respective academic departments were contacted to solicit student interest. The disciplines identified from those available as being critical to success were; mechanical engineering, naval engineering, computer science, and electrical/computer engineering. Once the respective departments were notified the process of selecting the team members began. Resumes were reviewed and interviews with promising students were conducted. Adding a distinct challenge the Perseus II project schedule ran off the academic 2 semester calendar at Stevens. This complicated the team formation as projects of this type are typically conducted as part of the senior design program. The mechanical engineering department was the only one of the critical disciplines to express a willingness to allow for students to participate across the three semesters necessary for Perseus II. Two mechanical engineers joined the team with Perseus II identified as their senior design.

The solution to filling out the rest of team was enabled by the ability of qualified undergraduate students at Stevens to participate in independent research. Several steps were taken to address the challenge of filling out the rest of the team. The most important step came from the initial 2 mechanical engineering students. The networked nature of students and the campus allowed for the team to begin to self-form. The initial 2 students identified potential participants who had the necessary abilities and a reputation for hard work. These students were contacted and those that expressed an interest were interviewed by the project advisor. If after the interview the students expressed a desire and willingness to participate an individual plan was established to allow for participation. Five additional team members joined the project through this process, an electrical engineer, a mechanical engineer, a naval engineer, a computer science student, and an engineering management student. This third mechanical engineering student had limited, but critical experience with computer engineering and was designated to work with the single electrical engineer given the expected heavy electrical engineering workload of the project.

By the end of the first semester two of the students opted not to continue. Projects of this magnitude require anywhere from 10-20 hours/week from student participants. This is in addition to other academic and extracurricular requirements. This is a significant workload and students dropping out once the full scope of the required effort is understood are not unusual. It is not an ideal situation for anyone involved but previous experience indicates that a smaller, focused team dedicated to success, and with the willingness and ability to put in the effort is preferable to a larger group putting forward significantly different levels of effort. The departure of the two students left the team with no dedicated electrical engineer presenting a particular challenge the remaining students managed to overcome.

The Project

The fact that this is a student project does not imply there is an existing solution that would be used to judge the project's effectiveness. As such, Perseus II was truly an open-ended project. The problem statement the students received was simple and purposefully generalized, "… assemble an Unmanned Underwater Vehicle (UUV), Remotely Operated Vehicle (ROV), Autonomous Underwater Vehicle (AUV), or Unmanned Service Vessel (USV) in a relatively short period of time that is capable of searching for, locating, and collecting information on objects that are potentially unexploded ordnance (UXO)." Upon receiving this problem statement, the first thought that students communicated was: "this is cool" followed soon after by, "this is harder than I thought".

With this problem statement and some basic information on the search area, the teams then move forward with a process that essentially only had two constraints: 1) the relatively short period of time of eight months from problem statement to demonstration and, 2) each team received a maximum of $15,000 for developing their solution. The role of the advisor was to keep the project moving forward, but not to give direction or to provide solutions.

The Process

The description of the project was provided by the project sponsor: "The Office of the Secretary of Defense, Rapid Reaction Technology Office (RRTO) is sponsoring a student design, build, and demonstrate project to explore how effectively motivated, intelligent persons with just a general background in engineering (role filled by undergraduate students), with modest resourcing, and in a relatively short period of time, provide an underwater vehicle capable of locating potential unexploded ordnance (UXO) or discarded sea mines. Tasking would include to the greatest extent possible, locating, localizing (precision geo-location), providing precise object identity, armed/safe condition, material condition of the object, and identification of potential attachment points for recovery."

From this statement the goals and objectives were determined. Primarily to locate, localize, and identify UXO. Additionally, the team needed to design, build, and test a vehicle capable of supporting technologies that could accomplish the mission. Secondary goals pending the success of primary goals include the listed tasks of providing armed or safe condition, material condition, and attachment points for recovery lines. The team considered these secondary because they provided supplemental information that may aid recovery, but are not necessary to make a decision of whether the object was actually a UXO.

The major challenges that the team identified were vehicle design and water tightness, vehicle control and localization, and metal detection technologies. It was these primary areas that became the focus of the team's efforts.

Before any design took place, the team worked to develop a comprehensive understanding of customer needs based on input and communication directly from the sponsor. The sponsor provided the following scenario to better establish a related UXO mission, "a diver sees a suspicious object underwater. In this scenario, before Explosive Ordnance Divers (EODs) would be sent into the water, a low cost yet effective field vehicle would be sent in to search around the reported area and analyze the situation. The vehicle would enable users to locate all UXO within the search area, and report useful information about the ordnance it finds."

Stakeholder needs were then quantified into requirements for the system. The compiled lists of primary and secondary needs based on the project statement documentation provided by the sponsor are defined below.

Primary Needs

- Locate, localize, and provide object identity of UXO
- Operate at depths up to 40 feet
- Search an area of 50'x150'
- Spend no more than $15,000 in the development of the vehicle
- Complete mission in under 45 minutes duration

Secondary Needs

- Document research, information, and methods
- Develop courses of action and timelines
- Document selected and rejected courses of action

- Provide report and briefing outlining course of action chosen for incorporation into the vehicle

Concept Selection

Based on the needs defined above and the budgetary and time constraints the team developed a mission scenario or concept of operations and a system design concept that called for a underwater vehicle with sparse supervisory control towing a surface platform that enabled communication of sensor data, vehicle position, and control via a land based user interface (Figure 1).

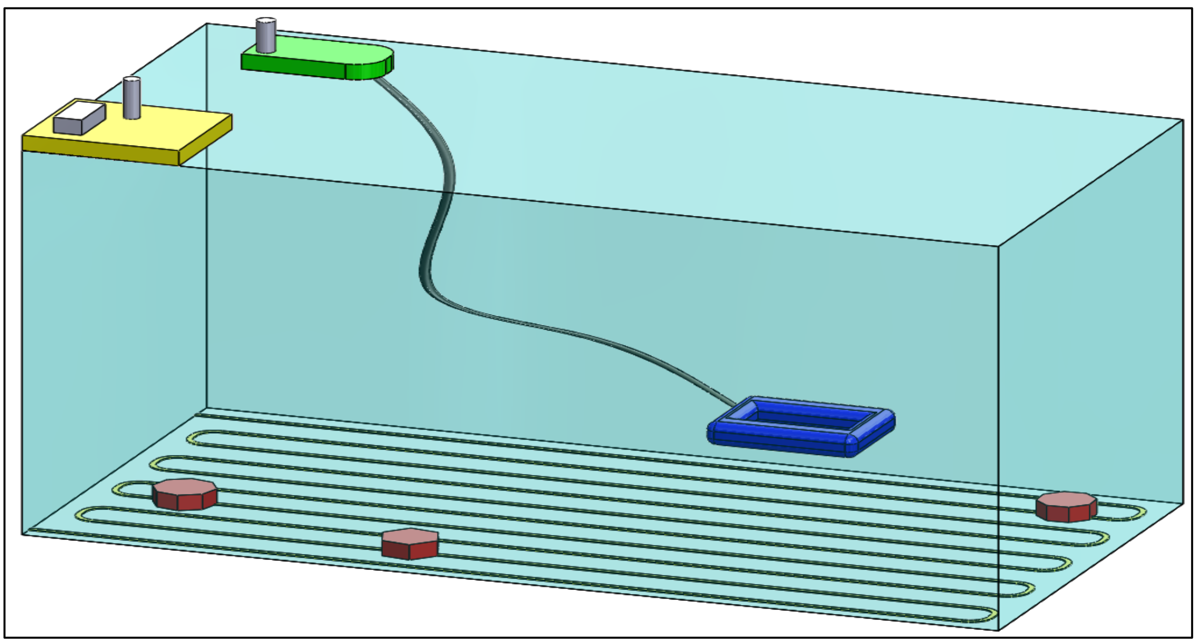

Figure 1: System Concept

The team developed a layered, multi-sensor approach to first identify potential targets, then to convey as much information as possible from the target to the surface along with the target location. Sensors on the UUV with direct real-time feeds to the surface included multiple video cameras, a magnetometer to identify material properties, and parallel lasers that were implemented to approximate the objects dimensions. The dimensional information was then to be cross referenced against a database of know UXO on the user interface computer to provide a list of potential UXO that match the measured characteristics. The system also consisted of a surface platform towed behind the UUV equipped with a GPS, wireless communication gear and off-the-shelf marine grade side scan sonar. The SONAR was intended to provide a large area picture of the search area adding another layer to the vehicle based sensors. The team later determined the SONAR had another potential use. The position of the UUV could be determined from the SONAR and coordinated with the surface platform GPS fix. The system was also intended to utilize a USBL or Ultra Short Baseline navigation system for highly precise underwater positioning of the UUV and UXO. Unfortunately the USBL system was not completed in time for the demo forcing the team to rely on a buoy release mechanism for UXO positioning.

Design

The major concepts evaluated with respect to vehicle design included thrust methods, vehicle form, vehicle structure, and thrust configurations. Concept trees and combination tables were developed, and a decision matrix was conducted to determine thrust configuration.

Propulsion methods that were considered included commercial and custom thrusters, as well as ballast systems for depth control (Figure 2). Specific options included commercial brushless motor thrusters, commercial brushed DC thrusters, custom-fabricated thrusters, or repurposing commercial-off-the-shelf (COTS) bilge pumps. The team considered complexity, cost, reliability and performance and ultimately selected brushless thrusters as the best choice, maximizing performance while minimizing complexity and risk.

