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Executive Summary

The Umptysquatch VI submarine is a two human, propeller powered submarine. The general dimensions of the submarine are as followed:

-Max Height – 27 inches

-Width – 26 inches

-Length –192 inches

The Umptysquatch VI team will work together in completing the following tasks:

-Design and fabricate a reliable control system

-Design and fabricate the most efficient propulsion system

-Finish fabrication in time for adequate in water testing time

Past Umptysquatch teams have designed propeller driven submarines that set high standards for us. However, the previous teams had combined propellers with innovative ideas; we have decided to take on a different path this year with the main objective of speed. In addition, almost none of our previous teams had gotten a chance to practice before the races, but we intend to put that habit to a halt. With our pristinely built hydrodynamic hull by Umptysquatch team 3.2 we have the ability to achieve maximum speed. Plus, having time put aside to practice will be a huge benefit that we have never had before to attain perfect buoyancy, and give our pilots time to adjust to the systems prior to ISR 12.

Umptysquatch VI Project Mission Statement

The objective for Umptysquatch VI is to utilize our hydrodynamic hull to design and manufacture the most effective system to maximize our speed. We also aim to achieve a speed of five knots and complete all runs attempted.

Sussex Tech Engineering Project Started: September 24, 2012

Introduction

Our Team

The Umptysquatch VI team this year is made up of 12 high school students that have come together through their common interest in the field of engineering. We all possess a desire to further our knowledge by designing and manufacturing a human powered submarine. With guidance from our project manager and classroom instructor, Mr. Christopher Land, we will accomplish our goals. Mr. Land was an engineering officer in the United States Navy and served on the ballistic missile nuclear powered submarine USS Henry M. Jackson, SSBN-730. After his service he became the teacher of Engineering Technology at Sussex County Technical School.

Our Organization

The Engineering Technology course at Sussex County Technical School provides a realistic learning experience for high school students. The course integrates a physics lecture where the pupils gain knowledge from theories that include kinematics, electricity, magnetism, and oscillatory motion. Having a well-rounded foundation of these physics concepts allows us to effectively construct and design multifaceted systems such as a submarine.

Students are constantly working on an assortment of projects that incorporate all of the information and skills we acquire during class. In alternating years, the juniors and seniors design and manufacture a submarine for the International Submarine Race. While this is the highlight of our high school careers, we have other major projects, and we enter other competitions along the way. These competitions include the Young-Science Achievers Program, formerly known as the Bell Labs Science Grant Program, and the Skills USA/VICA skills based competition. Our past teams have competed at the national level in the Automated Manufacturing Competition and won first place in New Jersey for the past seven years in a row for Skills USA/VICA.

As part of the Engineering Technology curriculum at Sussex Tech, freshman students begin by becoming proficient in Siemens NX Design. They then use their design skills to take apart a simple machine, and design a scaled model of it on the computer. Sophomores are introduced to Computer Aided Manufacturing (CAM), using our Featurecam program, so that they can actually prototype their computer designs from raw materials on CNC machinery. They then come up with a project that utilizes all of their skills. By the time each student makes it to junior and senior year, they will have obtained enough knowledge and skills to design and build a submarine. While the jump is great from these small projects to a larger one, such as the submarine project, with the guidance of our teacher we find the necessary resources needed to succeed.

Past ISR Involvement

Sussex County Technical School is proud to have competed in 5 International Submarine Races. In the 7th Annual Submarine Race, we received first place for best design outline and report, and we received the third fastest speed for the two person propeller driven category. During ISR 8, we won for the best use of composites and in ISR 9 we were awarded third place for overall performance, in addition to first place for innovation. Through ISR 10 we received the awards for Best Design Report and Best Spirit of the Races. Therefore, we hope to contribute to this list of achievements during ISR 12.

Origin of the Umptysquatch Name

The story of the origin of the Umptysquatch name is simple. Here it is; back in 2002 during the initial design work on Umptysquatch I; the time came where the team had to fill out the Team Registration Form for ISR-7. At that time they already had their hands full starting off with no money, no scuba training, no sponsors, and most importantly, no experience in designing and manufacturing human powered submarines. As the Project Manager, Mr. Land called a meeting and announced that the Team Registration Form required them to have a name for the submarine. He informed the group that he did not want this to take more than five minutes as we had much more pressing issues to address. Michael Bruens informed him that they had already picked a name. "Great" Mr. Land said, "What is it?" "We want to name the submarine 'Umptysquatch.'" Mr. Land's exact words at that time were, "Over my dead body will we name this submarine Umptysquatch!" Michael Bruens immediate response to this was, "Okay, Mr. Land, then we're not racing it." To which Mr. Land replied, "Okay, the name is Umptysquatch." The students got the name from him originally because when he was in the Navy, they would refer to things that they did not know the name of as an "umptysquatch", like a "thingamajig". He used to use this term during physics lectures and the students all thought it was funny. As it turns out, it was probably the best name that they could have come up with since the press picked up on it and covered our team's story all over the country. During our performance at ISR-7 the

Diving Supervisor refused to refer to them as Umptysquatch. He preferred the following monikers:

"Umptyscratch"

"Humptysquash"

"Alwayscrash"

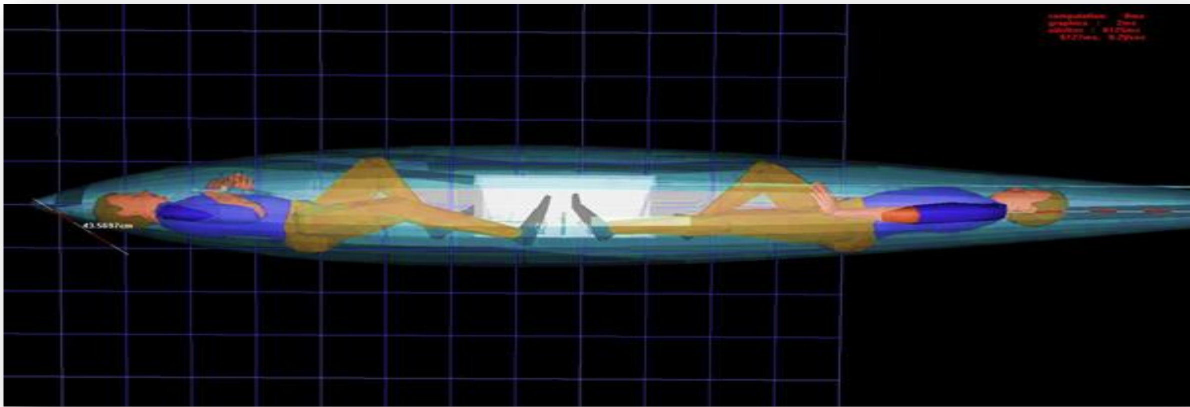
"Sasquatch"

They learned to love the ridicule, and the name has stuck with our teams ever since.

Design Philosophy

Most people overlook how difficult it can be to decide what direction to go in for the submarine project. One would think it is difficult to decide whether to participate or not in the ISR, although, for our shop and team Umptysquatch-VI that was the easy decision. The hard part was to decide to make our goal speed or innovation, and new hull or old hull. Last year with Umptysquatch V we tested our design ability and went propellerless. This was a daring design that could have been tweaked and entered again this year. However another option and direction was to go for speed. Our team is not known for being the fastest, so many students wanted to go for our own speed record.

With both directions we knew there was a lot of work involved, but with both ideas we wanted to involve technology that we already had developed. We knew that there were many benefits with either idea despite each choice having its own challenges. We spent a couple weeks listing pros and cons till we came to a conclusion that everyone on the team agreed and was on board with. Our final decision was to focus on the shop speed record, and shoot for over five knots. As well, we came to the conclusion after many debates to go with a one-person hull that we already had from a previous submarine. This hull is a teardrop hydrofoil and is the perfect shape and hydro-dynamics necessary to increase our speed. One thing held us back; we wanted to use two people. We did a space analysis and figured out we could fit two of our team members into it safely and efficiently. These decisions then became the basis of our design project.



Teamcenter

For the past submarines we have used Siemens NX 6.5- 8 software for our designs and 3D modeling. This year we were presented with NX 6.5-8 integrated with Siemens Teamcenter. Teamcenter allows us to be organized and have more control over the project. Originally drawings and models could be opened from anyone in the class. They could make changes and save over finalized designs. This caused a huge problem with losing files. Teamcenter allows everyone on the project to be registered to the parts they made and organizes them in a database. All the files are in the database and can only be deleted by the DBA or administrator. Also parts and assemblies can be checked and even finalized so no one can alter them. This was a plus for us working on such a big project, Umptysquatch VI.

