St. George's School Robotics Team Paper for the 2016 ROBOSUB Competition

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Abstract— The St. George`s Robotics Teams (AUV) affectionately named 'Daedalus' represents the continued evolution of St. George`s Robotics innovation. Designed and constructed by St. George's Robotics Club Students in Grades 8-12, Daedalus is a re-design and improvement of our previous Robot Caesar. After damage that Caesar suffered at a previous competition our team took the opportunity for a rebuild and upgrade, primarily focusing on a new watertight hull, upgrading our propulsion system and installing new sensors and a computer system. The modularity of this new design should allow for easier modification and upgradability, eliminating cluttered systems and allowing space for future additions such hydrophones, sonar and cameras. Our team's goals for the competition are to have our working robot ready and able to complete basic competition parameters, recognizing that our lack in sensors will prevent us for completing the advanced tasks. For future years we hope to continue to refine and improve the functionality of our robot, building on our knowledge and completing more and more objectives each year. To the team, this AUV is more than just an AUV; this AUV represents the hard work, the everlasting perseverance, and the undying vision by all of the team members for the past half-decade. This AUV represents the product of countless hours of brainstorming, cooperation, and problem solving. More than anything, however, this AUV exemplifies the hopes and dreams that this team has possessed ever since its team members came together. Participating in this competition has been a distant aspiration for so many years; finally realizing this dream has truly been an unforgettable accomplishment.

I. Introduction

St. George's Robotics team's goal is to learn from and excel in creating an AUV that surpasses the expectation placed upon it as a creation of a High School Team. As a team who is competing against universities with only a limited budget we have often had to prioritize affordability over speed of production. We have had to innovate, reuse and refurbish using parts ranging from drills and underwater camera housings to bilge pumps. Throughout all this we have strived to expand our skills and knowledge through the challenges we overcome. In design our goals are to create an Autonomous Underwater Vehicle that is able to effectively compete in the Association for Unmanned Vehicle Systems International (AUVSI) Foundation and Office of Naval Research's RoboSub Competition. Our long term goals remain to continue to improve and refine our robot learning from our mistakes in order to create a more effective AUV. Design Strategy

II. Design Strategy

Our design follows the general structure of a standard dirigible airship. This design idea was originally expressed in our previous Robot Caesar and continues with improvement into Daedalus.

Figure 1. Our previous Robot Cesar's dirigible airship design.

The general idea behind the 'airship' design was a modular system that is easily replaceable, upgradeable and adaptable. As a high school team which recycles components and may not have the funds available to purchase top of the line equipment, the ability to constantly upgrade and replace systems is essential to the functionality of our AUV. The compartmentalization of electronics, computer, battery, gimbal and motors allows us to switch such parts out at any time. This year we have done just that keeping the original design but re-working and replacing many components. With the limited resources both in time and finances that we had, we spent them wisely upgrading and fixing systems that we identified as weak, faulty or inconvenient. Our team shied away from spending our time installing fancier sensors and instead worked on creating a platform for future years that was more reliable, easier to use and upgradable. We believe that in this area we have achieved success, as our robot has come forward in leaps and bounds from its condition from after last contest. With continued upgrading in future years our abilities and functionalities can greatly increase based of this strong platform.

It is clear that the St. George's Robotics Team is not a bringing an AUV into the competition this year that will amaze the audience by completing every challenge in lightning-fast time—far from this, in fact. We have set more realistic goals to strive for and hope to keep working with our robot each year to complete more and more challenges as we improve as a team. Regardless of what we accomplish at AUVSI, the team is quite proud of what has been achieved over the past years. Myriad challenges and setbacks plagued the team throughout the entire process; despite this however, the team has managed to pull together and put together a robot that accomplishes a great deal, considering the experience of the team.

III. VEHICLE DESIGN

Following the 'Dirigible Airship' design, the main 'body' of the AUV is a watertight acrylic cylindrical tube. The team opted for acrylic primarily because the material is transparent, making more apparent any leaks and any other issues issues in the water. Acrylic is also quite durable, an important quality considering that the tube houses the most critical parts of the robot. Waterproof end-caps with O-rings seal the ends and waterproof connecting wires transfer power and signal to tertiary systems of the AUV. This central cylindrical tube of Daedalus represents an upgrade from Cesar where the electronics, sensors, battery and computer were split between a smaller cast Acrylic Tube and a Plano Carbonate Waterproof Box. This upgrade allowed us to dispel with some of the waterproof cords that connected the two compartments and establish a lower center of mass for the robot. Major components are now housed exclusively in a larger Acrylic tube, with the exclusion of the motor stepper which is housed in a smaller acrylic tube below seen in Figure 1. This year there was an increase in focus surrounding the watertight integrity of the housing as Caesar had many of its systems damaged due to this problem in years past.