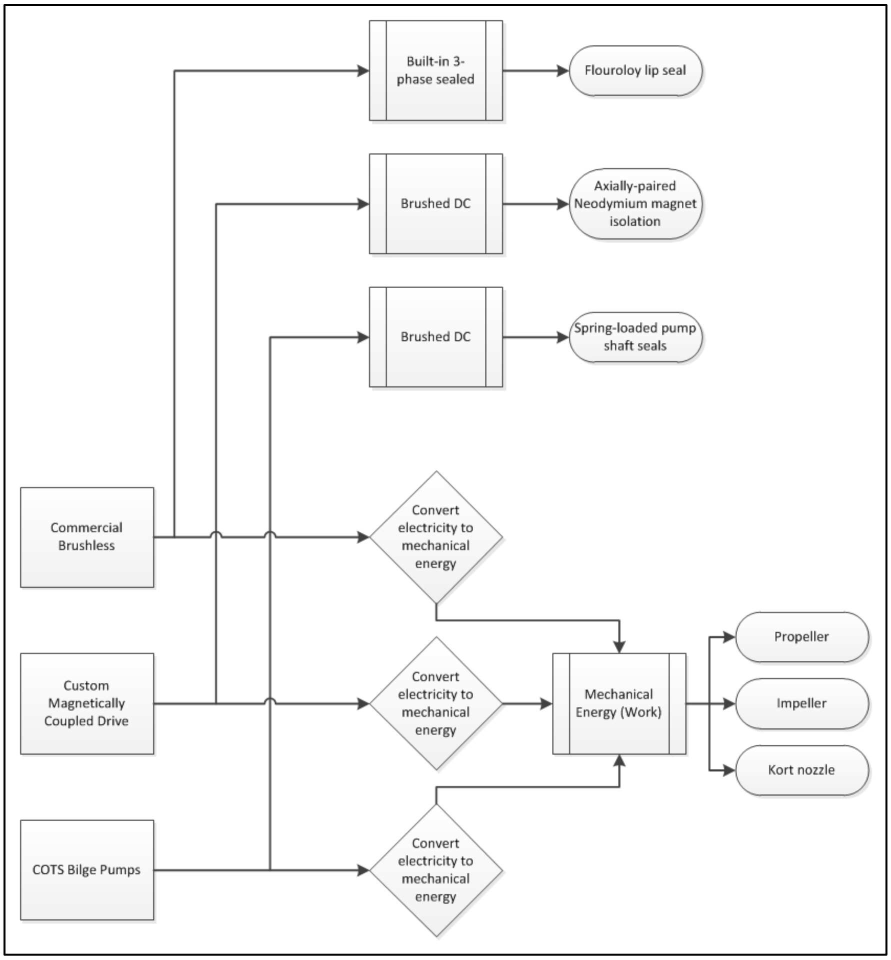

Figure 2: Propulsion Method Decision Tree

The considered vehicle form concepts are shown in the Figure 3 below. The three main alternatives considered were planar, cubic, and cylindrical. Research results indicated that:

- Cylindrical vehicle forms reduced drag in the primary direction of movement, but are harder to control and limits the amount of internal space available for electronics and batteries.

- Planar vehicles are optimzed for motion in the plane, and are easier to control while also increasing the storage within the vehicle.

- Cubic vehicles are not optimized for any direction, but lend the most internal space, as well as simplified control.

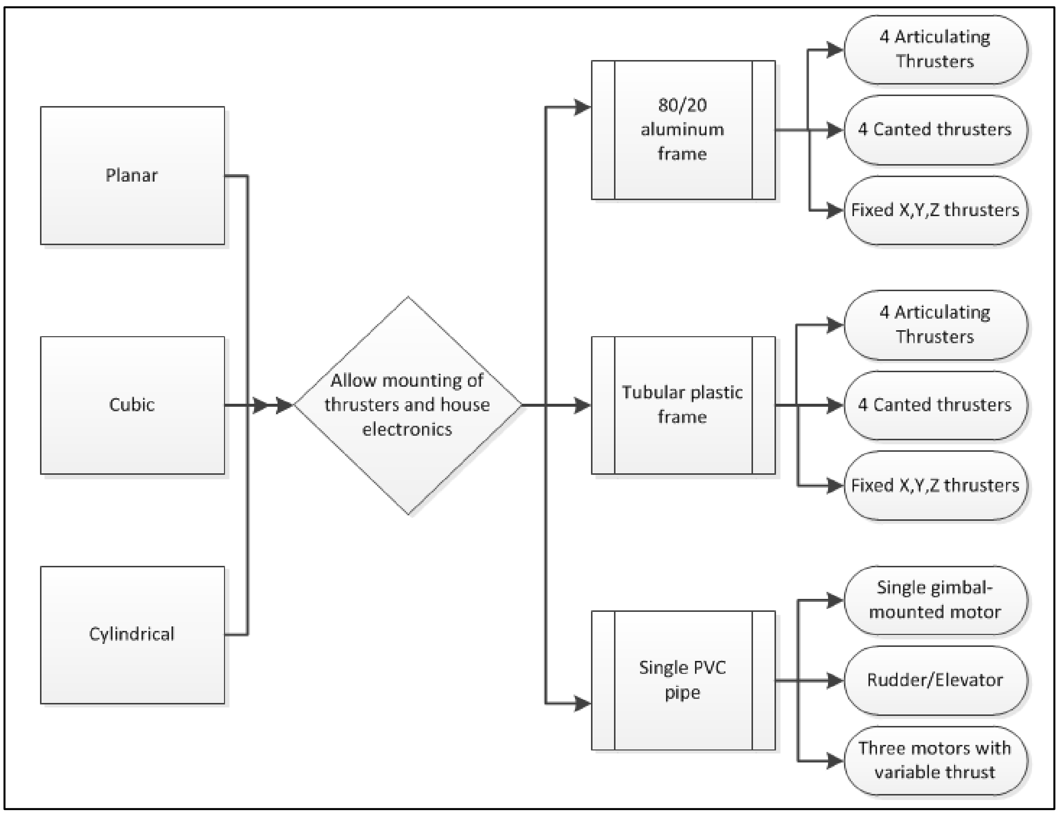

Figure 3: Concept Tree for Vehicle Form

Ultimately the planar design was selcted as it was best suited to the teams sea floor search mission which primarily required planar motion control. It also provided space for the large mission sensor payload required and satisfied the mission time reguirements with a form that sufficiently reduced hydrodynamic drag. The planar configuration allowed for a wider vehicle providing a more effective scan width with mission sensors.

The final prototype design called for a vehicle constructed with 4 fixed thrusters to allow for horizontal and vertical translational motions and yaw, or rotation about the vertical axis. Pitch, roll and sway motions were not desired and the vehicle was designed for stability by considering centers of mass and buoyancy in the design phase. Minimal adjustments to center of gravity and buoyance were provided with small moveable weights to account for the varied density of water from test sites to the final demonstration in Key West, FL.

The vehicle frame was designed using modular 80/20™ framing which permitted modularity in the design which the team determined would serve both their mission and the prototyping and refinement process inherent in any complex system design. Clear PVC hulls were used for the port and starboard electrical storage, and an acrylic tube was used in the front for its optical qualities which were necessitated by the visual nature of some of the sensors.

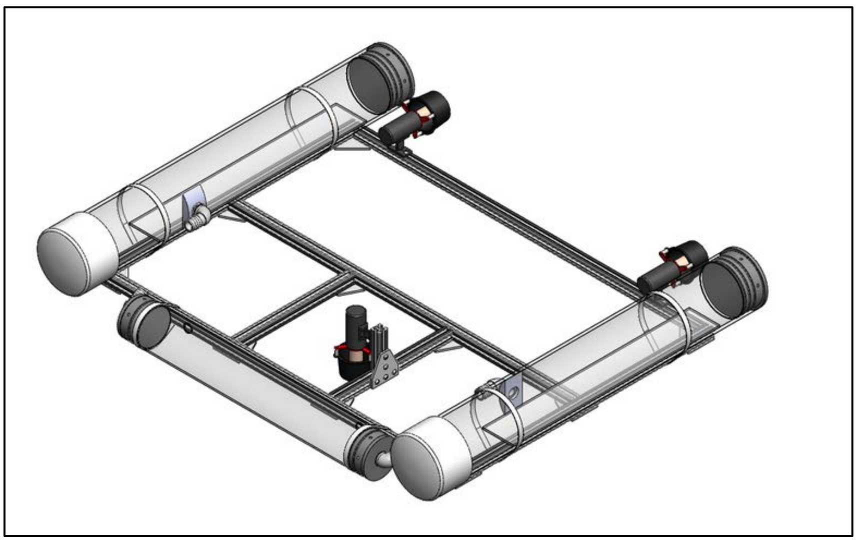

Figure 4: Final Prototype Model

Vehicle Control Software

All vehicle command, control, and communication as well as sensor data integration, and vehicle localization were handled by software developed by the student team using a UNIX-based approach (Debian 7) that was developed in C/C++. Figure 5 below shows the vehicle control software architecture.

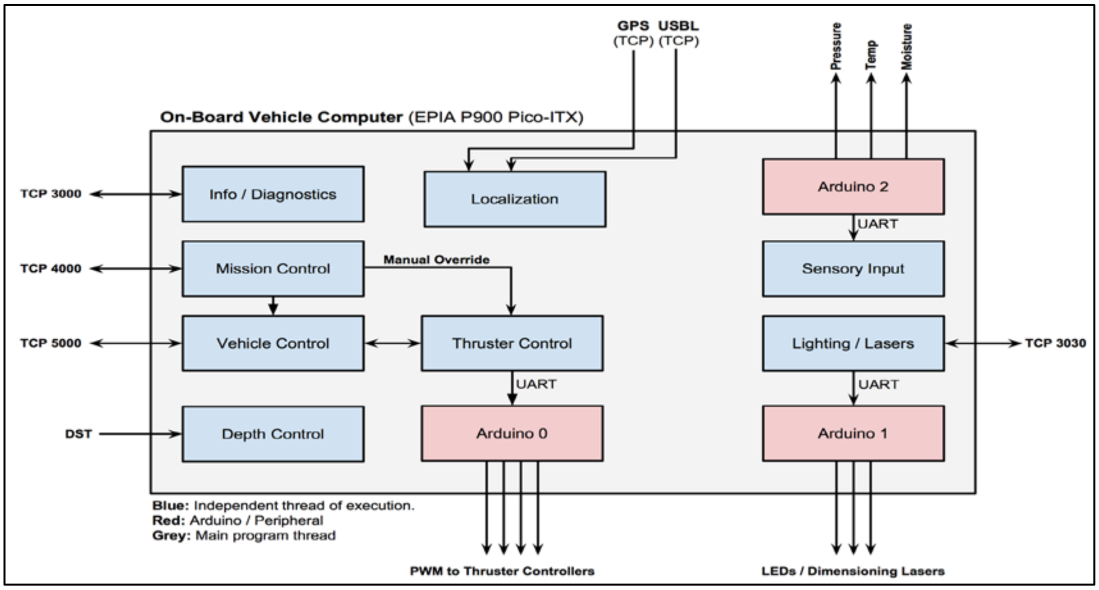

Figure 5: Vehicle Control Software

Sensor Payload

The combination of sensors selected for the mission included metal detection, cameras, and side scan sonar. Additionally, parallel line lasers were used in conjunction with the cameras to impose a length scale onto the image. All of the sensor outputs were built into the user interface in order to give the operator as much information as possible about target objects. The user interface also provided GPS data of the surface platform and the heading measurement obtained by an Inertial Measurement Unit mounted on the UUV. One screen of the interface is shown in Figure 6.