Teamcenter is based around a database (Microsoft SQL), which is a huge advantage for projects like Umptysquatch VI. Having all of our parts in a database is better than a filesystem because files can move around a filesystem and become lost, but the database always keeps track of part data and references to part data, so that parts that are used in any assembly cannot be deleted. Teamcenter also allows us to "tag" images and other arbitrary data to parts, so that they can be easily located. Pictures of the manufacture of submarine parts have been loaded into Teamcenter and attached to their respective parts, making design report construction more efficient.

We had to learn a few things of course. Learning how the software worked was quick but challenging. Since everything needed to be in the database, it made us learn how to export and import items to interact with the software. Adding attributes to our drafts to create paths. Making files able to receive information from another source. This made key notes and information appear right where it was needed. Making draft title blocks informative and useful without a second wasted. The design of Umptysquatch VI was very accurate because of the integration of the two softwares. It allowed multiple people to review and add their own suggestions, but not delete previous data. TeamCenter made you feel like we were more of a team, allowing the entire team to work together in a better way, ultimately leading to a better project.

Hull

The hull design was chosen when we decided to go for speed because Umptysquatch 3.2 had the best design for speed efficiency. During the early stages of the Umptysquatch 3.2 design, the team did extensive research on what characteristics define a hydrodynamic profile. They found that the Umpysquatch II's shape was desirable due to the Flat Plate Boundary Theory. This theory states that a solid figure will incur more drag on its parallel flat sides moving in a fluid rather than a hydrofoil possessing no flat sides. They chose the Eppler 837 hydrofoil due to it being the most efficient profile in our fluid flow analyses. They used a circular profile for symmetry, but they found that making the profile ellipsoidal reduced the total drag. The overall size of the hull was based on the dimensions of the human range of motion. To maintain the hull's hydrodynamic qualities the Umptysquatch 3.2 team had to maintain the hydrofoil shape by using a common length to beam ratio.

When we first looked at the hull we immediately needed to determine if two people could fit in the submarine, let alone powerfully pedal in it. After numerous "dry fit" measurements were taken, a full scale mock gear box was constructed and installed. Based on our CAD design with human modeling and actual tests with our pilots in the hull, our team was able to conclude that the submarine could accumulate two pilots.

Propulsion

The propulsion method we chose for Umptysquatch-VI took quite a bit of consideration on what we should go with. Our previous submarine was powered by a tail modeled after a Bluefin tuna's. While this method of propulsion was innovative it was ultimately an unreliable and ineffective system. We chose not to go with that idea again and focus more on speed than innovation, resulting in our choice to use a propeller instead of a fish tail. A propeller is much more reliable since it's a tried and true method for aquatic movement, used on boats and submarines alike. A reliable propulsion method is much better for a team who is going for speed rather than innovation because they know the propulsion method will work and can then focus design efforts hydrodynamics in order to streamline the submarine and further increase its top speed.

We also chose to have the submarine hold two people pedaling in tandem to increase the speed of the sub, an inspiration we owe to the Canadian based team OMER. With two people we would potentially double the power of our submarine. The man in the back will do the bulk of the propulsion work while the man in the front controls the submarine and provides extra speed and support in case the man in the back experiences fatigue, and vice versa. The design of this support system allows the submarine to consistently move at a higher speed normally seen in one man submersibles .To accomplish this goal one -way bearings were have installed inside of our gearbox. Analyses of the OMER designs demonstrates a similar principle with their gearbox propulsion causing the pedals to move in sync but we chose to improve upon their concept as we found a flaw in the safety of their design. The original gearbox allowed the pedals to spin even if another person was not pedaling which could injure a pilot should one's pedaling cease while the other continues at full speed. Another problem with this concept was that should one pilot's slow down while the other one continues at a constant speed he would have to fight against the other passenger. We addressed these concerns using one-way bearings which only apply torque to the propellers if the pedals are moving in the same direction.

We have also added a variable pitch system to our propulsion system allowing us to change how the propeller spins once we pick up speed. Like changing gears on a car, the variable pitch will allow the pilots to manually change the pitch of the propeller. Changing the pitch of the propeller will allow us to move more water behind the submarine and in turn make it progressively move faster. Utilizing these design tweaks in combination with the use of two people propelling the submarine we have the best chance to meet our speed objective.

Propeller

After analysis of the past methods of designing a well-fit propeller blade for the Umptysquatch submarines, we decided to take a different approach. Reusing the hull from Umptysquatch 3.2 gives us an advantage of reusing past propeller designs and/or propeller design methods, but since the blades from Umptysquatch IV were downsized due to the shroud, Umptysquatch 3.2 blades achieved the most desirable thrust. Even though Umptysquatch-3.2 had the most efficient propeller design; we still wanted the maximum thrust out of the propellers to push our submarine as efficiently as possible. In theory, a propeller with one blade would be the most efficient propeller providing zero slip. The more blades on the propeller, the more slip it produced because of the flow distribution around each blade. However, with one blade, there will be balancing problem when it's rotating. The next best thing would be a two blade propeller. This will also benefit us because the more blades a propeller has, the more the acceleration will improve.

The next step on designing a propeller is to design a hydrofoil profile. To develop the profile we use a program called "OpenProp" (R.W. Kimball and B.P. Epps, "OpenProp v2.4 propeller/turbine design code," http://openprop.mit.edu, 2010). This program allows us to easily develop the profile of the hydrofoil and the full shape of the blade. In order for use to use this resource, we uploaded it to our MATLAB program. With MATLAB we were able to design the propeller blade and model it with Siemens NX. The blade is about16 inches. The overall diameter is about three feet. In the NX model, the bottom of the blade is very thick and round. The reason for this is that the program was trying the produce as much lift as possible in that general area. The closer a point is to the center of where it is rotating, the less linear speed it needs to make a full rotation as compared to a point farther away from the center, thus making the hydrofoil profile very round.

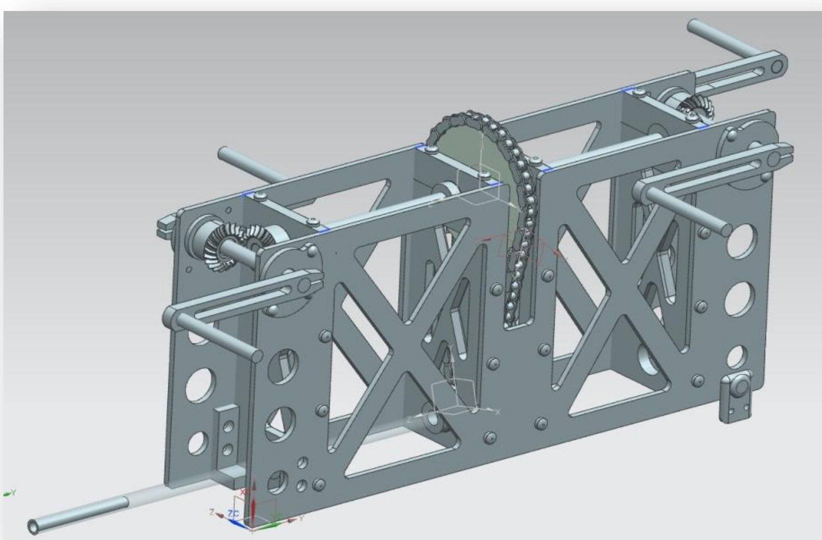
Since the blades were customized for our submarine, the Angle of Attack (AOA) will not be as aggressive as our past propellers. In the past (for both fixed pitched and variable pitched) our AOA's were 30, 31, and 37 degrees, which are very aggressive. This time our AOA is 0 to 15 degrees, which is a more reasonable value. This is also good for the 1:3 drive train ratio; it will be much easier for our divers to pedal at 100 rev/min without having to accelerate that much water in 7mm wet suits 20ft under water breathing through a SCUBA regulator. Not to mention that over time the maximum power that a human can output will decline over time. Roughly 0.75hp will be lost due to the conditions as applied to the available human power.

Variable Pitch

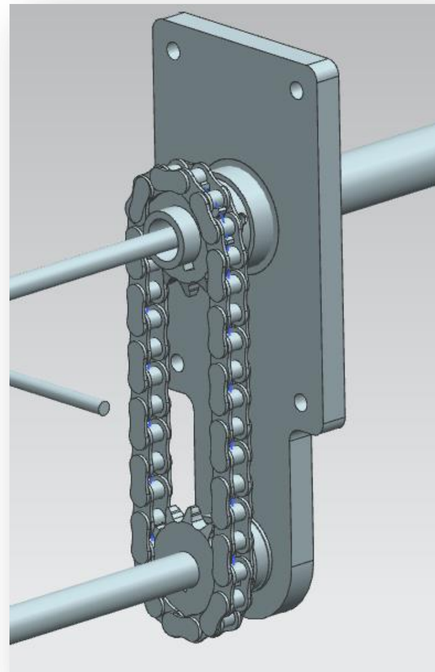
Although the propeller's pitch has been designed for maximum efficiency at the maximum design speed of the submarine, it is not optimal at lower speeds. This is comparable to the familiar idea of riding a bike up a hill while changing the gears. One could travel up the hill in first gear which would be normality but one could also ride up the hill in tenth gear and make the same journey. The lower gear is noticeably more efficient during times when it's hard to pedal, which is exactly like the propeller. We then reviewed previous Umptysquatch IV variable pitch designs, and we worked out a way to make these systems more efficient, and adapt it to Umptysquatch VI. It is to our understanding that this system will increase our speed during the runs. In order to change the pitch of the propeller we have a hand controlled shift that will manually change the pitch and thus allow us to adapt our variable pitch strategy should desire more or less speed, peddle faster or slower, more force or less.

Drive Train

The drive train for Umptysquatch-VI consists of both a forward and an aft aluminum gear box. Umptysquatch VI is designed for two people to peddle foot to foot. The forward gear box converts peddling motion into a common shaft rotational motion. The rear gear box raises the drive shaft to align it with the center of the submarine. We found our inspiration for this type of foot to foot type drive system after looking at the world speed record holders, Omer's drive train. Except, we found one major flaw in their system that both people ether have to go or stop which is bad if one person is peddling slower or one person's foot slips off the peddles. So unlike OMER's two person gear box that has the two sets of peddles hard linked together, we designed our front gear box to make the peddles using one way bearings, so that if one person stops the other can keep going. We chose to use the one way bearings for this design for two reasons, first for redundancy meaning that if something happens to one set of cranks or gears the other pilot can still finish the race. Secondly the one way bearings help to prevent one peddler form lagging on the other and slowing them down.



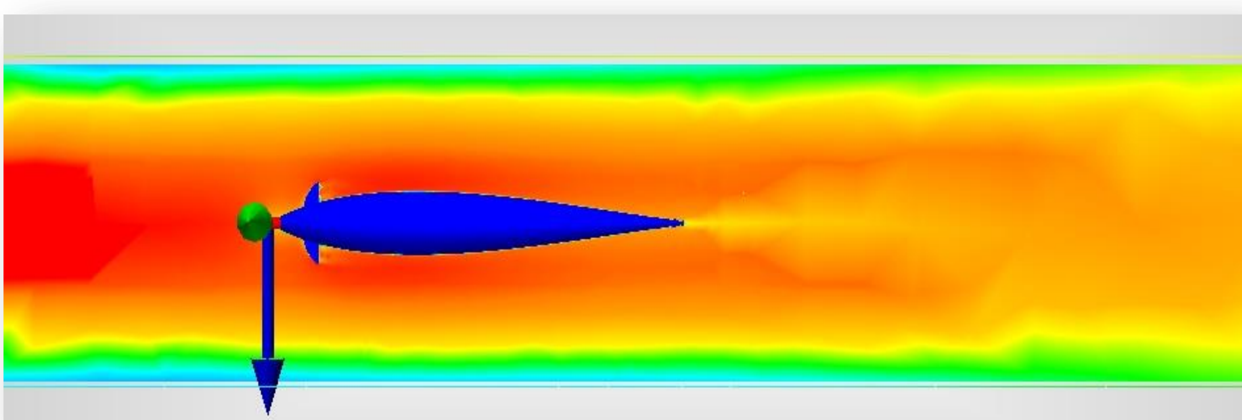
We decided to use helical bevel gears in the front gear box to make the system run smoother and stronger because with helical bevel gears more than one tooth will be in contact with each other at every instant. We also put our gear ratio in the front gear box in order to keep the rear gear box small. The key word when talking about the drive train is modularity. The whole front gear box can be removed by removing two pins and pulling. We also made the front gear box's top shaft easily removable so we can change gear ratios if needed. The need for a rear gear box arouse when we realized that we could not run a shaft through the center of the hull due to our rear pilots. We therefore decided to drop the shaft lower in the submarine and the rear gear box became a necessity to bring it back up. The rear gear box was designed with all exposed components for easy access. We chose to use mountain bike peddles that lock on to the drivers shoes for more power and to minimize the risk of our pilots feet slipping off the peddles.



Control

Fins

The fins for Umptysquatch-VI are heavily based on the fins used on Umptysquatch-IV. Computational Fluid Dynamics Analysis done early in the design showed that these fins

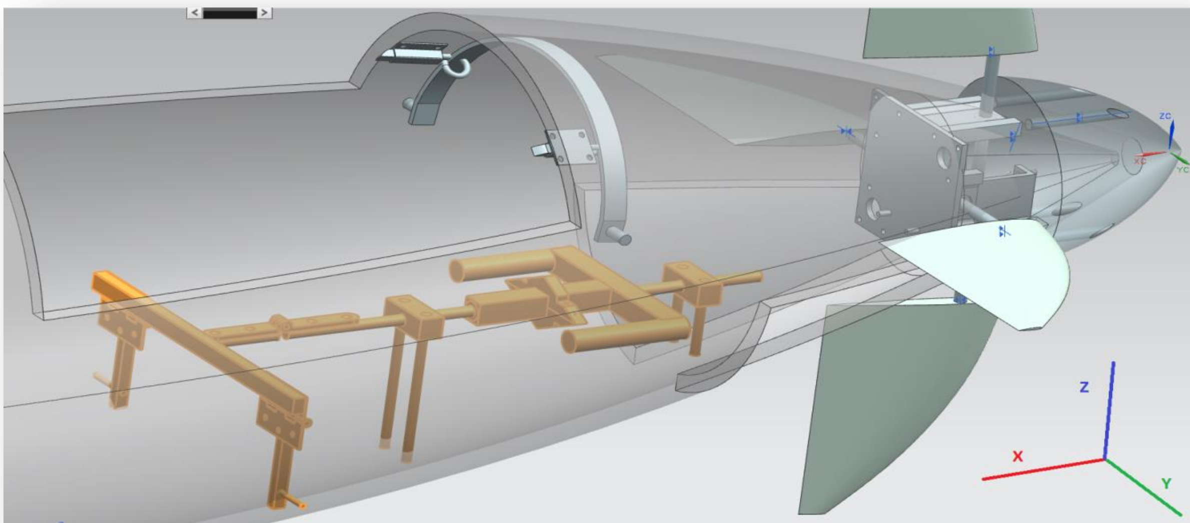


produce 14 pounds of force to turn the sub. In order to use the actual control fins from Umptysquatch IV, adapters were made to connect the 0.5" shaft on the fin to the 0.5" shaft on the control box.

The fin designed is optimized for low drag and manufacturability. The fin is a symmetric hydrofoil, so that it presents minimal surface area to the water while maintaining laminar flow from leading edge to trailing edge. The symmetry of the fin also aids in its manufacture.

Control Stick

The purpose for designing the control stick was to have the submarine easily controlled without extensive training. To do this I made the controls similar to that an aircraft control



stick while trying to conserve as much space as possible. I found that the best way to do this was to have the x axis control the elevator (positive x= nose down, negative x= nose up) and the rudder be controlled by twisting the control stick handles around the x axis. (See picture below)

The control fins will only have a maximum travel of 10° in each direction and the control arm is 2" long from pivot point to tip. Since $2\sin(10°) =$ ½ total travel distance =

0.35, the control cables being moved .35" any direction would extend the control fin to its maximum $10°$. This gives the driver only a small amount of leverage on the fins. Another reason for the leverage is so that the bearing which will be pressed in inner sliding ring will not be torqued out of place. If there is + or -.1" inch of play:

$0.35(2) = 0.70"$ total travel, $\quad 0.1 * 2 = 0.20"$ total play $\quad \frac{0.2}{0.7} = 29\%$

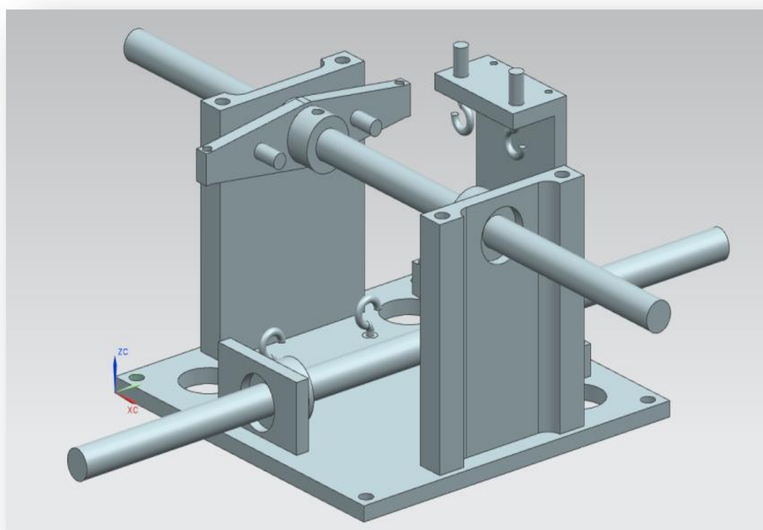
This means that almost 1/3 of the control stick travel would do nothing. To fix this I made a control arm which has about a 4.5:1 ratio. The ratio was limited to 4.5 because of the size of the sub. With this ratio:

$total\ travel * ratio = 0.7" * 4.5 = \ 3.15"$ total travel.

We were only concerned about this for the elevator control and not the rudder control because the rudder fin has a much more direct connection to the control stick than the elevator fin. In addition, this hull has been used before and had no problems with turning meaning it should go straight with minimal rudder adjustment. We are more concerned about the elevator controls because the buoyancy of the submarine may vary.

Another design consideration was to use pulleys or a control cable. We chose to use the control cable because using the pulley system would require positioning several pulleys in the front of the submarine decreasing room and increasing time to assemble significantly.

Control Box



The control system for any human powered device primarily consists of two parts: the interface end, where the human controls the vehicle, and the actuator end, where the actions of the human are carried out. The control box for Umptysquatch-VI represents a departure from previous control box designs in that all of the components for the actuator end of the system are in one contiguous box: the rudder and elevator axes are not separated.

The interesting thing about the Human Powered Submarine competition is that, if you need to use the controls, there's something wrong. Since the course is a 100 meter straight run, there's nothing to perturb the submarine as it careens down the course at a walking pace. The control system only exists to correct for slight inaccuracies in the start of the sub's movement and imperfections in the hull that cause the submarine to list or turn. Given this, the control surfaces only move ten degrees left and right.

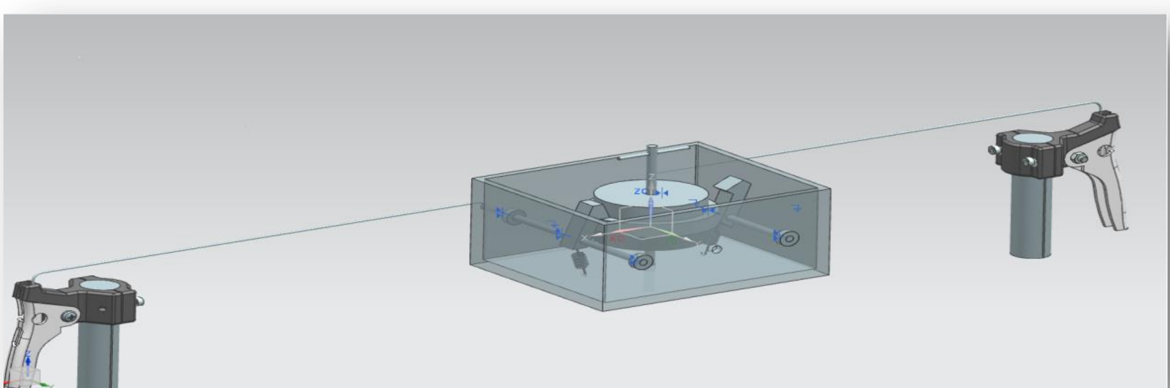
The control box also serves to re-center the control surfaces when the driver lets go of his interface. Two springs are attached to each control arm (mountings shown above) to return each axis to its original position. The hooks on the base plate are threaded in so that their position can be adjusted. These springs have a small stroke (approximately ½" inch), but they are strong enough to provide 20 pounds of restoring force at the end of the control axis' travel.

For ease in assembly, the base plate of the control box has 0.05" deep pockets which each component sits in. These pockets locate the components and prevent them from sliding around during assembly. This was added because these components, at one point in the design, were going to have to be placed on the base plate without being able to see them. The locating pockets were added to make this process easier.

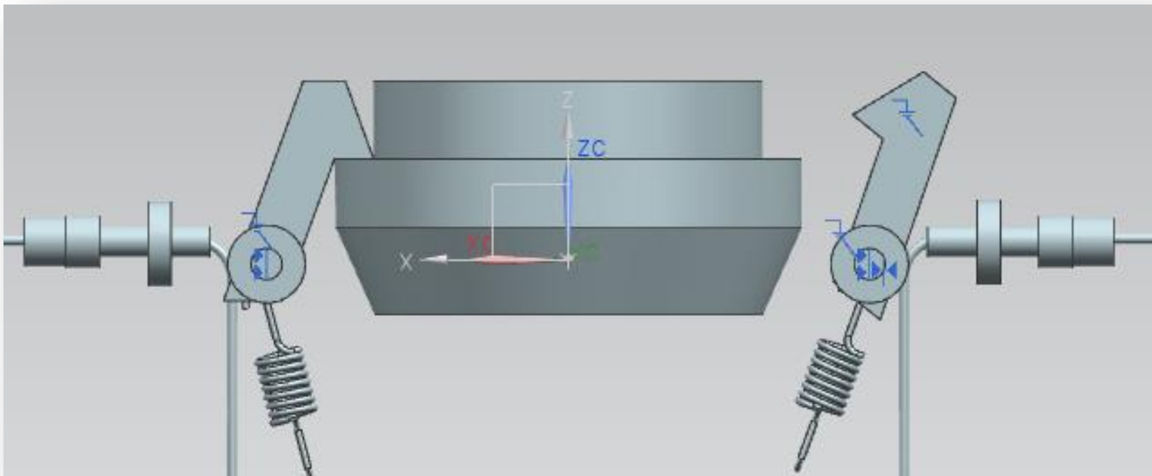
Safety

Emergency Pop-up Buoy System

Mr. Land told the safety system design team, "the safety system is the most important system in the submarine project, but you all will get no credit or congratulations if it works and will get all the blame if it does not work." Given this, we knew how important this system was and that we did not want to fail or falter in design. After at least five different systems



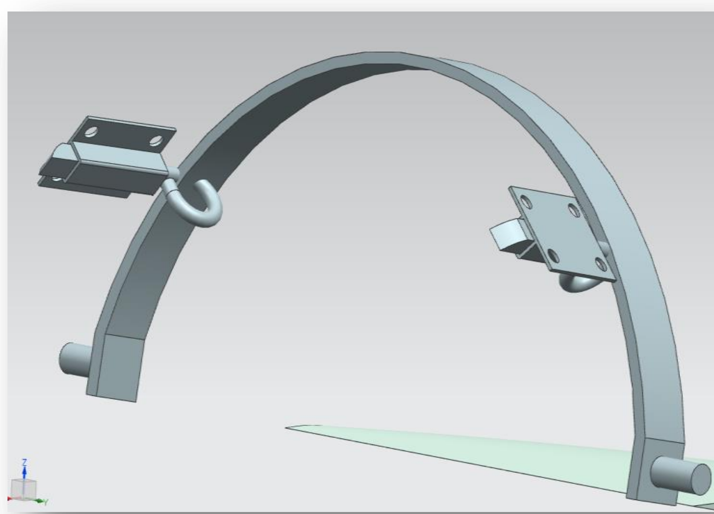
designed and rejected for various faults, we decided a simple design was best suited for this submarine. The safety system went through many different changes making us realize how difficult it is to design a system we have full trust in. The system we selected is one we can trust. This design was difficult due to the fact that we had to design one system using one buoy but has a release mechanism that two people can use. This was due to the space constraints and the fact that we had the goal to use one buoy for two people.



(One pilot squeezing causing the lever arm to contract against buoy, one pilot releasing causing the spring to rotate the shaft (this will release the buoy))

Access Hatch

The Umptysquatch VI team has created several hatch release designs, but in the end we selected a simplistic design using hard linkages and only 4 moving parts. Our first design was a twist lock much like a watertight hatch on a boat. After much deliberation and planning we decided it would be too complicated to mount all necessary hardware and have a positively buoyant hatch. Our next design consisted of using one latch with a handle on the outside and a pull chain



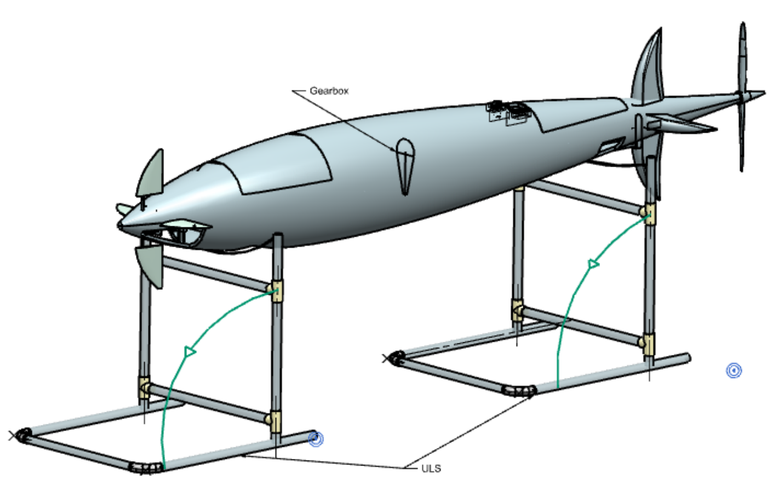
for the inside but we concluded that the handle would cause a considerable amount of drag.

We then thought of a "punch out" bar right above the pilot. It would be a bar that would follow the contour of the submarine and be hard mounted to our two latches securing the hatch and keeping it from rocking. The rear end of both hatches will feed under the hull with a cantilever design. The punch out bar will have a pull ring leading to the outside like the voice box on a doll. We will put a secondary line leading to our pilot for ease of removal. We did this so one pull will easily release the hatch. The rear hatch is triangularly shaped with one end having a cantilever to hold it down and one single latch with a pull ring on the other side for release.

Underwater Launch System (ULS)

The concept of the Underwater Launch System (ULS) originated from feedback of prior Umptysquatch divers. There was a safety concern due to the large propeller radius and our support divers near the stern of the sub. In addition, there was also concern over the lack of control of the initial direction of the submarine at launch. With previous designs, our support divers attempted to coordinate their handling of the submarine and allow the submarine to start its run parallel to the centerline of the race course. In reviewing past underwater video footage, we noted that a wide variety of launch angles (both vertical and horizontal) was occurring from race to race. The design goal for the ULS was to remove the human interaction with the static (i.e. pre-race) support of the submarine.

The ULS supports the submarine at a zero pitch angle and parallel to the race course centerline. On commencement of the race, the submarine will accelerate while the ULS folds downward in a forward direction thus releasing the submarine from



its static supports. The design is similar to the gantry of a rocket launch pad. Since the ULS cradles the submarine level and straight in a consistent manner, the submarine will enter the race course level and straight.

Fabrication

Hull

We are using the hull from U3.2 and this is it was made. The first step that was taken to construct the U3.2 hull was to prepare a full size plug. They constructed this skeleton of half of the profile by placing plywood cross sections of the hull profile at specified hull length positions.

Two part foam was then poured into the cavity formed by the linked cross sections to create a rough model of half of the submarine. The next phase was to create the hull by building the mold from the plug. The mold was made using a series of fiberglass matting, bi-axial matting, and roving. Once the mold was completed it was time to move to the actual U3.2 hull. This was formed using a foam sandwich core construction schedule. The lamination schedule consisted of one layer of fiberglass matting followed by a layer of foam, and then covered by a layer of fiberglass cloth. These materials were vacuum bagged to minimize the amount of air in the hull parts.

Propulsion

Propeller

We selected a 2 inch 6061 aluminum cylinder piece for the propellers to be made out of. Then, we had to turn down the end of the cylinder to half an inch so it could attach to the variable pitch system. After that, the stock was set up in a 4Th axis mill. The, machine did a rough pass with a half inch end mill. Following that, it used a rough surface mill with a half inch ball mill do the finish pass with a .02 inch stepover.

Variable Pitch

The variable pitch hub will be machined in two pieces; the first half is made of aluminum, and will house the twin holes into which the propellers will attach (the boss structures of the propellers will interlock, and will be held in place by two quarter inch pins inserted into the forward face of the hub). This part of the hub is designed to withstand the generated torque and thrust of the drive shaft and propeller blades. The second half (the tail cone) was also machined out of 6061 Aluminum on our CNC lathe.

Drive Train

For the manufacture of our drive train we decided to use aluminum frames and a majority of steel drive components. We custom manufactured the outer forward gear box walls out of ¼ inch Aluminum plate in our CNC mill to help ensure accurate placement of the holes. We opted to go with thicker ½ inch aluminum plate for the inner forward gear box support walls as well as the aft gear box frame, for more support. These where also custom manufactured using our CNC mill. The inner and outer gear box walls are screwed together using ¼ inch screws into threaded holes. 5/8 inch steel was used for all the shafts running forward to aft with the exception of the 1 inch hollow pipe going from the rear gear box to the propeller to allow the use of a variable pitch system. We chose to use steel instead of aluminum because of steel's rigidity which makes the key ways less likely to distort over time. This is especially important because all of our sprockets that we purchased rely on key ways to fix them to the shafts. We cut all of our key ways using our manual mill and files. Both pedal shafts were turned out of titanium for extra strength. At any point where the shaft is held by the gear box frame there is a radial ball bearing. The upper shaft's bearings are held in place by screw down bearing holders that allow for easy shaft removal. The bearings on the pedal shaft were first pressed into custom milled pockets that are attached to the outer gear box wall with ¼ inch fasteners. The cranks themselves were machined out of aluminum and clamp on to the pedal shafts. We decided to purchase our two sets of helical bevel gears and customize them instead of making them from scratch. We removed material from the back of one from each set to insert our one way bearings and then pressed them on with Loctite to ensure that they do not slip. The other gear in each set was pressed on to the shafts. We installed shaft collars to keep the shafts from moving forward or aft. All drive chains are #40 stainless steel roller chain to avoid rust and our chain tensioners where custom milled out of Delrin.

Control

Fins

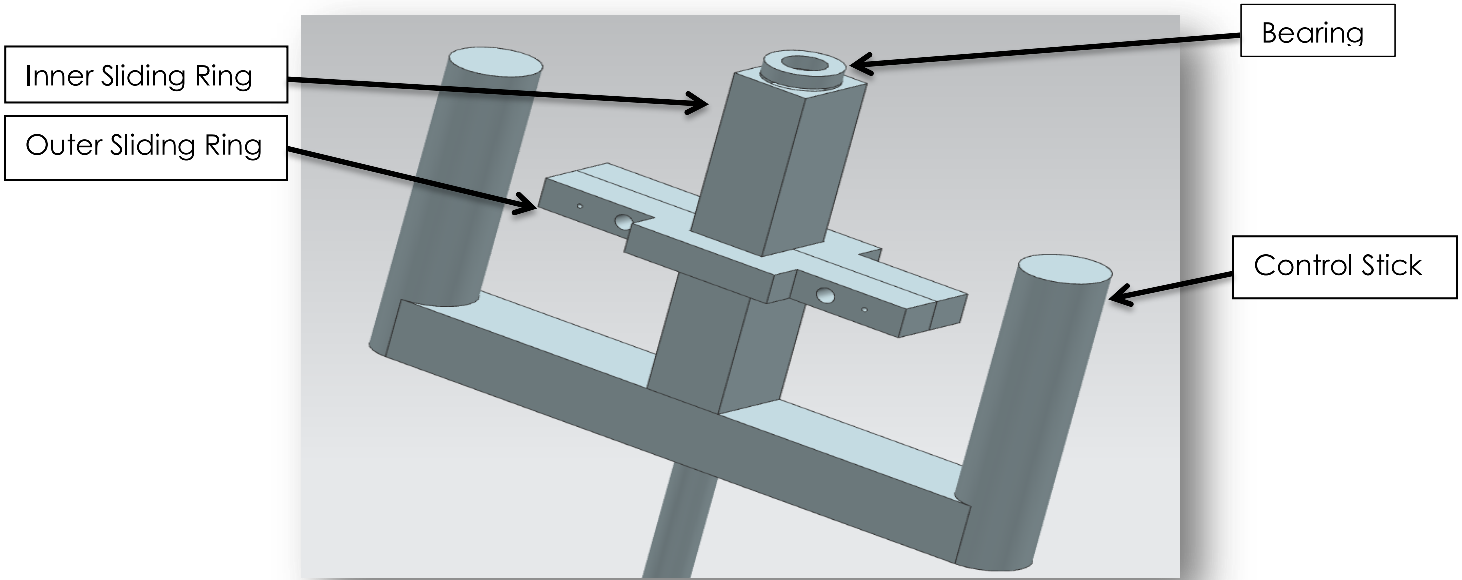
The fin will be manufactured using a similar fiberglassing process to the hull. A mold will be CNC machined consisting of two halves of the mold. The two halves will be assembled to make the cavity of the mold, in which the mounting rod will be placed. This will be filled with a mixture of fiberglass resin and microspheres, which will cure in a reduced atmosphere.

Control Stick

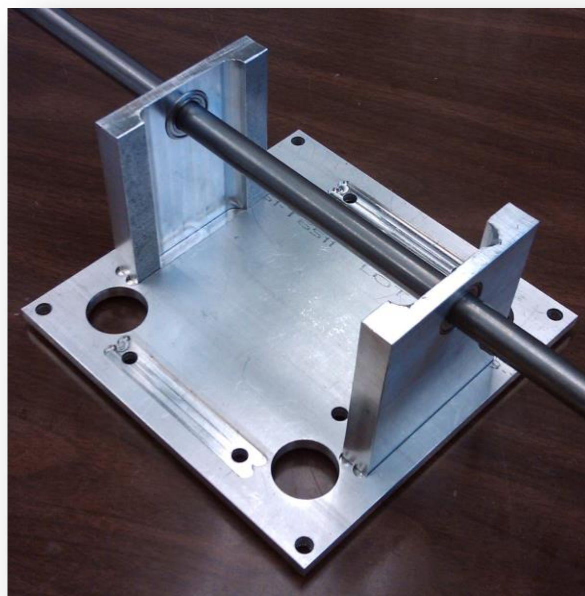
All of the parts on the control stick are made out of aluminum. Almost all of the parts except for the outer sliding ring and the hinges are cylinders or rectangles accounting for little machining. Most of the rectangles and cylinders that make up the assembly are held together with welds and bolts. The hinges will be purchased so we will not have to worry about manufacturing them.

To manufacture the outer sliding ring we will cut the part in half first, machine it and then bolt the two pieces back together using the larger holes on it. nThe only other part that is needed to be machined is the inner sliding ring which has a bearing which will be pressed into the end of it (the hole needs to be accurate to - .0005 inches for the bearing to be pressed on).

Control Stick



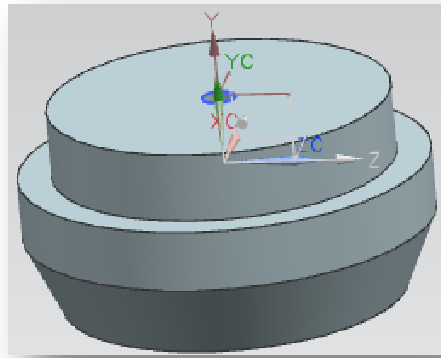
Control Box



The manufacturing of the front control box was executed on a CNC Mill. For each part, a set of tool paths was developed using Siemens NX Manufacturing that maximized cutting efficiency and minimized machining time. Then, stock was cut and sized to meet the specification developed on the computer. The stock was then mounted in the machine and the NC program runs, cutting the part. Critical dimensions are then verified for each part. After manufacturing, the assembly of the front control box is simple, by design. Parts are connected with ¼-20 machine screws, with the exception of two welded pieces. The front control box is primarily made from 6061 Aluminum, which was chosen because it is easy to machine, and strong enough for this non-drivetrain application. 7000 series Aluminum, although stronger, was not deemed necessary for this application.

Safety

Emergency Pop-up buoy system



The functionality of the safety system relies on the unique shape of our buoy (the shape is similar to a hockey puck, but when viewed from the side it looks similar to a stepped pyramid) which is held in place by two levers. The levers fit the shape of the buoy, and can only rotate radially from the center of the buoy.

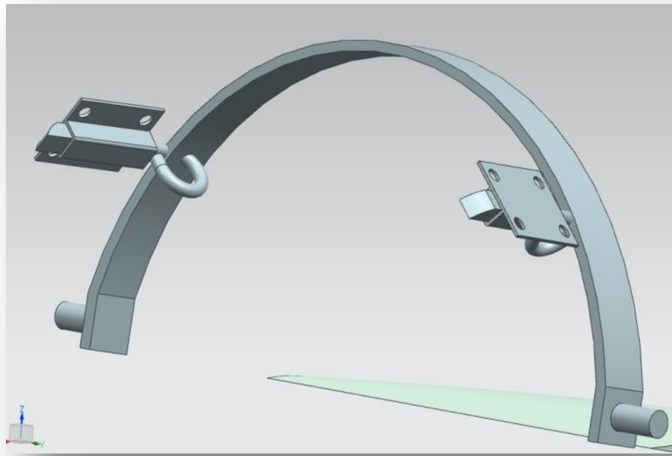
The levers are each pulled into the open position by springs, and held in the closed position as long as the lever's respective pilot continues to squeeze on his or her brake handle. Should either pilot release their grip for any reason, the lever will be pulled open by the springs, and allow the buoy to float up and alert the Navy divers. The top part of the buoy flush is with the hull, so that it doesn't affect hydrodynamic performance before it releases. The buoy box is constructed of wood while the other parts are made from Aluminum. The size of the box is approximately 5x6x3 inches.

Restraints

The system of restraints in this submarine is used to suspend and restrain our pilots within the hull. The restraints have to be sturdy, while at the same time easy to remove in case of emergency. The system works by combining shoulder pads and slings into a harness of sorts. The pilot is lowered into the sub, strapped in to the harness, and ready to go. The restraints are easily released using Velcro straps so that they can be rescued without incident in case of an emergency.

The padded restraints are used for our pilot in the front of the submarine. The straps are for our pilot in the back. Restraints need to be removable in case of emergency and construction / repair of the submarine. This was taken into consideration when discussing possible restraint devices.

Access Hatch



The hatch system is a 5 piece system and is fairly simple to make. It is made out of a 1 inch wide and 1/8 inch thick Aluminum band formed to the inside of the hull by bending and pressing it to the outside until we get the desired curve. Holes are then drilled at the ends of the band to which are attached two ½ inch pegs and with a small bolt mounts them to each side of the bar. A 2"x2"x 1" block of wood is mounted on the inside of the hull with a small hole to accommodate the pegs. Two small pieces of chain attach the pull rings to the bar.

Underwater Launch System (ULS)

It was determined that the most efficient and cost effective method of manufacturing the ULS would be to use standard two inch polyvinylchloride (PVC) piping and fittings. The lower portion of the PVC structure will be filled with concrete to give it the proper ballast to remain fixed to the basin floor during the submarine launch. The top portion of the structure will also be weighted to allow it to fall away from the submarine upon launch.

Training

According to the rules set forth in the International Submarine Race Manual, a SCUBA certification is required for any team member entering the water at the races. Over the past summer 4 team members earned their PADI open water certification. Additionally, one student already had their certification, another student earned it on their own time and our instructor is a certified Open Water diver. Plus we have another helpful addition to our team who is also certified, Mr. Andre Savard. Thus giving us 8 certified divers to be utilized during the International Submarine races to make the set ups run quicker and smoother.

Testing

Before we set off to the races with our submarine we will test the submarine primarily for proper neutral buoyancy, control and for safety. Once all the systems have been checked and are working, we will practice steering and driving the submarine for additional practice. We should mention that testing of our submarine has become a challenge due to the tough economic times; our school has drained our pool, where we have previously tested our submarines. Finding a place to test our submarine is a difficult but necessary challenge to overcome so that we can be properly prepared for the race.

Conclusion

The design/build effort for Umptysquatch VI represents Sussex County Technical School's 12th year of involvement with the International Submarine Races. This would tend to make the reader understand that Umptysquatch is a very experienced team when it comes to the design and fabrication of a human powered submarine. It is important to note that the only common thread between the six Umptysquatch teams is the Project Manager. All students are new to the project, and thus must learn to work on such an immense project largely in a "trial under fire" learning environment. Once again, the students involved in the project have worked together to design and build a complex machine that must operate in the unforgiving submerged environment. This group of young engineering students has effectively planned and executed this challenging design/build project in a direct, aggressive and efficient manner well beyond their years.

As with our previous entries, we estimate that we have invested approximately 10,000 man-hours in the design and manufacture of Umptysquatch VI. As with all of our submarines, we have invested a significant amount of time into the design phase. Fabrication did not actually start until January 2013. At this point, we believe that this has paid off in that the majority of our systems are working as designed without major field adjustment.

