Talon 1

(One-Manned Submarine)

Florida Atlantic University

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Abstract:

The Florida Atlantic University Human Powered Submarine Club has been a long time contender in the ISR competition since 1989. Over the past few years FAU's Human Powered Submarine Club has innovated to improve on development and design of the current human powered submarine, named *Talon 1*. The mission of this project was to create a human powered submarine that achieves maximum speed in short time over a straight distance. The hull design was based off a Gertler shaped hull constructed out of a fiberglass and polyester resin matrix. Research and development has been done on the construction and implementation of a thermo-molded polycarbonate nose cone. Neutral buoyancy is accomplished through the addition of removable blocks of polyurethane foam. The propulsion is provided from the pilot and transmitted through a gear box to the drive shaft with a connected twin blade propeller. With the CFD modeling, the steering and control surfaces are being re-vamped to be more efficient and ergonomically compatible with the submarine pilot. The controls will allow the pilot to maintain a current heading and/or make course changes as needed with relative ease. The submarine can

be fully disassembled and can be used as a transport feature and for routine maintenance and repairs. Safety features include the manufacturing of a "dead-man" system to alert other divers of the pilot's condition. The results of these improvements and designs make *Talon 1* a high performance machine that will contend in any length drag race.

Introduction:

The Florida Atlantic University's Submarine Club was founded in 1989 and over the years has participated in nearly all of the bi-annual International Submarine Races. From these races, the club received a modest number of awards and accolades which has helped to continue the clubs existence at Florida Atlantic University. In the 11th ISR the one man submersible *Talon 1* received four awards, Absolute Speed, Fastest in Propeller, Smooth Operators, and 2nd Overall. The best aspects of our sub include straight line speed which will prove beneficial in ISR races.

The FAU Human Powered Submarine Team is comprised of 27 active student members. The team is registered as a club on campus- Human Powered Submarine Club. The club is open to any enrolled student at Florida Atlantic University and students across disciplines are encouraged to join. Club members learn from each other's unique set of skills, mistakes, past experiences, as well as form lifetime bonds.

Figure 1: ISR Team Photo

Aim:

The aim of this report is to describe in detail the design and construction of *Talon 1*, Florida Atlantic University's human powered one-man submarine. This includes aspects of the hull design, static trim, stability, propulsion system, control system, system aspects, ergonomics and safety. This report will cover the entire process from start to finish and provide specific details to enable the reader to potentially build their own human powered submarine.

Hull Design:

Talon 1 hull was originally constructed and finished in 2009. This hull was outfitted and competed in the 10th ISR in the same year. The initial design is essentially an elongated Gertler shape with and extended parallel mid body. Overall, its length is 10 feet, 25.75 inches tall and 21 inches wide. It features a large forward hatch which enables entry and exit from the sub and windows running along the front midsection of the hull with a clear nose cone to further increase visibility.

The basic hull design was created in SolidWorks using the physical constraints of a premade hull and the anatomy of multiple potential pilots. To ensure that a human would be able

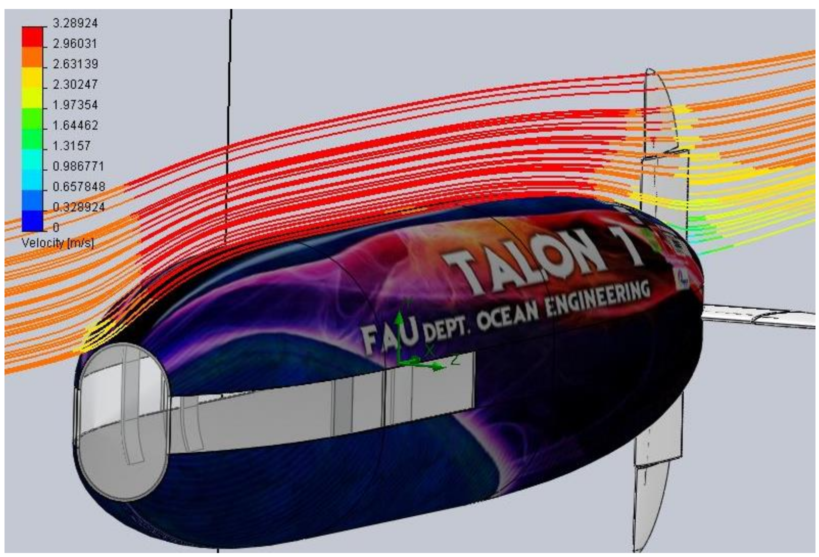
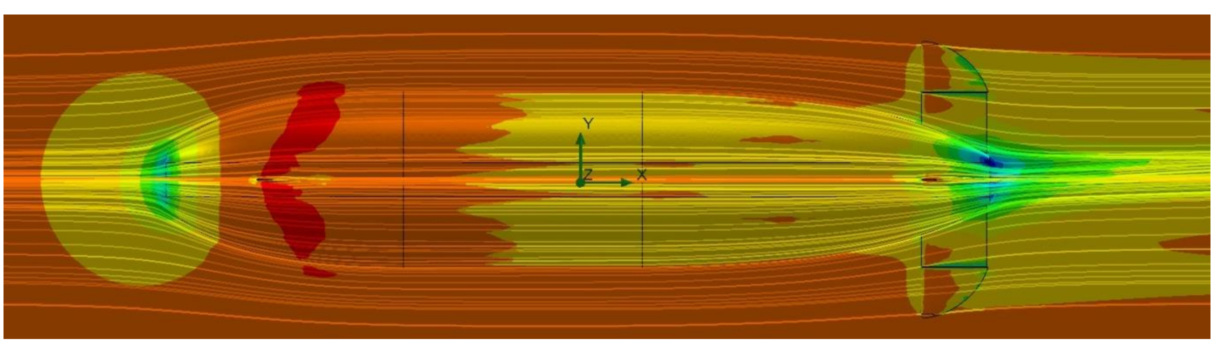


Figure 2: CFD Modeling 3D View (Above) CFD Modeling Top View (Below)



to operate the submarine effectively, the diameter of the hull of the premade shells had to be increased and several designs were proposed. After consulting with FAU Faculty members with experience in fluid dynamics, it was determined that the most practical option would be to create a longitudinal five inch spacer. This basic hull shape was then entered into a computational flow dynamics modeling software that revealed areas of turbulence/drag as well as flow separation points on the hull (See Figure 2). Through the initial CFD modeling, optimal locations for hatches, windows, and control surfaces were located and selected.