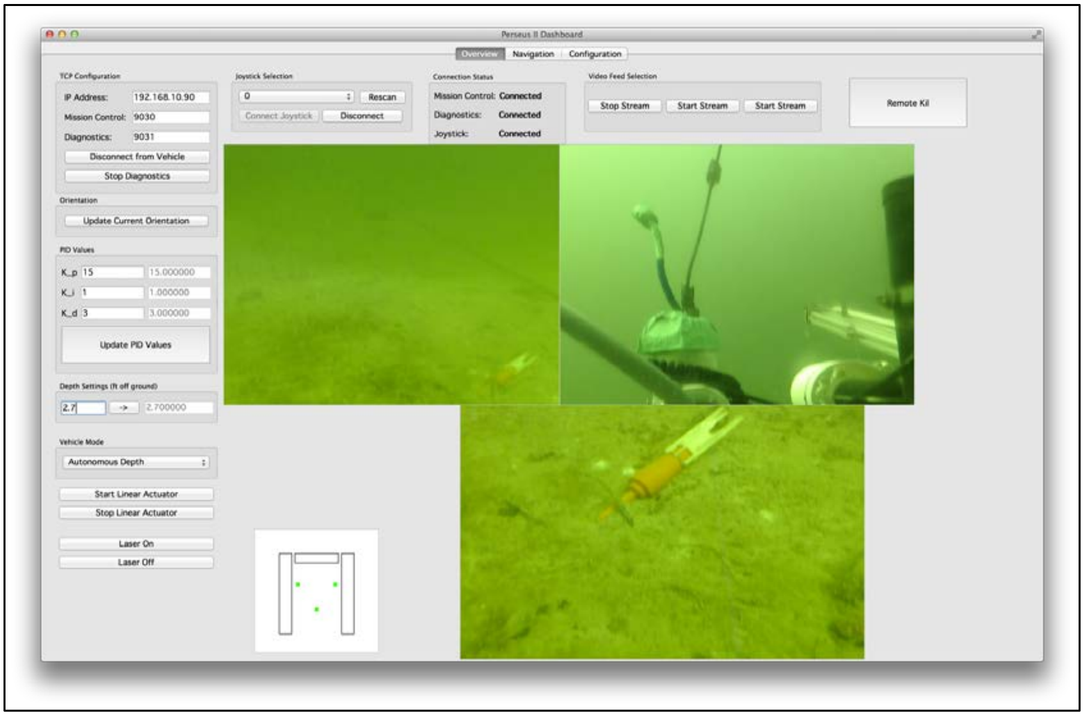

Figure 6: User interface showing 3 camera views.

Laser Dimensioning

As the vehicle was to operate beyond the sight of an onshore operator with minimal visual size reference for underwater objects the team developed a system utilizing two parallel vertical line lasers. The lasers projected forward from the UUV on either side of a live feed camera. The lasers were at a fixed distance of six inches apart along the entire distance of the camera feed. The two lasers converge on screen. So by taking a picture of an object with the line lasers on either side of the object (if it’s smaller than six inches) or actually on the object (if larger than six inches) the pixel distance from each line laser gives the user six inch visual reference on screen. By finding the pixel distance of the measurement in question, the actual measurement of the dimension in question can be closely estimated. Figure 7 below shows the laser measurement system as seen from the user interface.

Figure 7: Laser dimensioning

Positioning and localization

One of the primary challenges of this, or any underwater vehicle project is vehicle localization and positioning. The team opted to develop an ultra-short baseline (USBL) acoustic positioning system of their own design and fabrication. The acquisition of a commercially available system was beyond the project budget. The designed system involved instantaneous determination of position using a transmitter and three receivers. The GPS position of the transmitter at the surface was to be known, and the time delays of an acoustic signal sent to the three receivers mounted on the vehicle were to be measured. Time delays were then to be converted to distances, and from there position calculated.

This effort proved to be overly ambitious but the team developed a working model scale prototype that functioned in lab trials. The results of one such test are shown in Figure 8. The corresponding time delay results in a distance of ~3.3” vs. the actual 4” distance. Given the cost of a commercial system is on the order of $35,000 and the students spent about $1,500 on parts to develop the model system which had the ability to implemented on the Perseus vehicle the results are impressive.

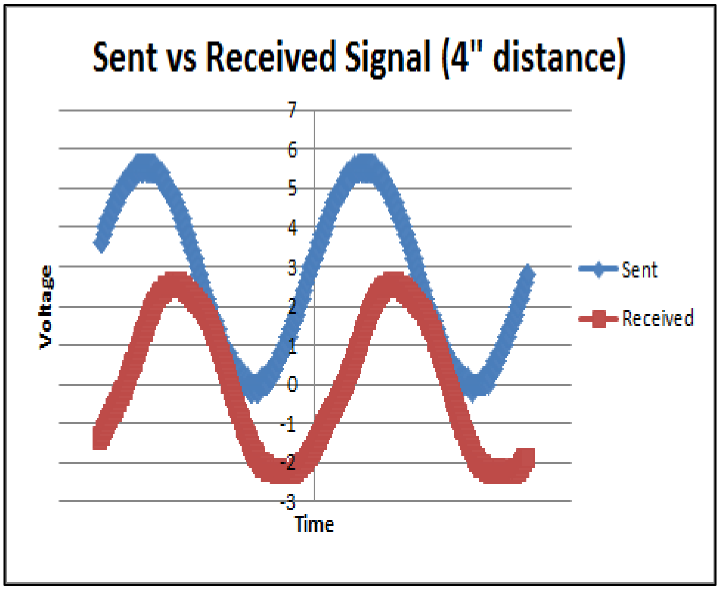

Figure 8: USBL Model results

To account for the possibility that USBL would not work within the necessary time frame, a supplementary method of target localization was proposed. This subsystem ejected neutrally buoyant marker buoy assemblies when triggered by the user interface. The buoys consisted of a weighted anchor and a brightly colored float joined by a long length of fishing line such that when released, they would anchor to the sea floor near a target and rise to the surface (Figure 9).

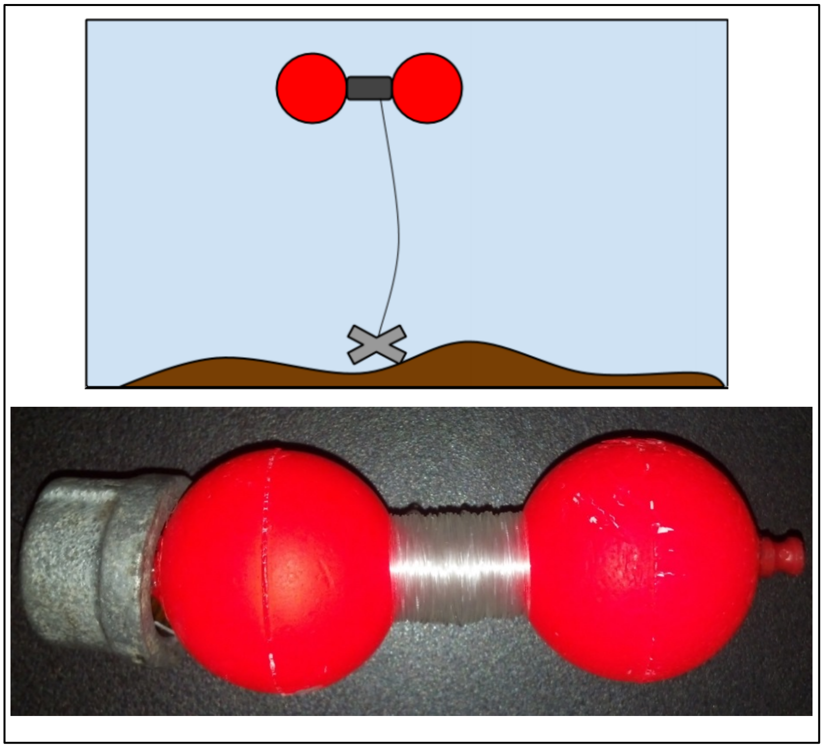

Figure 9: Marker Buoy

Prototyping

In addition to the modular extruded aluminum 80/20 used for the frame and the readily available PVC and acrylic tubes the team made use of 3D Printing to rapid prototype parts for the vehicle, especially electronics mounting brackets and trays. Figure 10 below provides examples of a CAD modeled part and its 3D printed counterpart, which was ultimately used in the vehicle.