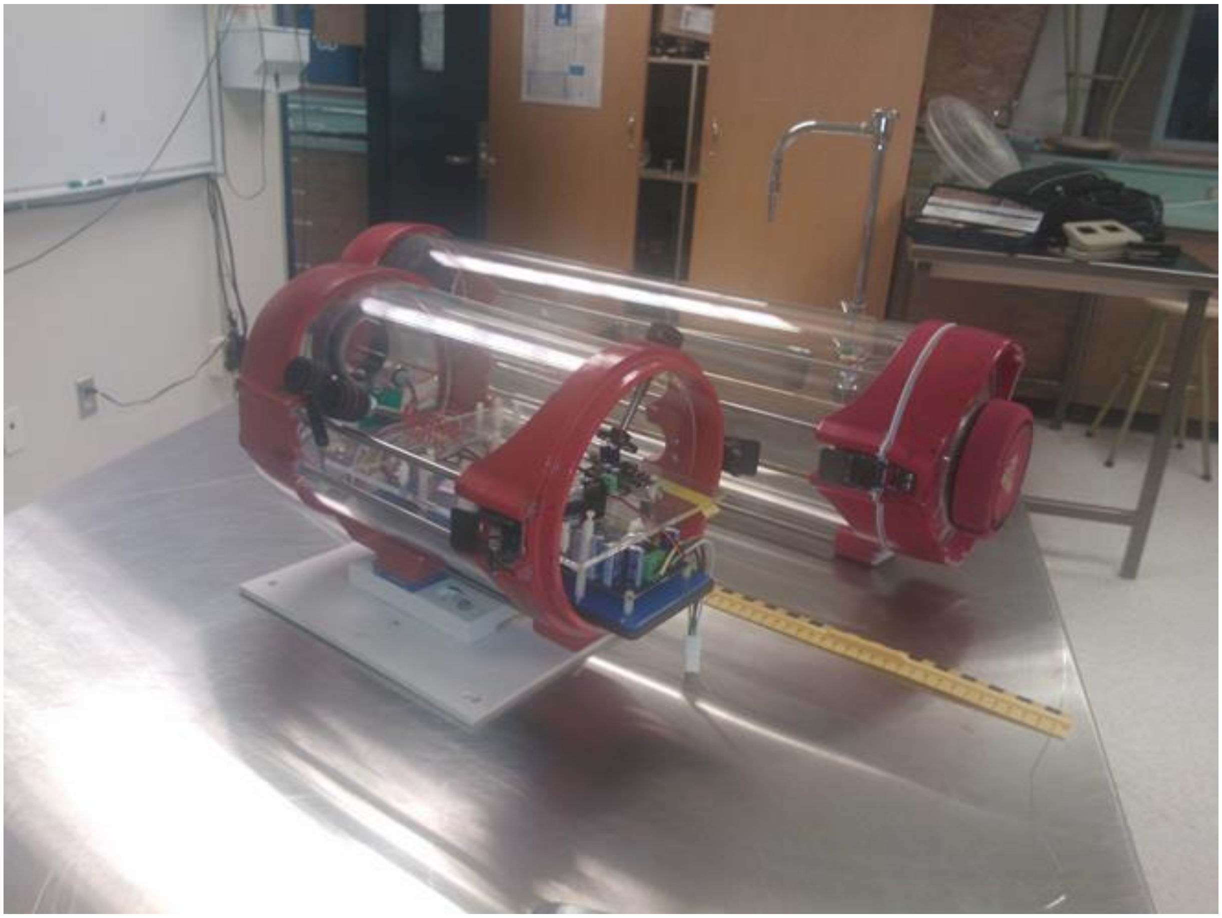

Figure 2. Upgrade in main acrylic housing tube, foreground is the old model, in the background is the new larger replacement component