The main hatch of the sub was designed to accommodate most materials and divers. After calculating the pressure differential at our estimated top velocity, it was determined the structure of the hatch would have to be considerably reinforced as well as optimizing the hatch size. The pressure differential was found using Bernoulli's equations for incompressible fluid:

$$rA(dx/dt)DV = -A(Dp) \qquad \textbf{(1)}$$

The forward hatch on *Talon 1* provides a 26 inch x 19.5 inch opening which provides plenty of room for the pilot to enter and exit. The final hatch designs yielded, at 7 knots, a pressure differential of 1250 to 1290 lbs. on the main hatch. This large opening also ensures that in an emergency the pilot can be removed quickly and efficiently from the sub. That hatch features 281 small 0.145 inch holes, visible in Figure 3, which enables the venting of exhaust gases from the pilot to ensure consistent buoyancy.

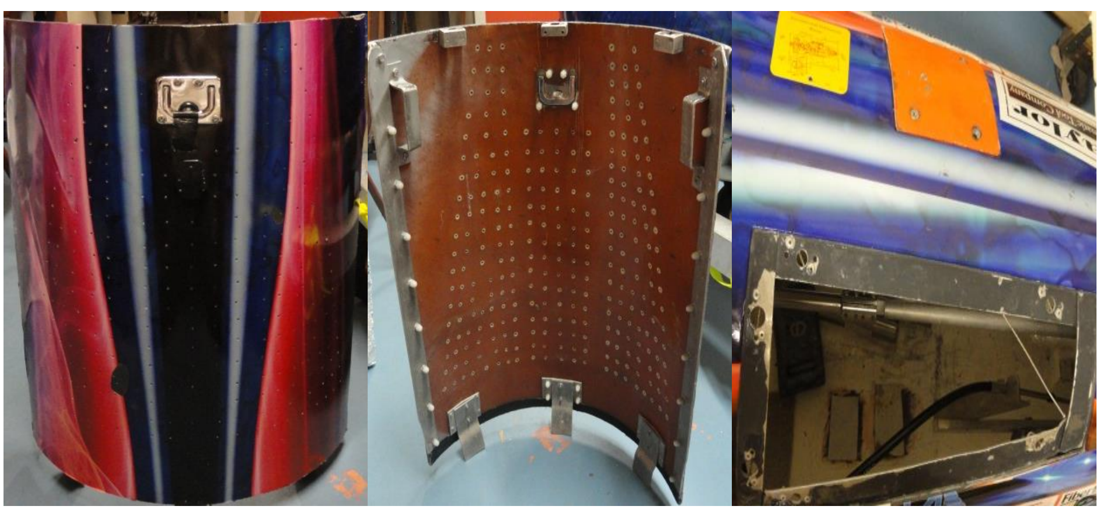


Figure 3: Forward, Service, and Buoy Hatches

It is secured to the sub by three spring loaded latches that are connected by a single aluminum rod as shown in Figure 4. The latch mechanism is simple and effective to operate. A pull label with arrow on the hull simply describes the latch mechanism's operation.

Figure 4: Forward Hatch Latches

Located on the aft of the hull, a service and dead man buoy hatch (Figure 3 Bottom Photo). The service hatch enables the crew to access the rear of the sub and is affected by 58 lbs. Specifically, the control system, propulsion system, and emergency buoy. The service hatch is secured to the sub with six screwdriver quarter turn self-ejecting fasteners for quick and simple access. The dead man buoy hatch is located on the port side and is sized to 5 inch by 4.5 inch creating 32 lbs. pressure differential. The size of these two hatches creates approximately 32 lbs. of force on the dead-man hatch, and approximately 58 lbs. on the rear service panel found using equation (1).

Conventionally spaced fairings on the top, bottom, port, and starboard hull surfaces are a source of drag on the hull. They protrude from the sub 4.947 inches at their leading edge, located 9.79 inches from the stern of the sub (Figure 5 Dimensions).

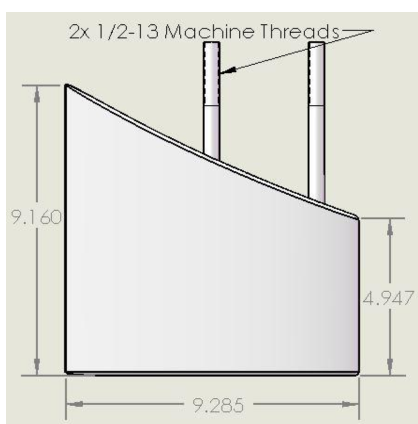


Figure 5: Fairing with Dimensions

Extending out on these fairings are the steering control surfaces of the sub. To determine the fairing offset from the surface of the hull, CFD models were examined and measurements taken to place the controls surfaces the edge of the boundary layer for clean laminar flow. Fairings and fins were molded from a 2-part female mold with *Easy Flo 60 Liquid Plastic*. Fairings are mounted with ½" threaded aluminum bars and nuts.

One of *Talon 1*'s notable features is the abundance of windows, approximately 4.95 square feet; Figure 6 shows pilot visibility while operating the sub.

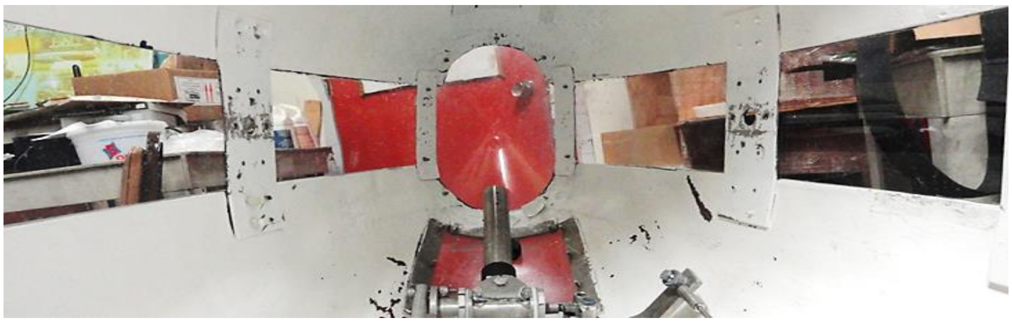


Figure 6: Pilots Visibility

A 5 inch Acrylite, acrylic sheet, band enables the pilot to look aft of the sub, assisting in navigation during open water testing. A polycarbonate nosecone enables forward visibility along with a 8 inch x 7 inch window located on the bottom of the bow. This enables the pilot to view the lit race course line. The nosecone is manufactured from a thermoformed polycarbonate sheet and a female mold. The female mold was crucial to get the perfect exterior finish and dimensions. Using tooling gel coat, fiberglass and resin, the female was molded over the CNC milled MDF male mold.

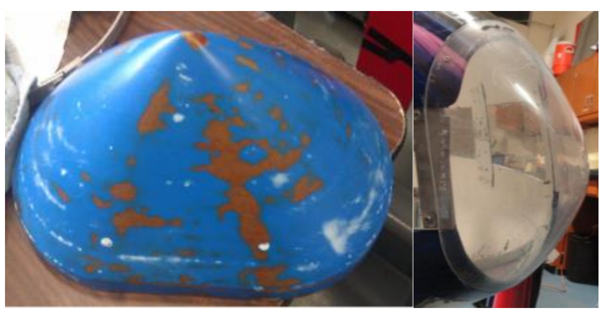


Figure 7: Front Nose Cone Mold & Final Product

A local prototyping company, Do Mac Inc. provided the tools, machines, and knowledge necessary to form the nosecone. The side and bottom windows were cut from a sheet of 0.250 inch acrylic sheet. To form the windows to the hull, a heat gun was utilized to preheat the material to 250°F at key points and then clamped into position until cooled (Figure 7). Windows and nosecone are mounted by stainless steel machine screws, flush to the hull surface.

Fabrication of the hull started with prefabricated sections from an AUV, donated by the FAU Sea Tech Campus in Dania Beach, Florida. These sections were prepared by dividing it into four sections. Five inches was spaced out between the top and bottom sections to accept an aluminum band of the same size that would span the entire length of the sub. The bottom two hull sections were fused back together and aluminum bands installed connecting all sections of the hull. An aluminum rib was fitted for a rear hatch support as well as a universal mounting point. Hull fabrication snapshots can be seen in Figure 8 and a step by step visual break down is provided in Figure 9. During fabrication of the hull, fiberglass and resin were used to mate all section and spacers together. These

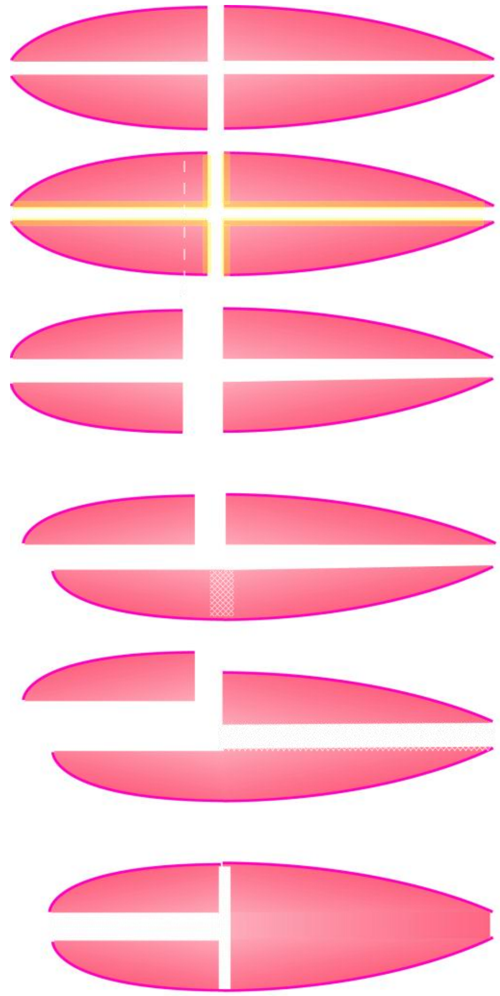


Figure 8: Hull Fabrication Reference

Figure 9: Hull Fabrication. Pre-fabricated hull from AUV was originally yellow

materials were ensured to match and mate with original materials of the AUV hull. By mating all of these surfaces together, a hull of more than adequate strength on stiffness was formed. Overall the hull weighs 150 pounds with internal supports, fairing compounds and paint.

Static Trim & Stability

The buoyancy of the submarine is mainly created using pourable closed cell polyurethane foam. The sub is approximately 80 lbs. negative in the water, including buoyancy created by the water displacement of the hull and all the components. According to Archimede's Principle, the buoyant force on an object is the weight of the fluid that it displaces.

$$B=rVg \qquad \textbf{(2)}$$

Therefore, in order to make the submarine buoyant, foam inserts must displace at least 80 lbs. plus their own weight in water. The density of water is 62.43 lbs./ft^3 therefore 1.28 ft^3 of foam was the minimum amount needed to offset the negative buoyancy with the final volume to be 1.93 ft^3. This amount of foam is more than necessary to make the sub neutrally buoyant, however further analysis will be performed showing how this adds to stability.

In the past the volume was displaced by 2lb/ft^3 pourable polyurethane foam that was poured into different molds and shapes to make foam inserts. Now the pourable polyurethane foam has been switched to 1.75lb/ft^3 extruded polystyrene foam. The pourable polyurethane foam was in need of replacement because the foam shrunk causing the gel coating to crack and deteriorate. The extruded polystyrene foam was chosen as a replacement because it is easier to shape than the pourable polyurethane as well as weighing less. The extruded polystyrene foam retains its shape better than the pourable polyurethane which eliminates the problem that the pourable polyurethane foam demonstrated. The pieces of the extruded polystyrene foam must be large enough for buoyancy purposes but strategically placed to give the pilot ample room to operate the submarine and aid in egress situations if necessary. The blocks interlock in the sub for support during runs and transport.

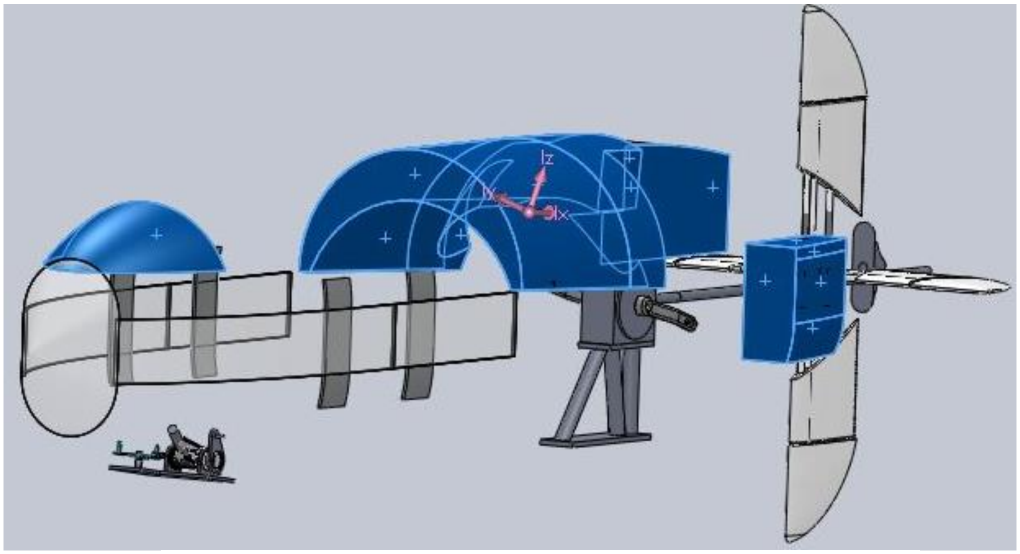


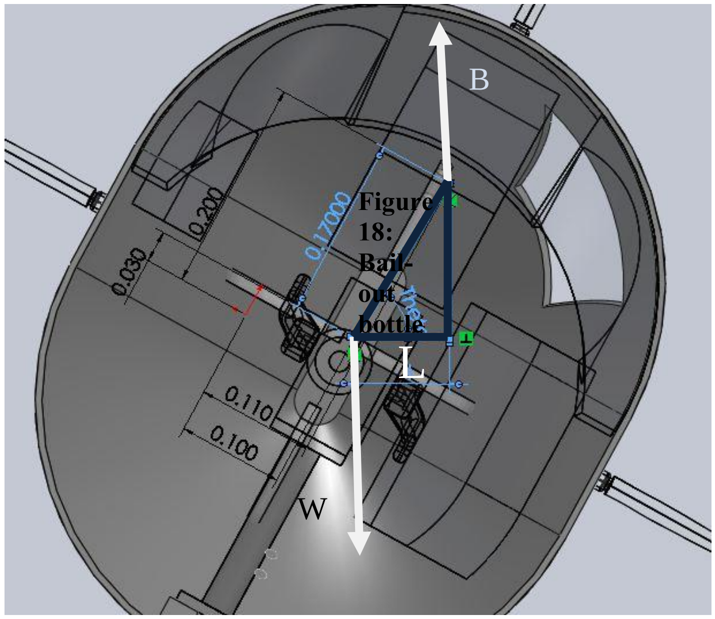
Figure 10: Foam placement and center of buoyancy.

Figure 10 shows the foam's placement within the sub along with other components. It also contains the center of mass of the foam as calculated by SolidWorks. This pink axis represents the center of buoyancy for the sub. The location of this center along with the buoyant force exerted by the foam is the main contributor in the stabilization of the sub.

During the runs the propeller produces feedback torque on the sub in the opposite direction of its rotation. This torque is directly linked to the power the pilot can input to the propeller. Assuming the pilot can average 500 Watts and max at 620 Watts at a rotational speed of 1.8 rps on the low end, values found through testing, the torque at the crank can be found using the power formula. (ω is in radians per second.)

$$P = \tau\omega \qquad (3)$$

This calculation concluded a prop torque after a 1:3 gear ratio equal to 14.7 Nm and a max of 18.3 Nm. The sub's high center of buoyancy and lower center of gravity generate a counter torque which stops the sub from spinning under this torque. Figure 11 shows how the angle creates a moment couple of the buoyancy and center of gravity to counter this torque. This is the main reason the sub was designed to have 30 lbs. of extra lift. Besides the possibility of the foam losing some of its buoyancy under compression, and the flexibility of ballast placement to establish the subs trim, extra buoyancy produces a much higher counter moment to cancel out



torque roll. We have designed the sub to have a heavy side and a buoyant side to offset the centers horizontally as well as vertically. Since the sub sits neutral in the water, the values of B and W from the above figure are equal which makes the counter moment a couple represented by M = B*L, where L is a function of the separation of the centers (h=0.17m) and Theta which is the compliment to the roll angle. The final counter moment equation is as follows.

$$Mc=B*h*Cos(Theta) \tag{4}$$

Setting the previous torque values equal to Mc while using the calculated value of B and h, the total roll can be calculated and verified as in a reasonable zone. The angle can be approximated at 10.1 degrees to 12.6 degrees max. These numbers are satisfactory compared to the 14-17.6 degrees experienced when only the 80 lbs. of the subs negative weight are compensated for. Weight compensation is the reason why any extra buoyancy was welcome in the design as long as it did not inhibit the pilot.

After the sub is trimmed out in the lengthwise perspective, the pilot is not considered because he/she will be neutral. This allows for a less dynamic approach to sub's trim, which allows for multiple pilot types. For sub's surface operation, the main hatch is negatively buoyant, when it is removed the sub becomes buoyant and it is easier to handle.

Propulsion System

The propulsion system in *Talon 1* converts human power to forward thrust using a standard bike configuration with one exception. Instead of sprockets, a sealed gearbox is used containing a spiral bevel and pinion gear system. Power is transferred to the rear of the sub using a fixed drive shaft. There is absolutely no stored energy system within the sub propulsion systems per the EISR & ISR regulations. The gearbox was recycled from a retired ISR submarine, FAU-Boat. The propulsion systems goal is to achieve maximum power transfer from pilot to propeller with minimized power loss.

When designing the propulsion system the first challenge was to define the biggest variable factor of the sub, the pilot. The initial designs for the sub had the pilot in a "superman" position, lying face down while pedaling and steering. To define the amount of power that team members could provide over a specified time interval, an aluminum training stand was constructed utilizing the recycled gear box, 154 mm crank arms and twin blade propeller. This stand was outfitted with an 80 ft^3 aluminum tank, tachometer w/ recorder, and set at the bottom of FAU's test pool. Current members preformed multiple one minute runs in the superman position. The data collected was analyzed in MATLAB. The mean average for all participants was 2 cycles per second and the strongest runs yielded 2.6 cycles per second. Converting it to rpms, a range of 120 to 156 rpms will be expected from the pilots during competition runs before optimization. It is to be expected that during the course of the runs, the pilot's power input will decline. An average max time interval of one minute was defined for training and design consideration by taking the 100 meter ISR course length and dividing it by our lowest expected speed of 5 knots.

Longest Expected Run Times: (100 meters) / (5 knot) = 38.8768898 seconds (5)

One minute time intervals allow for ample time to orient yourself with the gear system, and optimize peddling speed. Practice will prove an increase in overall endurance through extended run times.

The pilot wears bike shoes clipped into an egg-beater style pedal and 127 mm aluminum bike crank. Egg-beater style pedals and shoes are preferred as it allows the pilot to push and pull on the pedal ensuring maximum power delivered. The 127 mm aluminum cranks have been modified from a standard 170 mm bike crank. The shorter crank decreases the amount of leverage available to the pilot and increases the effort required, but the final rpm of the propulsion system is increased. This ensures that the pilot can input the maximum amount of energy into the system and avoids free spinning. The pedals and cranks are seat on a square ended axel protruding from the sealed gearbox.

The gearbox as mentioned before was recycled from the FAU-Boat. A complete service was preformed replacing all seals and bearings before it was mated to *Talon 1* or the training stand. This service was completed in house by the Department of Ocean Engineering machinist Frederick Knapp. The gearbox was constructed from an aluminum block, it measuring 5.856 x 6.000 x 2.950 inches (BHW, Modeled in Figure 12). Inside, a 1:3 steel ground spiral bevel and pinion gear system and transfers the power to a stainless steel output shaft to the stern. To protect and lubricate the gears and bearings it is filled with 0W motor oil. The gear box is mounted on an extension and mount that fabricated to fit our modified hull. They were designed using Pro Engineer and a CNC to mill the parts. The mount was modeled to fit the curvature of the hull exactly. The mount is 14” long and the gear box can be moved accommodating pilots from 5’6” to 6’3”. There are a total of 13 different adjustments allowing placement of the pilot in the optimal position.

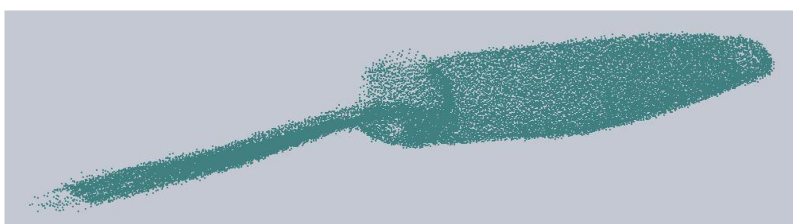


Figure 13: *Talon 1* Prop Point Cloud

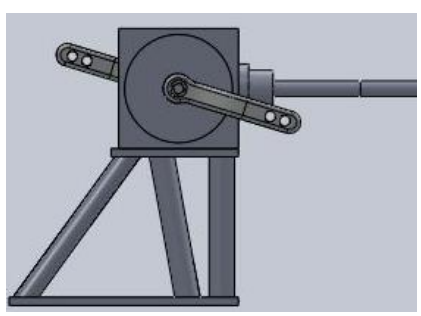


Figure 12: Gear Box and Extension

Talon 1 has a 0.750 inch direct drive shaft connected to the gear box. The shaft is connected using a shaft coupler using hex head machine screws. The shaft is mounted to the rear of the sub with two mounting brackets, one on the inside and one on the outside. The brackets were also milled on the CNC tapered exactly to the 3D curvature of the tail. They are bolted together to create a crimping force as well as mounted to the tail of the hull. Inside these brackets is a plastic bearing mount that seats the sealed bearing. Corrections to shaft alignment can be made using brass shims between the gears box and extension.

Without a well-shaped propeller, the pilot's power will not be transferred efficiently. *Talon 1's* current propeller was hand shaped and welded together by previous club members; however it was subjected to heavy analysis and it was optimized by reverse engineering. Figure 13 shows a laser scan of the prop which aided the fabrication process. Finding the propeller's strengths and weaknesses using wing section theory will help *Talon 1* achieve higher speeds. The current restriction of Talon's top speed is the size and orientation. The current prop is a long two bladed prop which closely resembles an airplane propeller. A large downside of this prop is the lack of skew. Air and water are different mediums with different surface tensions and compressibility, therefore the props should be very different to advance through these mediums. Adding skew to the prop would help adapt this propeller to its aquatic conditions.

Control Systems

The fins were designed with the idea of minimizing separation and flow disturbance. They were designed using basic fin lift/drag theory, as well as incorporating a NACA cross-sectional shape. The NACA shape was decided on in efforts to reduce drag and obtain maximum lift. The lift equation used is based on infinitely thin foils.

$$\textbf{Lift} = \mathbf{rAV^2\ (0.5)\ (Coefficient\ of\ Lift)\ (Angle\ of\ Attack)} \qquad \textbf{(6)}$$

Considering the symmetry of the wing over the chord length this was believed to be fairly accurate. A flat leading edge was believed to cause the flow over the wing surface to be more laminar, as opposed to a curved leading edge. However, the entire fin system will be raked back 7 degrees in order to make their leading edges perpendicular to the water flow that is attached to the curvature of the hull according to CFD models (see Figure 15). This new angle should cause the fins to perform as originally calculated. The MATLAB script for the fin design is included below as Figure 14.

```
%input design parameters
%l= fin length in inches
% c1= base chord length in inches
% c2= tip chord length in inches
% need alpha to be +/- 8 degrees

knot= input('please enter velocity in knots: ');
length= input ('please enter fin length in inches: ');
base= input('please enter base chord length in inches: ');
tip=  input('please enter tip chord length in inches: ');
alpha= input('please enter angle of attack of foil (+/- 16
       degrees)\n(disreguard Drag for alpha > +/- 8 degrees): ');
knot2mpersec= knot*.514;

V=knot2mpersec;          %designed vehicle velocity [m/s]
ft2m= 1/3.28;
in2m= (1/12)*ft2m;
rho=1024;                %density of salt water [kg/m^3]
mu=1.3*10^(-6);          %kinematic viscosity [assumed] [m^2/s]

h=1*in2m;                % elemental blade thickness [m]
l=length*in2m;           %fin length   [m]
c1=base*in2m;            %base chord length [m]
c2=tip*in2m;             %tip chord length [m]
A=((c1+c2)/2)*l;         %fin area [m^2]

cL=1.2*alpha/16;         % lift coefficient
cD=.004;                 %drag coefficient (for alpha < 8 degrees)
R=(V*((c1+c2)/2))/mu;    %Reynolds number
lift=.5*rho*V^2*A*cL;
drag=.5*rho*V^2*A*cD;

fprintf('Lift %f N \n Drag %f N \n Reynolds # %e \n cL %f \n
               cD %f \n', lift,drag,R,cL,cD)
```

FIGURE 14: Fin design- MATLAB script

The fins are positioned at the edge of the sub's boundary layer and outside of the prop's radius. This location gives the fins a more laminar flow field while keeping their turbulent wake out of the props flow field. The sub has had bow dive planes in the past, but recently the rear stabilizing fins have been reinstated as the dive planes once they were converted from static to articulated.

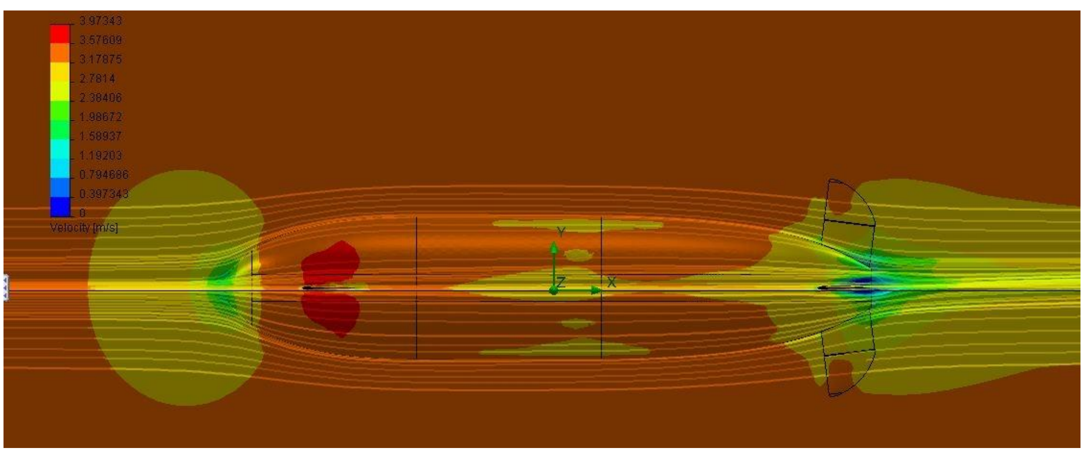
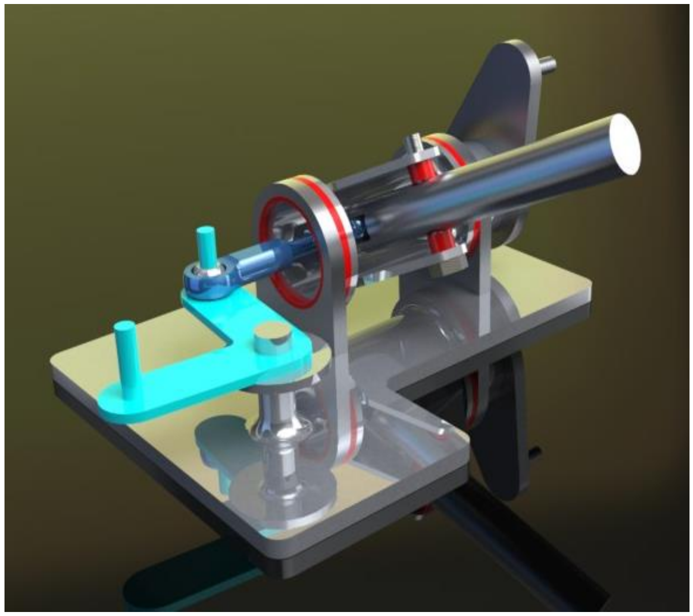


FIGURE 15: Side view of CFD model of *Talon 1* with raked control fins.

These fins are all controlled by a 2 axis joystick linked to the fins by Teleflex cables. The joystick modeled in Figure 16 allows the pilot to adjust the sub's lateral steering as well as dive planes simultaneously while operating the craft. The Teleflex throttle cables are used because



unlike bike cables, they have the capability to apply push as well as pull. The tension-compression feature allows the full motion of the joystick to be transferred to one side of the rear steering configuration. With the ability to push, the cable acts more like a flexible connector rod, which allows us to use one rigid cable to the stationary mount of the joystick base. In the rear of the sub, the sets of control rudders and dive planes are linked together with horseshoe styled linkages which also act as the lever arms for the steering linkages.

Design For Aspects

Talon 1 was designed to be easily manufactured, assembled, transported and repaired. Manufacturing of the submarine was completed on FAU Boca Raton campus due to time and financial constraints. One major fabrication inhibitor was that systems were designed so that the submarine could be built using on-campus resources. For more complex or specialized tasks such as the polycarbonate nosecone and the vinyl exterior wrap, local sponsors were sourced for assistance. When manufacturing the fins molds a two sided mold was made for easy part removal. To aid the thermoforming process 0.125 inch polycarbonate was utilized. This was done to allow the polycarbonate to fully form to the radius of the female mold.

To completely assemble and prepare the submarine, about six man hours are required. The submarine is assembled using standard sized hardware throughout the submarine. Most components are secured using standard 10-24 stainless steel Phillips screws. The hull is the main structural element of the submarine unto which all of the other systems of the submarine are fastened to. The vinyl wrap on the hull of the submarine allows for the appearance of the submarine to be easily modified. The utility hatch located towards the aft of the submarine provides ample access to the steering, propulsion, and dead-man safety systems. *Talon 1* also has easily removable foam which is fastened to the hull using Velcro strips.

Talon 1 can be easily moved from location to location on a composite cart. The cart is modified to the shape of the submarine to securely hold it without damaging the wrap. If the submarine is to be moved over a longer distance the cart is secured to a trailer and towed. The relatively light weight of the submarine means that it can be loaded and unloaded easily with four people. The submarine can be fully assembled on dry land and then transported to the dive location. The propeller of the submarine is easily removed and stowed during transport.

The parts of the submarine were designed so that they are either able to be reproduced using common materials or are designed to last the lifetime of the submarine. The nose cone of the submarine is difficult to readily reproduce, so it is formed from impact resistant polycarbonate. The rear of the submarine has large brackets mounted so that components can be easily removed and modified or repaired. The foam of the submarine was designed so that the submarine is over-buoyant as the process to reproduce the foam pieces is lengthy and requires large amounts of material. The gearbox quickly disassembles for service and repair. The drive shaft is constructed from 0.750 inch aluminum stock which was turned down on a lathe to balance it. The gear box, dead-man system and the steering control assemblies can be easily removed from the submarine for maintenance.

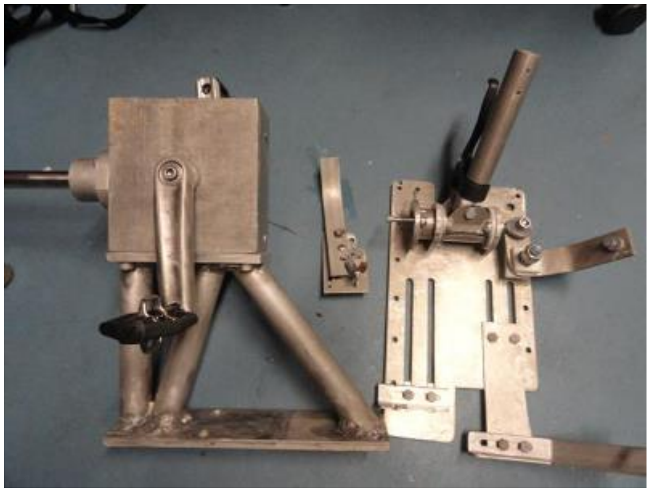
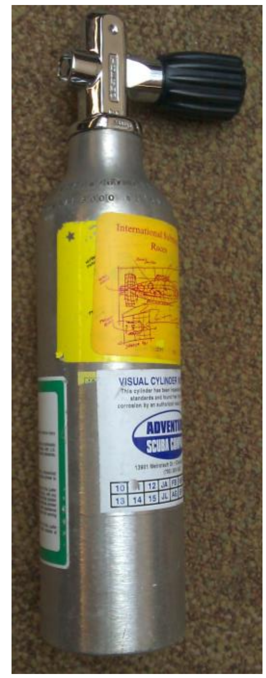


Fig 17: Gear Box, Deadman Latch, and Steering Assembly

Maintenance can include cleaning, lubrication, tightening or shifting of the gears, mounts, or sprockets. Driving, steering and safety components are regularly checked and maintained to ensure maximum performance.



Ergonomics & Safety

Talon 1 is simply designed in a similar manner to a bicycle. Not only in the sense that it uses pedals rotating around a shaft and a simply geared transmission, but in the sense that it is designed to optimize the user input. No system is good if it is distracting or in some form impeding the pilot's objective. The steering and dead-man systems are designed to be as low impact on the pilot's attention as possible.

The main propellant for the pilot is air. The original design incorporated a 45 ft^3 scuba tank that was placed in the back of the sub while the pilot breathed from a regulator and a 9ft hose. This design was redone with an 80 ft^3 tank directly under the pilot in the sub. The larger tank in the front of the sub allows for longer run times and faster swap outs. Another concern with our short tanks was not being compatible for international use. The new tank mount area accepts a standard size tank if it needed. This new tank location is just as unobtrusive as the previous design; just better utilizes dead space in the bow.

The final concern regarding air is in the case of an emergency. If for any reason the main regulator stops working, a 3 ft^3 pony bottle (pictured in Figure 18) is strapped to the pilot with its own regulator to ensure an entirely redundant air source that stays with the pilot during emergency egress.

Figure 19: Hatch and Buoy

Movement of the gearbox was primarily done to allow room for larger pilots. The pilot's height restrictions limited the range of people who could safely operate the submarine. With the gearbox moved backwards and new foam installed, taller pilots can fit into the craft. The front foam block is also positioned so that it can be used as a brace for intense pedaling.

Another feature that is flexible to multiple users is the adjustable restraint straps. The pilot pushes against shoulder straps to apply force to the pedals and can be adjusted to any height by preference. The straps have brightly colored quick releases taken from weight belts and in an emergency pilots can be removed quickly.

To indicate such an emergency, the emergency pop-up buoy is located on the rear upper quarter panel of the submersible. The mechanism releases a 5 inch by 4.5 inch hatch allowing two white and blue buoys (Figure 19) to float to the surface. These buoys and hatch are attached to the mechanism by a highly visible white 1/8" rope that is 33.0 feet (>10.0 meters) long. The visible white rope is simply stored in an acrylic tube, similar to a throw bag to minimize the opportunity for mechanical failure.

Figure 20:
Steering joystick with dead man handle in use

To enable in the rescue effort, it is crucial that sub is visible. This is done by using paint and lights. A white diver strobe light protrudes from a hole immediately in front on the top tail fairing and is activated before the sub enters the water. The strobe's battery life is at least 3-5 hours. It is particularly useful when attempting to locate the sub in low visibility situations. In addition to the strobe, the fins and propeller have orange painted tips. The contrasting paint colour helps bring attention to the protrusions from the hull. This also ensures the safety of support divers while the sub is in operation.

The planned "dead-man" styled locking mechanism utilizes a spring loaded bicycle brake handle affixed to the steering joystick in the front of the submarine (see Figure 20). The brake cable is run to the aft of the submarine and operates a spring loaded lever. It locks the hatch by seating the lever inside of a latch. The spring loaded lever's default position is open so that the pop-up buoy will float to the surface when the bicycle brake handle is not compressed, or any the tension is lost in the system for any reason; Therefore achieving the "dead man" style release mechanism.

To keep the pilot safe and on course, the sub has several mounted gauges in the cockpit area. The diver's air supply gauge is located in the front and can read from inside and outside the sub. There is a dive computer mounted in the sub providing constant depth feedback which avoids diver related injuries from rapid ascension and allows for constant depth runs. A compass is also utilized to aid in open water navigation. During our test runs at the beach, it is very easy to lose a straight line when using a sandy bottom as a reference. Use of a compass helps the pilot stay on track and closer to support divers.

Conclusion:

The "*Talon 1*" submarine has lasted through several generations of club members and seen multiple competitions and is still a contender due to proper design modifications. Each generation has made their changes and it is continuously modified to improve performance and match its dynamic goals. The advancement of computer technology and 3D modeling allows for more precise and accurate manufacturing of parts and designs. The use of computer programs allows creative and innovative ideas to be manufactured and tested. Between the design, craftsmanship, management, and constructive testing of the sub is an invaluable opportunity to learn and apply valuable skill sets. From these learned skill sets the completion of new designs to optimize the efficiency and performance of the sub will continue to exceed new limits and set new expectations. Not to mention having fun modifying, racing and engineering!

Index of Equations

(1)	Bernoulli Equation	Where r = density of water, A = area, DV = change
(2)	Archimedes principle	Where r = density of the water, g = gravity,V = volume displaced.
(3)	Power Formula	Where τ = torque, ω = angular velocity
(4)	Counter Moment Eq.	Where B = base, h = height, theta = roll angle complement
(5)	Run Time Eq.	Where distance is meters and speed is knots
(6)	Lift Equation	Where r = density of water, A = area, V = velocity

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