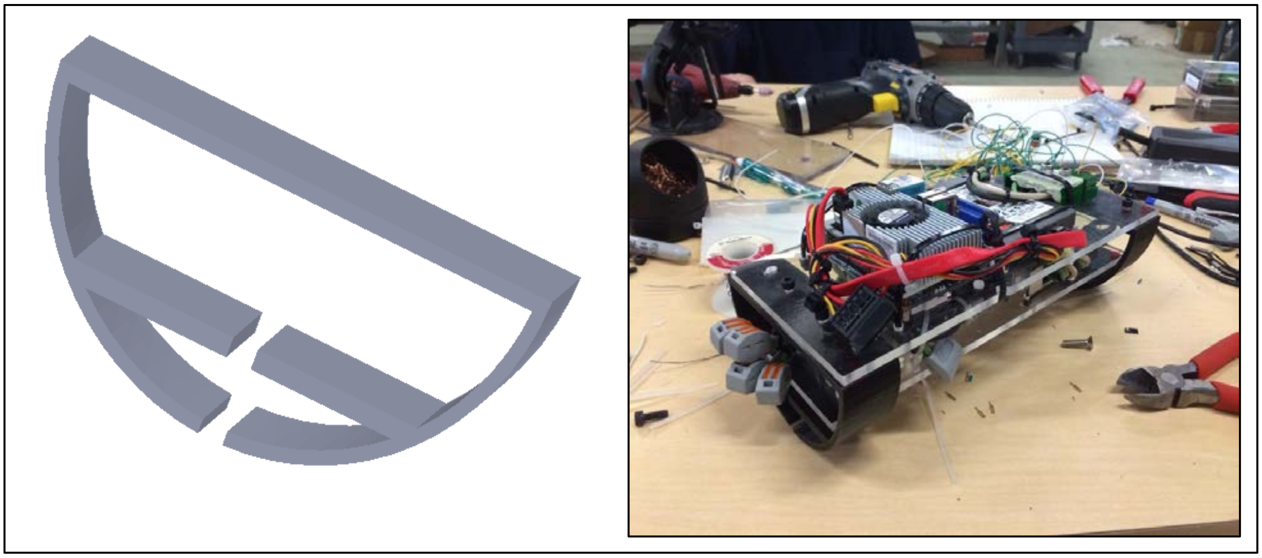

Figure 10: Electronics assembly with 3D printed support frame

Testing

The team was encouraged from the start of their project to build testing into their schedule. Additional they were advised to leave sufficient time for redesign and the integration of solutions into their prototype based on these test results. They were directed with a simple mantra, “test early and test often”. The extensive regiment of testing covered individual sensors, sensor integration, software, water tightness, buoyancy, stability, thruster power, control, and final full system testing. The students implemented theoretical information from classes and self-directed research to actual hands on tasks and gained extensive new knowledge in related technical fields. More importantly they ended up with a functional system that worked (Figure 11).

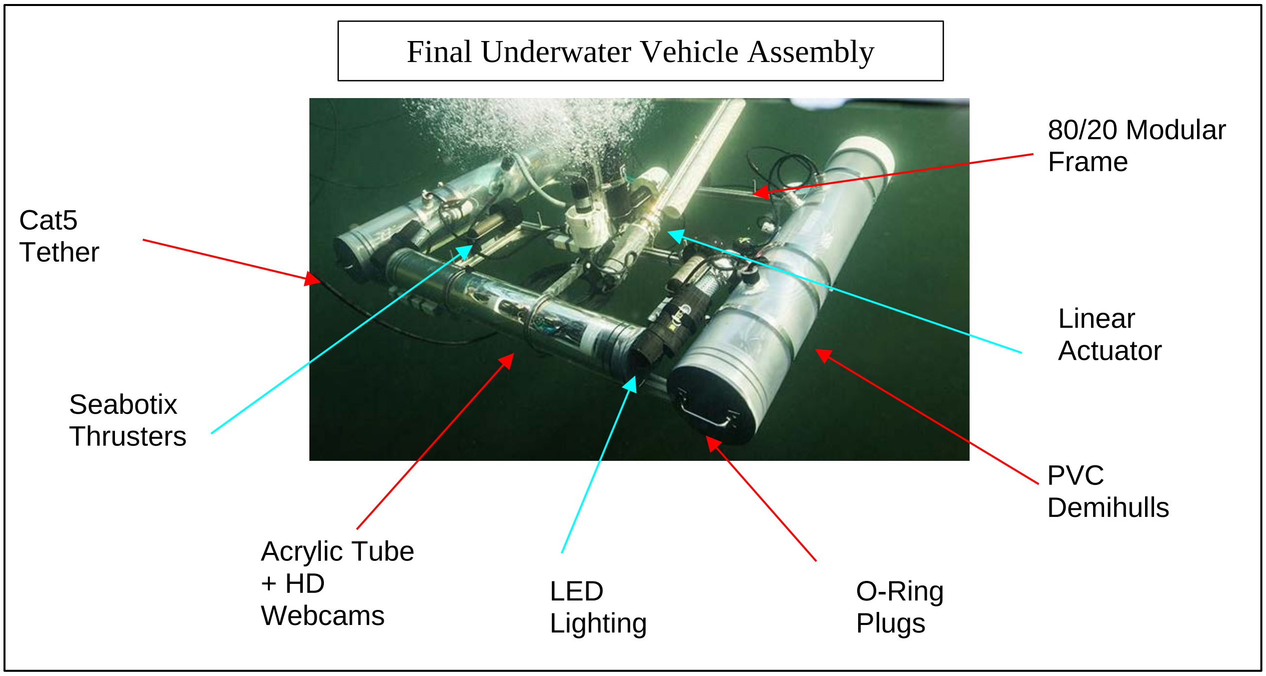

Figure 11: Final Vehicle Assembly

Demonstration

The Stevens Institute of Technology Perseus II Team traveled to Key West, FL from November 17th-22nd to demonstrate the project to RRTO and other interested stakeholders. The final demonstration run consisted of a 45 minute timeslot that was allowed for each student team. The team was successful, and located two of the six target UXO objects and correctly identifying a false positive in the time allotted. Figure 12 below shows the user interface view from one UXO find.

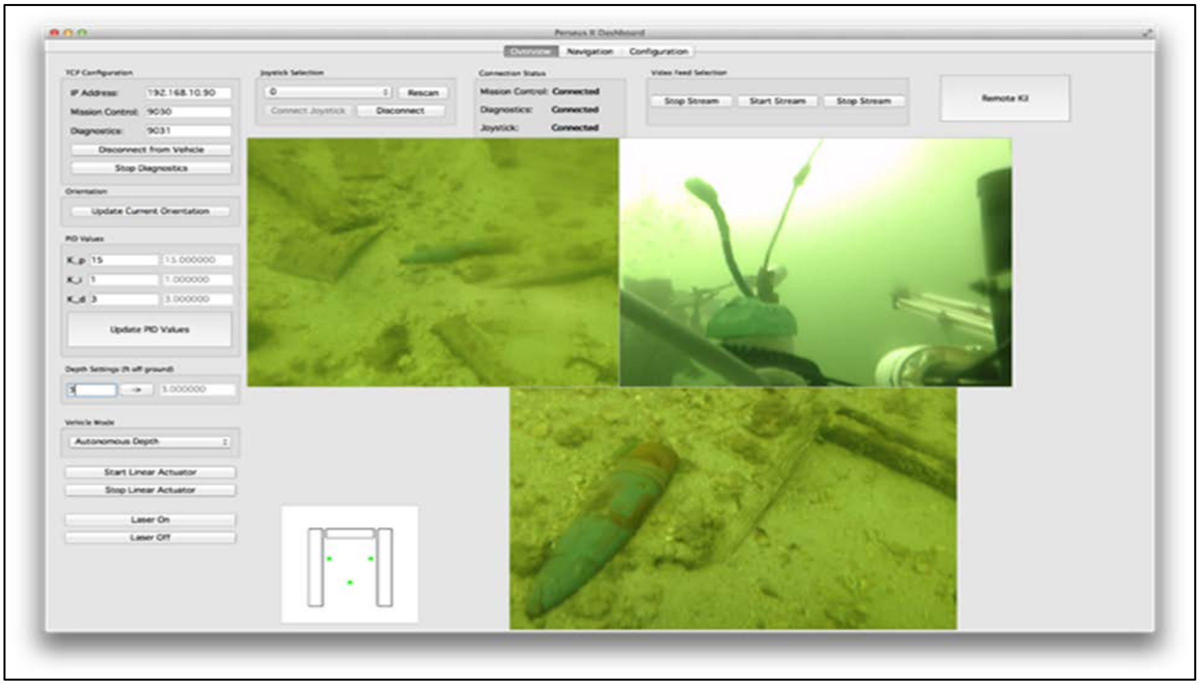

Figure 12: User interface view of UXO from demonstration

The team's vehicle was quickly assembled and operational during the first days of the demo week. This time left plenty of opportunity for refinements and trials prior to the actual timed demonstration. During these runs the team managed to find other UXO as well as a vehicle, a couch, and a small hammerhead shark. The team was informed by the locals that the shark was a harbinger of good luck. They certainly had success and no doubt there was some luck involved but the primary reason for their success was the incredible effort they put forward in a thoughtful, intelligent and technically appropriate manner. The educational impacts are hard to quantify but the student team's assessment of the project was best summarized by them in a follow on presentation. "Perseus II exposed the team to real engineering challenges. The knowledge gained and lessons learned have made this project a truly rewarding experience."

General outreach and after demo presentations

Over the course of the Perseus II project the students had the opportunity to present multiple times to their sponsor and other interested stakeholders. Beyond these briefing and reports the project engendered significant interest on campus and from media outlets. These post projects opportunities allowed the students to learn to develop a coherent message that could best describe a technology to specific audience with disparate technical knowledge. The Perseus II team presented to or conducted demonstrations for:

- The US Naval Facilities Engineering Command
- The Principal Deputy, Assistant Secretary of Defense for Research and Engineering
- Liberty Science Center's Engineer Week Event
- New Jersey Sea Grant Middle School Technology Camp
- Fox News
- NJ Tech Weekly
- NJ.com
- NJ Today
- Voice of America

Four of the Perseus II students also developed a miniaturized UUV they dubbed microROV. This hand held system used many of the same concepts of their full scale system and operated with the same demo mission of finding UXO underwater. This microROV was developed in one month from concept to final implementation at the USA Science and Engineering Festival in April 2014. The student developed, designed and implemented exhibit was a tremendous success. Over the course of 2 ½ days the team reached out to thousands of interested people. The majority of these interaction were with individuals in the K-12 range allowing them to learn what engineers do, how and what they learn, and the positive impacts that science and engineering are having and will have on our future.