This year there was a major replacement of the propulsion system that sits adjacent to the ‘body’ of the AUV. The goals of the rebuild were to improve navigational accuracy, increase hydrodynamic performance, and to reduce stress on the frame and gimbal by lowering weight. Beside performance considerations, the design improved safety for competition divers. Cesar’s propulsion consisted of dual acrylic tubes machined to specifications mounted on either side of the ‘body’ in a pusher consideration with gimbals allowing for the adjustment of angle of attack. Propulsion in Cesar was provided by recycled handheld drill motors mounted within the watertight acrylic tubes connected to the battery by waterproof cables. In order to maximize thrust large propellers were chosen for Cesar. This old setup posed several problems. First off it was large and heavy, the weight putting stress on the frame and the gimbal which adjusted the vertical angle of attack of the thrusters. This caused many malfunctions during testing of the thrusters and wear on the gimbal. Secondly, we hoped that by replacing the propulsion system we could generate more thrust and grant more accurate navigation. Finally, the large propellers posed a safety risk for the divers in the AUVSI competition. For these reason we chose a complete replacement of the propulsion drive system. Our upgraded system is powered by two waterproof 12V motors; these were taken from marine bilge pumps. The waterproof nature of these motors removed the need for a waterproof housing which cut down on the weight and strain of the system. These motors are housed within a 3-D Printed housing which was specifically designed for this purpose. This housing which was tested with several iterations is streamlined and easily accessible to allow for easy replacement of worn out or faulty motors, while also featuring a nozzle for increased efficiency. This design represents a significant improvement over the propulsion system shown in Figure 1 as this design reduces size, weight and improves safety and functionality.

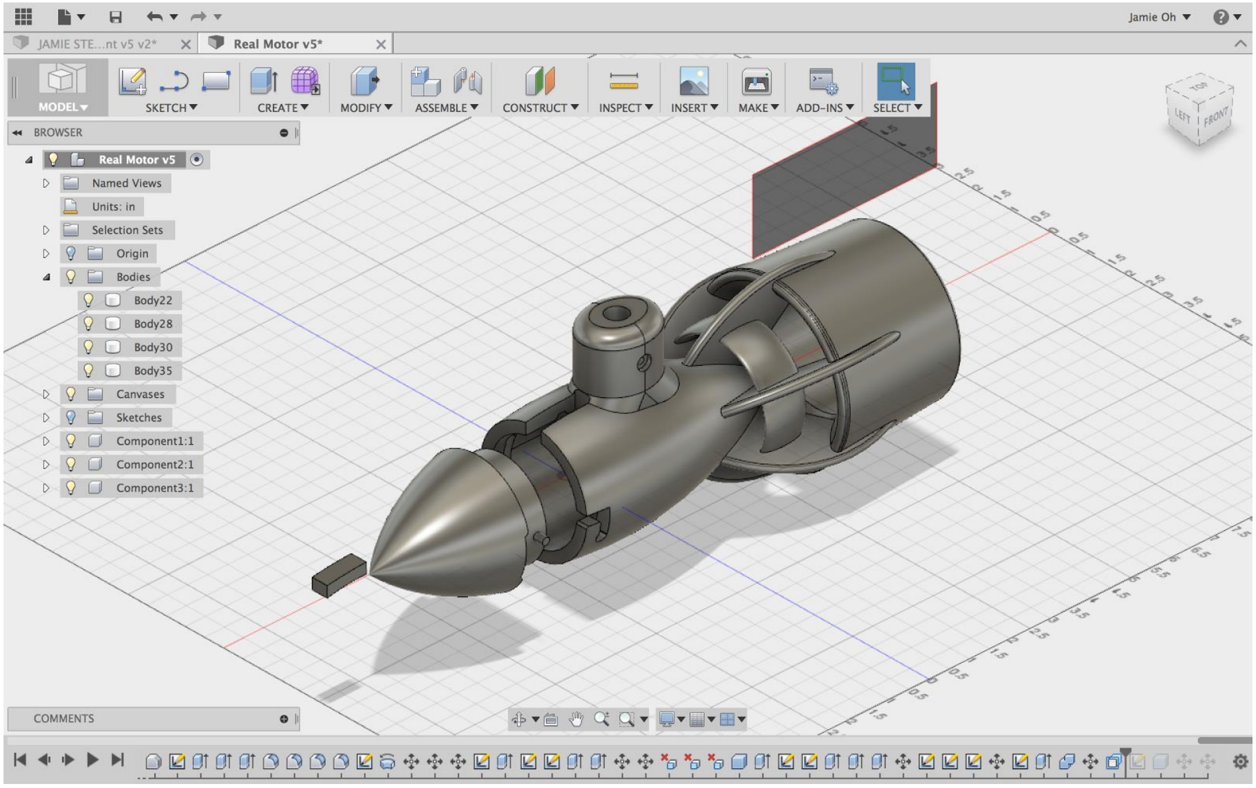

Figure 3. Computer generated model of 3-D printed motor nacelles

Also aiding with propulsion system is a Hall Effect sensor. By placing four magnetic sensors on the worm gear and a transducer which varies based on magnetic field at a fixed location adjacent to it, the degree to which the worm gear has turned can be determined. Checking the orientation of the propulsion thrusters (Angle of attack i.e. whether they are level, tilted upward/downward, etc.) before powering them on is, of course, crucial in ensuring the AUV travels in the direction intended.

This year we upgraded our depth sensor by switching from a dry depth sensor to a harsh environment depth sensor better able to withstand competition conditions. This was chosen as the cost of this sensor was worth removing the inconvenience and additions necessary to accommodate this inferior sensor. In addition to this sensor the AUV also boasts an Oceanserver OS-5000 Digital Compass.

Another upgrade was made in how we communicate with the AUV. Communication was changed from a wireless to a wired fiber-optic connection. This removed some of the challenges that we ran into with attempting to connect wirelessly to a robot that is meant to live underwater.

As the AUV will be fully submerged, it was imperative that all of the electrical components were protected from shorting out due to contact with water. This was accomplished by the purchase and use Ikelite ICS underwater connectors for the many areas on the AUV that require a waterproof seal around the wire. While somewhat costly, this provided much needed peace of mind for the most vulnerable parts of the robot.

Our computer was also upgraded this year from a DreamPlug Marvell SheevaTM Core to a Roboard RD-100 with 32bit x86bit CPU running 1000MHz with 256MB DRAM compatible Linux and DOS. This was chosen as it suited our needs and had a built in servo control, significantly reducing the interior electronics and wiring of the AUV.

For software ensuring that the code ran properly was a big challenge, given the very limited testing time the team had. The programming team worked intensely to get the software working as smoothly and as quickly as possible; with only a few members having full knowledge of the API used, this was difficult, but as the team's mission strategy for the AUV this year was not overly complex, the programmers were able to make do with the little time they had. The code for all of the software for the AUV was written in C++. In this situation, C++ was the language of choice due to its efficiency, flexible object-oriented and function based architecture, and relative simplicity to debug and understand. Most of the programmers on the team come from a Java/Python background, so C++ was a fairly natural transition into a more powerful language. The main challenge for the team was to find a way to keep everyone in tune with what was meant to be accomplished, as there were numerous aspects of the software that had to be dealt with. For instance, because each of the sensors relied on different APIs, it was sometimes difficult to debug code that one team member had worked on.

These components, upgrades and areas of focus our team chose aided our goals of creating a platform that is easier to use, more reliable and represents a step forward that can be built upon in the future.

IV. Experimental results

Due the constraints placed upon us as a High School Team, namely time and facilities we have had fewer opportunities for testing than we have wished as our members are involved in many other activities. Due to this our testing has been limited to individual component tests on land and few water tests. Our pool tests primarily showed us the issues that were present within our communication and propulsion systems. The challenges that we encountered within the testing led us to the overhaul of both of these systems as discussed above. Specifically the challenges of communication when the robot was in the water, and the necessity to remove it each time communication was established lead to the overhaul of that system. The stress placed on the motor frame and gimbal system by the old propulsion system as well as the challenges in uncontrollable variables of the old systems led to a full replacement of those systems. The final flaw revealed by the water tests was our issue with watertight integrity that had plagued Caesar. This led to the increased focus on more effective strategies and care placed into this area and was one of the reasons we addressed the issues of our split hull design.

This year our overhaul of the propulsion system led us to switch to a 3-D printed design which was extensively tested. We worked with several iterations, during which we made the model more streamlined, improved its locking mechanism, and structural integrity. Our programming team worked endlessly testing out of water. They started by testing and refining the classes that ran each component individually, making sure each part was usable and reliable. Then as more and more components were completed, they began integrating the different pieces into larger and larger scale programs. They also tested some of the more abstract parts like the PID controllers separately first before integration. This allowed the Software aspects of the robot to make as much progress as early as possible, without needing to rush the hardware.

V. Acknowledgements

The utmost respect and appreciation goes to Mr. Andrew Kay, who took countless hours out of his busy schedule to tirelessly supervise the team throughout the entire process, providing many tips and unending insight to ensure that the robot would function as well as possible at the competition. Without the dedication and commitment of Mr. Kay there would be no Robotics Program at St. George’s let alone any Robot or the opportunity for our team to travel to San Diego for this amazing experience. For his contribution we are forever grateful. In addition due to our limited budget as a High School team we are very thankful for our team’s generous sponsors: Whealthfields Lohmann (Hong Kong) Ltd., the St. George’s Parents’ Association, and Stollco Industries. Their contributions have truly helped make the team’s participation in the 2016 RoboSub Competition possible.