U.S. Navy Engineering Internship

Our World Underwater Scholarship Society
Naval Surface Warfare Center, Carderock, MD
Summer 2008
Final Report

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Acknowledgements

Working with world class engineers is not something most college students are given the opportunity to do. My time as an intern at the Naval Surface Warfare Center at Carderock, MD, was the most humbling experience I have had to this day and I am honored to have worked along side so many of these brilliant engineers and researchers. My time at NSWCCD was due to the Board of Directors at Our World Underwater Scholarship Society and I am extremely grateful for everything that was done to allow me this experience. I would like to thank George Wozencraft, Martha Sanders, Jim Corry, and everyone else involved with making this experience possible. Also, I would like to thank especially Dan Dozier for coordinating much of my time at NSWCCD, and Toby Ratcliffe, who was my mentor and made every effort to make my experience incredible.

1.0 Introduction

As my first semester ended at St. Louis University, thoughts of possible internships filled my mind. As an Aerospace engineer, I was told that obtaining an internship for the summer going into my sophomore year was nearly impossible. I met with a family friend, Toby Ratcliffe, over winter break and toured the Carderock facility. I was amazed at the facility I had passed by so many times, but never knew the complexities of the complex that lay within. Toby and I stayed in contact over the following weeks of break, and she alerted me to the possibility of an internship through the Our World Underwater Scholarship Society.

I contacted the society and was put in direct contact with George Wozencraft who then guided me through the application process. I was excited for the prospect of getting involved in an engineering field, especially one who's medium, water, was so very closely involved with aerodynamics. I was granted the internship during my second semester after the Board of Directors met, and did my best to focus on school with the prospect of actually putting so many years of education into practice. I hope that my educational choice as an aerospace engineer (now at the University of Maryland) can provide a unique insight into the similarities and differences of the two mediums, water and air, that have been studied and researched by both Naval and Aerospace engineers.

1.1 Arrival

Upon arrival at Carderock, I met again with Toby Ratcliffe, who guided me to the room where many other interns were filling out paperwork. This paperwork took a couple of hours (I will talk about this later) and afterwards, Toby showed me to my office. I met with Dan Dozier the following day, who in collaboration with Toby, had come up with an enthralling list of possible experiments I could work on over the course of the summer. On the second day, I was introduced to the group I would be working with on an enormous facility called the "Rotating Arm" and immediately dove into work.

2.0 The Projects I Worked on

Over the course of the summer, I worked on five different projects. As a result of the variety of work I participated in, I was able to make many conclusions and comparisons between hydro and aerodynamics. The projects discussed, for the most part, will be without exact data values because of certain confidentialities, but graphs and pictures will be provided to aid in the understanding of what exactly occurred.

2.1 Particle Image Velocimetry

The first experiment I worked on was conducted in the rotating arm basin, which is one of two large scale rotating facilities that exist today (one is at Carderock, the other is in Europe). The rotating arm basin is a 260 ft. diameter cylindrical basin that has an arm centered in the middle that rotates up to 50 knots (the equivalent of 75 miles per hour) in 2 revolutions. The depth of the water in the basin was 20 feet, which means nearly 8 million gallons of water filled the basin. I was surprised at how dark the facility was, but learned that in order to keep algae out of the water, light has to be minimized and used only when experiments are occurring. Fans also blew over the water to prevent stagnation when experiments were not occurring.

The first week working on this experiment entailed mainly rigging for the actual experiment. The project leaders that I worked most directly with and who were in charge of setting up the particle image velocimetry (PIV) apparatus were Scott Percival and Ali Etebari. Paisan Atsavapranee was the main project lead. All three of these engineers were incredibly intelligent and were quintessential to my learning experience on the rotating arm. Before I explain what we built, the definition of PIV must be established.

PIV is a technique used to assess how a medium, such as water or air, flows around an object. In our case, the object was the aft section of a DDG-1000 destroyer scaled down to mimic exactly the details of the hull of a full scale DDG-1000. The order of objects is the apparatus was destroyer, lasers directly behind and perpendicular to the destroyer, and cameras behind the lasers (pointed at the props of the boat). First, particles of similar buoyancy to water are spread in the channel through which the test will be conducted. Two cameras are then set up to take a picture of the particle field that is illuminated by two high powered lasers, placed behind the DDG-1000. The lasers used are similar to the ones used by ophthalmologists, but are funneled through a special lens which refracts the laser beams into a fan so that a large section of particles is hit by light, thus illuminating a field of particles. The two lasers are calibrated in a manner that allows the cameras to take photos at the same time the lasers flash.