Learning outcomes

Assessing the learning outcomes of a project like Perseus II is difficult, there is no straightforward test that can be administered and student evaluation is largely in the form of faculty assessments based on project outcomes, submitted documents, and presentations. Assessment is critical however and difficulties aside an attempt was made to try to provide some quantitative results of the project.

The five participating students were each provided a self-assessment survey to quantify their learning outcomes from participation in Perseus II. These surveys were based on ABET's 2015-

2016 Criteria for Accrediting Engineering Programs, specifically Criterion 3, Student outcomes (a)-(k)[2]. In several instances the questions were applied to multiple disciplines associated with the Perseus II project including those represented by team members and those not. For each questions the students were asked to provide relevant comments. The provided survey and the completed surveys submitted by the students are included as Appendix B in this paper. Four of the five students completed the survey and the results were analyzed. The fifth student is participating in the US Navy Nuclear Propulsion Officer Candidate (NUPOC) program and was not available for the survey.

The students were instructed to use a 1-10 scale representing a spectrum of educational impact for assessing impact of participation in Perseus II on the 11 criterion 3 outcomes with 1 indicating no impact and 10 indicating a very significant impact. Additionally they were provided the following example:

Outcome (a): How did you participation in Perseus II impact your “ability to apply knowledge of mathematics, science, and engineering”

i. In your chosen engineering discipline: 1 2 3 4 5 6 7 8 9 10

If for instance you were pursuing a mechanical engineering (ME) degree and through the course of the Perseus II project you gained significant new ME relative knowledge and reinforced information from classes throughout your UG career relative to ME that enhanced your ability to apply ME knowledge you would select something on the higher end of the spectrum to represent what you feel is a significant educational impact.

ii. In a discipline/s of your Perseus II teammates : 1 2 3 4 5 6 7 8 9 10

If for instance you were pursuing a mechanical engineering (ME) degree and through the course of the Perseus II project you gained significant new naval engineering relative knowledge, for example the knowledge and ability to assess and design for the effect of hydrostatic (buoyance & static stability) and hydrodynamic forces on a marine vehicle you would select something on the higher end of the spectrum to represent what you feel is a significant educational impact and *enhanced ability to apply this knowledge. If you did not have any significant learning or enhancing of your abilities in other disciplines you would select something on the lower scale.*

A review of the survey results indicates that in all 11 criterions the students' participation in Perseus II led to large positive impacts on their learning. A summary table is available in Appendix A. Following is a brief summary for each criterion based on the surveys submitted to date.

(a) How did you participation in Perseus II impact your "ability to apply knowledge of mathematics, science, and engineering?"

Within the students chosen disciplines the average score out of 10 was a 9 indicating a significant impact. Within disciplines of Perseus team members but not the students major the average was 7.2 indicating that the students were learning across their disciplines and providing some evidence beyond faculty assessment that the students were learning from one another. In disciplines not represented by Perseus team members the average was 7.4. This result is slightly skewed by the significant effort the team needed to put into learning and applying electrical engineering specific materials and processes with this specific discipline receiving 10 out of 10 from all respondents. Another discipline where the students reported significant impact was system engineering.

(b) How did you participation in Perseus II impact your "ability to design and conduct experiments, as well as to analyze and interpret data?"

The average score for this criterion was a 9.8 indicated a significant educational impact. This is due largely to the test early, test often philosophy the team adopted over the course of the project.

(c) How did you participation in Perseus II impact your "ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability?"

The average score for this criterion was a 9.5 indicated a significant educational impact. The entire Perseus II project is directly aligned with this criterion. The fact that the project had an actual mission demonstration and engaged stakeholders and sponsors added tremendously.

(d) How did you participation in Perseus II impact your “ability to function on multidisciplinary teams?”

This criterion scored a 10. All students indicated that they had significant positive impact on what is a critical skill required of nearly all engineers. This is a difficult skill to teach without a hands-on multi-disciplinary project. The inclusion of this criterion and a focus on it may lead more schools to develop multi-disciplinary project based learning modules.

(e) How did you participation in Perseus II impact your “ability to identify, formulate, and solve engineering problems?”

Within the students chosen disciplines the average score was a 9 indicating a significant impact. Within disciplines of Perseus team members but not the students major the average was 7.5 and in disciplines not represented by Perseus team members the average was 7.8. The results of the out of discipline learning again point to significant impact with electrical engineering again skewing non Perseus II disciplines higher. Without the electrical engineering the results would have been closer to 6 out of 10 only indicated moderate impact.

(f) How did you participation in Perseus II impact your “understanding of professional and ethical responsibility?”

The average score was 8.25. Based on the survey comments some of the students interpreted the overall UXO mission as a professional and ethical responsibility. Additionally they learned about the long term responsibilities associated with decisions such as dumping munitions.

(g) How did you participation in Perseus II impact your “ability to communicate effectively?”

Within the students chosen disciplines the average score was a 10 indicating a very significant impact. Within disciplines of Perseus team members but not the students major the average was 9.8 and in disciplines not represented by Perseus team members the average was 9.0. All responses point to a significant positive impact. Beyond the inherent communications requirements of a multi-disciplinary complex project such as Perseus the students participated in numerous presentations to interested stakeholders on campus and off as well as multiple media demonstrations. These interactions allowed them to hone their presentation skills and learn to develop a message based on the target audience from high level engineers to middle school students.

(h) How did you participation in Perseus II impact you with respect to “the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context?”

The average response was 8.8 indicating a high impact. The UXO mission ties into all of these issues and the students experienced first-hand the requirements for understanding problems beyond the engineering portions that is required to solve complex societal problems.

(i) How did you participation in Perseus II impact you with respect to your “recognition of the need for, and an ability to engage in life-long learning?”

The average response was a 9.5 indicating a very high impact. Survey comments indicate that the participating students enjoyed and thrive on solving challenging problems. In a sense they are life-long learners and their participation reinforced the desire to and the understanding that you need to continue to stay current beyond their academic endeavors.

(j) How did you participation in Perseus II impact you with respect to your “knowledge of contemporary issues?”

The average score here was a 7.3. The lowest of the criterions yet still indicative of a positive impact due to participation. The specific UXO issue is contemporary and the students gained additional insights from interactions with the sponsor and other stakeholders. They also participated in several follow on STEM outreach initiatives.

(k) How did you participation in Perseus II impact you with respect to your “ability to use the techniques, skills, and modern engineering tools necessary for engineering practice?”

Within the students chosen disciplines the average score was a 10 indicating a very significant impact. Within disciplines of Perseus team members but not the students major the average was 8.0 and in disciplines not represented by Perseus team members the average was 9.0. All responses point to a significant positive impact. This was a complex system design project with real deliverables and real stakeholders. The students recognized this and implemented what they learned over the course of their respective academic careers as well as new knowledge gained specifically from this project through individual research and working directly with their teammates across disciplines. All of these efforts helped to reinforce this prior and new knowledge.

Conclusions

The Perseus II project proved to be a success with respect to the project sponsor, the students, their faculty advisor, and Stevens. The sponsor received valuable information and insights on possible solutions to the underwater UXO problem. Explosives Ordnance Division experts who attended the demonstration were interested in several student concepts and were clearly engaged and pleased with the real time observational capabilities of the student developed system. A follow on presentation to NAVFAC also indicated a high level of satisfaction with a particular interest in low cost solutions to the challenges of underwater localization. The students were provided with the opportunity to engage in a challenging real-world project with an engaged sponsor. The experience they gained by participation in Perseus II was incredibly valuable not only with respect to the learning outcomes but to their growth as individuals and young engineers. The learned through experience the processes and tools that can and should be implemented for a challenging, multi-disciplinary project to help ensure success. Of particular note, based on discussions with the student participants was the opportunity to move beyond the standard student design project. This project provided hands on experience with a difficult system integration problem that instilled lessons on system engineering, system integration, test & evaluation, and the iterative process of developing and demonstrating a functioning system. The follow on opportunities for outreach and community interaction enabled the students to hone their communication skills. And everyone involved was able to broaden their network of engineering colleagues across all of the project stakeholders.

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Appendix A: Survey Results Summary

Criterion	**Question**	**i: In your chosen engineering discipline**	**ii: In a discipline/s of your Perseus II teammates**			**iii: In a discipline/s not represented your Perseus II team**				**Student major**	**Student #**
a	How did you participation in Perseus II impact your "ability to apply knowledge of mathematics, science, and engineering"		ME	NE	CS	EE	CE	EM	SE		
		7		8	8	10	5	8	8	ME	1
		10	7	9		10	8	6	7	CS	1
		10		6	7	10	4	6	6	ME	2
		9		9	5	10	7	5	8	ME	3
		9	***7.0***	***8.0***	***6.7***	***10.0***	***6.0***	***6.3***	***7.3***	***Average***	
			7.2			7.4					
b	How did you participation in Perseus II impact your "ability to design and conduct experiments, as well as to analyze and interpret data"	9								ME	1
		10								CS	1
		10								ME	2
		10								ME	3
		9.8								***Average***	
c	How did you participation in Perseus II impact your "ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability"	8								ME	1
		10								CS	1
		10								ME	2
		10								ME	3
		9.5								***Average***	
d	How did you participation in Perseus II impact your "ability to function on multidisciplinary teams	10								ME	1
		10								CS	1
		10								ME	2
		10								ME	3

