# S u b Zero

Springstead High School

Hernando County Schools

12th International Human Powered Submarine Race – June, 2013

TECHNICAL REPORT

## SUBZERO
## EXECUTIVE SUMMARY

SubZero is the newest entry for Springstead High School from Hernando County Schools. After the 2011 ISR, the returning students as well as the students new to the team this race undertook the challenge of conceiving, designing, engineering and building a new two-man entry for the 12th ISR.

Long hours were spent in the after-school "Sub Club" at Springstead High School as well as SCUBA instruction for many of the team members. SubZero was begun in August, 2011.

## INTRODUCTION

The SubZero race team consists of 14 high school students, 5 of whom participated in the 2011 race. Three team members are in college and raced with Sublime in 2011 and 2009.

## DESIGN PHILOSOPHY

The students chose to build a two-person, propeller driven submarine with both occupants pedaling. The basic idea is to get the maximum human power with the minimum amount of wetted surface area. The students hypothesized many different configurations. They settled on a design philosophy that maximizes efficiency in a minimal hull shape, by using only one drive mechanism.

Previous entries by Springstead High School were built around a bicycle chain mechanism. The SubZero team realized that the chain mechanism would not hold up to these forces.

## DESIGN AND FABRICATION

### Hull Construction

The students measured themselves and drew out full-scale drawings of how to manipulate positioning so that both pilots could be in a natural pedaling position. They then designed a hull that would allow that positioning to be possible.

The sub began as a male plug constructed from plywood. Each station was drawn from a table of NACA 66-0015 coordinates. An elliptical shape was created by utilizing a fixed ratio ellipse generator. After all the station bucks were carefully placed on a central beam, students ripped thin cedar strips and fastened them on to the stations.

SubZero was designed to be 15 ft. 8 in. long and have a maximum

diameter of 25 inches. The bow was rounded to facilitate turning maneuverability.

The half plug was sanded and covered with visquen and coated with mold release wax. The students manually laid up two half hulls using two layers of 12oz. bi-axial cloth with one layer of matt in between. The two halves were then joined together and the hull was fared out with polyester resin and microspheres.

The areas where windows were needed were cut out and the removed parts were used as molds for the lexan windows, which were manually formed.

One of Team SubZero's educational goals is for all of the students to participate in as many of the aspects of submarine construction and operation as possible. This necessitates that the submarine design be adaptable for pilots ranging from 5ft tall and 90 lbs. to 6ft. 3in tall and 225 lbs.

## Control Surfaces

The students unanimously voted to use a single joy stick steering configuration. Over 6 months they designed and built several different systems with input from aeronautical engineers and aircraft mechanics. Field tests in the Gulf of Mexico demonstrated that without a long enough lever arm, the wrist was not strong enough to actuate the rudders. Consequently, the students scrapped six months of work and redesigned the rudder mechanism to be a longer arm that would swing athwartship and give them the mechanical advantage necessary to operate the rudders.

SubZero has two vertical and two horizontal control surfaces that are actuated by Teleflex cables. On the forward third of the submarine three stabilizing fins are attached to help with tracking and provide a pivot point around which the force of the elevators and rudders can work.

## Hatch and Safety

Two hatches sit on the port side of the submarine for most of the length of the pilots' bodies. Slide latches that are next to the pilot's face, and easily accessible, can be accessed from both the inside and the outside. The emergency float/dead man system operates on a continuous line that is held by both pilots, and if either of them releases the spring-loaded handle, the float will be deployed on a nylon line.

## Propulsion

The amount of human power generated in a two man submarine would be too great for a standard bicycle frame. We determined that a new approach, without the bicycle chain and gearbox, was the only thing that would stand this much force. The team worked with a local machinist, learning how to use a metal lathe and a milling machine to create a straight 6 to 1 gear drive.

The gears were off the self, but the remainder of the drive mechanism was home made. This entailed turning hubs for ball bearing races, machining pedal cranks, and welding supports for the gear train. This produced a robust mechanism that will stand up to our strongest pilots.

We realized that pedaling counter-clockwise, which is unnatural, did not produce nearly as much power. Therefore the only way to have two pilots connected to one crank system was to have one pilot on his/her stomach and the other pilot on his/her back so the two would both be pedaling in the normal clockwise direction.

Our first drive shaft was a stainless steel tube which, when torqued by two pedalers, began to “s” bend in the middle. We replaced it with a thick-walled stainless steel pipe that the students turned on the lathe. A plastic shield protects the rear pilot from the turning shaft.

A new propeller was created from flat stainless steel stock. It was heated red hot and forged into the shape dictated by the Java Prop program. Additional strengthening and filling was done with tig welding. Hand sanding and polishing completed the propeller.

## Life Support and Safety

Two 30 cu.ft. scuba tanks are mounted fore and aft. The front tank is located directly below the pilot’s chest, and the rear tank is located on the ceiling above the pilot. The pressure guage is easily visible to the pilot. They are both strapped into the submarine. Each pilot also wears an easily accessible spare air on his/her chest.

Safety has been a primary design concern. Collisions are possible, so the bow is heavily reinforced. There are two windows. The front window allows the front pilot to navigate the submarine and also allows the safety divers to view the pilot’s face continually. Another window is placed on the side directly in line with the face of the rear pilot, so that safety divers may view him as

well. Visibility through both windows is excellent.

The hatches float free easily when released. The pilots' feet are secured to the pedals by placement in modified dive fins that have been secured to the pedals. The straps are painted fluorescent orange for visibility. Their feet may easily be released by slipping the back strap off. The sub has a strobe light that provides a ready location.

Both hatches have clearly marked rescue squares. Both the propeller blades and the dive fins are painted fluorescent orange at the tip.

Perhaps the most important safety device is our attention to safety during design and practice.

## TESTING

SubZero's two primary testing locates are the Gulf of Mexico and the Weeki Wachee River. By race time we will have logged dozens of testing hours. Team SubZero's challenge in testing is our commitment to allowing any student who wishes to be a pilot the opportunity to do so. With 9 new team members, many hours have been spent getting the students acclimated to the conditions of submarine racing and practicing their scuba diving skills. Team members from previous races who will be part of the team again will be put in a supervisory position as well as be divers and pilots

Every weekend last fall from August through October, and again, now this spring until the race date, the team will practice with the submarine, primarily in the Gulf of Mexico. They will operate in about 5 ft. of water and critique and refine the sub's performance. Testing so far has revealed numerous issues that have had to be resolved.

Measurements of air consumption under stress have been made. The air supply for each pilot has twenty to twenty-five minutes capacity depending on who the pilot is.

## TRAINING

The SubZero team has certified 7 new divers. Scuba instruction was done in the spring of 2012 so as to give them time to become experienced.

Team members train using stationary bicycles, actual bicycling, and running. Several of our team members compete in high school athletics such as track and soccer. Although each team member trains according to his/her own, needs, they all are provided with plenty of

swimming and diving experience during our in-water testing.

Our launch team will consist of four divers, each with a specific responsibility. All teams members will be trained in each support position and we must have total interchangeability, because who is piloting changes.

## PROJECT SUMMARY

Our goal continues to be to inspire students to pursue careers in engineering. SubZero is a team effort in the best sense, and great satisfaction comes from watching a new group of high school students every two years discover the joys and frustrations of taking learning beyond the theoretical book knowledge of the classroom and into the realm of practical application.

Students with varying academic and career interests join forces to not only create a viable human powered submarine, but apply critical thinking and problem solving skills to the project – the same skills that will be required whether the student goes on to a university for engineering, a tech school, or the military.

This year's teams consists of 9 new students, 5 students who are returning from the 2011 race, and 3 students who are from the 2009 race. All of the returning students are either in college or are seniors who have been accepted to universities around the country. Fourteen of them are current high school students most of whom are graduating in the AP or IB programs.

SubZero is a model of how to do a lot with a little. The students have read extensively and have "picked the brains: of experts in many fields. When it comes down to the nuts and bolts of the submarine, these students have designed and fabricated everything themselves. The have constructed the plug to lay up the hull, built the drive train from scratch (excluding the actual gears), and hand forged the propeller.

When Springstead High School/Hernando County Schools first became involved with the ISR in 2003, our budget consisted of small donations from friends and relatives. Ms. Susan Duval, principal of Springstead High School, has been extremely supportive over the years. We have grown in size and support with each race that passes. This year we are fortunate enough to receive grants from the Hernando County Education Foundation, AT&T STEM grant, and Progress Energy STEM grant. If STEM is, as even President Obama has stated, pivotal to the future of America, projects such as SubZero build an interest, at the grass roots high school level, in

the young students who will go on to be university engineering students, and ultimately a driving force in our nation.

In addition to the support we have received from our principal and the grants orchestrated through the Hernando County Education Foundation, we receive invaluable assistance from local sources. A local boat builder taught the students how to lay up a fiberglass hull. A local machinist instructed the students in the use of metal machining tools. A local bicycle shop and scuba instructor gave discounts on equipment. And the list goes on. All of these people see that an investment in high school students who are tackling a project such as this is a worthwhile endeavor, and we are eternally grateful.

The bottom line, as always, is for high school students to learn theoretical and practical engineering concepts and be exposed to networking with college engineering students and professors, as well as professional staff at Carderock. Additionally, some current, and many former team members are part of ROTC. Exposure and networking with MUDSUs and naval commanders could definitely influence their future.

Our philosophy continues to be to allow any student who is interested in piloting the submarine to be allowed to do so. Although we realize this may put us at a disadvantage in the race as compared to teams with one dedicated pilot, it's a disadvantage we embrace and plan to run with, right over the finish line in first place.