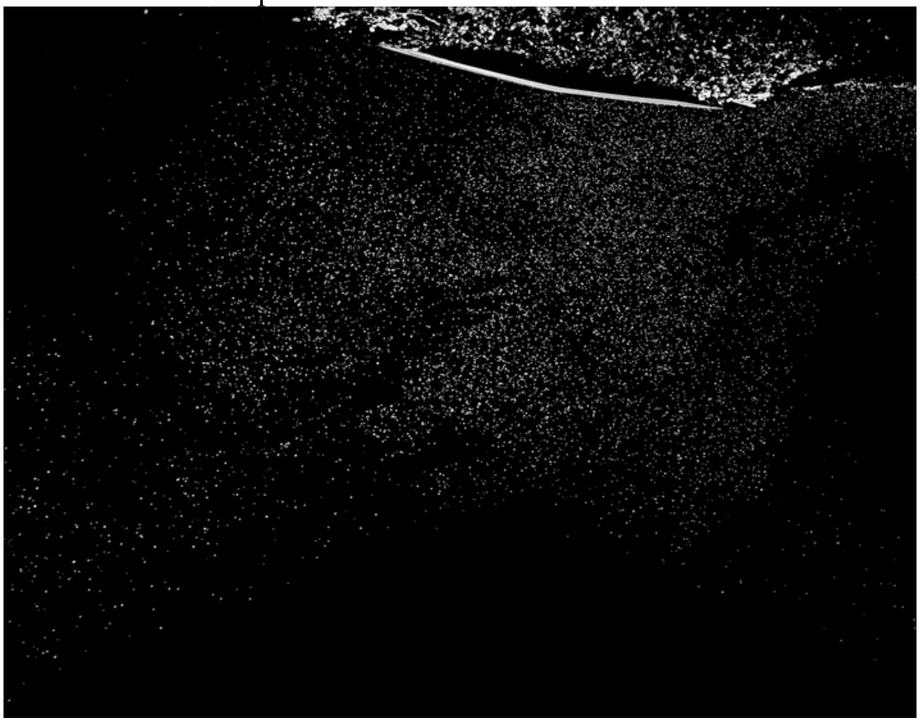

Figure 1: An unprocessed PIV frame, showing the particles moving around the destroyer as it moves through the water (the light white line at the top of the frame is the hull of the destroyer).

The boat was moving through the water during this process so that flow could be observed. From these pairs of images, which are snapped milliseconds apart in order to catch the same particles, software deciphers matching particles in different frames and from these particles, a vector field can be made.

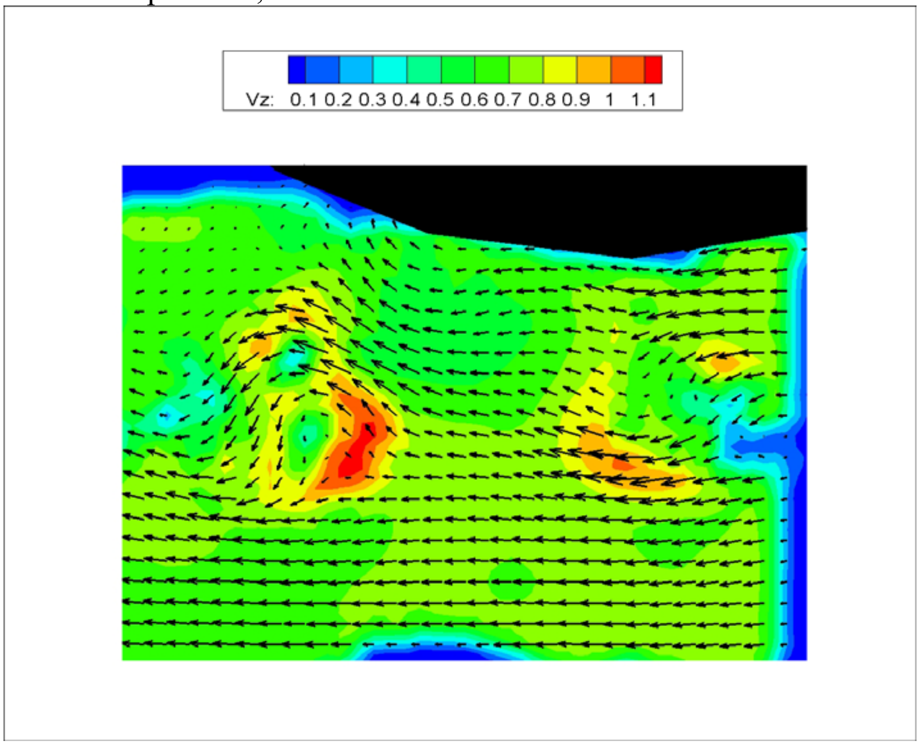

Figure 2: A processed set of raw images, such as the one above, result in a vector field as seen in this image.

A vector field is a picture that indicates the magnitude and direction of a medium. In Figure 2, the vector field indicates the direction and magnitude of the water moving around the props of the boat. The direction is indicated by the arrow, the horizontal magnitude (this will be explained later) is indicated by the size of the arrow, and the color indicates the velocity of the water (coming out at the observer), blue being the slowest, red being the highest. The third dimension, velocity, which is a time dependant function, is achievable because there are two images being compared at different points in time.

Setting up, or rigging, this experiment comprised the first two weeks of my internship. Scott was in charge of the actual apparatus that would be used to mount the boat, lasers, cameras, and the apparatus that would spread particles in the water. First, the cage was built using aluminum beams that were fastened together to the framework of the carriage attached to the rotating arm. This carriage could move along the arm so that the PIV system could be at any radii along the 130 ft. arm. When I learned that the carriage was capable of achieving multiple radii, I realized that a principle I had learned in my Physics class the past year was being put to use.

Elementary linear velocity is described by the equation $V=d/t$, d being distance and t being time. Because of the unique attribute of rotation, both linear and rotational velocity are present when conducting experiments on the rotating arm. This means that the velocity of a ship turning can be recorded, along with the ships linear velocity. The equation describing rotational velocity is $\omega=\theta/t$, where θ is the angular displacement and t is time. Thus the relationship between angular and linear velocity is $V=r\,\omega$, which indicates that as the radius of a rotating object increases from its origin, so does its linear velocity. This is an important factor when observing data and in the set up process involved with measuring a ships velocity when turning.

Once the cage was finished, we set up the "rake" apparatus, which was a long aluminum beam that had several shorter perpendicular beams at the bottom, like an inverted telephone pole. On each perpendicular piece, plastic tubing was attached to brass piping which spanned the length of each individual cross beam. It was through this pipe that the particles were dispensed into the water. The rake was attached to a pulley system so that it could be hoisted into and out of the water, and was placed directly behind the DDG-1000. As mentioned before, particles were dispensed in a pre-data, half turn run. The particles were hollow glass spheres with a diameter of either 50 or 100 micrometers that were coated with silver. These particles resemble dust. After being mixed in a 50 gallon barrel, these particles were dispensed on the pre-data run while the arm rotated at a linear speed of .5-1 knots. The run would commence immediately afterward because of the tendency of the particles to travel outwards because of centrifugal force.

Setting up the lasers was the most delicate part of the experiment, as fiber optic cables had to be laid out very carefully along the length of the arm. This was Ali's specialty. Once the fiber optics were attached to the lasers that were placed behind the boat, the actual laser generating machines were craned to the center carriage, which was a closed room containing multiple data collection and analysis computers. Because there are two lasers creating a field from opposite sides of the ships hull, two had to be crated out and placed carefully in the carriage.

The experiment was conducted with several different variables: yaw, roll, velocity, and radial length of the carriage from the center. Multiple runs were executed with these variables constantly changing. I learned that as a ship turns, it rolls out of its turn; this can be seen in both figures 1 & 2 (the white line and the black hull form, respectively). Thus, angular velocity and roll are intrinsically related and had to be compensated for in a dependant manner.

I worked on this project for about a month. I got to take out a small boat to adjust the roll of the model, helped with "seeding" the water, and occasionally made proper yaw adjustments to the boat. The result of the experiment is demonstrated by figure 2; a vector field that shows the flow of water around the props of a turning boat.

This experiment is what triggered the comparison of hydro and aerodynamics in my mind. On my first day working on this experiment I saw that there were airfoils on the top beams of the rotating arm. An airfoil is essentially an airplane wing and I was completely baffled as to why something intended for making things fly would be on an arm meant to stay on the ground. I asked Ali about this and was told that because the arm moves at such high speeds, lift can reduce the amount of friction between the wheels propelling the arm and the track they lay on. This was, however, not the primary purpose of the airfoils. I was told that they were placed there to reduce vibrations. I had no idea what this meant, so Ali gave me a quick lesson in fluid dynamics. When a bluff body (a box, beam; anything not made specifically to be aero or hydrodynamic) moves through a medium, it oscillates because the medium sheds vortices around the object it passes. These oscillations are described by Strouhal Numbers. These numbers describe the oscillations experienced by a bluff body; the equation is $Sr = (f*L)/v$, where f is the frequency of vortex shedding, L is the length of the object observed, and v is the velocity of the fluid. When high Strouhal numbers occur, vibration accompanies because of alternating vortices. A good example of this occurs when paddling is a canoe or any type of water craft. When paddling slowly, one may realize that his or her paddle shifts from side to side. This occurs because the velocity is low and the alternating vortices cause pressure changes on either side of the paddle, causing it to shift (or vibrate). By introducing airfoils to the arm, the Strouhal numbers were reduced because these airfoils are not bluff bodies but are specifically designed to reduce vibration and create lift. Not only was this method of vibration reduction used in the above water component of the test, but also below water with roped twisted around certain areas to decrease vibrations that would cause inefficient data recording. This technology can be seen in everyday life; for example, most SUV antennae have a small spiraling column along their length. This is done to reduce vibration to increase the clarity of the radio signal.

2.2 Delta Drogue/SHARC Testing

After the first month of what had been an incredible experience working on a fast moving, state of the art test facility, I moved on to working at another state of the art facility in the high speed basin. The high speed basin is a 2,968 ft. long basin (over half a mile long) that is 51 ft. wide and 10-16 ft deep (depending on where you are in the basin). The experiment was run on carriage 5 which runs at 50 knots top speed. The carriage is a moving platform that runs on electrical cables attached overhead. The models being tested are attached to these carriages and either mounted in a fixed position or is dragged.

On this experiment, I got the chance to work with several senior managers at carderock. I worked most closely with K.C. Eisenberg and Debby Furey, who both extremely brilliant individuals and who made my experience on this test very fulfilling. The purpose of this experiment was to verify the amount of drag produced by and apparatus called a SHARC, brought in by a private contracting company. The purpose of the SHARC is to keep two drogues, which are parachute shaped objects that are strung on lines with the intention of decreasing the amount a boat drifts without using its engines, from becoming entangled when placed close to one another. The means by which we found the drag on the SHARC was by first testing the drag force on several different size drogues, ranging from 20-48” diameters, at several different speeds. These drogues were then attached to the SHARC and run at the same speeds. From the recorded drag force values on the SHARC with the drogues, the drag force recorded with just the drogues could be subtracted, leaving just the drag on the SHARC.

During the test, I helped with rigging the drogue apparatus and was in charge of the data collection system. We used a program called Snap Master to record the raw data. Once each run had been executed, I would take the recorded values and input them in excel. K.C. Eisenberg then made the choice of letting me do some of the actual data analysis, which was extremely rewarding as I was able not only to participate in the experiment but also see the results of what I had participated in. The calculations involved simple mathematical operations that could all be done in excel, such as standard deviations, subtractions, polynomial extrapolations, and graphing. The following is the result:

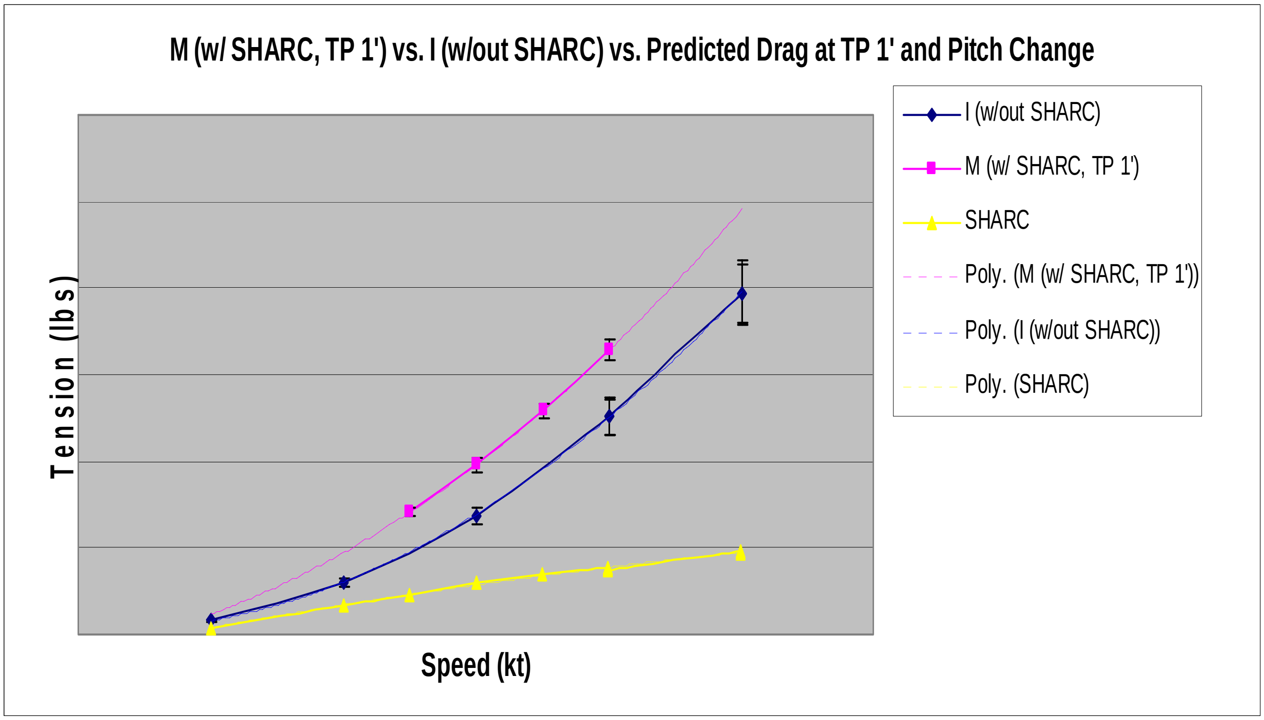

Figure 3

During this experiment, the effect of high Strouhal numbers could be seen again, causing the drogues (which are an extreme case of a bluff body) to shift from side to side causing inaccurate data. To fix this problem, K.C. proposed that we cut a small hole in the middle of the drogue to let water pass through it and thus decrease the tendency of the drogue to move around. I went home and researched this method that night and found that this technique has been employed by those involved with the making of parachutes. A parachute with a hole in the middle is called an apex pull down, or APD chute. Again, aero and hydrodynamics had presented themselves as comparable. An APD is a parachute with a hole in the middle, just like that of our drogue; however, the hole in the middle of the chute is pulled down so the chute takes on a doughnut shape when filled with air. Because the center is pulled down, there is an increase in the surface area conducive to drag and increase in stability because air passes more freely through the chute. I proposed this aerodynamic idea to K.C. and it was met with approval and hopefully will aid designers and experimenters in the future.

2.3 Seaperch

After nearly a month and a half of experimenting, my internship took a rather unique turn. My mentor, Toby Ratcliffe, is in charge of the outreach program at Carderock. Toby has been involved in outreach to young minds in many forms ranging from girl scouts to internship mentoring. At Carderock, she runs a program that is incredibly successful called SEAPERCH that has reached throughout much of Montgomery county. The program's motto, "Teach, Build, Become" is certainly lived up to. The eyes of many of the students completely glaze over once they get their hands on tools and as one student said, “After attending this program, I realized that I was able to do this.”

A “Seaperch” is a remotely operated vehicle (ROV) that was designed by students at MIT with the intention of young students as the builders. The vehicle is made of cut PVC pipes and simple elctronics that could be found at Radioshack. Toby conducts the training seminars at Carderock and then takes a team of a few engineers and interns to summer camps, middle schools, and grade schools throughout the county. Once at these places, the trained engineers *help* the students build their Seaperch. Almost all of the work done in the process is done by the students; this included drilling holes for and mounting motors, potting (waterproofing) the motors, and soldering the electronics.

I was able to spend a day in the classroom helping students build their Seaperches and also attended their maiden voyage, which took place in the 140 foot basin at Cerderock. I was also able to attend a first time trial in Prince Georges county at the PG Sports and Learning Complex. I got in the water and helped as the students attempted to maneuver their perches through obstacles we had set up earlier that morning. This outreach program is truly incredible. Watching some of these kids build their perches took me back to a younger age, where making Lego creations comprised almost all of my free time.

Figure 4

2.4 Virginia Class Submarine

Working with a Virginia Class Submarine taught me why so many pages of security forms had to be filled out. Things such as speed and certain components of the sub are highly classified to the point where the sub has to be covered up when tours are given. This said, I apologize if some of the information given seems sparse.

This experiment was conducted in the Maneuvering and Seakeeping Basin which is 360 ft. long, 240 ft. wide, and ranges from 20-35 ft. deep. The sub was an ROV scale model capable of executing different typed of programmed runs. The purpose of the experiment was to observe the effects on the maneuverability of the sub when one of three sonar devices mounted on the side of the submarine was placed in a different position. The reason the sonar device had to be moved was because one of the devices spanned a connection point (the submarine is assembled in three separate pieces). By moving the sonar device from the connection point, time and therefore money would be saved in the assembly process of a full scale sub.

Aby Roy, a graduate from the University of Maryland, conducted this experiment. Aby explained much of the submarines systems to me and patiently answered all of my questions. Due to the classification of the sub, many of my questions could not be answered. However, many questions lead to a much deeper understanding of this project and helped me understand the projects I had worked on in the past. For example, prior to this experiment I understood the processes and data collection methods used but never fully grasped how the data collection tools actually functioned.

After asking Aby how forces were actually measured, he cleared up my confusion. I learned that most instruments function by recording changes in the voltage running through the instrument. These voltages are then converted into known physical units such as lbs. For example, one of the instruments used in measuring the forces on the control surfaces (such as the sternplanes and rudder) of the submarine is a dynamometer. Like many instruments, the dynamometer works by transmitting a known voltage to what is called an “A to D” box, or an analog to digital box. Current is run through the tubular instrument into a extremely thin metal wire that is arranged in a zig-zag pattern. Due to the chemical and physical properties of the metal, when a force is applied to it bending it, it lets more voltage through. Once this voltage is recorded it can be converted into lbs, so that the forces on the rudder and sternplanes could be observed for the different maneuvers applied.

The Virginia class submarine was incredibly intricate with regards to the instrumentation. Some of this instrumentation included a fully functional ballast system, emergency surfacing instrumentation (incase radio control is lost), a computer capable of storing data and executing several specific runs, and an Acoustic Doppler Current Profiler (ADCP). The ADCP was one of the most interesting parts of this experiment. The ADCP is placed on the bottom of the submarine where the transducers send out sound waves and upon return identify the velocity of the medium being traveled through.

The instrumentation of the submarine is not only important for data collection, but also to ensure that the submarine is actually acting as a scale model would. The most critical component to making the scale version maneuver as the full scale would is making sure the BG corresponds between the two. The BG is the vertical distance between the center of gravity and the center of buoyancy. If this value is off, the data results serve no purpose. Also, the model must be ballasted by adding foam or weight so that it sits in the water with a specified area of the hull submerged and a specified area above the surface. Along with this, the pitch of the model at rest must be ±.5 degrees. This can be adjusted manually by adding weight as mentioned before, or by adjusting the trim remotely from the control tower by moving water from the aft to the forward, or visa versa, ballast tank.

I helped in this experiment by executing some of the runs, and by remotely driving the sub back to the docking station when each run had finished. Four main runs were performed.

1. Horizontal Overshoot: The purpose of the horizontal overshoot was to test the effectiveness of the rudder which controls the motion of the model to the left and right. The information gathered indicates the yaw overshoot when the rudder angle is reversed from a specified degree to the opposite degree. For example, if the model is set to turn left at 10 degrees, it will turn left and then turn right to see how much the model yaws.
2. Vertical Overshoot: The purpose of this maneuver was to test the effectiveness of the sternplanes, which control the depth of the submarine. Like the vertical overshoot, the ordered angle was reversed midway through the run, but now the amount the model pitched after the change in direction was the intended data.
3. Rise Jam: The purpose of the rise jam was to record the effectiveness of the sternplanes, outer and inner, when one set jams into full rise. The functionality of the remaining planes is the intended data, as they are used to prevent the model from completely rising to the surface. Pitch angle, roll angle, and speed were measured.
4. Dive Jam: This experiment is similar to that of the rise jam, but occurs when either both of the outer or inner sternplanes jam into full dive. The same data is recorded as the rise jam.

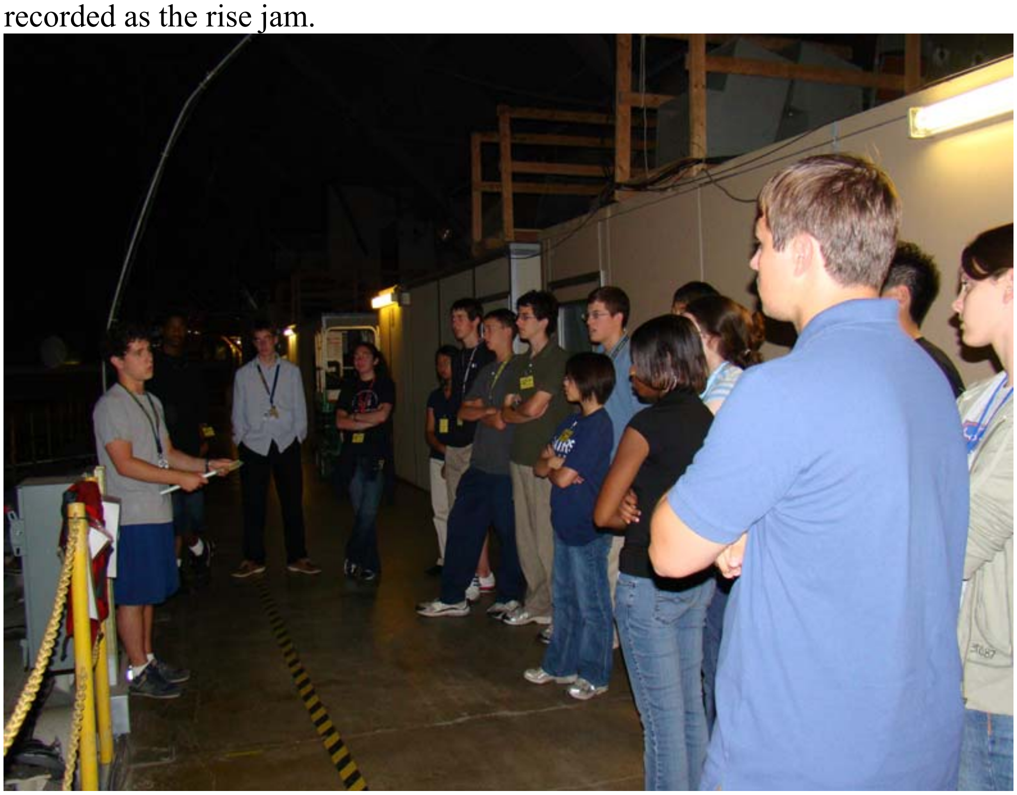

Figure 5: I was asked to give a brief explanation of the experiment to the high school interns at Carderock

Many people do not realize it but almost all branches of the military are becoming more and more reliant on remotely operated vehicles. I have taken up a particular interest in remote technology as it has proven itself extremely efficient in war. Currently, Predator Spy planes are being used in the Middle East by the military and are helping keep our troops out of the line of fire. Working on this project really hit home with me because my father, younger brother, and I fly remote control airplanes. In fact, our garage has been turned into a model airplane shop with airplanes hanging from the ceilings and walls. Getting to work with a remote controlled submarine in this sense, was right up my alley as I had a pretty fair understanding of how remote vehicles work (although none of the ones I had ever seen had been this complex).

2.5 Wave Profiler

The time spent on my last experiment is due to the generosity of Toby Ratcliffe and the thoughtfulness of Dan Dozier and Jim Rice. My time spent on this project was almost entirely research that I was allowed to do on my own, and I owe a great amount of thanks to Toby for funding my time spent. Toby approached me towards the end of my internship with the concept of coming up with an alternate method to measuring wave height. The instruments currently used such as "sonics", are extremely accurate, which put a little bit of pressure on my shoulders to come up with a good design. Toby introduced me to Jim, who helped me figure out the equipment that I would be using. While going over possible means of measuring wave heights, one particular instrument stood out because of the relative simplicity; it is called a Linear Variable Differential Transformer (LVDT). This device is comprised of a thick metal tube with an open shaft in the middle. A rod with a ferromagnetic tip is placed in this opening, and can slide up and down. The thick outer tube has three solenoids, or coils of wire, in the frame. A current is placed in the middle, or primary, coil, which causes an inductance between the primary and secondary coils. When the rod with the ferromagnetic tip slides past these coils, the inductance changes causing the voltage reading to change (we used a voltmeter to record this change in voltage). From this information the linear distance the rod moves can be recorded.

Jim rice took a lot of time explaining this to me and helped me understand how to set it up. The next step in the process was designing the float that would rise and fall with the waves, driving the core rod into the tube. Ten different designs were tested. The designs were of different density foam and different shapes including cylindrical, wedge, cone, and right triangle shapes. This testing was performed in the miniature model basin, which is a 40 foot long basin that is 2 ft. wide and 2 ft. deep. Wave heights of up to two inches were made by a small wave maker at one end of the tank. A prototype profiler (figure 6) was used that reduced the expected friction that would occur using an LVDT and also made much clearer which floats would work best. The responsiveness of the floats was determined by a grid made with a china marker on the glass viewing side of the tank that was compared in video to the height excursions indicated by the tip of the attached rod on the marked prototype.

Figure 6: Prototype

From the data recorded, it was determined that a conical float would be the most effective because it eliminated certain problems. For example, the wedge shaped float required that two rods be inserted so it would not turn when waves approached. However, this was a problem because the LVDT had only one rod, meaning a uniform conical shape would be a great compromise as it has the same geometrical qualities as the wedge.

After this was accomplished, the second prototype of the wave profiler was set up. It consisted of the LVDT attached by zip ties. This piece of the research posed some problems. Now that the float had been decided on, accurate height measurements and consistent wave profiles had to be established. This was a problem because the friction between the tube and the rod had become greater and the weight of the rod was near equal to the force of buoyancy exerted by the small foam cone. Just as this happened, an engineer walking by informed me that the size of my float had to be less than 1/10 the length of the propagated waves. I had been hesitant at first because the “footprint”, or circumference of the cone between submerged and surfaced, had to be reduced as much as possible to provide the best data. However, with this new knowledge, I once again redesigned the cone. This time, I made it significantly larger and hollow (figure 7).

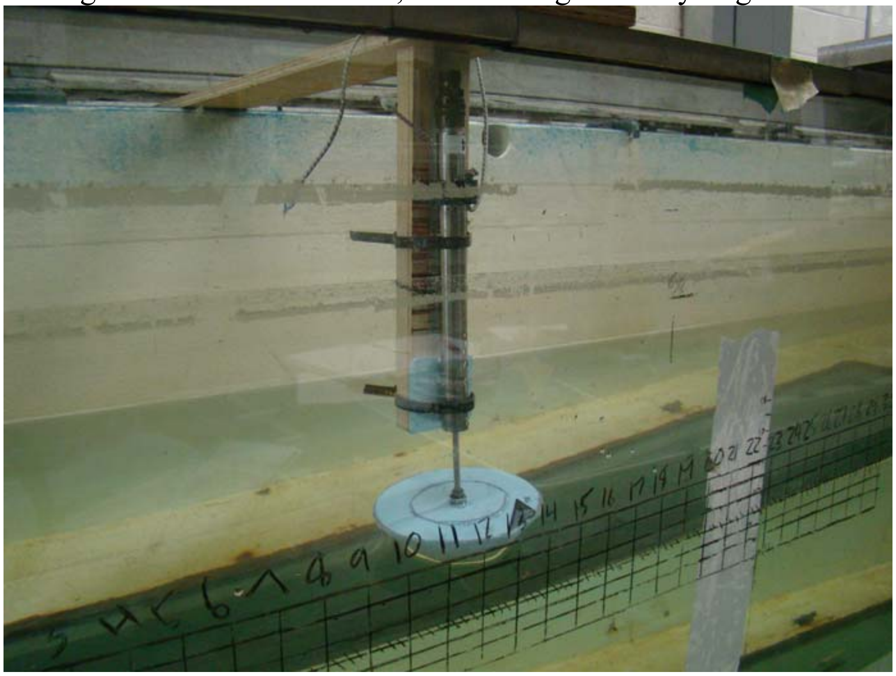

Figure 7: Prototype II with grid and final cone

Also, because the basin was smaller the waves reflected back very quickly leaving about a 30 seconds window for data collection. Another engineer pointed out that I might have a process called seiching occurring. Seiching is when a standing wave is produced in a bounded body of water, which would have effected my data collection. To avoid this problem, I used the equation $T=2L/h\sqrt{gh}$, where T is the maximum period of wave propagation to avoid seiching, L is the length of the tank, g is the force of gravity, and h is the height of the water. From this I found the max period was .32 seconds. I adjusted the wave maker to avoid this problem.

Dan Dozier stopped by midway through this process, and he offered me some extremely useful advice regarding the manufacturing of the cones. Dan, Toby, and I brainstormed about possible alternative methods to an LVDT for about an hour. The ideas that were presented were extremely valuable to the process of completion of the profiler and will be used in future testing. Dan was also kind enough to have three cones factory made for me so that they were completely uniform plastic. These pieces were not used because of time constraints but will be used, again, in further testing and at the very least as concept designs (I will be returning to Carderock over the school year to continue working on the profiler, and a patent is possibly in line thanks to the efforts of Dan and Toby).

Once this was done, final data collections were made and the final version of the wave profiler was assembled. Along with the assembly of the actual LVDT and float, I also soldered the cable connected to the LVDT. It was placed on the side of a model being tested for other purposes and the LVDT was hooked up and calibrated into the already working data collection system (figure 8).

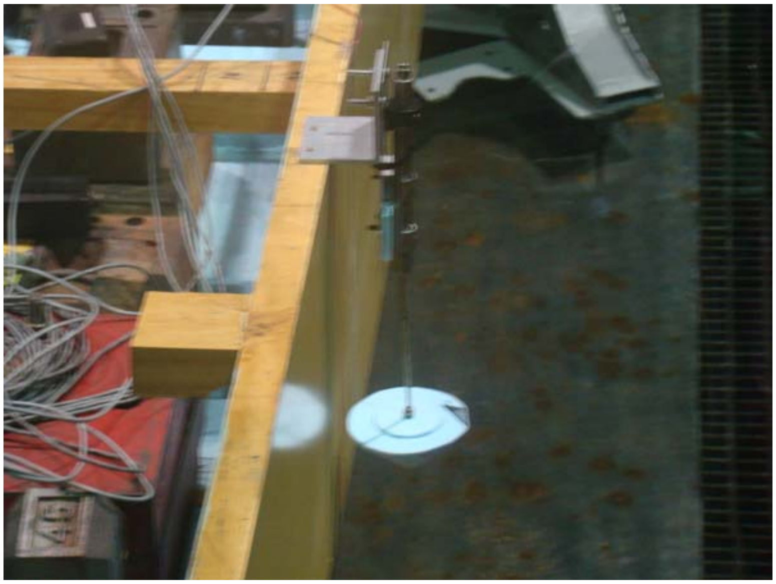

Figure 8: The final wave profiler hooked up and attached to the side of the model.

The result of the profiler was that it recorded wave heights when the model was standing still. However, once the model moved, the force on the float in the direction of motion (the x-direction) caused friction between the rod and the opening in the tube. This caused the float to submerge because the force upward (the z-direction) of buoyancy was not great enough to overcome the frictional force between the rod and tube, known as static friction.

3.0 Memorable Experiences

My time at Carderock was work filled, but was also incredibly fun and eye opening.

3.1 Security

After I was offered the position as an intern, I received the paperwork that needed to be done in order to work at a government facility. Of these seemingly endless forms, the SF-86 was the most unexpected. The SF-86, or Security Form-86, was filled with questions. I had to list every single place I had lived in my life, all countries I had visited, and had to give many references to be contacted for further background check information. This was a little overwhelming, as it came during my final exam week, but was also very eye opening to the level of security at a government job. I had heard of forms like these, but never imagined that they would apply to me.

Once this was completed and I had begun my work, I had to complete an online course that addressed security threats from the internet. I also attended a mandatory seminar further addressing these threats and was absolutely amazed at the seriousness of the situations presented.

3.2 High School Robotics Team

The high school robotics team from a local county high school came for a tour one afternoon, and Toby asked me if I would stop by at lunch for pizza. As a college student I am inclined to jump at any opportunity involving free food, and accepted. I arrived at around noon as everyone was already eating, and was then introduced to the group of students. Their teacher then prompted them to each ask me one question. I was a little caught off guard, but was happy to talk to them, student to student. The first question I was asked was "what made you decide to be an aerospace engineer?" I had to answer this question honestly and responded, "When I was ten, I saw the movie Top Gun for the first time, and was hooked." My response was met with laughter, and it was meant in jest, but not entirely. I continued to explain to them that both of my parents were in the United States Air Force and I had grown up around military bases, attending air shows and eventually becoming entirely obsessed with flight. From this I explained that, as I hope I have shown in this paper, aero and hydrodynamics share many similarities.

It was very eye opening to see this group of young men and women in the same shoes I was in just a few years back. It was great getting to know some of them for the afternoon and was very rewarding to be asked questions that prior to the internship, I would not have been able to answer. This experience showed me how much I had actually learned, as I had not had the time to really stop and think about it before.

4.0 Conclusion

This experience was by far the most rewarding I have ever had in my life and owe much thanks to all involved with the Scholarship Society and the engineers I worked with at Carderock. I hope that this paper has shown the similarities between aero and hydrodynamics and done so in a manner that is understandable. I also hope that anyone who reads and has questions or comments will feel free to contact me at cgibeily@hotmail.com. I encourage all students to apply for this internship, as it is sure to be rewarding beyond imagination.