		10			***Average***	
e	How did you participation in Perseus II impact your "ability to identify, formulate, and solve engineering problems"	7	7	10	ME	1
		9	8	4	CS	1
		10	6	7	ME	2
		10	9	10	ME	3
		9	***7.5***	***7.8***	***Average***	
f	How did you participation in Perseus II impact your "understanding of professional and ethical responsibility"	6			ME	1
		7			CS	1
		10			ME	2
		10			ME	3
		8.25			***Average***	
g	How did you participation in Perseus II impact your "ability to communicate effectively "	10	10	10	ME	1
		10	9	7	CS	1
		10	10	9	ME	2
		10	10	10	ME	3
		10	***9.8***	***9.0***	***Average***	
h	How did you participation in Perseus II impact you with respect to "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context"	6			ME	1
		10			CS	1
		9			ME	2
		10			ME	3
		8.8			***Average***	
i	How did you participation in Perseus II impact you with respect to your "recognition of the need for, and an ability to engage in life-long learning"	10			ME	1
		8			CS	1
		10			ME	2
		10			ME	3
		9.5			***Average***	

j	How did you participation in Perseus II impact you with respect to your "knowledge of contemporary issues"	7			ME	1
		6			CS	1
		6			ME	2
		10			ME	3
		7.3			***Average***	
k	How did you participation in Perseus II impact you with respect to your "ability to use the techniques, skills, and modern engineering tools necessary for engineering practice"	10	7	10	ME	1
		10	9	9	CS	1
		10	6	7	ME	2
		10	10	10	ME	3
		10	***8.0***	***9.0***	***Average***	

Appendix B: Students Survey

Provided Survey & Instructions:

Below are questions directly related to the student outcomes section of the ABET 2015-2016 Criteria for Accrediting Engineering Programs. I would like for you to "self-assess" how you participation in Perseus II impacted your UG education specific to these 11 outcomes. I am interested in some specific questions relative to all 11 outcomes and general comments you may have either positive or negative. Please use a 1-10 scale representing a spectrum of educational impact for your assessment with 1 indicating no impact and 10 indicating a very significant impact. For example let's consider outcome (a):

(a): How did you participation in Perseus II impact your "ability to apply knowledge of mathematics, science, and engineering"

i. In your chosen engineering discipline: 1 2 3 4 5 6 7 8 9 10

If for instance you were pursuing a mechanical engineering (ME) degree and through the course of the Perseus II project you gained significant new ME relative knowledge and reinforced information from classes throughout your UG career relative to ME that enhanced your ability to apply ME knowledge you would select something on the higher end of the spectrum to represent what you feel is a significant educational impact.

ii. In a discipline/s of your Perseus II teammates : 1 2 3 4 5 6 7 8 9 10

If for instance you were pursuing a mechanical engineering (ME) degree and through the course of the Perseus II project you gained significant new naval engineering relative knowledge, for example the knowledge and ability assess and design for the effect of hydrostatic (buoyance & static stability) and hydrodynamic forces on a marine vehicle you would select something on the higher end of the spectrum to represent what you feel is a significant educational impact and enhanced ability to apply this knowledge. If you did not have any significant learning or enhancing of your abilities in other disciplines you would select something on the lower scale.

iii. In a discipline/s not represented your Perseus II team :

The same concept would be applied to sub question (iii)

iv. Comments:

In this section please add comments that you feel are relative to this specific outcome. Feel free to include both negative and positive comments and any suggestions.

Perseus II Student Self-assessment of ABET Student Outcomes (a-k)

a) How did you participation in Perseus II impact your "ability to apply knowledge of mathematics, science, and engineering"
   i. In your chosen engineering discipline: 1 2 3 4 5 6 7 8 9 10
   ii. In a discipline/s of your Perseus II teammates :
      a. Mechanical Engineering: 1 2 3 4 5 6 7 8 9 10
      b. Naval Engineering: 1 2 3 4 5 6 7 8 9 10
      c. Computer Science: 1 2 3 4 5 6 7 8 9 10
   iii. In a discipline/s not represented your Perseus II team :
      a. Electrical engineering: 1 2 3 4 5 6 7 8 9 10
      b. Computer engineering: 1 2 3 4 5 6 7 8 9 10
      c. Engineering management: 1 2 3 4 5 6 7 8 9 10
      d. Systems engineering: 1 2 3 4 5 6 7 8 9 10
   iv. Comments:

b) How did you participation in Perseus II impact your "ability to design and conduct experiments, as well as to analyze and interpret data"
   i. 1 2 3 4 5 6 7 8 9 10
   ii. Comments:

c) How did you participation in Perseus II impact your “ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability”

   i. 1 2 3 4 5 6 7 8 9 10
   ii. Comments:

d) How did you participation in Perseus II impact your “ability to function on multidisciplinary teams”

   i. 1 2 3 4 5 6 7 8 9 10
   ii. Comments:

e) How did you participation in Perseus II impact your “ability to identify, formulate, and solve engineering problems”

   i. In your chosen engineering discipline: 1 2 3 4 5 6 7 8 9 10
   ii. In a discipline/s of your Perseus II teammates : 1 2 3 4 5 6 7 8 9 10
   iii. In a discipline/s not represented your Perseus II team : 1 2 3 4 5 6 7 8 9 10
   iv. Comments:

f) How did you participation in Perseus II impact your “understanding of professional and ethical responsibility”

   i. 1 2 3 4 5 6 7 8 9 10
   ii. Comments:

g) How did you participation in Perseus II impact your “ability to communicate effectively ”

i. In your chosen engineering discipline: 1 2 3 4 5 6 7 8 9 10
ii. In a discipline/s of your Perseus II teammates : 1 2 3 4 5 6 7 8 9 10
iii. In a discipline/s not represented your Perseus II team : 1 2 3 4 5 6 7 8 9 10
iv. Comments:

h) How did you participation in Perseus II impact you with respect to “the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context”

i. 1 2 3 4 5 6 7 8 9 10
ii. Comments:

i) How did you participation in Perseus II impact you with respect to your “recognition of the need for, and an ability to engage in life-long learning”

  i. 1 2 3 4 5 6 7 8 9 10
  ii. Comments:

j) How did you participation in Perseus II impact you with respect to your “knowledge of contemporary issues”

  i. 1 2 3 4 5 6 7 8 9 10
  ii. Comments:

k) How did you participation in Perseus II impact you with respect to your “ability to use the techniques, skills, and modern engineering tools necessary for engineering practice”

i. In your chosen engineering discipline: 1 2 3 4 5 6 7 8 9 10
ii. In a discipline/s of your Perseus II teammates : 1 2 3 4 5 6 7 8 9 10
iii. In a discipline/s not represented your Perseus II team : 1 2 3 4 5 6 7 8 9 10
iv. Comments:

Returned Surveys:

ME 1:

Perseus II Student Self-assessment of ABET Student Outcomes (a-k)

a) How did you participation in Perseus II impact your "ability to apply knowledge of mathematics, science, and engineering"
   v. In your chosen engineering discipline: 1 2 3 4 5 6 **7** 8 9 10
      a. I would give higher but for the fact that a large portion of what I learned was practical knowledge that is not covered in any class! The project was much more of a lesson in how things work than the alternative, which is how to do calculations about how things work. Qualitative over quantitative, and I do think that both should have a place in the curriculum.

   vi. In a discipline/s of your Perseus II teammates :
      a. Mechanical Engineering: 1 2 3 4 5 6 7 8 9 10
      b. Naval Engineering: 1 2 3 4 5 6 7 **8** 9 10
      c. Computer Science: 1 2 3 4 5 6 7 **8** 9 10
         i. Learned a ton about naval and CS. I don't know that I gained CS skills so much as a broader knowledge of the architecture of an embedded system such as what Ethan designed. My naval knowledge was expanded but that feels closer to ME and was less of a step out from my fluids class than, for instance, the electrical work we did was a step out from circuits class
   vii. In a discipline/s not represented your Perseus II team :
      a. Electrical engineering: 1 2 3 4 5 6 7 8 9 **10**
      b. Computer engineering: 1 2 3 4 **5** 6 7 8 9 10
      c. Engineering management: 1 2 3 4 5 6 7 **8** 9 10
      d. Systems engineering: 1 2 3 4 5 6 7 **8** 9 10
         i. OK, I guess if we don't count mike as EE, then this would also be a 10. Otherwise I think with respect to management we all certainly got a taste of trying to manage the complexity of the system, as well as the team dynamic including effective assignment of resources to tasks, and identifying critical paths to successful project outcomes. It's hard for me to separate out the systems from the EM in this case.
         ii. Computer engineering: I think it could be argued that much of what ethan does is CE, but I think of CE as development of the hardware. More of our work involved the interface between

different sets of hardware, which I would throw in the CS category.

viii. Comments: see above

b) How did you participation in Perseus II impact your "ability to design and conduct experiments, as well as to analyze and interpret data"

   i. 1 2 3 4 5 6 7 8 **9** 10

   ii. Comments: The main thing that comes to mind here is the whole crustcrawler debacle. I'd give a ten except that if we really mastered experimentation we probably could have tested those thrusters in a more non-destructive manner. Seriously though, there were multiple occasions where I think we had to step back and do some serious testing to get a better understanding of our system's behavior, and while they didn't always involve the collection of numeric data, the principle is the same: develop a hypothesis, test it, and then draw conclusions and improve your understanding.

c) How did you participation in Perseus II impact your "ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability"

   i. 1 2 3 4 5 6 7 **8** 9 10

   ii. Comments:

      - The guidance we received early on was a critical part of our ability to design this system. Our advisor was relentless in challenging our assumptions and our expectations, and I think that as we embraced that attitude of thinking through a problem while it is still a concept -- that's where the true "design" of this project really took off.
      - I think the relevant constraints here are economic, health and safety, and manufacturability. Obviously the presence of a finite budget can drive home an understanding of the economics of a problem. Safety was a consideration throughout, particular related to electricity and rapidly rotating propellers. And of course, since we were the ones who had to manufacture the prototype, manufacturability was always a factor in every design decision, and in fact it was often the main factor (80/20, using pipe instead of custom machined hulls, etc).
      - I don't know that this outcome makes a lot of sense to me….if a constraint is there, what are you going to do, ignore it?