From an educator's perspective, I believe that the International Submarine Race represents one of the most challenging, demanding, and rewarding experiences to students (and teachers!) today. I think participating in the ISR pays big dividends to the overall engineering community at large. I have 6 graduating seniors this year. They are currently accepted to and planning to attend the following post-secondary institutions in the fall:

Student	Institution	Major
Max Bareiss	Rowan University	Mechanical Engineering
Joseph LeRoy	County College of Morris	Mechanical Engineering
Marcanthony Rigatti	United States Army	Civil Engineering
Brianne Speranza	Clarkson University	Electrical Engineering
Mark Stark	Sussex County Community College	Mechanical Engineering
Alexander Wells	Arcadia University	Creative Writing

I think this table sums it all up. This makes all the late nights, weekends, blood and sweat worth it. These kids are going into the real world with their eyes wide open, and their brains fully engaged. They know it is not easy, but they also know that if it was…everyone would do it. I could not be prouder of group of young men and women than I am for the UmptySquatch VI Team. The truth is, I am really proud to be part of the team.

At the time of writing this conclusion, we are still heavily involved in the manufacture of Umptysquatch VI. As far as the schedule goes, we are behind, but it is typical progress based on our previous submarines. I continue to be amazed at the resolve of my students. They continue to work on this seemingly impossible project with the confidence that as a group they can accomplish anything. They are EXACTLY what companies are begging for with regard to new employees. They are EXACTLY the kind of employee that will help return America to the forefront of engineering, design and manufacturing. They are the future.

Personal Reflections

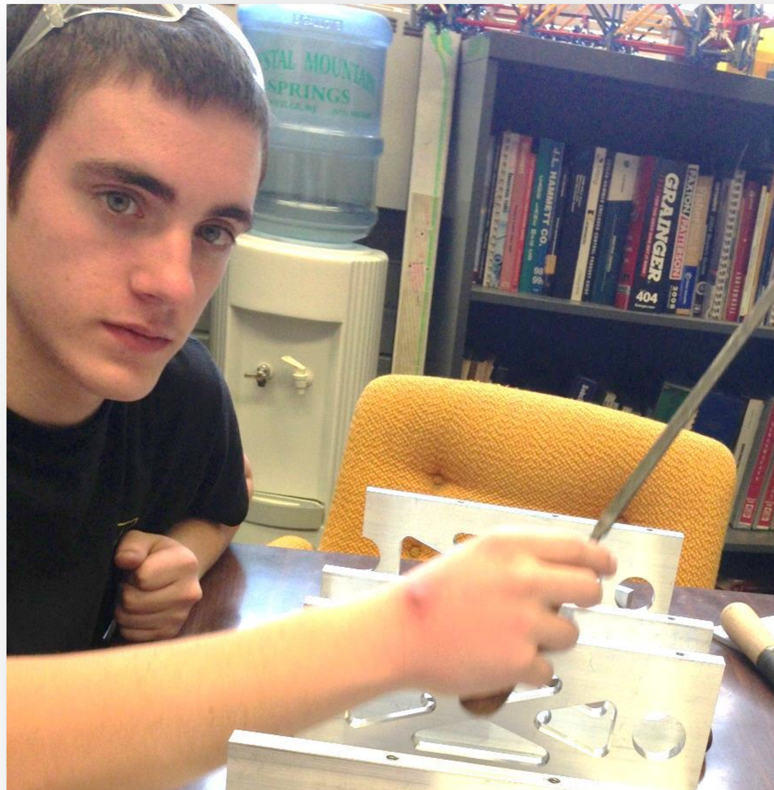
Max Bareiss

Participating in the ISR is something that I've thought about a lot since my freshman year. Now that it's actually happening, it's one of the most challenging and intense projects I've ever been a part of. Although I've done a lot of other competitions with compressed timescales, the ISR tops them all. There is nowhere else a high school student can create an assembly of dozens of parts that all have to fit together. If just one bearing block is out of place by even a thousandth, the whole assembly grinds to a halt. This project brings out teamwork in such a way that I never thought I would be able to experience in high school.

Joe LeRoy

The ISR tests your willpower, persuasiveness, and engineering ingenuity in a team oriented environment. It pushes students and teaches how to perform under stress in a real world engineering project. The pressure and tasks mold one's way of thinking and helps to train your mind to think like an engineer's and perform under pressure to get work done. For me I loved the challenge and the project going from nothing to a fully functioning submarine. I really appreciated the teamwork involved and learning how to communicate to get work done. Being part of a team like Umptysquatch VI really changed my perspective of how a work place operates. Everyone has to communicate together and collaborate to pull of such a massive project.

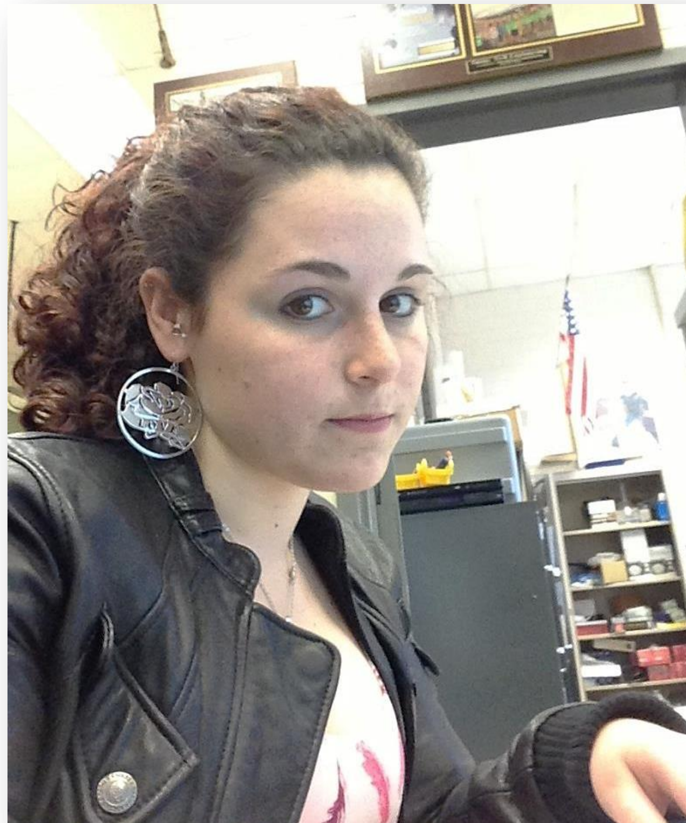
Marcanthony Riggati



Ever since I entered Sussex County Technical School I wanted to be a part of the ISR and compete with colleges when we are only in high school. That looks good for our School and our students, and the ISR is an experience that I did not want to miss. As the years went on I still had the same anticipation to be a part of ISR, if anything I had more. But when the time came to be a part of the ISR all that went away and the anticipation turned into motivation. The year started off a little slow mainly because we needed to decide what we were going to focus on, innovation or speed, which is and should be a slow process because that's the base of the whole project.

I am a very enthusiastic person that never gives up, that's why I joined the Army so I can put my talent to good use and this project is going to help me work with a team in a stressful environment.

Brianne Speranza

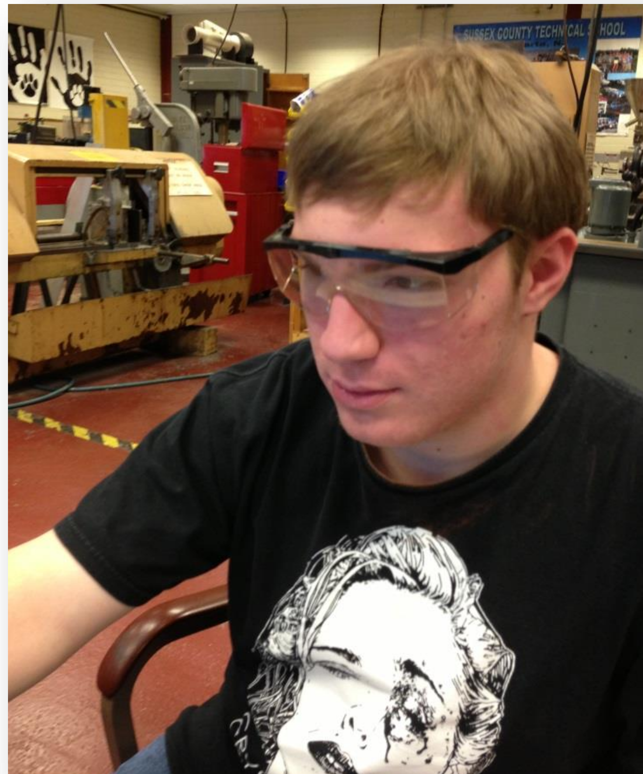


Once you come to Sussex County Technical School and join the Engineering program, you immediately know about the International Submarine races. From the pictures, to plaques, to the huge submarine taking up space in our shop, is all I really knew, and even less about how to build a real submarine. Therefore once time came in my senior year to start this project, yes I was scared but my excitement masked any doubts. A project of such immense scale takes a lot of dedication and drive. Each person on our team had the desire to complete this project which is why we were able to complete this so well, even as high school students. Our team always had its fair share of ups and downs but I could never ask her a better group of people to work with. Overall despite each setback, a slow moving design process, and hours on the computer, nothing makes me feel more prepared for college and life than the chance to build a complex system such as a submarine.

Mark Stark

"This is no ordinary project!" Mr. Land yelled. That was two years ago when Umptysquatch 3.2 was being built. I had always watched that video and it didn't mean much to me. Now that I am a senior and working on the project I now see how true that is, this is not any ordinary High School project. High school projects are usually pre-assigned by the teacher and only last a few weeks. This submarine however… takes all year, is totally designed by the students. And if we do something wrong, there will be real life results and the submarine drivers could be injured.

Alex Wells



This year's submarine project has really shown me what it means to be part of a group effort. Every single member of this team has contributed to the creation of this human powered submarine and now our plans have finally come to fruition. To see something go from a simple drawing to being a reality is a wonder to behold and unfortunately something not everyone will experience in their lifetimes. I am proud to have been a part of this effort and to have left my mark in the creation of something such as Umptysquatch VI. I will remember what I have done here for the rest of my life.

Billy Cochrane

This was my first experience in a scholastic setting which was not designed for my success. In all other activities in school, everything pushes you toward success/the completion of your goals, but during the ISR I had to really want to succeed to accomplish my goals. This was a great experience overall, and I think I've come out of it with a few life lessons and a positive attitude, and whether or not we win anything, that was worth it for me.

Michael Griffin

Throughout the course of the submarine build I have learn more than I can possibly put into words. However one of the main lessons I will take away from this project is that having a well thought out and planned design makes a world of difference. Prior to this project I was the kind of person who would get an overall concept and deal with the details as needed but after seeing how well this project is coming together the difference is night and day. I must also admit when we first started this project I thought I knew what I was getting into. Having been part of one or two very large projects, I WAS WRONG, this project is on a whole other level devotion. I also learned what it feels like to own a part of a project both for the good and the bad. It was a terrible feeling having to go to the and having to declare a problem you caused, but at the same time nothing can describe the feeling of watching everything come together for the first time and work flawlessly. What I have learned on this build will stick with me for the rest of my life and aid me in all my future projects.

Tyler Hepp

Starting the submarine project seemed like a long way off my freshman year but before I knew it, it was the end of my sophomore year and Mr. Land asked us if we had an idea of whether or not we wanted to do a submarine project. Naturally without thinking all of the students said yes but before pursuing it Mr. Land made us stop, examine, and think about what we were getting into. For two weeks before the end of school we sat at our conference table discussing whether or not to do the submarine project and then we had to decide for speed or innovation. Heading in the general heading of speed and a two man submarine we still could see a long road before us. We were just at the base of the mountain and had a hard climb ahead. After taking week after week of deciding certain pathways to go down and what should be used or scrapped we came to a semifinal plan.

It was just one complete drawing of the submarine and every system in it. It looked excellent and we were all proud but we still had a lot left to do. Feeling accomplished and proud was short lived. We soon started to make all of the parts we designed and that was more of a challenge than previously thought. Due to the new Teamcenter integration into our system we had a bunch of new processes to learn and discover. After a few weeks on the phone with NX help we finally sorted out the last of the bugs and Bethesda Maryland was in our sights. Seeing this submarine come together never really hit me until Mr. Land had brought up the fact that there was no instruction booklet on premade pieces just to assemble.

This submarine was once just a figment of our imagination and now we have made it a reality. I am a proud member of Umptysquatch VI and I truly value everything this project has taught me and I look forward to using the knowledge.

Mason Hoffman

The idea of making a human powered submarine interested me greatly. I felt it was a good opportunity to learn team skills and work on such a big project. When we decide to do the sub, the whole class all wanted too. In the beginning of the project we spent a lot of time designing. We figure the better the design, the better the product. This thought was correct our design paid off. I was to help produce the design report as well. I found this knowledgeable. I figured out the Teamcenter software and saw how interacted with our other software NX 8. I found being a part of this project very exciting and a little stressful. The team worked well together and I feel we stepped up to the plate.

Jimmy Orr

Building a human powered submarine is no easy task. It is difficult in every way. It is taxing on the mind, body, and soul. This project was very energy draining. This project taught me how important a good team is. In the experience with designing the safety system it was difficult coming in redesigning a system over and over again but it had to be done because we had to have absolute faith in the system that protects our pilots' lives. Having a safety system that could be used for two people and use one buoy was very mind draining. We did this all with using something mechanical in mind. We did not want to use pneumatics or magnets (even though they were considered). I will without doubts remember the experience and try take lessons from it that benefit my future team experiences.

Teja Young

When we decided to enter the 12TH ISR, I did not know what to expect. But what I did know is that this is a major commitment we're making and there is no turning back. I personally think that I was the most scared out of the other teammates because I felt like I was the least experienced. So during the designing stage of the submarine, I felt like I wasn't experienced and couldn't put forth as much effort as everyone else could. Later on in the manufacturing stage, to my surprise, I became a lot more involved than I would have ever thought. I was doing a lot of fiberglass work, turning down shafts to make the gearbox fit, and manually milling part for other teammates. The best part was that I was enjoying the manufacturing stage of the project. This project didn't just make my resume look good; it brought out my strong points and skills. These skills I developed will stick with me for the rest of my life. The project also taught me it is important for teams to work together because everyone has different strong points and is a big and powerful responsibility of producing a fully functional machine that will run underwater which will reflect on how hard we worked to make it that way. This is an experience that will never forget.

Budget/Finances

We cannot thank our sponsors enough for supporting us with both materials and technical advice/guidance throughout our design/build endeavors. The Umptysquatch VI Team actually consists of fewer sponsors than in the past due to our use of existing materials and the tough economic conditions existing today. The sponsors for the Umptysquatch VI project are summarized below:

1. Fonzarelli's Collision and Auto Repair, Agusta, New Jersey: Outside hull body work and paint.
2. Thorlabs, Newton, New Jersey: Fasteners and financial support.
3. Boca Bearings, Boynton Beach, Florida: Radial bearings for all gearboxes and shafts.
4. Elite Divers: Provided us with free air fills and new scuba divers with discounted equipment. In addition donated use of all scuba equipment for students for ISR-12.
5. Sears Hardware, Newton, New Jersey: Fasteners and other assorted hardware
6. Hobbytown, Newton, New Jersey:
7. Mr. Andre Savard: Provided us with invaluable mentorship and expertise.

In general our Project Manager is responsible for negotiating sponsor relationships, while it the project team members' responsibility to identify needed technology and material items. As in the past, we have found that it is much more feasible and useful to approach companies with specific material requests than to ask for blanket funding. A summary of the costs and financial value of this project is shown in the following table:

Quantity	Item Description	Unit Price	Extended Price (Real Value)	Actual Price Paid
4 People	Scuba Training	$800.00	$3,200.00	$3,200
30 hours	Bodywork/Paint	$65.00	$1,950	$0.00
4 People	Scuba	$1,500.00	$6,000.00	$0.00

Quantity	Item Description	Unit Price	Extended Price (Real Value)	Actual Price Paid
	Equipment			
1 Lot	Fiberglass Materials	$500.00	$500.00	$500.00
5 gallon	Gelcoat	$85.00	$425.00	$425.00
10 gallon	Polyester Resin`	$70.00	$700.00	$700.00
1 gallon	MEKP	$93.00	$93.00	$93.00
1 Lot	Fiberglass Disposables	$200.00	$200.00	$200.00
2	Pressure Treated Lumber	$15.00	$30.00	$30.00
1 Lot	Assorted Hardware	$1500.00	$1500.00	$1500.00
1 Lot	Radial Bearings	$900.00	$900.00	$450.00
		TOTALS	**$ 15,498**	**$ 7,098**

The table shows several items at an actual price paid of $0.00, which is due to donations by our various sponsors. As can be seen in the summary table, the project value of our submarine is $15,498. Thanks to our gracious sponsors, we were able to complete this project for $7,098. Given the extremely difficult economic times that our country is enduring at this time, we cannot thank our sponsors enough for their continued support. Without their help, we would not be able to continue to be associated with this challenging engineering design experience.