d) How did you participation in Perseus II impact your "ability to function on multidisciplinary teams"
   i. 1 2 3 4 5 6 7 8 9 **<u>10</u>**
   ii. Comments: This was without question a multidisciplinary project, and I think that the success of the vehicle demonstrates that we functioned as such, otherwise the project could not have been successful

e) How did you participation in Perseus II impact your "ability to identify, formulate, and solve engineering problems"
   i. In your chosen engineering discipline: 1 2 3 4 5 6 **<u>7</u>** 8 9 10
      - Again, this is debatable, but it's not like we were sitting around doing thermodynamic or stress calculations. Maybe my expectations are off because I spent the last year in grad classes. I do think we successfully implemented many mechanical subsystems.
   ii. In a discipline/s of your Perseus II teammates : 1 2 3 4 5 6 **<u>7</u>** 8 9 10
      - In general we all supported each other, but I think the ultimate solution to all the CS problems came from ethan, and naval stuff we deferred to Don (bollard pull, star CFD etc). Again, this is a difficult question because the line between Naval and ME is somewhat blurry to me.
   iii. In a discipline/s not represented your Perseus II team : 1 2 3 4 5 6 7 8 9 **<u>10</u>**
      - I guess we had no choice but to solve the electrical problems, because no one else was going to.
   iv. Comments:

f) How did you participation in Perseus II impact your "understanding of professional and ethical responsibility"
   i. 1 2 3 4 5 **<u>6</u>** 7 8 9 10
   ii. Comments: I don't really see this as a big factor in our project. We're not trying to sell a product to the public or build something that people will depend on like a bridge. I did appreciate the fact that our task was inherently constructive.

g) How did you participation in Perseus II impact your "ability to communicate effectively "
   i. In your chosen engineering discipline: 1 2 3 4 5 6 7 8 9 <u>10</u>
   ii. In a discipline/s of your Perseus II teammates : 1 2 3 4 5 6 7 8 9 **<u>10</u>**
   iii. In a discipline/s not represented your Perseus II team : 1 2 3 4 5 6 7 8 9 **<u>10</u>**
   iv. Comments: I don't know that it made us good presenters, but it certainly provided lots of practice and publicity.

h) How did you participation in Perseus II impact you with respect to “the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context”

   i. 1 2 3 4 5 **<u>6</u>** 7 8 9 10
   ii. Comments: This one goes along with (f). It’s a big picture question, but we were a goal oriented team. It feels a bit arrogant to suggest that senior design projects are/should be having global, economic, environmental, or societal impact. For the most part, they are a benefit to the students, and every once in a while you get lucky and have one that goes a bit further.

i) How did you participation in Perseus II impact you with respect to your “recognition of the need for, and an ability to engage in life-long learning”

   i. 1 2 3 4 5 6 7 8 9 **<u>10</u>**
   ii. Comments: This is what it’s all about. If we weren’t self-directed learners, the thing would have sat on the dock for a week in key west.

j) How did you participation in Perseus II impact you with respect to your “knowledge of contemporary issues”

   i. 1 2 3 4 5 6 **<u>7</u>** 8 9 10
   ii. Comments: I would say this project gave us a very detailed view of one specific contemporary issue. Seems like a stretch to expect what is a small engineering design problem appropriate for a small team of students to be having some kind of high level societal impact or involvement.

k) How did you participation in Perseus II impact you with respect to your “ability to use the techniques, skills, and modern engineering tools necessary for engineering practice”

   i. In your chosen engineering discipline: 1 2 3 4 5 6 7 8 9 **<u>10</u>**
   ii. In a discipline/s of your Perseus II teammates : 1 2 3 4 5 6 **<u>7</u>** 8 9 10
   iii. In a discipline/s not represented your Perseus II team : 1 2 3 4 5 6 7 8 9 **<u>10</u>**
   iv. Comments:
      i. This is what I was getting at before…with respect to ME we were in the realm of the practical.
      ii. CS/NE I would say my understanding of the techniques grew immensely but my implementation of them was limited
      iii. EE: same idea, somebody had to do it, so we all stepped up.

CS 1:

a) How did you participation in Perseus II impact your “ability to apply knowledge of mathematics, science, and engineering”

    i. In your chosen engineering discipline: 1 2 3 4 5 6 7 8 9 **10**

    ii. In a discipline/s of your Perseus II teammates :

        a. Mechanical Engineering: 1 2 3 4 5 6 **7** 8 9 10

        b. Naval Engineering: 1 2 3 4 5 6 7 8 **9** 10

        c. Computer Science: 1 2 3 4 5 6 7 8 9 **10**

    iii. In a discipline/s not represented your Perseus II team :

        a. Electrical engineering: 1 2 3 4 5 6 7 8 9 **10**

        b. Computer engineering: 1 2 3 4 5 6 7 **8** 9 10

        c. Engineering management: 1 2 3 4 5 **6** 7 8 9 10

        d. Systems engineering: 1 2 3 4 5 6 **7** 8 9 10

    iv. Comments:

The Perseus II project required us to step out of our comfort zone and learn technologies and methodologies un-encountered in a classroom environment. Often times, undergraduate classes will only discuss the theory of a technology, whereas Perseus ii required implementation. The software system inside Perseus II contains many mathematically complex algorithms to control the vehicle’s position and mission sensors. These control systems are traditionally only taught in theory, however the Perseus II project required a functioning implementation.

b) How did you participation in Perseus II impact your “ability to design and conduct experiments, as well as to analyze and interpret data”

    i. 1 2 3 4 5 6 7 8 9 **10**

    ii. Comments:

When we were deciding what motors to use on the vehicle, we conducted numerous tests and experiments to determine which off-the-shelf product was best suited to the mission requirements. We interpreted data from voltage, current, and thrust measurements to choose an efficient and cost-effective solution.

c) How did you participation in Perseus II impact your “ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability”

   i. 1 2 3 4 5 6 7 8 9 **10**

   ii. Comments:

The Perseus II project was under strict budgetary constraints. This required us to choose a design that was feasible and in the scope of the mission. We needed to do extensive research when choosing parts to ensure that we got the most out of our $15K budget. We couldn’t afford a $10,000 component, so we were forced to come up with a $500 solution instead.

d) How did you participation in Perseus II impact your “ability to function on multidisciplinary teams”

   i. 1 2 3 4 5 6 7 8 9 **10**

   ii. Comments:

One of the largest benefits of the Perseus II project is it’s inter-disciplinary nature. Being able to work with people in different fields is an important skill in industry. The Perseus II project brought together people from the following backgrounds: Mechanical Engineers, Engineering Management, and Computer Science.

e) How did you participation in Perseus II impact your “ability to identify, formulate, and solve engineering problems”

   i. In your chosen engineering discipline: 1 2 3 4 5 6 7 8 **9** 10

   ii. In a discipline/s of your Perseus II teammates : 1 2 3 4 5 6 7 **8** 9 10

   iii. In a discipline/s not represented your Perseus II team : 1 2 3 **4** 5 6 7 8 9 10

   iv. Comments:

One problem we ran into was latency introduced into our video stream. Using standard streaming software, there was a 1-2 second delay in the video stream from the vehicle. This made remote control nearly impossible. By designing and developing custom streaming software, we were able to decrease latency to 200ms. This was a huge step forward in vehicle control.

f) How did you participation in Perseus II impact your "understanding of professional and ethical responsibility"

  i. 1 2 3 4 5 6 **7** 8 9 10

  ii. Comments:

g) How did you participation in Perseus II impact your "ability to communicate effectively "

  i. In your chosen engineering discipline: 1 2 3 4 5 6 7 8 9 **10**

  ii. In a discipline/s of your Perseus II teammates : 1 2 3 4 5 6 7 8 **9** 10

  iii. In a discipline/s not represented your Perseus II team : 1 2 3 4 5 6 **7** 8 9 10

  iv. Comments:

Throughout the Perseus II project, our team gave numerous presentations to stakeholders of various technical backgrounds. Perseus II taught us how to alter our presentations to appeal to both a technical, as well as a non-technical audience.

h) How did your participation in Perseus II impact you with respect to "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context"

  i. 1 2 3 4 5 6 7 8 9 **10**

  ii. Comments:

i) How did your participation in Perseus II impact you with respect to your "recognition of the need for, and an ability to engage in life-long learning"

  i. 1 2 3 4 5 6 7 **8** 9 10

  ii. Comments:

The project showed us how rapidly technology advances, and that effort is required to maintain an up-to-date skill-set. If you fall behind, you'll end up using old technology while those around you develop a better product using current technologies.

j) How did your participation in Perseus II impact you with respect to your "knowledge of contemporary issues"

   i. 1 2 3 4 5 **6** 7 8 9 10

   ii. Comments:

k) How did you participation in Perseus II impact you with respect to your "ability to use the techniques, skills, and modern engineering tools necessary for engineering practice"

   i. In your chosen engineering discipline: 1 2 3 4 5 6 7 8 9 **10**

   ii. In a discipline/s of your Perseus II teammates : 1 2 3 4 5 6 7 8 **9** 10

   iii. In a discipline/s not represented your Perseus II team : 1 2 3 4 5 6 7 8 **9** 10

   iv. Comments:

Our team used various design tools throughout the Perseus II project. For example, mechanical design of the vehicle was done in Solidworks, electrical designs were drawn with Eagle CAD, and software was version controlled with Git. These are just a few of the engineering tools used. An important part of the engineering design process is taking advantage of the tools at our disposal to be as efficient as possible. This is important given our budgetary and time constraints.

ME 2:

Perseus II Student Self-assessment of ABET Student Outcomes (a-k)

a) How did you participation in Perseus II impact your "ability to apply knowledge of mathematics, science, and engineering"
   i. In your chosen engineering discipline: 9
   ii. In a discipline/s of your Perseus II teammates :
      a. Mechanical Engineering: 9
      b. Naval Engineering: 9
      c. Computer Science: 5
   iii. In a discipline/s not represented your Perseus II team :
      a. Electrical engineering: 10
      b. Computer engineering: 7
      c. Engineering management: 5
      d. Systems engineering: 8
   iv. Comments: The primary challenges I faced during the Perseus II project were related to Electrical Engineering. Significant knowledge was gained in the process of tackling these challenges.

b) How did you participation in Perseus II impact your "ability to design and conduct experiments, as well as to analyze and interpret data"
   i. 10
   ii. Comments: Evaluating the function of performance of numerous components (ex. motors) required extensive testing. Returning to the motors as an example, a meaningful test did not simply involve turning a motor on and off to see if it spun. Rather, data pertaining to current draw and power consumption was collected and compared with the specifications of the battery bank to confirm that requirements could be met and to estimate motor runtimes. My ability to design and conduct experiments such as these was greatly enhanced.

c) How did you participation in Perseus II impact your "ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability"
   i. 10
   ii. Comments: Of all lessons learned through my participation in Perseus II, my ability to design a system was improved the most. I have designed many things both for hobbies and for assignments, but in most cases I did so without the discipline to pair design efforts with engineering practices. With the guidance of

my advisor, I learned to apply engineering principles to the solution of a problem rather than to tackle it head-on without a well-defined strategy. For example, when selecting a component, I was taught to identify all the tasks the component was required to perform. Then, I could select the most appropriate component while referring to the known requirements. Previously I would buy a number of components somewhat haphazardly and hope that one of them would work – this is wasteful and does not lend itself to successful designs.

d) How did you participation in Perseus II impact your "ability to function on multidisciplinary teams"
   i. 10
   ii. Comments: I have worked on teams many times but Perseus II was the most intense project. Working effectively, sharing ideas constructively, and settling differences were all challenges that my teammates and I learned to solve.

e) How did you participation in Perseus II impact your "ability to identify, formulate, and solve engineering problems"
   i. In your chosen engineering discipline: 10
   ii. In a discipline/s of your Perseus II teammates : 9
   iii. In a discipline/s not represented your Perseus II team : 10
   iv. Comments: The project taught me to adopt a budget-conscious approach to problem solving. The high expectations for the team coupled with the fixed budget meant that any purchases had to be well justified by supporting research or analysis.

f) How did you participation in Perseus II impact your "understanding of professional and ethical responsibility"
   i. 10
   ii. Comments: The goal of Perseus was to find a solution to a very real problem with dangerous implications. While working on this project I felt responsible for making sure that this problem could be solved in an effective manner.

g) How did you participation in Perseus II impact your "ability to communicate effectively "
   i. In your chosen engineering discipline: 10
   ii. In a discipline/s of your Perseus II teammates : 10
   iii. In a discipline/s not represented your Perseus II team : 10
   iv. Comments: Frequent presentations, teleconferences, and the final demonstration gave me the opportunity to refine my communication skills and learn to speak at length about the technical topics related to the project.

h) How did your participation in Perseus II impact you with respect to "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context"
   i. 10
   ii. Comments: Perseus II was a multi-disciplinary project. It could not have been completed successfully without the proper application of lessons from several areas of study. My participation helped me appreciate the value of a broad education that lends itself to multi-disciplinary projects like this one.

i) How did you participation in Perseus II impact you with respect to your "recognition of the need for, and an ability to engage in life-long learning"
   i. 10
   ii. Comments: As a student, it can be difficult to connect the lessons learned in school with their real-world applications. Because of this, investing the time to learn new things can seem unappealing. However, Perseus demonstrated how my education could be used in a real-world application and it made the relevant coursework more interesting and worthwhile.

j) How did you participation in Perseus II impact you with respect to your "knowledge of contemporary issues"
   i. 10
   ii. Comments: The issue Perseus aimed to solve was one that I was not previously aware of. I am now extremely aware of the need to locate unexploded ordnance. On a more general level, I am also aware of the challenges faced when dealing with equipment in a maritime environment – an issue that was of serious concern just a few years ago.

k) How did you participation in Perseus II impact you with respect to your "ability to use the techniques, skills, and modern engineering tools necessary for engineering practice"
   i. In your chosen engineering discipline: 10
   ii. In a discipline/s of your Perseus II teammates : 10
   iii. In a discipline/s not represented your Perseus II team : 10
   iv. Comments: Perseus demanded a lot from my own discipline, but it also demanded a lot from electrical and computer engineering. Seeing some of these techniques and skills applied by my teammates during the project, even in the few cases when I was not directly involved, gave me a high level understanding of those techniques that I did not have before.

ME 3:

Perseus II Student Self-assessment of ABET Student Outcomes (a-k)

a) How did you participation in Perseus II impact your "ability to apply knowledge of mathematics, science, and engineering"
   v. In your chosen engineering discipline: 10
   vi. In a discipline/s of your Perseus II teammates :
      a. Mechanical Engineering: 10
      b. Naval Engineering: 6
      c. Computer Science: 7
   vii. In a discipline/s not represented your Perseus II team :
      a. Electrical engineering: 10
      b. Computer engineering: 4
      c. Engineering management: 6
      d. Systems engineering: 6
   viii. Comments:
      a. I personally was given the opportunity to test my electrical knowledge in the attempt to create a low-budget USBL (ultrashort base line) trilateration system which has benefitted me greatly in gaining knowledge in the field of electrical engineering. Designing the electrical layout as well as choosing various electrical components taught me a lot about tolerances and design constraints in electrical subsystems.
      b. Use of many google cloud applications (drive, sheets, docs, slides, etc…) has taught me how necessary these applications are to having a smooth running successful project.

b) How did you participation in Perseus II impact your "ability to design and conduct experiments, as well as to analyze and interpret data"
   i. 10
   ii. Comments:
      i. Brushless Propulsion system: In the project we used three-phase brushless thrusters which ultimately failed us, luckily during testing. Given only the motor and motor controller the team was able to create baseline experimentation to make sure the motors satisfied our UUV's goals. Eventually we brought the experiment to the bollard pole test and made a thrust-power curve which eventually allowed us to find an error in the manufacturer's data sheet.

c) How did you participation in Perseus II impact your “ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability”
   i. 10
   ii. Comments:
      i. The budget given to us was $15,000 which for these systems is usually enough money for one of the many subsystems that exist in the project. Given that the devices we planned to use (such as thrusters, transparent PVC, picoITX board) were relatively expensive, the team needed to make sure the design was economically feasible throughout the entire design process. Along with this the ability for the system to actually be produced in real life was definitely a top priority since a design means nothing unless it can be implemented in a way that allows for the actual creation of the UUV to be feasible.

d) How did you participation in Perseus II impact your “ability to function on multidisciplinary teams”
   i. 10
   ii. Comments:
      i. The nature of the project was multidisciplinary which meant that certain subsystem progress could be halted by the lack of progress in another subsystem. Along with this each member understood the reality of the other disciplines on the team. For example, the mechanical engineers wouldn’t expect the computer scientist to create a fully autonomous code overnight so that the ME members could take the UUV apart the next day and do some more work. This realization is extremely important when looking for team members in future projects. Even if one doesn’t have the knowledge of how to create something in a different discipline, one should understand the complexity of the task and design in such a way that doesn’t make the other disciplines have to do more work.

e) How did you participation in Perseus II impact your “ability to identify, formulate, and solve engineering problems”
   i. In your chosen engineering discipline: 10
   ii. In a discipline/s of your Perseus II teammates :
      i. Mechanical Engineering: 10
      ii. Naval Engineering: 5
      iii. Computer Science: 7

iii. In a discipline/s not represented your Perseus II team :
   i. Electrical engineering: 10
   ii. Computer engineering: 7
   iii. Engineering management: 6
   iv. Systems engineering: 5
iv. Comments:
   i. Since the system was heavily integrated, problems could have come from any number of subsystems, and the ability to identify where the problem came from, as well as how to solve it played a huge role in creating a working UUV. The best example I can give is the erratic response of one of the surge thrusters during our initial testing. Anytime the robot was dipped in the water one of the surge thrusters would go to max power and would hold there until there was a full system hard reset. Eventually it was found that there was a noise issue due to the water coming in contact with steel and aluminum which creates a galvanic battery. This electrical field induced noise on an unshielded signal cable to the motor controller. The solution was to ground the entire UUV's metal structure, as well as replace the signal cable with a shielded cable.

f) How did you participation in Perseus II impact your "understanding of professional and ethical responsibility"
   i. 10
   ii. Comments:
      i. This project was funded by RRTO and the DOD. It was understood that this project must be done in a fashion that was considered professional by both of our sponsors.

g) How did you participation in Perseus II impact your "ability to communicate effectively "
   i. In your chosen engineering discipline: 10
   ii. In a discipline/s of your Perseus II teammates :
      i. Mechanical Engineering: 10
      ii. Naval Engineering: 10
      iii. Computer Science: 10
   iii. In a discipline/s not represented your Perseus II team :
      i. Electrical engineering: 10
      ii. Computer engineering: 10
      iii. Engineering management: 7
      iv. Systems engineering: 10

iv. Comments:

    i. If the team wasn't talking about the project at any given time, the members were probably asleep. I think the team was always discussing problems and attempted solutions to the problems randomly throughout the day, usually via a text group message chat. Regardless it was understood that we all needed to respond quickly to e-mails, or other messages, since there was a strict time constraint to finish the project.

h) How did you participation in Perseus II impact you with respect to "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context"

   i. 9
   ii. Comments:

       i. Having practical knowledge to take existing parts and or theories and being able to apply them in a fashion that allows a problem to be solved is a large part of what this project showed me.

i) How did you participation in Perseus II impact you with respect to your "recognition of the need for, and an ability to engage in life-long learning"

   i. 10
   ii. Comments:

       i. Challenging oneself with a problem to be solved engages the brain and it's a great feeling to solve the problem, or learn why the problem wasn't able to be solved. By removing the things we don't know we don't know we becomes more intelligent and are able to make less mistakes in the entirety of our lives.

j) How did you participation in Perseus II impact you with respect to your "knowledge of contemporary issues"

   i. 6
   ii. Comments:

       i. The project only showed us one issue, the accumulation of disposed munitions in the waters. But it did show that there are issues out there that are not well known by the public, and possibly should be known by the public.

k) How did you participation in Perseus II impact you with respect to your "ability to use the techniques, skills, and modern engineering tools necessary for engineering practice"

  i. In your chosen engineering discipline: 10
  ii. In a discipline/s of your Perseus II teammates :
    i. Mechanical Engineering: 10
    ii. Naval Engineering: 5
    iii. Computer Science: 6
  iii. In a discipline/s not represented your Perseus II team :
    i. Electrical engineering: 10
    ii. Computer engineering: 6
    iii. Engineering management: 6
  iv. Systems engineering: 6
  v. Comments: