CAPSTONE REPORT

MCG 4322A

SUB 1A

Group Members

Jonas Chianu (8090727)

Otito Situ (8315067)

Munachiso Izuora (8069751)

Siyuan Ji (7696601)

Kenneth Oguejiofor (8327214)

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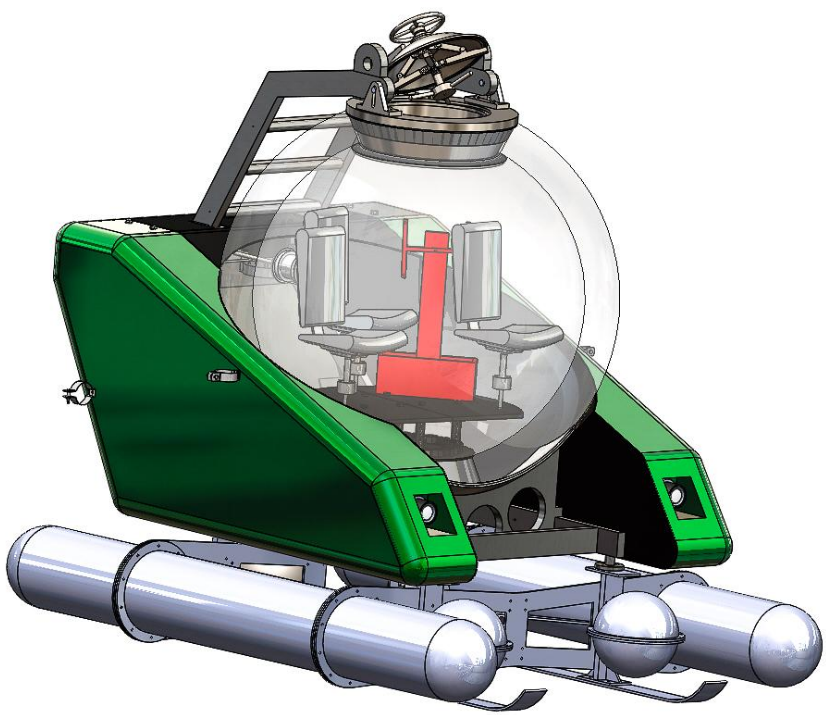
Abstract

This report introduces the design of a manned submersible for Aquatica, a Canadian company established to design, manufacture and sell various submersible models. A primary goal of Aquatica is lowering the cost involved with building, owning and operating manned submersibles while maintaining functionality and the highest standards of safety. In this proposed design, which is focused on developing a parameterizable, manned submersible capable of operating at depths ranging from 300-1000m. All design considerations,as well as criteria specified by the mandate are outlined. The efficacy of this design lies in the interconnectivity of the major components like the ballast tanks, pressure hull, frame and hatch. Housing and sealing the interior of the submersible is of utmost importance as pressure ratings at depths of 1000m are high. The use of dynamic sealing methods as well as strategic positioning of o-ring seals and gaskets are employed in this design. The compact design of our submersible is aimed at reducing overall drag while providing easy storage options that will be a plus for consumers.



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1. Project Charter

1.1. Mandate

The mandate is to design the hull of a versatile manned submersible. The design process will reduce costs, while maintaining the necessary functionality and safety. We will be collaborating with the ballast team to incorporate their design with ours. The design must allow for parametrization to satisfy various market needs and accommodate various depth ratings. Our responsibilities include the design of the submarine hull, frame, hatch, seals and access mechanisms. We will be designing:

- A Control panel mount and seating assembly.
- A Release buoy
- Attachment points for lifting and anchor points.
- Electrical component mounts such as thrusters, batteries and lights.
- To accommodate the ventilation system.

1.2. Requirements

- Submarine should be properly sealed and be corrosion resistant.
- Submarine should be capable of withstanding pressures up to 100 atm.
- Submarine should be capable of seating a pilot and two passengers.
- Submarine should be designed to accommodate thrusters, compressed air tanks e.t.c.

1.3. Constraints

- Submersible must attain speeds from 2 to 6 knots
- Diving depth between 330m and 1000m.

1.4. Criteria

- Submersible should be as light as possible.
- Lower costs involved with manned submersibles while maintaining high standard of safety (reduce shipping and operating cost).

1.5. Design Optimization

The inputs for our GUI are depth, number of passengers and material. Changes in depth rating causes an increase in the hull shell thickness to resist the pressure. The pressure leads to changes in the frame cross-section as a result of the changes in the hull, while changes in the hull leads to modifications in the penetrators and seals. The number of passengers causes a change in the inner diameter of the system which alters the frame cross section. Lastly, the material refers to the frame material which could be either aluminium, stainless steel or titanium. Each leads to a different mass effect on the overall system.

2. Proposed Design

2.1. Solution Description

The design of this submersible was modelled to be parameterized for different applications, with varying inputs such as; number of occupants and depth. It features an acrylic transparent pressure hull, which is the observation deck and serves as the primary source of buoyancy for the submersible. The pressure hull is mounted on metallic support frames (Figure 1), curved to the shape of the spherical hull; providing adequate support and rigidity. On either side of the hull are two fairings for housing the lights, batteries and other electrical components. The fairings feature cavities to support buoyancy. The thrusters are located on the outer walls of the fairings. Oxygen tanks and carbon dioxide scrubbers are mounted onto the steel frame and enclosed within the fairing, at the rear of the submersible. The submersible's pressure hull can be accessed by climbing a ladder structure on the frame and passing through the hatch on the top of the acrylic hull. As one of the major parts of our solution, the hatch is sealed using silicone rubber o-ring seals mounted to machined grooves on the hatch door and hatch seat. Electrical components, ventilation system and drop weight shaft are passed into the hull by a penetrating feedthrough directly below the hull.

Complete System

The complete system layout of this submersible consists of: the hatch which is the major access mechanism of the system, the acrylic pressure hull which is the observation dock; housing the passenger seats, control panel mount, release buoy handle wheel and ventilation system.

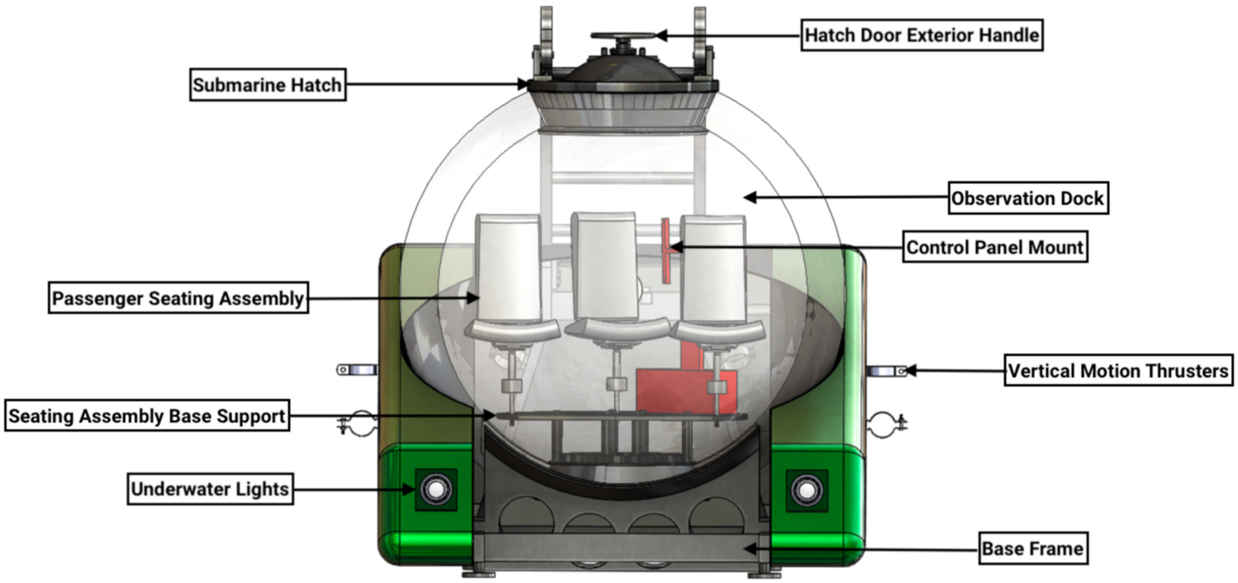

Figure 1: Front View of Complete Submersible Design

The frame gives rigidity to the structure and serves as a platform to mount other key components of the design such as fairings, compressed air tanks, oxygen tanks and carbon dioxide scrubber. Thrusters and underwater lights are also mounted on the fairings. The fairings house the battery packs for the submersible and as a result of their streamlined shape, also improves hydrodynamics and reduces drag.

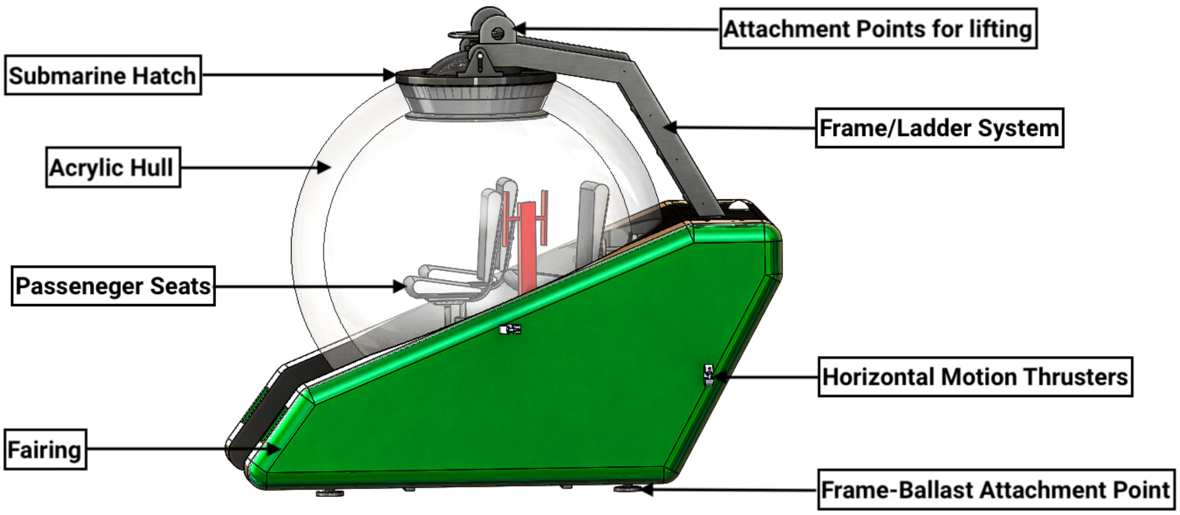

Figure 2: Side View of Complete Submersible Design

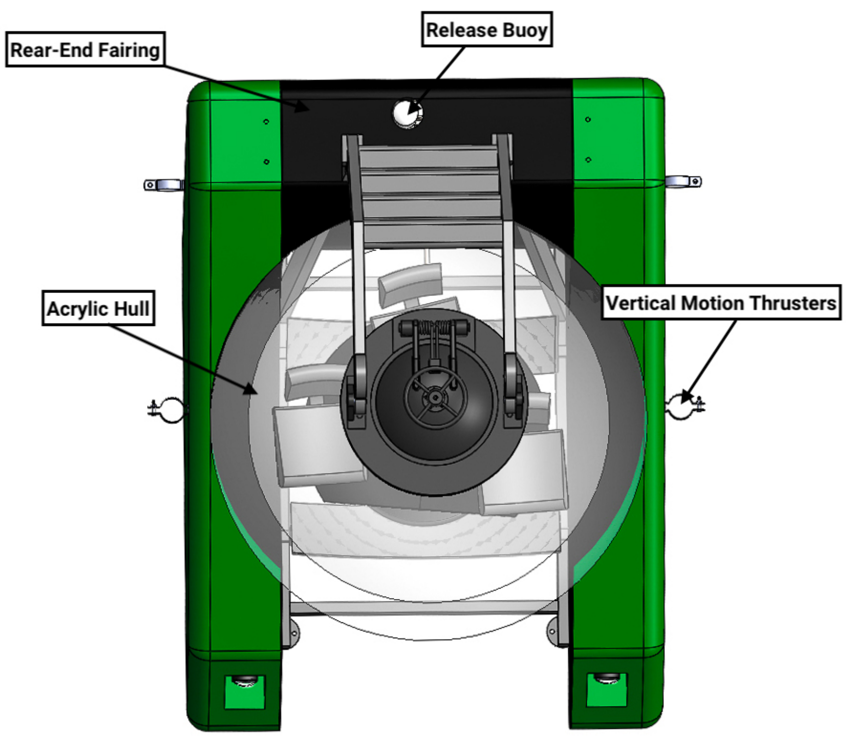

Figure 3: Top View of Complete Submersible Design (Hatch open)

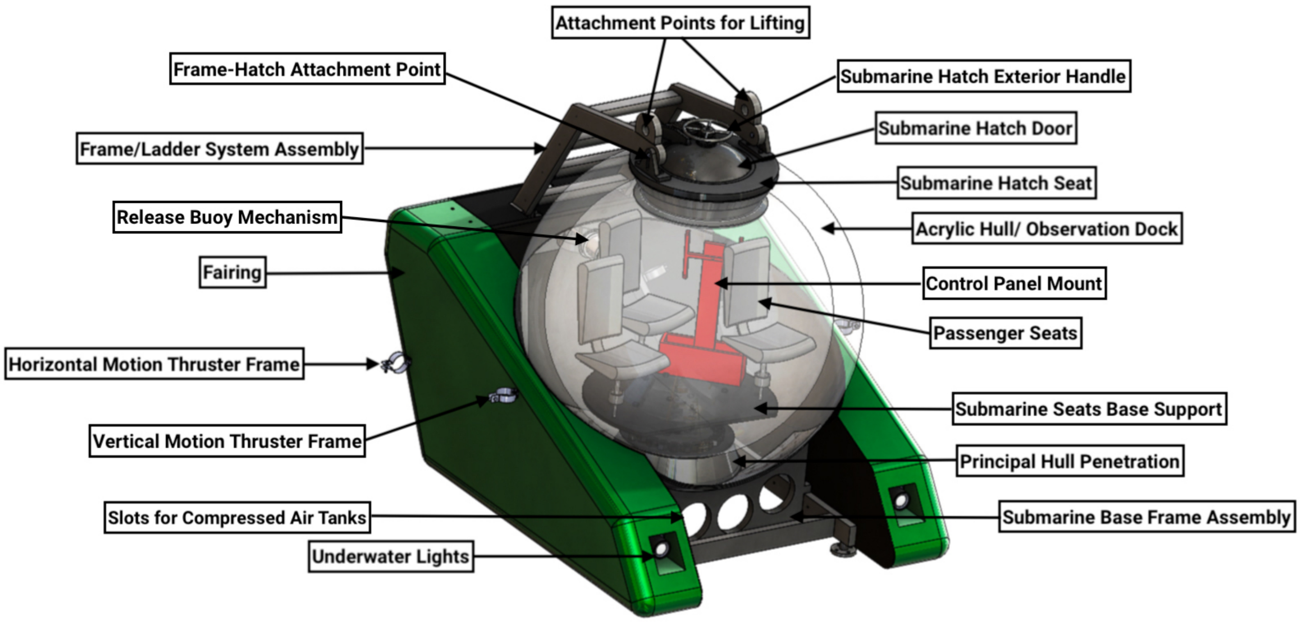

Figure 4: Submersible in Forward Facing Position

Acrylic Hull

The electrical components, the ventilation system and the drop weight shaft are situated within the bottom penetrator.

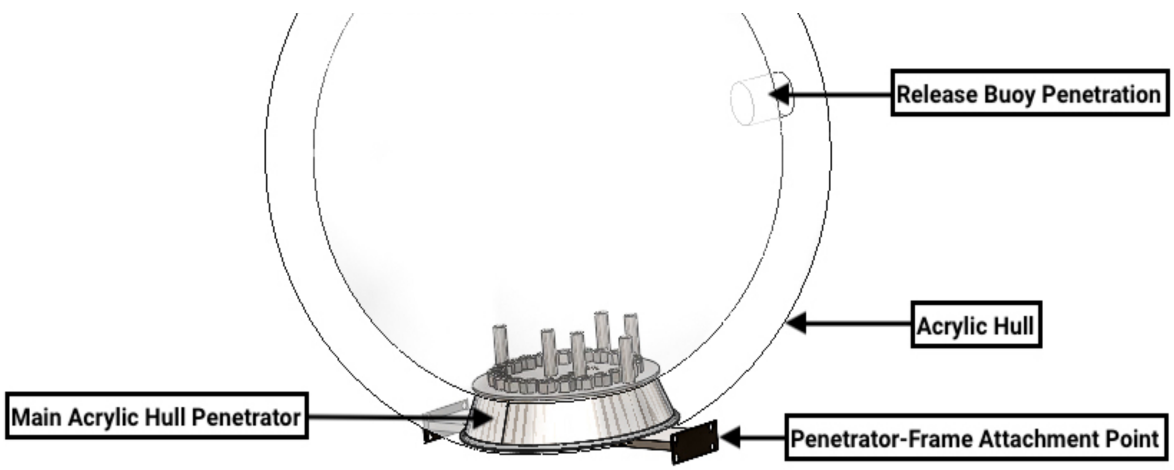

Figure 5: Isometric View of Acrylic Hull and Penetrations

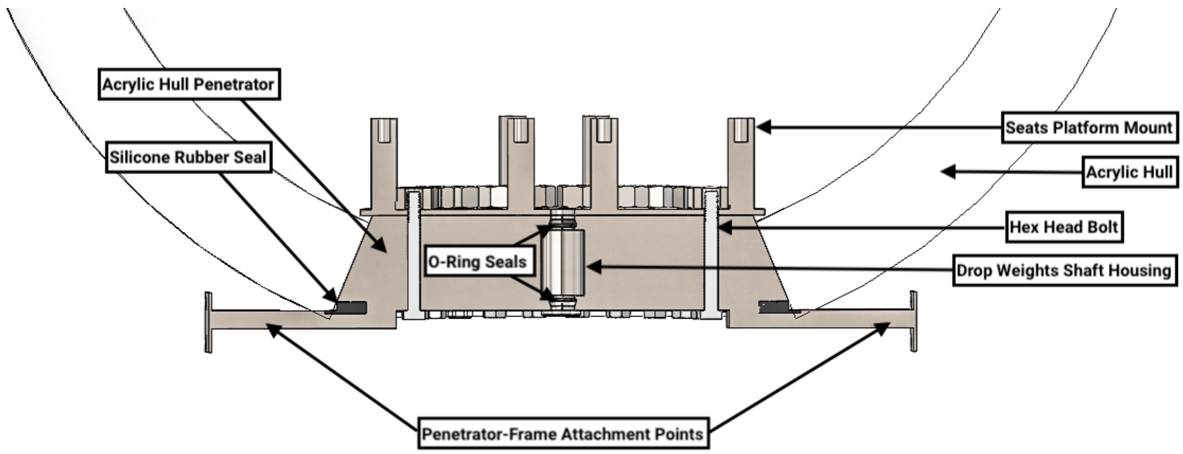

Figure 6: Cross-Sectional View of Main Acrylic Hull Penetrator

Frame

The frame of this submersible is made out of stainless steel, in order to be corrosion resistant, easy to manufacture and affordable. The bottom frame is lined with rubber surfaced support for the acrylic hull to avoid direct contact with the frame.

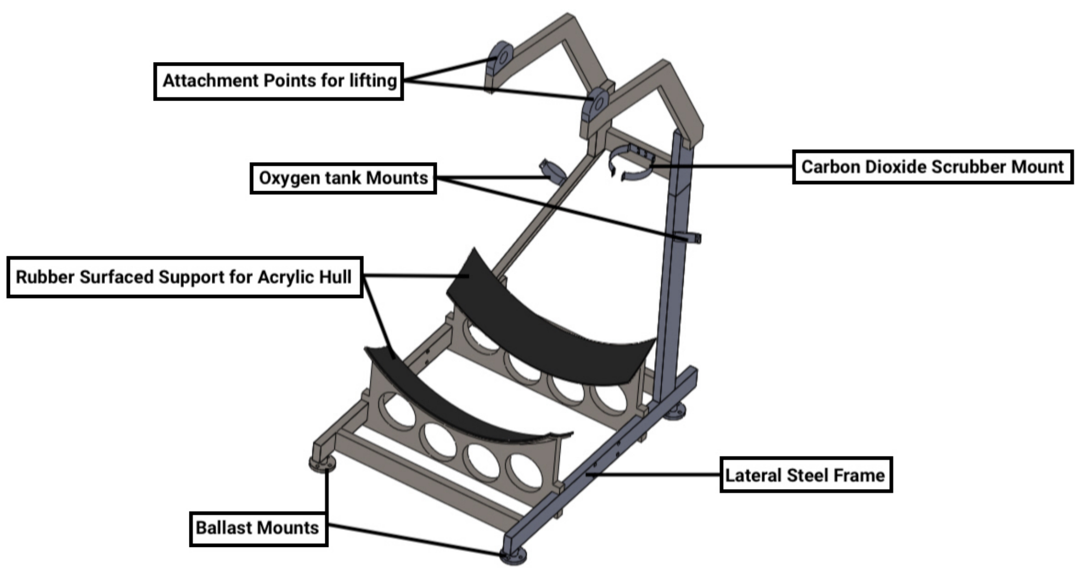

Figure 7: Isometric View of Frame Assembly

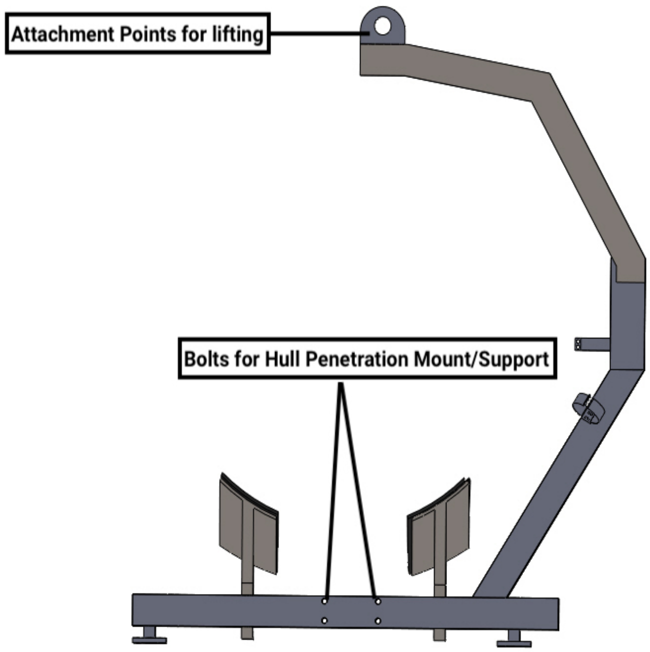

Figure 8: Side View of Frame Assembly

Hatch

The hatch has 3 main parts: the hatch door, the hatch seat and the locking mechanism. The hatch door comprises of a shell shaped body, with a cylinder bushing welded to the top. The cylinder bushing holds the principal shaft of the locking mechanism. An o-ring is mounted onto a machined groove on the hatch door and sealed with hatch seat when the door is closed. The hatch seat, which is conical in shape, is assembled with the hatch door with a hinge mechanism. A silicone rubber seal machined to the hatch seat serves as a seal for the hatch seat-hull assembly. At the bottom of the hatch seat, there is a flange which is fastened to the hatch seat. The principal shaft runs through the hatch seat at its closed state. The locking blocks mount pressure to a flange/o-ring assembly when the door handle is turned to a locked position. Inside the bushing, there is a dynamic seal and a thrust ball bearing. Whenever the passengers rotate the interior handle, the locking arm seat moves down, which in turn forces the end of the locking arm to move upward as a result of a lever linkage mechanism. This sequence of movements successfully mount pressure to the o-ring seal and locks the hatch door.

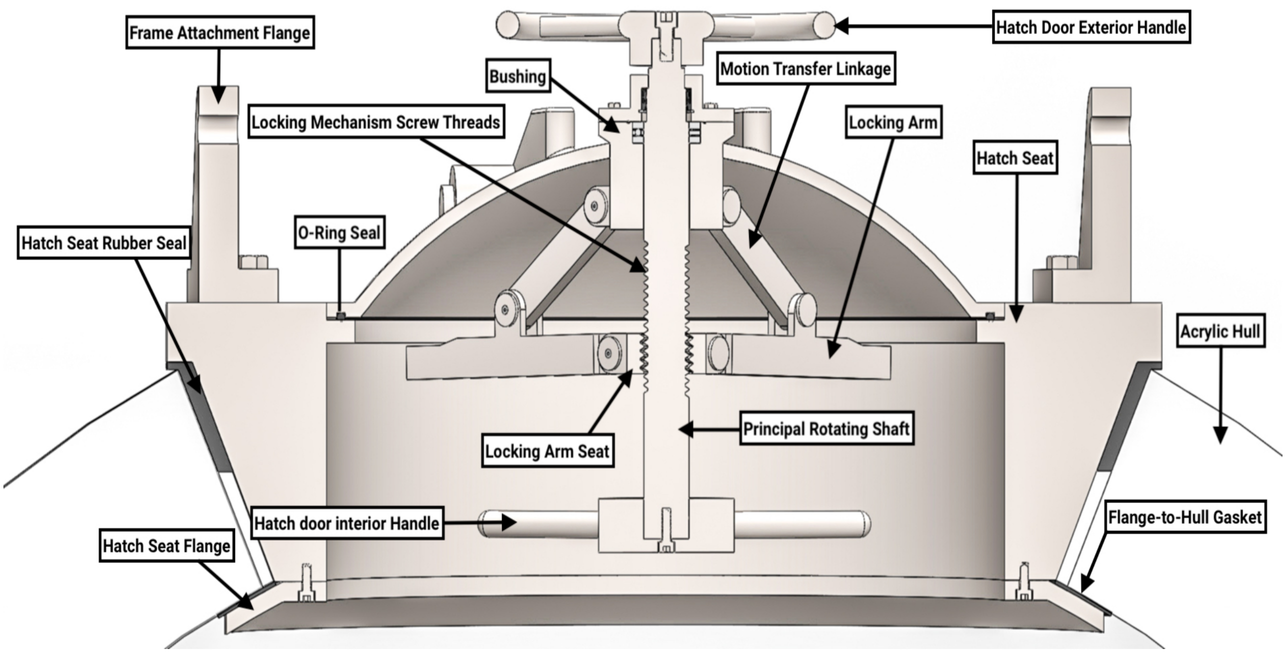

Figure 9: Cross-sectional View of Hatch

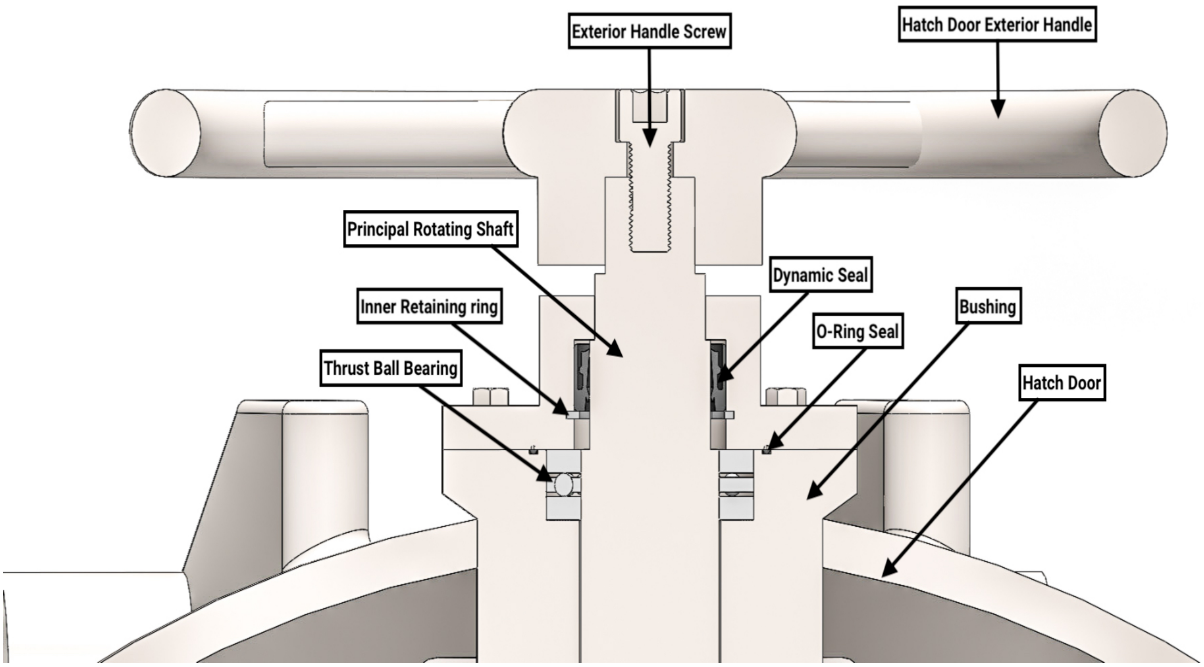

Figure 10: Cross-Sectional View of Hatch's Locking and Sealing Mechanism

Fairing

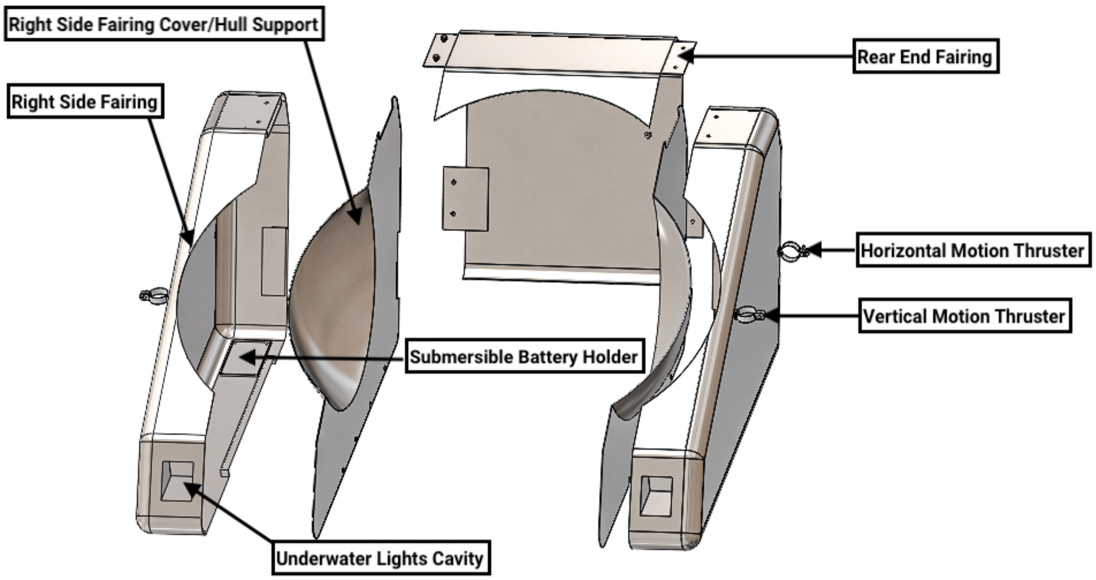

Figure 11: Exploded View of Fairing Assembly

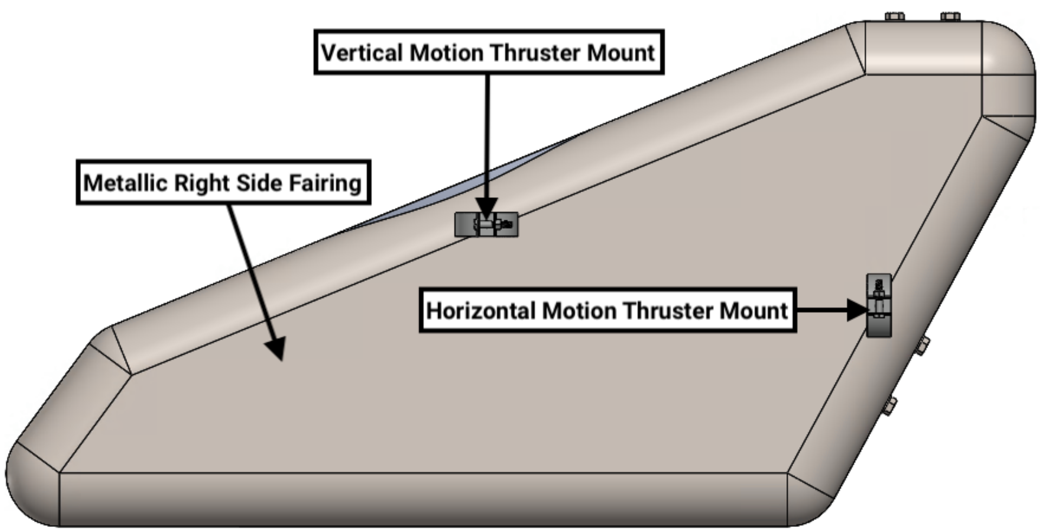

Figure 12: Side View of Right Side Fairing

Seats

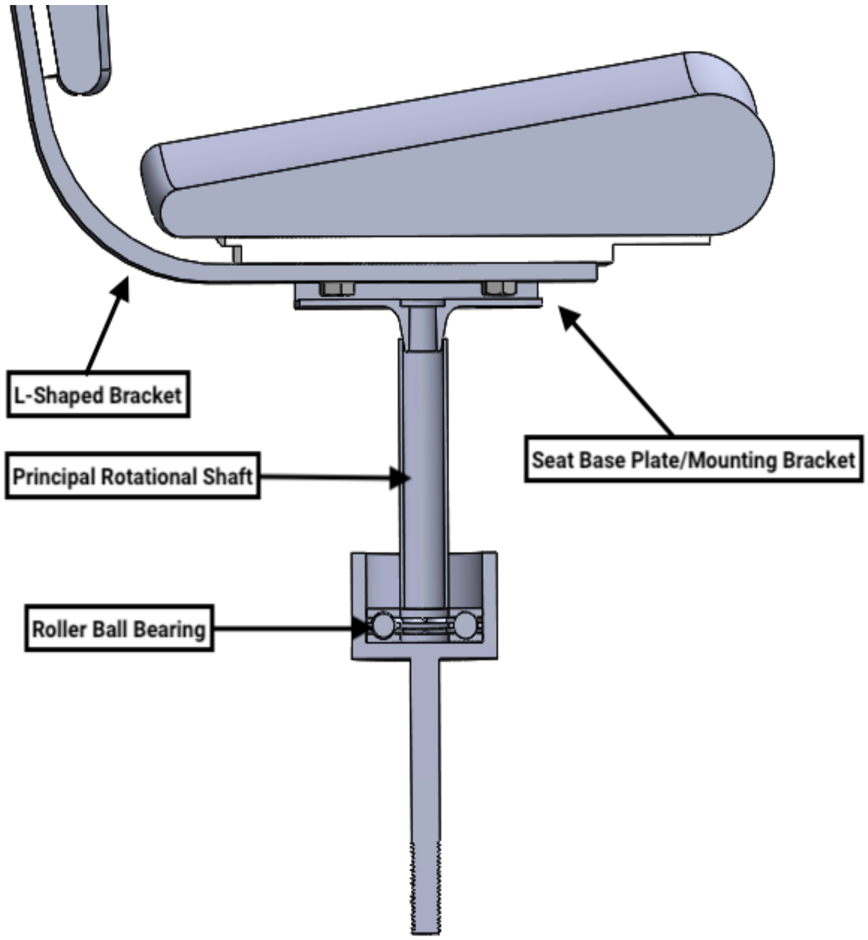

Figure 13: Cross-sectional View of Passenger Seat

Seating Assembly

The seating assembly is made up of two semi-circular plates mounted on top of a plate with cylindrical extrusions. The plate semi-circular plates are screwed into the platform cylindrical extrusions to keep the platform in place. The seats are singular mounted seats with threaded tips which are rotated into place on the seating platform.

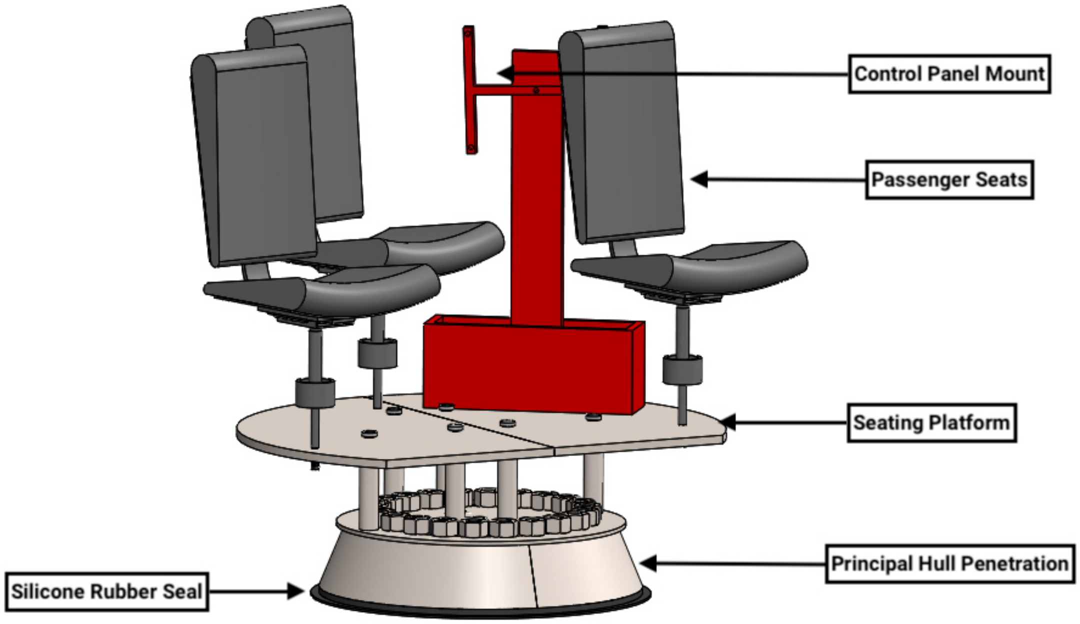

Figure 14: Isometric View of Seating Assembly

Underwater Lights

The underwater lights are two conical bulbs (Figure 15) mounted within the fairing at the anterior position of the submarine. The wires are fed through the fairing towards the battery. The lights are covered by a plastic light housing cover.

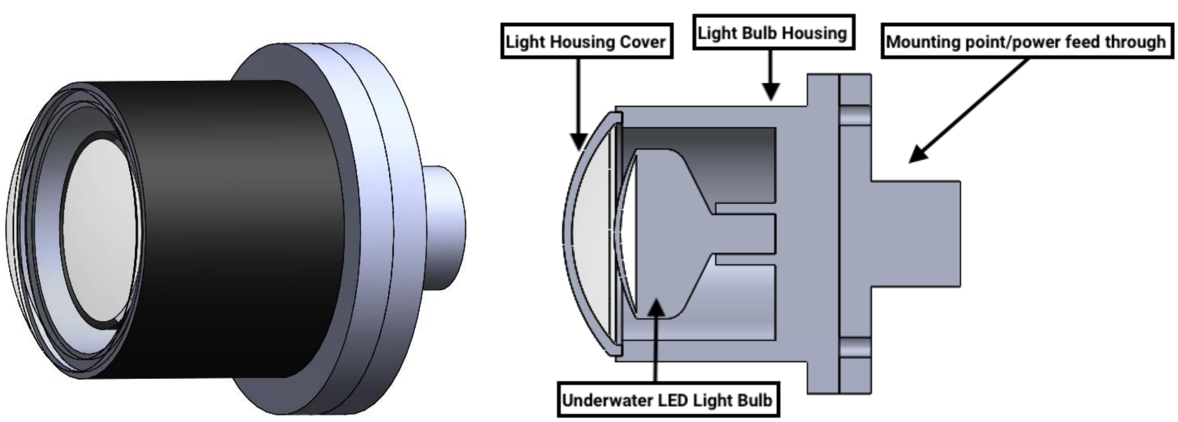

Figure 15: Cross-sectional View of underwater headlights

Hatch-Hull Connection

Mounting the submersible's hatch to the acrylic hull as seen in Figure 16 below, utilizes a flange system as well as a rubber gasket and silicone rubber seal in it's assembly. The silicone rubber seal is machined along the outer wall of the hatch seat to create a sealing pressure combined with the weight of the hatch assembly. The flange is attached to the hatch seat with the use of screws that run along the circumference of the flange. The main purpose of the flange is to provide a soft landing interface between the steel hatch seat and the acrylic hull. In addition, the flange serves as a means to mount pressure on the rubber gasket - in between the hatch seat and flange, in order to create an adequate sealing pressure.

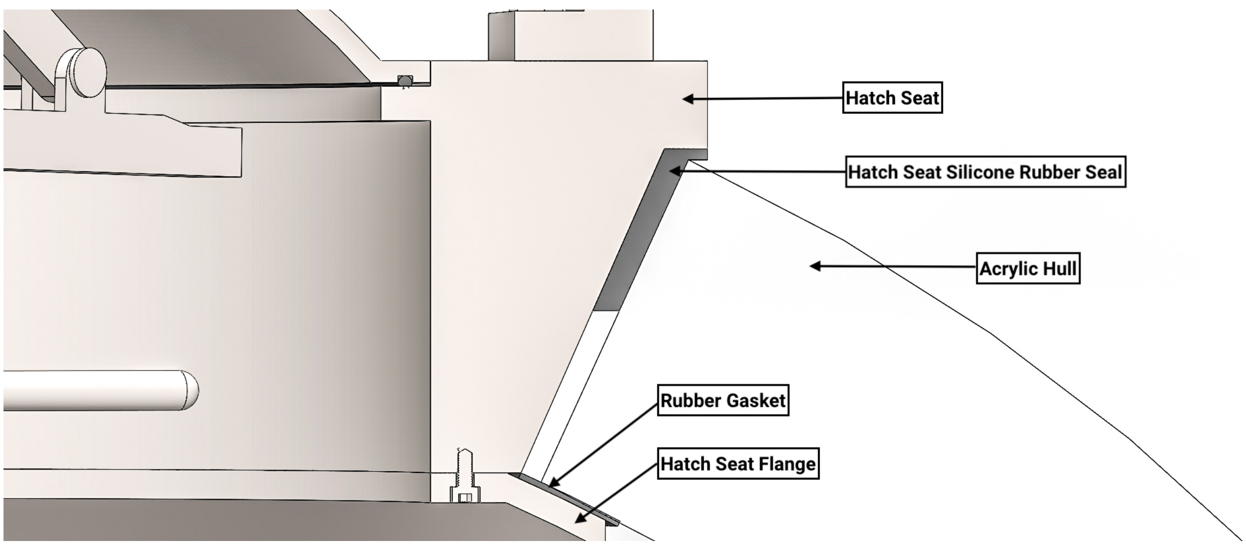

Figure 16: Cross-sectional View of Acrylic Hull to Hatch Seat Connection

Frame-Hatch Connection

The top section of the frame is equipped with a ladder system which eases access into the hatch. The frame is connected to the hatch by ears located on either side of the hatch seat. This assembly is fastened by bolts and nuts as seen in Figure 17.

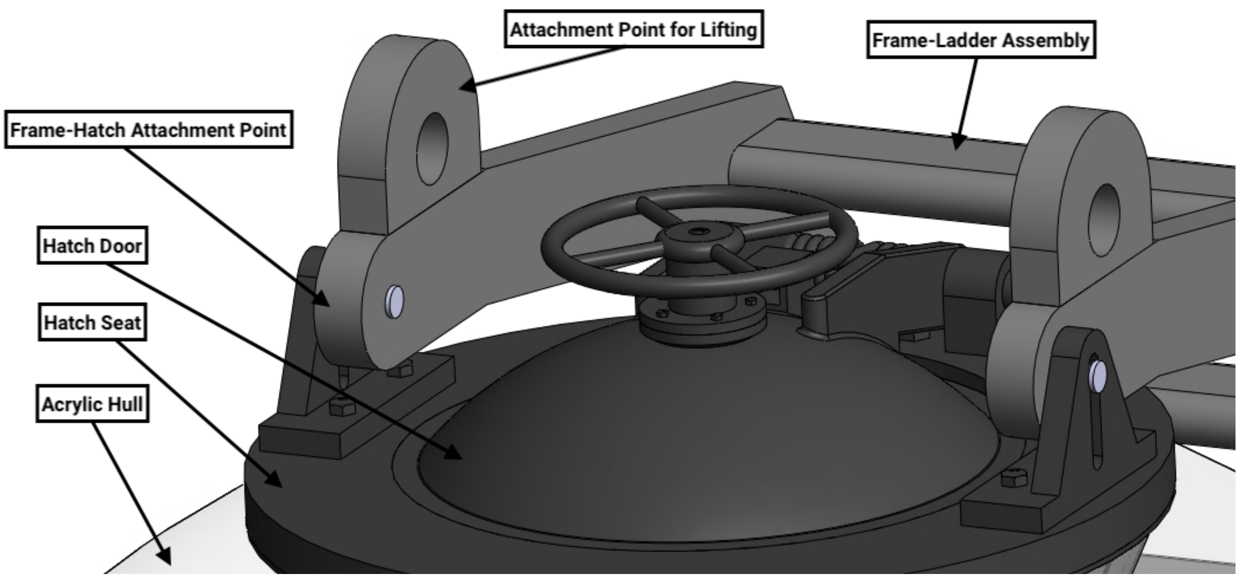

Figure 17: Frame to Hatch Assembly

Frame-Fairing Connection

Lateral beams that run along the sides of the fairing give rigidity to the entire structure. This assembly is fastened by hex head screws as seen in Figure 18.

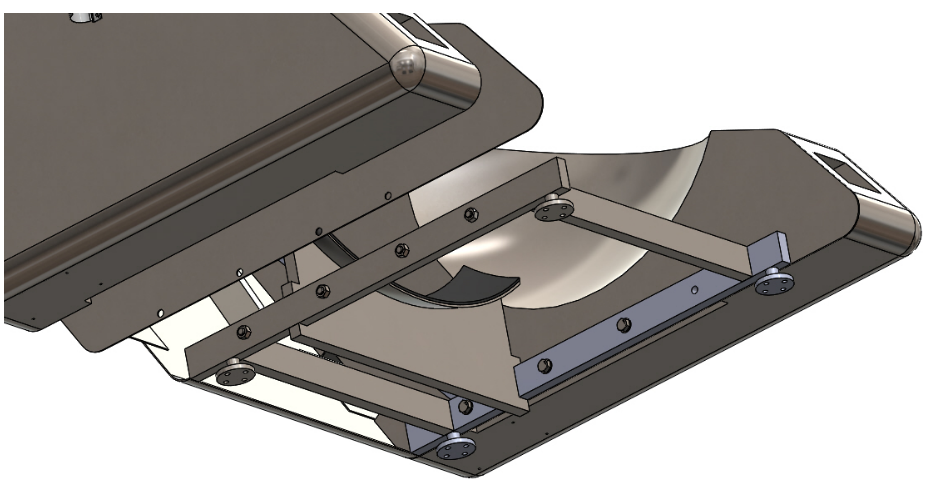

Figure 18: Frame-Fairing Assembly

Release Buoy

The release buoy is a scotch yoke operated release mechanism. A shaft is passed from the hull through a sealed feedthrough. The rotary motion of the shaft is converted to linear motion. This linear motion dislodges the pin from the marker buoy (Figure 19). The dislodged buoy is made of HDPE and floats to the surface as a result of buoyant force. The release buoy penetration is sealed by flanging the silicone rubber seal against the edge of the acrylic hull. The release buoy penetration is on the rear portion of the acrylic hull and is mounted on the fairing (Figure 20). The feedthrough shaft has two roller bearings to reduce the shaft deflection and has two o-rings in grooves on both sides of the feedthrough openings (Figure 21).

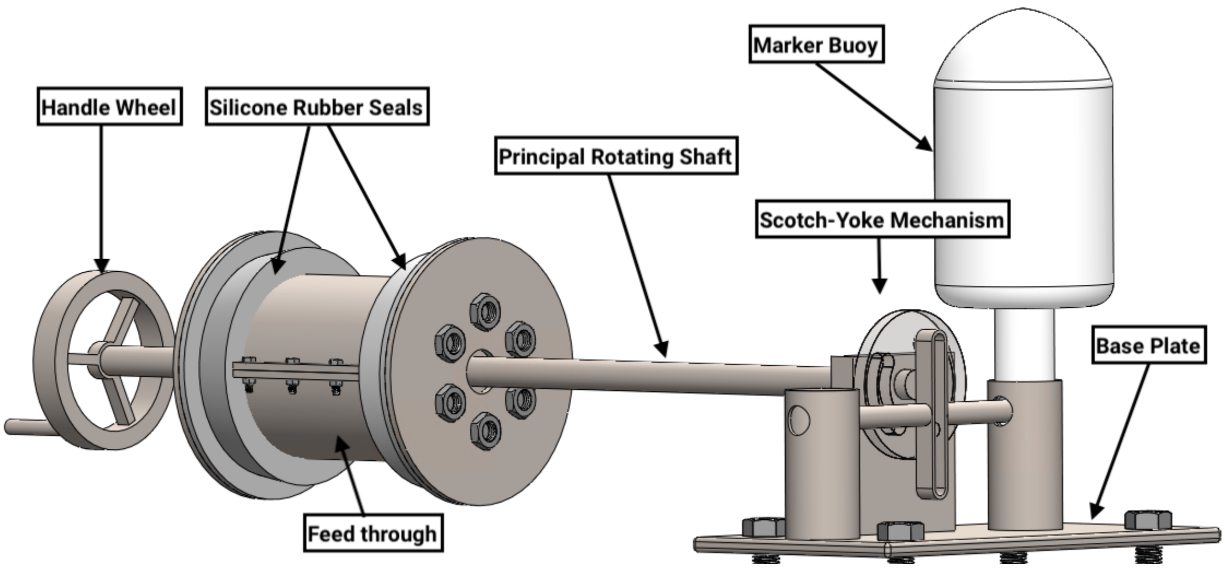

Figure 19: Release Buoy Mechanism

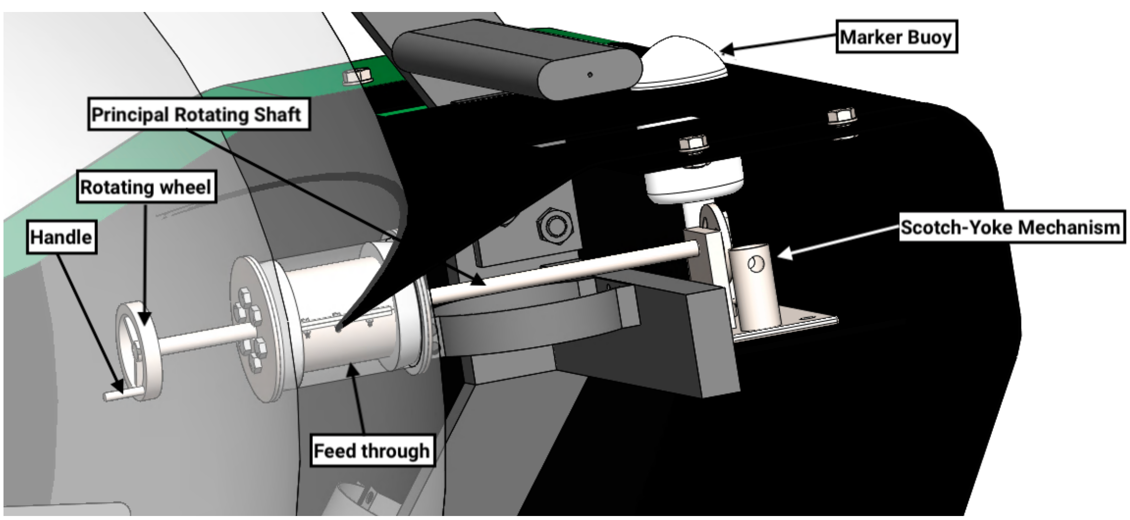

Figure 20: Release Buoy Interconnectivity

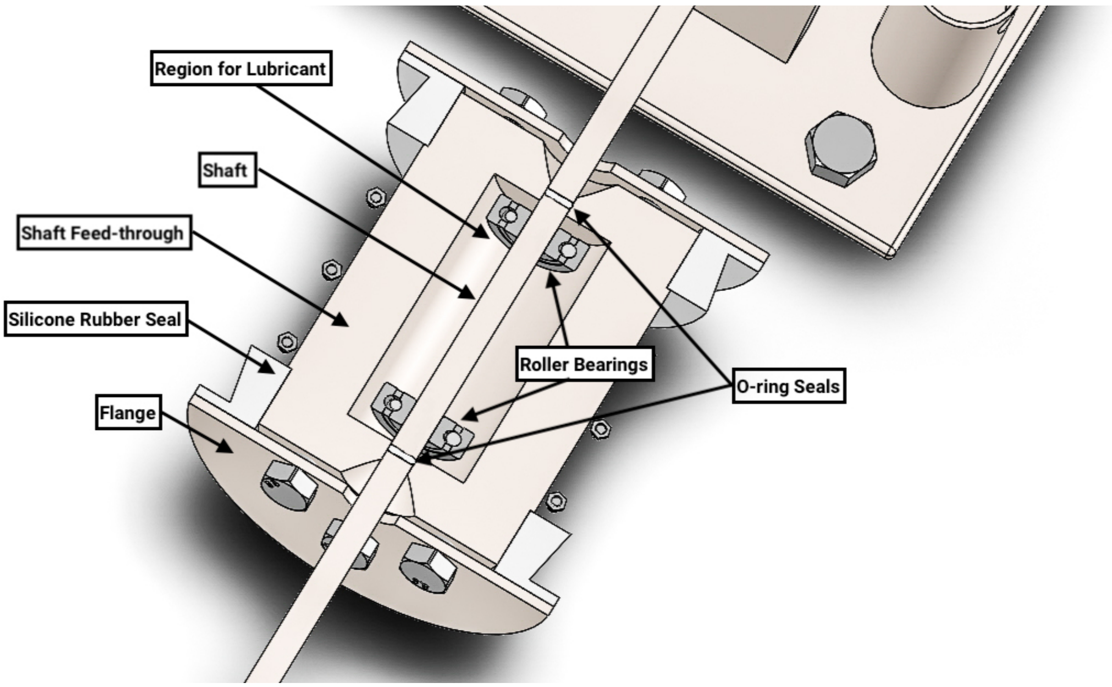

Figure 21: Cross section of the Release Buoy Feedthrough

2.2. Discussion on Interconnectivity

The ballast team shared a schematic of their desired connection points which we complied with. Their structure features 4 square platforms which we connect to.The ballast system is mounted directly below the frame of our submersible (Figure 22). The bottom section of the submersible's frame is designed to house the compressed air tanks directly above the ballasts, reducing the required piping length to empty the ballasts. The ballast group decided to design a chassis system instead of designing only the ballasts and the associate systems. Their decision reduces the maneuverability of our system, increases the drag and reduces our compactness. Our competitors, Triton, U-Boat worx and Ocean Deep incorporate the ballasts within the frame and covered in the fairing. The ballast group was responsible for providing a drop weight solution but did not follow through in the end. We were informed we would be passing a shaft through our hull to release the drop weights, the shaft and adequate sealing were designed in our bottom penetrator.

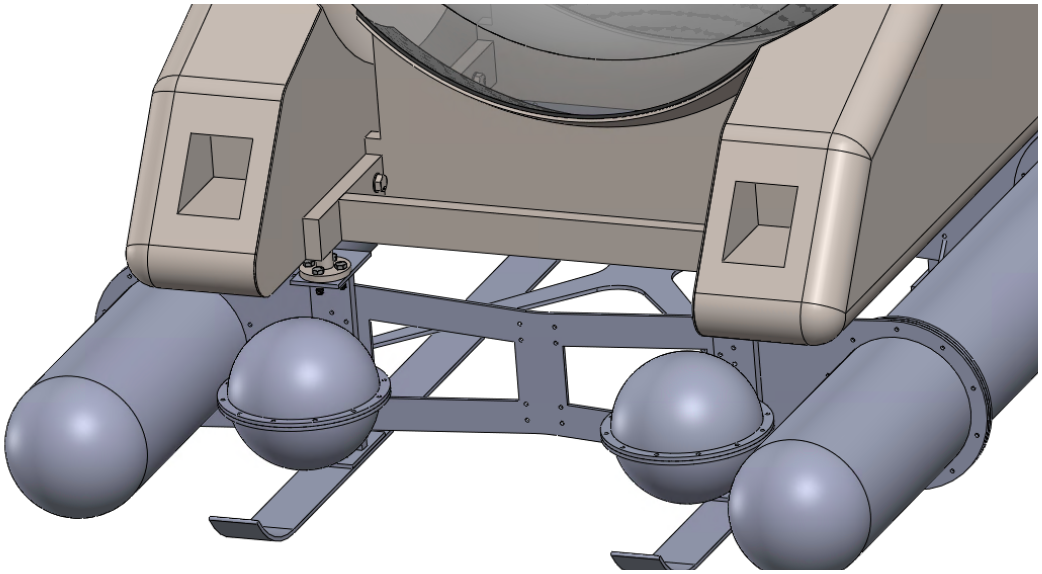

Figure 22: Isometric View of Ballast-Hull Assembly

Lateral support is provided by a frame design which features two metal beams that run across the sides of the submersible. The two beams are connected by steel reinforced frames upon which curved, rubber surfaced steel sheets are mounted in order to provide additional support and rigidity for the acrylic hull. The frame of this submersible also provides mounting points for key components such as the oxygen tank, carbon dioxide scrubber as well as the major penetration at the bottom of the acrylic hull. Ballasts mounts are located at the four bottom corners of the steel frame. The mounting points for the ballasts are in the form of pressure pipes that are fastened to each other by bolts and nuts.

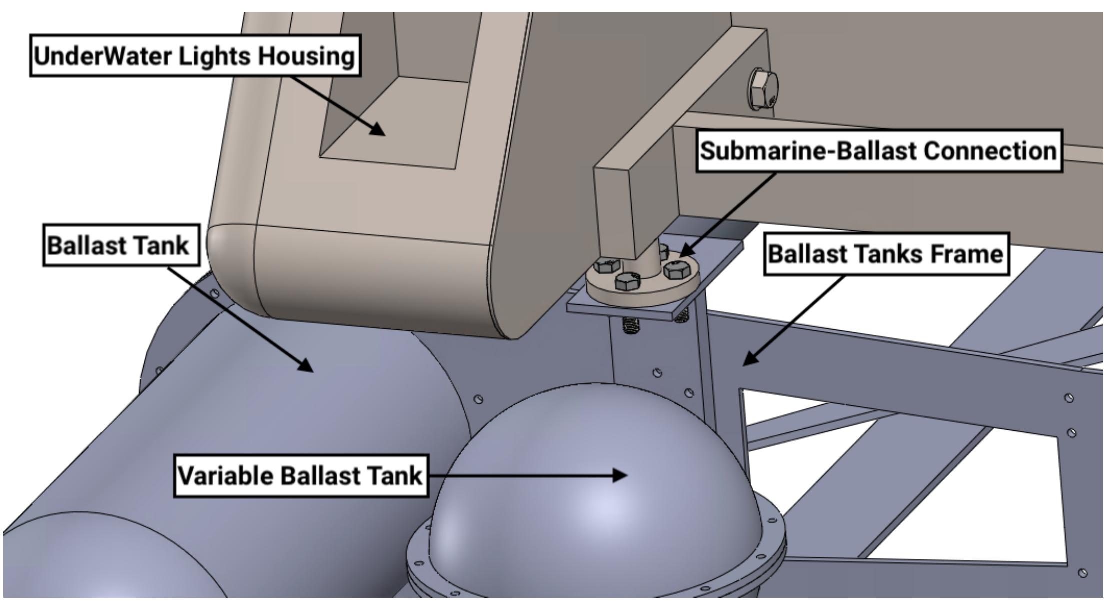

Figure 23: Ballast-Frame Assembly

3. Parameterization

3.1. Parameterization Outline

The parametrization of this submersible is done to optimize major components in order to meet the consumer's needs. The flow chart in Figure 24 summarizes the effect that various input parameters have on the overall design of this submersible. The consumer can alter 3 parameters namely: preferred dive depth, number of passengers and material selection. The effect of altering each of these parameters is highlighted below.
Changing of the depth, alters the amount of pressure being exerted on the submersible and the parameterization below describes the changes the pressure change causes. If the pressure increases, the hull shell becomes thicker as seen in the analysis report. The increased thickness, causes increased weight on the frame. The weight on the frame leads to forces and bending stresses which we computed to achieve the required thickness. Similar to the hull, the hatch is exposed to pressure forces which try to make it buckle. The increased pressures lead to increased thickness in the hatch door calculated based on stress and yield criterion.

We are parameterizing for the number of passengers from 1 to 3 passengers. The change in the number of occupants leads to the change in the inner diameter, changes from 1.3 to 1.7m inner diameter. Lastly, we are parameterizing the material of the frame and fairing material. The different metals have varying densities and yield strengths which change the submersible's overall weight.

Parameterized Components

- Hull Shell Thickness: We parameterized the hull thickness for depths between 330m and 1000m for various internal diameters.
- Frame Cross-sectional Area: With the variation in the hull mass, we parameterized for the adjustment in frame thickness to accommodate the load acting on the frame.
- Hatch Door Thickness and Spring Diameter: As the pressure acting on the hull varies, the hatch door thickness varies and consequently the necessary spring diameter to lift the hatch door varies.
- Seal Dimensions: The seals are mounted in grooves along the penetrators, the inner diameter of the seal varies with the outer diameter of the penetrator (release buoy and bottom penetrator).

- Access Mechanism/Penetrator: As the dimensions of the hull change according to the users input for a depth or number of occupants, the depth of the penetrator changes to fit the new hull thickness

3.2. High Level Parameterization (Main Design Code Flowchart)

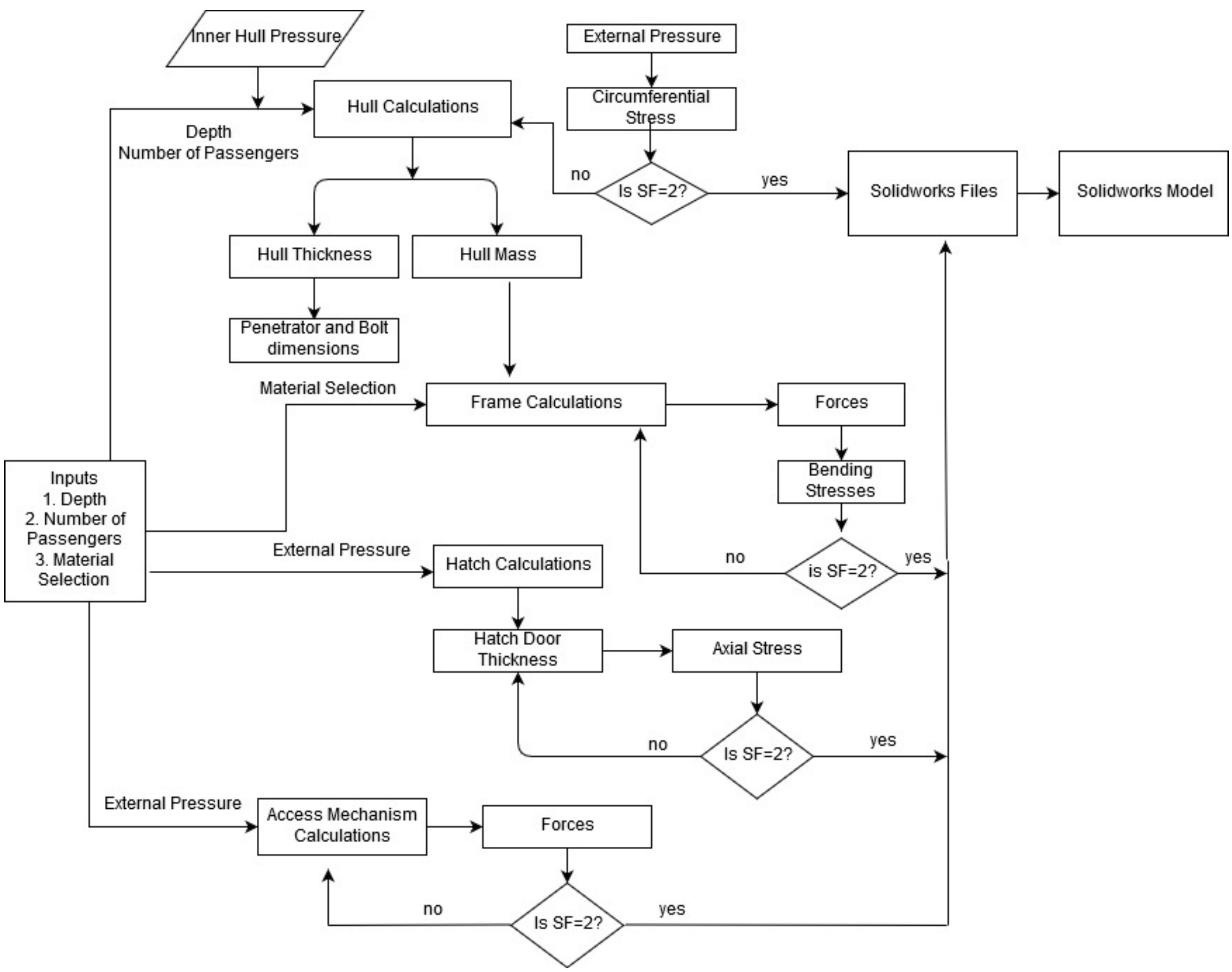

Figure 24: High Level Design Parameterization

3.3. Component Optimization and Discussion of Results

Table 1: Summary of Parameterized Parts

Assembly	Component Optimization Parameters	Type	Optimized Dimensions
Hull Shell	Hull Shell Thickness	Structural	3.45cm<t<17.8cm
Hatch	Hatch Door Thickness	Structural	0.4cm<t<1.1cm
Hatch	Spring Diameter	Structural	1.1cm< D<1.2cm
Frame	Cross-Sectional Area	Structural	$0.0026m^2<A<0.00645m^2$
Seating Platform Plate	Mount support length	Geometric	5cm<L<21cm
Seating Platform	Platform Diameter	Geometric	70cm<D<140cm
Fairing	Cross-Sectional Area	Geometric	$0.7m^2<A<1.9m^2$

The components which are parametrized are shown in Table 1 above. These are the components that change as a result of calculations, based on altering the parameters.

Hull shell

The component of the hull shell parametrically optimized is the shell thickness. For less pressure intensive depths, it would be more cost effective to reduce the amount of thickness on the hull, as well as make the system lighter. We parameterized for depths between 330 and 1000m and the hull thickness ranges from 3.45cm in the 330 m case and 17.8cm at 1000m deep. The 3.45cm thickness is difficult to design with, since most of our penetrators were designed for the thicker hull cases. The release buoy, being fully mechanical is affected significantly. The shaft length is reducing, the feedthrough has a channel for lubricant and has two bearings and seals on either side of the penetrator opening. A more complete solution would be to replace the scotch yoke mechanism with a system that is not affected by distance, like a hydraulic mechanism to dislodge the pin from the buoy. A similar problem is experienced for the hatch and the bottom penetrator. The hatch locking mechanisms became lower than desired, while the structures within the bottom penetrator had to be rescaled and re-arranged. The problem of low hanging locking mechanism was solved by doming of the hatch door.

Hatch

The thickness of the hatch door is optimized by determining the depth at which the manned submersible will operate. Using the formula for thin shell theory, an optimized range is acquired, like the hull, the hatch is parameterized for depths between 330 and 1000m and the thickness ranges from 0.4cm in the 330 m case and 1.1cm at 1000m deep. The difference between the two extremes is 7mm thickness. To save money, it would be feasible to operate with one hatch with a thickness of 1.1cm for all models at all depths. A similar occurrence is experienced with the hatch spring. The hatch thickness does not increase significantly, thus the spring thickness does not increase significantly either.

Seat Platform (Mount Support length**)**

This is the part is the stand on which the seats for the platform is based. Its final length is as a result of either the depth chosen or number of occupants selected. In both scenarios, the internal dimensions of the hull is subject to change, and in order to adequately accommodate for the required number of occupants, and give enough room for 3 people, the length of the support decreases.

Seat Platform (Platform Diameter**)**

The parameterization of the platform diameter is similar to that of the seat platform supports. Its final length is also a result of either the depth chosen or number of occupants selected. If a large depth is selected, the hull becomes larger, then the seat platform becomes larger too. In the case of the number of occupants chosen, a lower number of occupants chosen yields a smaller diameter and vice versa. The seat platform diameter then ranges from a minimum length of 70cm to a maximum length of 140cm

Fairing

The fairing covers the frame and houses some of the important parts within. The fairing is relative to the hull, such that any increase or decrease in the hull, leads to an increase or decrease in the frame and the fairing.

4. Discussion and Critical Review of Solution

The hull is a spherical acrylic hull with penetrations on the top and bottom for the hatch and component feedthrough respectively. There is a third penetration at the rear end of the submersible, for mounting the release buoy mechanism. Acrylic is the chosen material for the hull because of its lower mass in comparison to other options. The visibility that acrylic offers is also a merit of this chosen material. The submersible is parameterized for depth, number of occupants and material. The penetrations in the acrylic hull are cut at an angle to ensure that the seals are influenced by compressive forces from the conical hull surface. The change in depth, causes the hull's outer diameter to change. This change influences the diameter of the penetrations as well as the seal dimensions. The bottom penetrator is responsible for the passing of the ventilation system pipes, electricals and the drop weight shaft into the hull. Since the bottom penetrator serves as the main hull penetration, it is designed for easy accessibility and maintenance. In order to mount the principal penetrator, it will be fed into the submersible from the bottom of the hull and held in place by means of a machine while a worker connects the top plate to the bottom penetrator. The top plate is designed with 6 spherical extrusions which will be attached to the seating platform. The seating platform is composed of two semi-circular, metallic thick plates with a region cut off for accessibility and easy assembly and disassembly (Figure 14). The dimensions of the seating platform were selected to conform with the size of our hatch. All components of the hull would be brought into the hull through the hatch and all components of the hull reflect that. The hatch size is constant and we intend to use the same seating platform for the various hull sizes. To accomplish this, the length of the plate extrudes will be parameterized to increase or decrease in length. The platform serves as a means of mounting our seats and the control panel mount. The seats are singular screw on seats with the ability to rotate, while the control panel mount has a storage region for hardware and a mount for a monitor.

With the change in depth, the locking mechanisms and the seal mechanism in the hatch are altered. The change caused our locking mechanisms to be situated lower than necessary for smaller hull sizes. To counter this problem, we increased the doming on our hull to ensure the locking arms remain at the same level for all hull variations. For lower depths, we experience less pressure on our hatch door and thus we parameterized for the variation in the hatch thickness. The reduction in thickness, results in the reduction in spring diameter required to lift the hatch door. The hatch seat is flanged to the inner surface of the hull in order to keep the hatch seat in place. All parts of the hatch were designed with corrosion resistant materials.

The frame assembly is composed of metal beams, either aluminium, stainless steel or titanium, based on user input in the GUI . Within the curved frame structures are the mount slots for the compressed air tanks that will be attached to the ballast tanks. At the rear of the frame, a steel beam connects the left and right sides of the frame together. The CO_2 scrubber mount is situated in between the two side frames, at the rear of the submersible, while a mount is placed on either on the side frames. The ears that are used at the lifting points are in line with the centre of gravity of our submersible. We decided to place the lifting points on both sides of the top frame instead at four points along the submarine to ensure quicker deployments and recoveries.

The fairing assembly comprises two enclosed, hollow parts on the sides of the submarines that house the batteries and the lights. There are attachment points for the thrusters fastened to the sides at corresponding locations of the center of gravity and buoyancy in order to maintain functionality. It also possesses a large cavity that provides a substantial amount of buoyancy to our modelling. It is then closed off with the fairing cover and secured with bolts. The fairing design is aerodynamic in shape, minimizing drag.

A strategic combination of both custom silicone rubber seals and O-ring seals were implemented in the final design. The silicone rubber seals were placed at the interface between the penetrator and the edge of the hull penetration. The seal material is tough with a compressive yield of 30 MPa which proves its feasibility in the implementation in the final design.

Design Shortcomings are few but they exist. The bottom frame curvature, which the hull is supported on may be difficult to manufacture due to the geometry of the frame. The seating platform within the hull is a metal slab which we screw components into. The slab needs to be thick enough mount components on, but by increasing the thickness we increase the mass of the slab and the stress concentration on the bottom side of the hull. Extended periods of stress concentration could lead to failure of our hull.Earlier we discussed about the need to upgrade mechanisms to fully electrical or hydraulic. The mechanical components aren’t easily parameterized for changes in scenario. With the reduction in the shell thickness, the penetrators become too small to function at the designed dimensions.

5. References

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8. Oxygen Cylinder Sizes [Online]. Available: applied-inc.com/oxygen-cylinder-sizesandinfo. [Accessed Dec. 5th 2019].
9. Industry Liquid Air [Online]. Available: http://industry-airliquide.us/high-pressure-cylinders.

6. Appendices

A. Instructions for Installing and Running the GUI

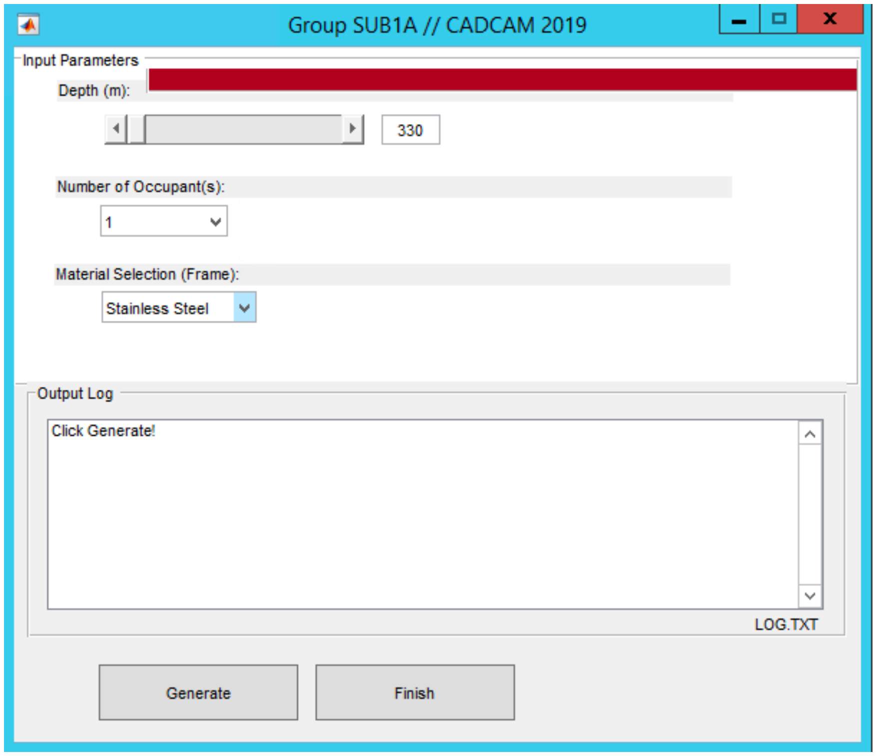

Figure 25: Screenshot of the GUI

Run GUI using MATLAB:

1. Navigate to Z:\2019\MCG4322A\Digital Files\SUB-1A\MATLAB
2. CLICK on the .m file named 'MAIN' TO open the GUI

The following is a description describing the GUI with reference to the figure shown above:

- Depth(m) : A slider used to select the user's preferred depth ranging from 330m to 1000m. The value is given on the right of the slider
- Number of occupants : A drop-down menu of the occupant capacities that the submersible will be occupied by.
- Material Selection (Frame) : A drop-down menu of different materials that can be chosen for the frame with different properties

- Generate(button) : This button runs the MatLab code and performs all the calculations within. The final Assembly in Solidworks can then be rebuilt for the new design based on the inputs listed above.
- Finish (button) : Closes the GUI and ends the session.
- Output Log (text box) : A log file generated by the MatLab code displaying useful information about the new design that includes the Center of Buoyancy

Run the final assembly using Solidworks:

1. Navigate to Z:\2019\MCG4322A\Digital Files\SUB-1A
2. Click on the '.asm' file named 'FINAL_SUB1A_ASSEMBLY''

B. Component Parameterization Flow Charts

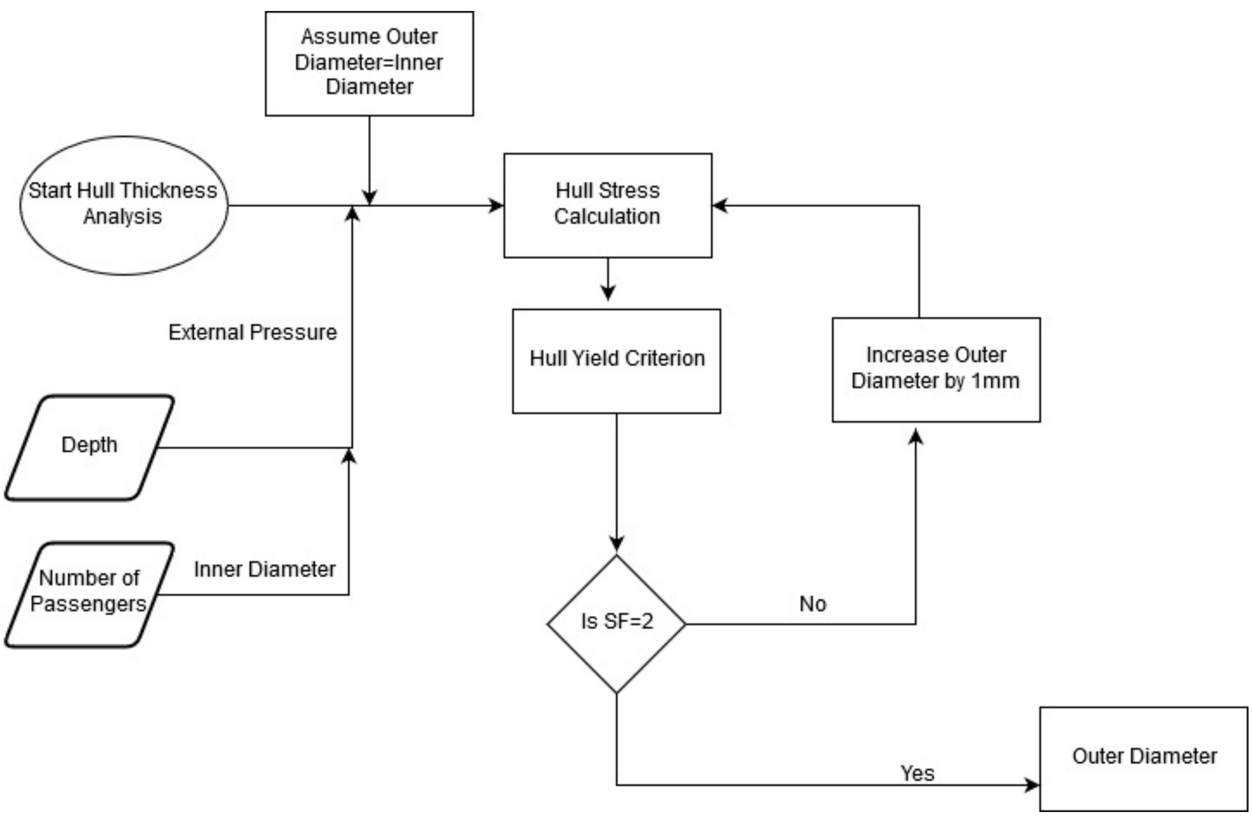

Figure 26:Hull Thickness Parameterization Flow Chart

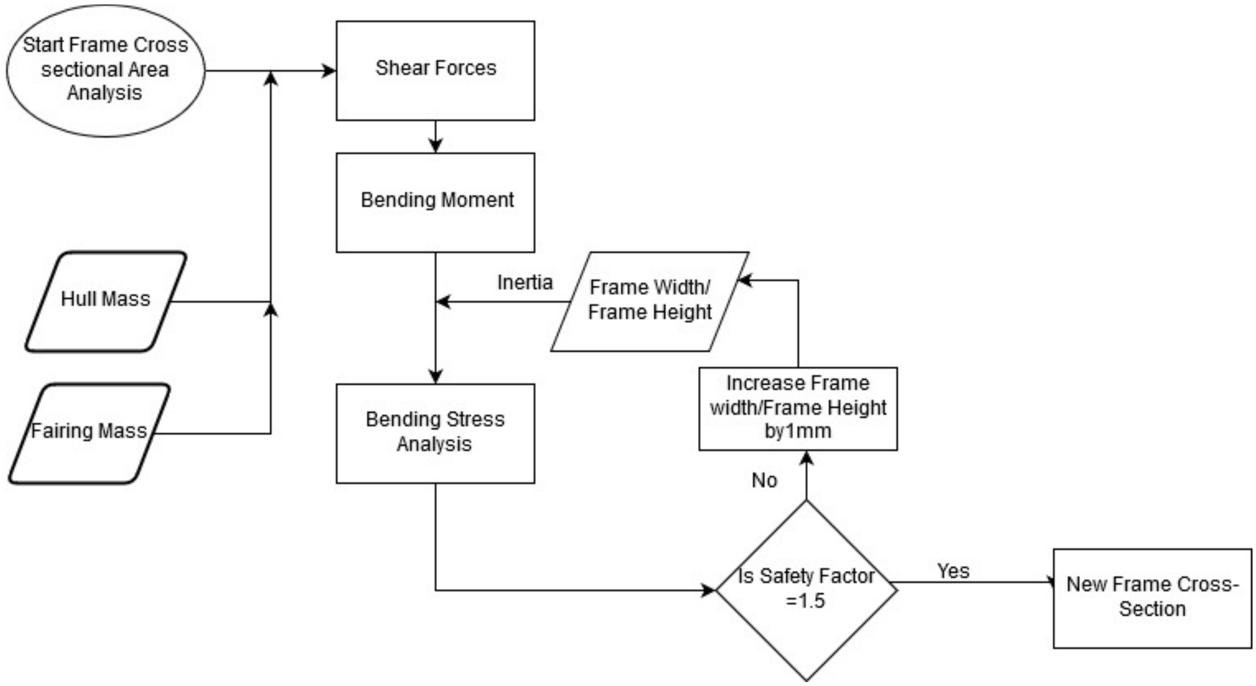

Figure 27: Frame Cross-Section Parameterization

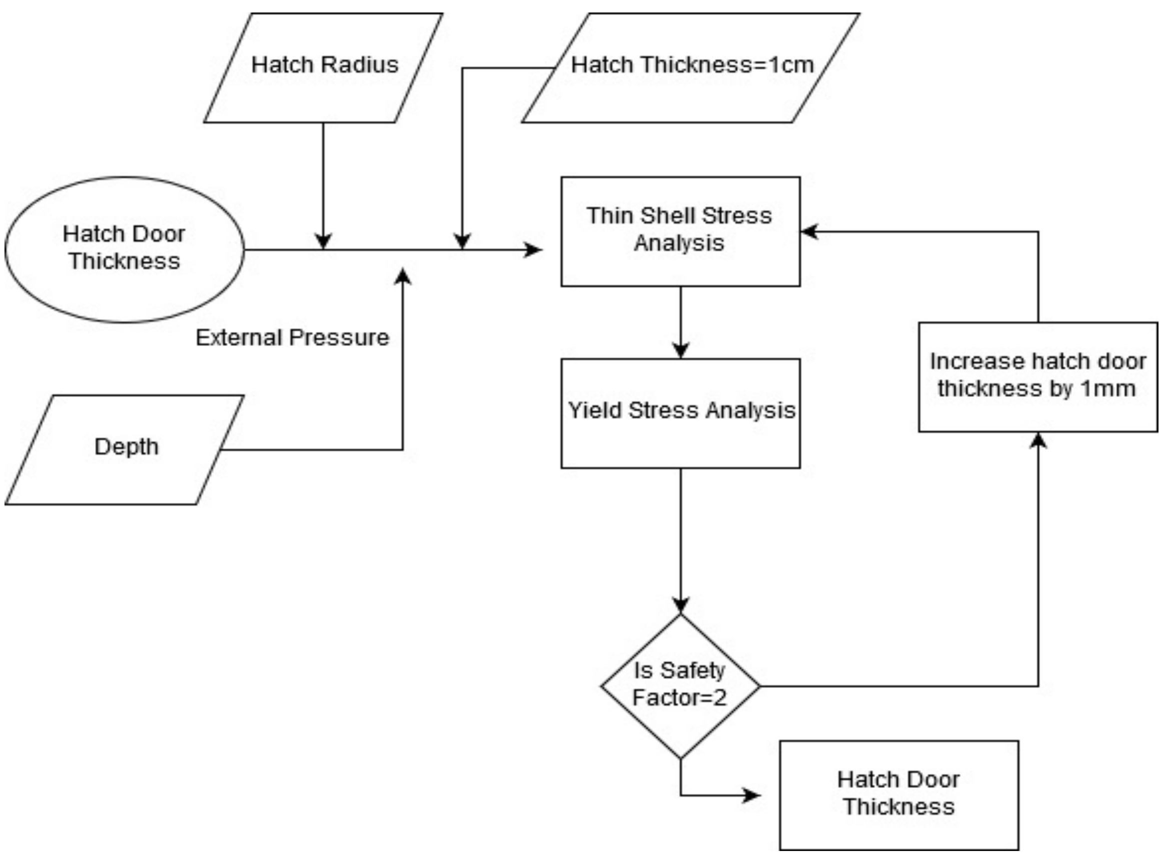

Figure 28: Hatch Door Thickness Parameterization

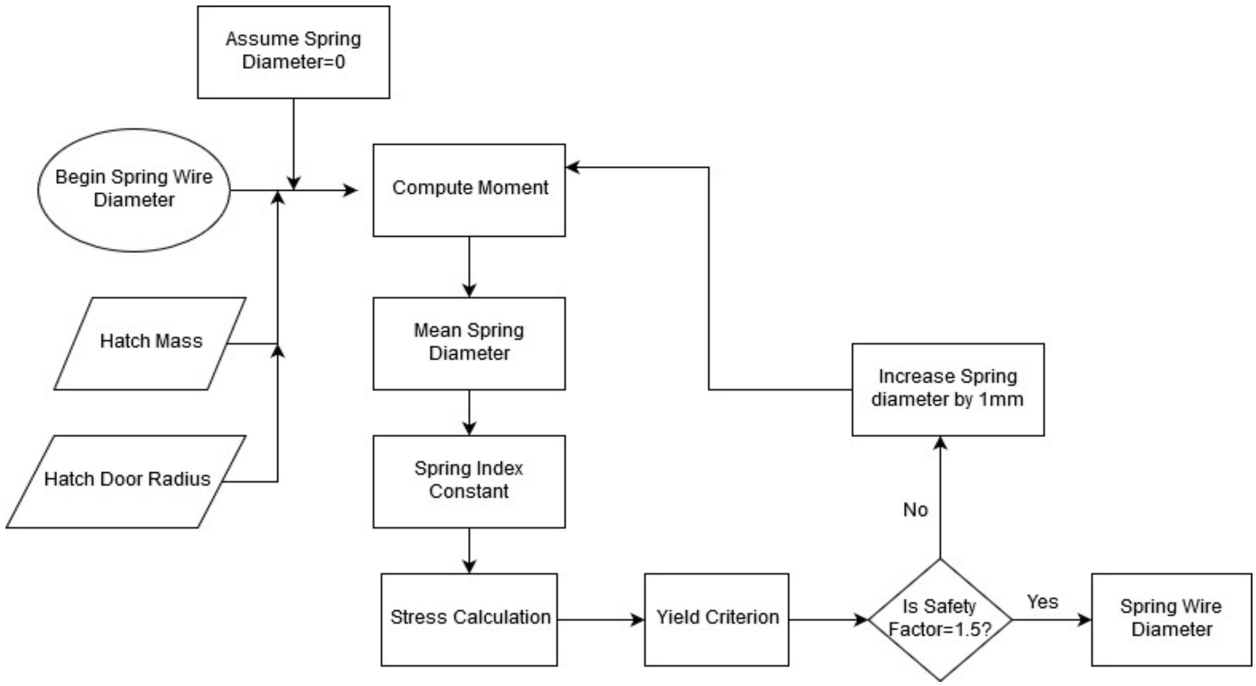

Figure 29: Hatch Spring parameterization Flowchart

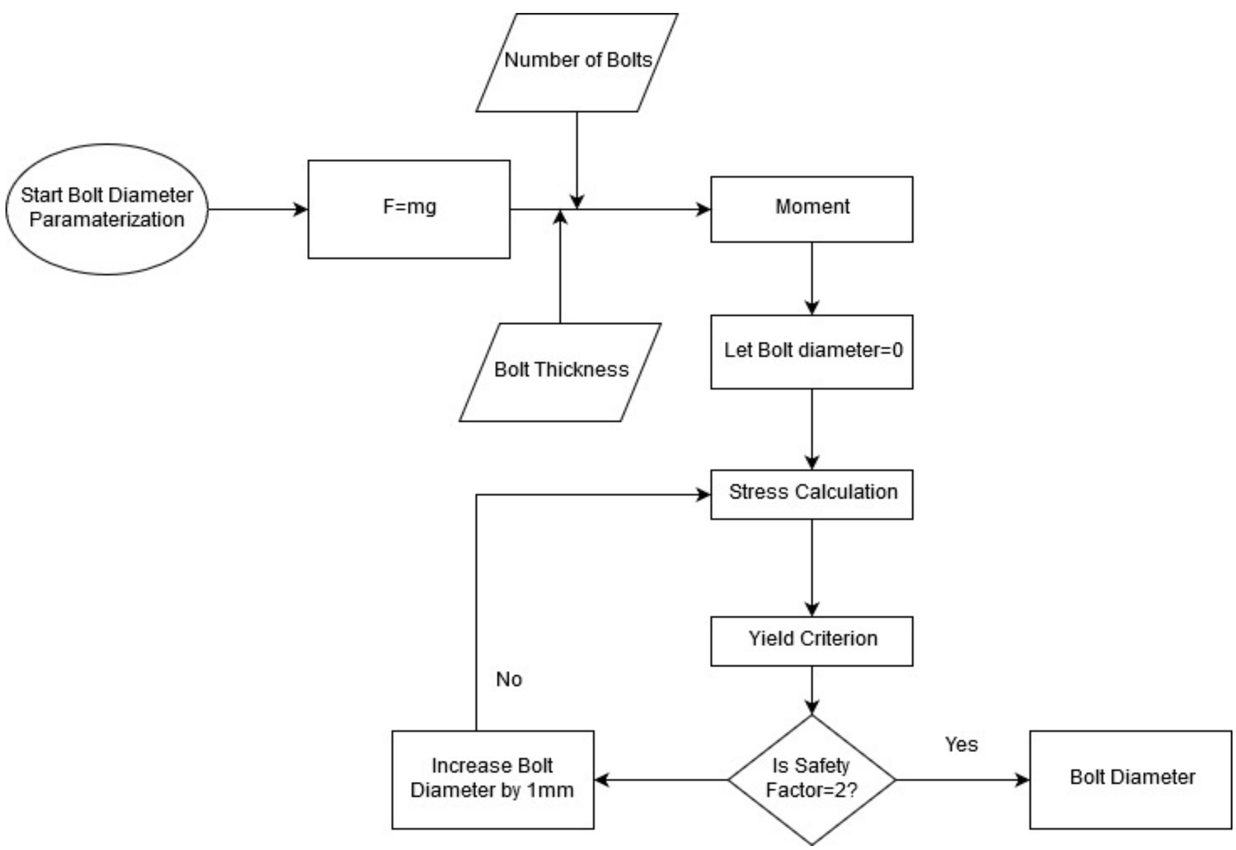

Figure 30: Bolt Diameter Parameterization

C. Design Code

```
%This function is the main "design" function.
function Design_code(depth,Occupants,Material)
  %Check if the user tries to run this file directly
  if ~exist('depth','var')
    cd Z:\SUB-1A\MATLAB\
    run Z:\SUB-1A\MATLAB\MAIN.m; %Run Main.m instead
    return
  end
%We deined Constants and Default Values for variables
  %default_outer_diameter = 1.7; %Units (m). Sets an initial diameter value.
  %default_inner_diameter = 1.7; %Units (m).
  [density_metal, yield_metal,ultimate_metal]=get_Frame_properties(Material);

  density_water=1029;  %The desity of sea water
 G. Elert, "Density of Seawater," Density of Seawater The Physics Factbook. [Online]. Available: https://hypertextbook.com/facts/2002/EdwardLaValley.shtml. [Accessed: 09-Nov-2019].

  density_acryllic=1180;
% The extruded Acrylic density Density of Selected Solids," Engineering ToolBox. [Online]. Available: https://www.engineeringtoolbox.com/density-solids-d_1265.html. [Accessed: 18-Nov-2019]
  strength_acryllic = 70e+06; %Units (Pa). Acrylic yield stress, Engineering Toolbox. [Online]. Available: https://www.engineeringtoolbox.com/young-modulus-d_417.html. [Accessed Oct. 9th,2019]

   inner_pressure= 0.1e+06; %Units (Pa)

  outer_pressure= calc_outer_pressure(depth);
```

```
%  Function to call call outer pressure as a result of inputted depth
    new_inner_diameter = calc_inner_diameter(Occupants);
%Function to calculate the new parameterized inner diameter

    default_outer_diameter = new_inner_diameter;

    %Function to call the new Outer Diameter
    new_outer_diameter = calc_outer_diameter(default_outer_diameter, strength_acryllic,
new_inner_diameter, inner_pressure, outer_pressure);
%A call to a subfunction to calculate the new shaft diameter.

    radius_hatch_door=0.275;


thickness_hatch_door=calc_hatch_door(outer_pressure,radius_hatch_door,yield_metal);    %Fu
nction to call hatch door thickness parameterization


    %Hull Properties
    Hull_Volume=((4/3)*(1/8))*pi*(new_outer_diameter^3-new_inner_diameter^3);
    Hull_Submerged_Volume=((4/3)*(1/8))*pi*(new_outer_diameter^3);
    Hull_Mass=Hull_Volume*density_acryllic;


    %Frame Dimensions
    Bottom_Frame_Height=0.22*(depth/1000);
    Bottom_Frame_Length=1.24*( new_outer_diameter / 2.02);
Side_Frame_Length=((2.25-0.37)+((1.5-0.45-0.15)^2+(0.42-
0.05)^2+0.6^2)^(1/2)+0.45)*( new_outer_diameter / 2.02);
```

```
Back_Frame_Length=1.24*( new_outer_diameter / 2.02)-(0.42*( new_outer_diameter / 2.02)-0.05)*2;
Top_Frame_Length=(0.95+1.265)*( new_outer_diameter / 2.02);

%Fairing Dimensions
Fairing_Back_Length=(0.5+0.3+((1.4-0.3)^2+0.6^2)^(1/2)+0.2);
Fairing__Cover_Side_Area=(1.4*2.4*( new_outer_diameter / 2.02)^2)/2;
Fairing_Side_Perimeter=0.5+0.3+((1.4-0.3)^2+0.6^2)^(1/2)+2.4+((2.4+0.6-0.5-2.1)^2+0.54^2)^(1/2)+((1.4-0.54)^2+2.1^2)^(1/2);

Fairing__Back_Volume=Fairing_Back_Length*(1.24*(new_outer_diameter/2.02)+(0.05*2))*0.005;

Fairing_Side_Total_Submerged_Volume=2*Fairing__Cover_Side_Area*(0.005*2+0.42*( new_outer_diameter / 2.02));

Fairing_Side_Total_Volume=(Fairing__Cover_Side_Area*0.005*2+Fairing_Side_Perimeter*0.42*( new_outer_diameter / 2.02)*0.005);
Fairing_Total_Volume=2*Fairing_Side_Total_Volume+Fairing__Back_Volume;

Fairing_Total_Submerged_Volume=2*Fairing_Side_Total_Submerged_Volume+Fairing__Back_Volume;
Fairing_Mass=Fairing_Total_Volume*density_metal;

Battery_Mass=220;
Hatch_Mass=(40.5938*(thickness_hatch_door/0.01)+419.58315)*(yield_metal/290e+06);
```

```
[platform_support_height,platform_support_diameter,platform_seating_mass,second_seat,third_seat]=calc_platform_dim(Occupants);

 penetrator_Total_mass=800*(new_outer_diameter-new_inner_diameter)/(2.05-1.7);


   %Function to parameterize the required oxygen by number of occupants
   [oxygen_tank_mass,oxygen_tank_submerged_volume]=calc_oxygen_tank_mass(Occupants);

   %Function to Parameterize the mass of compressed air necessary with  depth rating
   [compressed_air_mass,compressed_air_dia]=calc_compressed_air(depth);
   compressed_air_height=1.2954;

compressed_air_submerged_volume=4*(pi/4)*compressed_air_dia^2*compressed_air_height;

   empty_ballast_mass=800*(depth/1000);


   %Total System Mass without the frame

Total_Mass_without_frame=Hull_Mass+Fairing_Mass+Battery_Mass+Hatch_Mass+oxygen_tank_mass+compressed_air_mass+penetrator_Total_mass+platform_seating_mass;


   %Moment
   x=(1.265/2)*( new_outer_diameter / 2.02)+(0.1/2);

   XS_width=0.05;
```

```
%Function to evaluate the parameterized frame dimensions and
%properties.

[new_XS_width,new_XS_height,Total_Mass_no_ballast_dropweight,Frame_Total_Volume]=cal
c_XS_height(x,XS_width,Total_Mass_without_frame,density_metal,yield_metal,Bottom_Frame
_Length,Side_Frame_Length,Back_Frame_Length,Top_Frame_Length);


%Buoyancy Evaluation

Total_Submerged_Volume_no_ballast_dropweight=Hull_Submerged_Volume+Frame_Total_Vo
lume+Fairing_Total_Submerged_Volume+oxygen_tank_submerged_volume+compressed_air_s
ubmerged_volume;

Total_Submerged_Mass_no_ballast_dropweight=Total_Submerged_Volume_no_ballast_dropw
eight*density_water;

dropweight=Total_Submerged_Mass_no_ballast_dropweight-
Total_Mass_no_ballast_dropweight-empty_ballast_mass+200;

Total_Mass=Total_Mass_no_ballast_dropweight+empty_ballast_mass+dropweight;
Total_submerged_Mass=Total_Submerged_Mass_no_ballast_dropweight+2200;

Force_Gravity=Total_Mass*9.81;
Force_Buoyancy=Total_submerged_Mass*9.81;


%Fairing to Frame Bolting Parameterization
fairingtoframe_num_bolt=4;
```

```
shear_bolt_dia=calc_shear_bolt_dia(Fairing_Mass,yield_metal,fairingtoframe_num_bolt,
new_XS_width);
   fairingtoframe_bolt_dia=shear_bolt_dia;

   %Frame to Frame Bolting Parameterization
   frametoframe_num_bolt=2;
   Top_Frame_Volume=Top_Frame_Length*new_XS_height*new_XS_width;
   Top_Frame_Mass=Top_Frame_Volume*density_metal;
   Mass_joint=(Total_Mass-Top_Frame_Mass)/2;
   shear_bolt_dia=calc_shear_bolt_dia(Mass_joint,yield_metal,frametoframe_num_bolt,
new_XS_width);
   frametoframe_bolt_dia=shear_bolt_dia;

   %Hatch Spring Relations
   mass_hatch_door=40.5938*(thickness_hatch_door/0.01)+26.6957;
   radius_hatchdoor_to_spring=0.365;
   rod_dia=0.040;
   num_spring=2;
  ultimate_spring=1350e06; %steel ASTM A232 Text:R. C. Juvinall, K. M. Marshek, Fundamentals
of Machine Component Design, Wiley (2019).

   %Function to call Spring Wire Diameter
  spring_wire_dia=calc_spring_wire_dia(mass_hatch_door,radius_hatchdoor_to_spring, rod_dia,
ultimate_spring,num_spring);

   Mass=300/2+26.88/2;
   num_bolt=1;
   shear_bolt_dia=calc_shear_bolt_dia(Mass,yield_metal,num_bolt, XS_width);
```

```
ladder_bolt_dia=shear_bolt_dia;




%Declaring text files to be modified
%Files
log_file = 'Z:\\SUB-1A\\Log\\SUB-1A_LOG.TXT';
Hull_file = 'Z:\\SUB-1A\\SolidWorks\\Equations\\Hull.txt';
Frame_file = 'Z:\\SUB-1A\\SolidWorks\\Equations\\Frame.txt';
Fairing_file= 'Z:\\SUB-1A\\SolidWorks\\Equations\\Fairing.txt';
Hatch_file='Z:\\SUB-1A\\SolidWorks\\Equations\\Hatch.txt';
Penetrator_file='Z:\\SUB-1A\\SolidWorks\\Equations\\Penetrator.txt';

    %Write the log file
fid = fopen(log_file,'w+t');
fprintf(fid,strcat('depth =',32,num2str(depth),' (m).\n'));
    fprintf(fid,'***Hull Design***\n');
fprintf(fid,strcat('The Hull is made of acrylic.\n'));
fprintf(fid,strcat('Outer diameter =',32,num2str(new_outer_diameter),' (m). \n'));
fprintf(fid,strcat('Inner diameter =',32,num2str(new_inner_diameter),' (m). \n'));
fprintf(fid,'\n');
fprintf(fid,'\n');
fprintf(fid,'\n');
fprintf(fid,strcat('The Total Mass is =',32,num2str(Total_Mass),' (kg). \n'));
    fclose(fid);

    %Equation Files Linked to SolidWorks
%Hull File
fid = fopen(Hull_file,'w+t');
```

```
fprintf(fid,strcat('"Hull OD"=',num2str(new_outer_diameter),'\n'));
fprintf(fid,strcat('"Hull ID"=',num2str(new_inner_diameter),'\n'));
fclose(fid);
%Hatch File
fid = fopen(Hatch_file,'w+t');
fprintf(fid,strcat('"Hull OD"=',num2str(new_outer_diameter),'\n'));
fprintf(fid,strcat('"Hull ID"=',num2str(new_inner_diameter),'\n'));
fprintf(fid,strcat('"Hatch Door Thickness"=',num2str(thickness_hatch_door),'\n'));
fprintf(fid,strcat('"spring wire diameter"=',num2str(spring_wire_dia),'\n'));
fclose(fid);


%Frame File
fid = fopen(Frame_file,'w+t');
fprintf(fid,strcat('"Hull OD"=',num2str(new_outer_diameter),'\n'));
fprintf(fid,strcat('"Bottom Frame H"=',num2str(Bottom_Frame_Height ),'\n'));
fprintf(fid,strcat('"Bottom Frame L"=',num2str(Bottom_Frame_Length ),'\n'));
fprintf(fid,strcat('"XS height"=',num2str(new_XS_height ),'\n'));
fprintf(fid,strcat('"XS width"=',num2str(new_XS_width ),'\n'));
fprintf(fid,strcat('"Fairing to Frame Bolt Diameter"=',num2str(fairingtoframe_bolt_dia ),'\n'));
fprintf(fid,strcat('"Frame to Frame Bolt Diameter"=',num2str(frametoframe_bolt_dia ),'\n'));
fprintf(fid,strcat('"Compressed air diameter"=',num2str(compressed_air_dia),'\n'));
fprintf(fid,strcat('"Ladder bolt diameter"=',num2str(ladder_bolt_dia),'\n'));
fclose(fid);



%Fairing File
fid = fopen(Fairing_file,'w+t');
```

```
    fprintf(fid,strcat('"Hull OD"=',num2str(new_outer_diameter),'\n'));
    fprintf(fid,strcat('"Bottom Frame H"=',num2str(Bottom_Frame_Height ),'\n'));
    fprintf(fid,strcat('"XS height"=',num2str(new_XS_height ),'\n'));
    fprintf(fid,strcat('"XS width"=',num2str(new_XS_width ),'\n'));
    fprintf(fid,strcat('"Fairing to Frame Bolt Diameter"=',num2str(fairingtoframe_bolt_dia ),'\n'));
    fclose(fid);

    %Penetrator File
    fid = fopen(Penetrator_file,'w+t');
    fprintf(fid,strcat('"Hull OD"=',num2str(new_outer_diameter),'\n'));
    fprintf(fid,strcat('"Hull ID"=',num2str(new_inner_diameter),'\n'));
    fprintf(fid,strcat('"Number of Occupants"=',num2str(Occupants),'\n'));
    fprintf(fid,strcat('"Platform Height"=',num2str(platform_support_height),'\n'));
    fprintf(fid,strcat('"Platform Diameter"=',num2str(platform_support_diameter),'\n'));
    fprintf(fid,strcat('"second seat"=',num2str(second_seat),'\n'));
    fprintf(fid,strcat('"third seat"=',num2str(third_seat),'\n'));
    fclose(fid);


end

%Frame Material Parameterization
function [density_metal, yield_metal,ultimate_metal]=get_Frame_properties(Material)
    if Material=="Stainless Steel" %Stainless Steel 416
        yield_metal=290e+06;        %“416 Stainless Steel UNS S41600,” Ulbrich. [Online]. Available:
https://www.ulbrich.com/alloys/416-stainless-steel-uns-s41600/. [Accessed: 16-Nov-2019].
        ultimate_metal=580e+06;
        density_metal=7750;
```

```
  elseif Material=="Titanium" %titanium 5111
    density_metal=4430;                    %Titanium 5111 Timet [Online]. Available:
https://www.timet.com/assets/local/documents/datasheets/alphaalloys/5111.pdf [Accessed
Dec. 5th,2019]
    yield_metal=758e+06;
    ultimate_metal=862e+06;
  else

%Aluminium 6061-T6
    density_metal=2700;          %Aluminium 6061 MAtweb [Online]. Available:
http://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA6061T6 [Accessed Dec.
5th,2019]
    yield_metal=276e+06;
    ultimate_metal=310e+6;
  end
end

function outer_pressure= calc_outer_pressure(depth) % This function converts the strung depth
into external pressure
  density= 1029;
  gravity= 9.81;
  outer_pressure=density*gravity*depth+101325;
end

function new_inner_diameter = calc_inner_diameter(Occupants) %This function increases the
inner diameter based on the desired number of occupants.
  if Occupants==1
    new_inner_diameter=1.3;
  elseif Occupants==2
```

```
        new_inner_diameter=1.5;
    else
        new_inner_diameter=1.7;
    end
end

%This function calculates the new outer diameter of the hull
function new_outer_diameter = calc_outer_diameter(outer_diameter, str, inner_diameter, inner_pressure, outer_pressure)

          [7]
    %We are calculating the Circumferential Stress acting on the hull at
    %the inner radius



    n = 0;   %Initial safety factor

    while n<2
        outer_diameter = outer_diameter + 0.001;
        stress =-(inner_pressure*(inner_diameter/2).^3-outer_pressure*(outer_diameter/2).^3+(inner_pressure-outer_pressure)*(((inner_diameter/2)^3)*((outer_diameter/2)^3)/(2*((inner_diameter/2)^3))))/(((outer_diameter/2)^3)-((inner_diameter/2)^3));
        n = str/stress;
    end

    new_outer_diameter = outer_diameter;

end
```

```
%Hatch Door Thickness Parameterization
function thickness_hatch_door=calc_hatch_door(outer_pressure,radius_hatch_door,str)
    thickness=0;
    n=0;
    while n<2
        thickness=thickness+0.001;
        stress=(outer_pressure*radius_hatch_door)/(2*thickness);
        n=str/stress;
    end
   thickness_hatch_door=thickness;
end

%Frame Cross-sectional Area parameterization
function [new_XS_width, new_XS_height,
Total_Mass_no_ballast_dropweight,Frame_Total_Volume]=calc_XS_height(x,XS_width,Total_M
ass_without_frame,density_steel,str,Bottom_Frame_Length,Side_Frame_Length,Back_Frame_L
ength,Top_Frame_Length)
   n=2;
   XS_height=0.2;
   %XS_width=0.05;
   while n>1.5
       if XS_height>XS_width
           XS_height=XS_height-0.001;
       else
           XS_width=XS_width-0.001;
       end
       [new_moment,
Total_Mass_no_ballast_dropweight,Frame_Total_Volume]=calc_moment(x,XS_width,XS_heigh
```

```
t,Total_Mass_without_frame,density_steel,Bottom_Frame_Length,Side_Frame_Length,Back_Fr
ame_Length,Top_Frame_Length);
        Inertia=(XS_width*XS_height^3)/12;
        stress=new_moment*(XS_height/2)/Inertia;
        n=str/stress;
    end

    new_XS_height=XS_height;
    new_XS_width=XS_width;
end

%New Moment
function
[new_moment,Total_Mass_no_ballast_dropweight,Frame_Total_Volume]=calc_moment(x,XS_
width,XS_height,Total_Mass_without_frame,density_steel,Bottom_Frame_Length,Side_Frame
_Length,Back_Frame_Length,Top_Frame_Length)
    Bottom_Frame_Volume=Bottom_Frame_Length*0.22*XS_width;
    Side_Frame_Volume=Side_Frame_Length*XS_height*XS_width;
    Back_Frame_Volume=Back_Frame_Length*XS_height*XS_width;
    Top_Frame_Volume=Top_Frame_Length*XS_height*XS_width;

Frame_Total_Volume=2*Bottom_Frame_Volume+2*Side_Frame_Volume+Back_Frame_Volum
e+2*Top_Frame_Volume;
    Frame_Total_Mass=Frame_Total_Volume*density_steel;
    Total_Mass_no_ballast_dropweight=Total_Mass_without_frame+Frame_Total_Mass;
    new_moment=Total_Mass_no_ballast_dropweight*9.81*x;
end
% Bolt Diameter parameterization
function shear_bolt_dia=calc_shear_bolt_dia(Mass,str,num_bolt, thickness)
```

```
  F=Mass*9.81;
  Moment=((F/2)/num_bolt)*thickness/2;
  n=0;
  dia=0;
  while n<2
     dia=dia+0.001;
     stress=(Moment*dia/2)/((pi*dia^4)/64);
     n=str/stress;
  end

  shear_bolt_dia=dia;
end

%Spring Wire parameterization
function spring_wire_dia=calc_spring_wire_dia(mass_hatch_door,radius_hatchdoor_to_spring,
rod_dia, str,num_spring)
  n=0;
  dia=0;
  moment=mass_hatch_door*9.81*radius_hatchdoor_to_spring;

  while n<1.5
     dia=dia+0.001;
     mean_dia_spring=rod_dia+dia;
     c=mean_dia_spring/dia; %spring index
     %k=(4*c-1)/(4*c-4)+(0.615/c)
     k=calc_stress_concentration(c);
     stress=((k*32*moment)/(pi*dia^3))/num_spring;
     n=str/stress;
  end
```

```
  spring_wire_dia=dia;
end

%Spring Stress Concentration
function k=calc_stress_concentration(c)

   if c>=10
      k=1.075;
   elseif (9<=c)&&(c<10)
      k=1.08;
   elseif (8<=c)&&(c<9)
      k=1.09;
   elseif (7<=c)&&(c<8)
      k=1.1;
   elseif (6<=c)&&(c<7)
      k=1.125;
   elseif (5<=c)&&(c<6)
      k=1.15;
   elseif (4<=c)&&(c<5)
      k=1.2;
   elseif (3<=c)&&(c<4)
      k=1.275;
   else
      k=1.45;
   end

end

%Quantity of Oxygen Estimation per Occupant(s)
```

```
function [oxygen_tank_mass,oxygen_tank_submerged_volume]
=calc_oxygen_tank_mass(Occupants)
  if Occupants==3
    oxygen_tank_mass=234.14;
    oxygen_tank_dia=0.13462;          %Source Applied Inc Oxygen Cylinder Sizes [Online]:
https://applied-inc.com/oxygen-cylinder-sizes-and-info [Accessed Dec. 5th,2019]
    oxygen_tank_height=0.4191;
    oxygen_tank_submerged_volume=2*(pi/4)*oxygen_tank_dia^2*oxygen_tank_height;

  elseif Occupants==2
    oxygen_tank_mass=155.4774;
    oxygen_tank_dia=0.10922;
    oxygen_tank_height=0.4191;
    oxygen_tank_submerged_volume=2*(pi/4)*oxygen_tank_dia^2*oxygen_tank_height;

  else
    oxygen_tank_mass=92.851;
    oxygen_tank_dia=0.10922;
    oxygen_tank_height=0.2794;
    oxygen_tank_submerged_volume=2*(pi/4)*oxygen_tank_dia^2*oxygen_tank_height;

  end
end

%Compressed Air Estimation
function [compressed_air_mass,compressed_air_dia]=calc_compressed_air(depth)
  compressed_air_mass=(20.7884*(depth/1000)^2+137.458*(depth/1000))*4;        %Source
Industry Liquid Air [Online]:  https://industry.airliquide.us/high-pressure-cylinders [Accessed Dec.
5th,2019]
```

```
  compressed_air_dia=0.25*(depth/1000)^(1/2);

end

%Hull Platform Support Parameterization
function [platform_support_height,
platform_support_diameter,platform_seating_mass,second_seat,third_seat]=calc_platform_di
m(Occupants)
  if Occupants==1
    platform_support_height=0.05;
    platform_support_diameter=0.7;
    second_seat=1;
    third_seat=1;
    platform_seating_mass=37.57;

  elseif Occupants==2
    platform_support_height=0.12;
    platform_support_diameter=1;
    second_seat=2;
    third_seat=1;
    platform_seating_mass=33.04;

  else
    platform_support_height=0.32;
    platform_support_diameter=1.4;
    second_seat=2;
    third_seat=2;
    platform_seating_mass=28.51;
```

```
  end
end
```

D. Minutes (Team and Group)

Group Meeting Minutes

Group Minutes					
Attendees: Munachiso Izuora mizuo056@uottawa.ca Otito Situ osituo072@uottawa.ca Kenneth Oguejiofor kogue019@uottawa.ca Jonas Chianu jchia032@uottawa.ca Siyuan Ji jji006@uottawa.ca	**Absent:** N/a		**Date & Time:** 4th September 2019		**Venue:** CBY B02
Minute taker: Who is filling out this form?	Siyuan Ji		**Chairperson:** Who is organising the meeting?	Jonas Chianu	
	Task What has to be done?	**Action** What action is required to get it done?	**Who** Who is responsible?	**Duration** How long will it take to complete?	**Status** Has the task been completed?
1	Group Establishment	Availabilities for future meetings discussed	All	n/a	n/a
2	Communication	Facebook group messenger created	All	n/a	n/a
3	Information Gathering	Research on existing personal submarine models and submersibles	All	2 days	in process
4					
5					
Next meeting **Chairperson:** Jonas Chianu	**Minute taker:** Siyuan Ji		**Date & Time:** 6/09/19		**Venue:** SITE Lab

Group Minutes

Attendees:	Absent:	Date & Time:	Venue:
Munachiso Izuora mizuo056@uottawa.ca Otito Situ ositu072@uottawa.ca Kenneth Oguejiofor kogue019@uottawa.ca Jonas Chianu jchia032@uottawa.ca Siyuan Ji jji006@uottawa.ca	N/a	6th September 2019	2nd floor, STEM

Minute taker: Who is filling out this form?	Siyuan Ji	Chairperson: Who is organising the meeting?	Jonas Chianu

	Task What has to be done?	Action What action is required to get it done?	Who Who is responsible?	Duration How long will it take to complete?	Status Has the task been completed?
1	Getting information from web	Searching information about submarine brands; find out 4 companies satisfied design;	All	30 mins	Completed
2	Discussion	Identify specific submarine model to analysis; Identify the general parts of submarine; Identify the material of hull and frame; 3 occupant design will be deeply analyzed.	All	1 hour	Completed
3	Task distribution	Tito and Jonas on frames; Muna on hull; Siyuan on hatch; Jonathan on seal and access mechanics.	All	7 days	in process
4					
5					

Next meeting Chairperson:	Minute taker:	Date & Time:	Venue:
Jonas Chianu	Siyuan Ji	13/09/19	TBD

Group Minutes

Attendees:	Absent:	Date & Time:	Venue:
Munachiso Izuora mizuo056@uottawa.ca Otito Situ ositu072@uottawa.ca Kenneth Oguejiofor kogue019@uottawa.ca Jonas Chianu jchia032@uottawa.ca Siyuan Ji jji006@uottawa.ca	N/a	18th September 2019	CBY C011

Minute taker: Who is filling out this form?	Siyuan Ji	Chairperson: Who is organising the meeting?	Jonas Chianu

	Task What has to be done?	Action What action is required to get it done?	Who Who is responsible?	Duration How long will it take to complete?	Status Has the task been completed?
1	1st concept	Drawing of frame and hull	Kenneth	2 days	n/a
2	2nd concept	Drawing of frame and hull	Muna	2 days	n/a
3	3rd concept	Drawing of frame and hull	Jonas	2 days	n/a
4	Hatch Designs	Drawing of various hatch designs	Otito and Siyuan	2 days	n/a
5					

Next meeting Chairperson:	Minute taker:	Date & Time:	Venue:
Jonas Chianu	Siyuan Ji	20/09/19	SITE Lab

Group Minutes					
Attendees: Munachiso Izuora mizuo056@uottawa.ca Otito Situ ositu072@uottawa.ca Kenneth Oguejiofor kogue019@uottawa.ca Jonas Chianu jchia032@uottawa.ca Siyuan Ji jji006@uottawa.ca	**Absent:** N/a		**Date & Time:** 25th September 2019		**Venue:** CBY C011
Minute taker: Who is filling out this form?	Munachiso Izuora		**Chairperson:** Who is organising the meeting?	Jonas Chianu	
	Task What has to be done?	**Action** What action is required to get it done?	**Who** Who is responsible?	**Duration** How long will it take to complete?	**Status** Has the task been completed?
1	Cost Analysis	Drawing of frame and hull	Muna	5 days	completed
2	Release Buoy Mechanism	Release Buoy Concepts	Jonas and Muna	3 days	completed
3	Concept Drawings	Drawings	Jonas,Muna and Kenneth	2 days	completed
4	Hatch	Drawing of various hatch designs	Otito and Siyuan	2 days	completed
5	Report	Formatting and Submission	Otito and Siyuan	1 hour	completed
Next meeting **Chairperson:** Jonas Chianu	**Minute taker:** Munachiso Izuora		**Date & Time:** 2/10/19		**Venue:** CBY C011

Group Minutes					
Attendees: Munachiso Izuora mizuo056@uottawa.ca Otito Situ ositu072@uottawa.ca Kenneth Oguejiofor kogue019@uottawa.ca Jonas Chianu jchia032@uottawa.ca Siyuan Ji jji006@uottawa.ca	**Absent:** N/a		**Date & Time:** 28th September 2019		**Venue:** CBY
Minute taker: Who is filling out this form?	Munachiso Izuora		**Chairperson:** Who is organising the meeting?	Jonas Chianu	
	Task What has to be done?	**Action** What action is required to get it done?	**Who** Who is responsible?	**Duration** How long will it take to complete?	**Status** Has the task been completed?
1	Updated Final concept	Drawings	Kenneth and Siyuan	3 days	completed
2	Free Body diagrams	FBD drawings	Muna	3 days	completed
3	Centre of mass and Buoyancy centre	Calculations and results	Jonas and Otito	3 days	completed
4	Dimensioning	Submersible dimensioning	Jonas	2 days	completed
5	Report	Formatting and Submission	aKenneth and Siyuan	1 hour	completed
Next meeting **Chairperson:** Jonas Chianu	**Minute taker:** Munachiso Izuora		**Date & Time:** 4/10/19		**Venue:** CRX

Group Minutes					
Attendees: Munachiso Izuora mizuo056@uottawa.ca Otito Situ ositu072@uottawa.ca Kenneth Oguejiofor kogue019@uottawa.ca Jonas Chianu jchia032@uottawa.ca Siyuan Ji jji006@uottawa.ca	**Absent:** N/a		**Date & Time:** 4th, October 2019		**Venue:** CBY
Minute taker: Who is filling out this form?	Munachiso Izuora	**Chairperson:** Who is organising the meeting?	Jonas Chianu		
	Task What has to be done?	**Action** What action is required to get it done?	**Who** Who is responsible?	**Duration** How long will it take to complete?	**Status** Has the task been completed?
1	System Layout	Drawing	Kenneth	3 days	completed
2	Fairing and Frame Connection	Drawing	Muna	3 days	completed
3	Hull	Drawing	Jonas	3 days	completed
4	Frame	Drawing	Otito	3 days	completed
5	Hatch and Locking Mechanism	Drawing	Siyuan	3 days	completed
Next meeting **Chairperson:** Jonas Chianu	**Minute taker:** Munachiso Izuora		**Date & Time:** 11/10/19		**Venue:** CBY

Group Minutes					
Attendees: Munachiso Izuora mizuo056@uottawa.ca Otito Situ ositu072@uottawa.ca Kenneth Oguejiofor kogue019@uottawa.ca Jonas Chianu jchia032@uottawa.ca Siyuan Ji jji006@uottawa.ca	**Absent:** N/a		**Date & Time:** 16th, October 2019		**Venue:** CBY
Minute taker: Who is filling out this form?	Munachiso Izuora	**Chairperson:** Who is organising the meeting?	Jonas Chianu		
	Task What has to be done?	**Action** What action is required to get it done?	**Who** Who is responsible?	**Duration** How long will it take to complete?	**Status** Has the task been completed?
1	Seals and Penetrations	Analysis	Kenneth	5days	
2	Fairing	Analysis	Otito	5 days	
3	Hull	Analysis	Muna	5 days	
4	Frame	Analysis	Jonas	5 days	
5	Hatch and Locking Mechanism	Analysis	Siyuan	5 days	
Next meeting **Chairperson:** Jonas Chianu	**Minute taker:** Munachiso Izuora		**Date & Time:** 18/10/19		**Venue:** CBY

Group Minutes					
Attendees: Munachiso Izuora mizuo056@uottawa.ca Otito Situ ositu072@uottawa.ca Kenneth Oguejiofor kogue019@uottawa.ca Jonas Chianu jchia032@uottawa.ca Siyuan Ji jji006@uottawa.ca	**Absent:** N/a		**Date & Time:** 23rd, October 2019		**Venue:** CBY
Minute taker: Who is filling out this form?	Munachiso Izuora		**Chairperson:** Who is organising the meeting?	Jonas Chianu	
	Task What has to be done?	**Action** What action is required to get it done?	**Who** Who is responsible?	**Duration** How long will it take to complete?	**Status** Has the task been completed?
1	Seals and Penetrations	Analysis	Kenneth	5days	Ongoing
2	Fairing	Analysis	Otito and Jonas	5 days	Ongoing
3	Hull	Analysis	Muna	5 days	Ongoing
4	Frame	Analysis	Jonas	5 days	Ongoing
5	Hatch and Locking Mechanism	Analysis	Siyuan and Kenneth	5 days	Ongoing
Next meeting **Chairperson:** Jonas Chianu	**Minute taker:** Munachiso Izuora		**Date & Time:** 25/10/19		**Venue:** CBY

Group Minutes					
Attendees: Munachiso Izuora mizuo056@uottawa.ca Otito Situ ositu072@uottawa.ca Kenneth Oguejiofor kogue019@uottawa.ca Jonas Chianu jchia032@uottawa.ca Siyuan Ji jji006@uottawa.ca	**Absent:** N/a		**Date & Time:** 30th, October 2019		**Venue:** SITE Lab
Minute taker: Who is filling out this form?	Munachiso Izuora		**Chairperson:** Who is organising the meeting?	Jonas Chianu	
	Task What has to be done?	**Action** What action is required to get it done?	**Who** Who is responsible?	**Duration** How long will it take to complete?	**Status** Has the task been completed?
1	Hull and Sealing	Analysis	Kenneth	5 days	Ongoing
2	Fairing and Frame	Analysis	Otito and Jonas	5 days	Ongoing
3	Hatch	Analysis	Muna	5 days	Ongoing
4					
5					
Next meeting **Chairperson:** Jonas Chianu	**Minute taker:** Munachiso Izuora		**Date & Time:** 1/11/19		**Venue:** CBY

Group Minutes						
Attendees: Munachiso Izuora mizuo056@uottawa.ca Otito Situ ositu072@uottawa.ca Kenneth Oguejiofor kogue019@uottawa.ca Jonas Chianu jchia032@uottawa.ca Siyuan Ji jji006@uottawa.ca	**Absent:** N/a			**Date & Time:** 7th, November 2019		**Venue:** SITE Lab
Minute taker: Who is filling out this form?	Munachiso Izuora		**Chairperson:** Who is organising the meeting?	Jonas Chianu		
	Task What has to be done?	**Action** What action is required to get it done?	**Who** Who is responsible?	**Duration** How long will it take to complete?	**Status** Has the task been completed?	
1	Hull and Sealing	Analysis	Kenneth	5 days	Ongoing	
2	Fairing and Frame	Analysis	Otito and Jonas	5 days	Ongoing	
3	Hatch	Analysis	Muna	5 days	Ongoing	
4	Modelling	Update	Otito and Jonas	5 days		
5						
Next meeting **Chairperson:** Jonas Chianu	**Minute taker:** Munachiso Izuora		**Date & Time:** 9/11/19	**Venue:** SITE Lab		

Group Minutes						
Attendees: Munachiso Izuora mizuo056@uottawa.ca Otito Situ ositu072@uottawa.ca Kenneth Oguejiofor kogue019@uottawa.ca Jonas Chianu jchia032@uottawa.ca Siyuan Ji jji006@uottawa.ca	**Absent:** N/a			**Date & Time:** 9th, November 2019		**Venue:** SITE Lab
Minute taker: Who is filling out this form?	Munachiso Izuora		**Chairperson:** Who is organising the meeting?	Jonas Chianu		
	Task What has to be done?	**Action** What action is required to get it done?	**Who** Who is responsible?	**Duration** How long will it take to complete?	**Status** Has the task been completed?	
1	Penetration Sealing	Analysis	Muna	5 days	Ongoing	
2	Fairing and Frame	Analysis	Otito and Jonas	5 days	Ongoing	
3	Hatch	Analysis	Siyuan and Kenneth	5 days	Ongoing	
4	Seat	Design and Analysis	Otito	5 days		
5						
Next meeting **Chairperson:** Jonas Chianu	**Minute taker:** Munachiso Izuora		**Date & Time:** 15/11/19	**Venue:** SITE Lab		

Group Minutes

Attendees:	Absent:	Date & Time:	Venue:
Munachiso Izuora mizuo056@uottawa.ca Otito Situ ositu072@uottawa.ca Kenneth Oguejiofor kogue019@uottawa.ca Jonas Chianu jchia032@uottawa.ca Siyuan Ji jji006@uottawa.ca	N/a	21st, November 2019	SITE Lab

Minute taker: Who is filling out this form?	Munachiso Izuora	Chairperson: Who is organising the meeting?	Jonas Chianu

	Task What has to be done?	Action What action is required to get it done?	Who Who is responsible?	Duration How long will it take to complete?	Status Has the task been completed?
1	Seats and platform	Design	Tito	4 days	
2	Solidworks	Redesign	Siyuan and Kenneth	4 days	
3	Parameterization	Coding	Muna and Jonas	4 days	
4					
5					

Next meeting Chairperson:	Minute taker:	Date & Time:	Venue:
Jonas Chianu	Munachiso Izuora	22/11/19	SITE Lab

Group Minutes

Attendees:	Absent:	Date & Time:	Venue:
Munachiso Izuora mizuo056@uottawa.ca Otito Situ ositu072@uottawa.ca Kenneth Oguejiofor kogue019@uottawa.ca Jonas Chianu jchia032@uottawa.ca Siyuan Ji jji006@uottawa.ca	N/a	27th, November 2019	SITE Lab

Minute taker: Who is filling out this form?	Munachiso Izuora	Chairperson: Who is organising the meeting?	Jonas Chianu

	Task What has to be done?	Action What action is required to get it done?	Who Who is responsible?	Duration How long will it take to complete?	Status Has the task been completed?
1	Seats and platform	Design	Tito	4 days	Ongoing
2	Solidworks	Redesign	Siyuan and Kenneth	4 days	Ongoing
3	Parameterization	Coding	Muna and Jonas	4 days	Ongoing
4	Sealing Parameterization	Redesign and Coding	Muna and Jonas	4 days	
5					

Next meeting Chairperson:	Minute taker:	Date & Time:	Venue:
Jonas Chianu	Munachiso Izuora	29/11/19	SITE Lab

Team Meeting Minutes

Team/Partner Minutes			
Attendees: Jonas Chianu Daniel Howard-Lopez Ruikang Liu Olivier Royer	**Absent:**	**Date & Time:** Sept 18, 8:30am	**Venue:** CBY C011
Minute taker: Who is filling out this form? Jonas Chianu		**Chairperson:** Who is organising the meeting? Mihaita Matei	
Minutes			
During the meeting: 1. Set or obtain project criteria and restrictions 2. Discuss specification changes since the last meeting. 3. Discuss scope of project. 4. Discuss design changes (teams). Meeting minutes content: 1. Summarize specifications 2. Outline design changes 3. List components that are assigned to specific groups Discussed the different ballast designs group B had, and how it could be mounted or integrated with the hulls of the other groups. Next action: Group As will try to get an rough concept designs done by friday to show to Group A.			
Next meeting **Chairperson:** Mihaita Matei	**Minute taker:** Ruikang Liu	**Date & Time:** Sept 25, 8:30am	**Venue:** CBY C011

Team/Partner Minutes			
Attendees: ALL	**Absent:** NONE	**Date & Time:** 9/25/2019	**Venue:** CBY c011
Minute taker: Who is filling out this form? Ruikang Liu		**Chairperson:** Who is organising the meeting? Ruikang Liu	
Minutes			
we finished concept design and discussed about the way to merge the hull/frame and ballast system.			
Next meeting **Chairperson:**	**Minute taker:** Ruikang Liu	**Date & Time:**	**Venue:**

Team/Partner Minutes			
Attendees: Everyone	**Absent:** No one	**Date & Time:** Sept. 11 - 8h30 AM.	**Venue:** CBY Coll
Minute taker: Who is filling out this form? Olivier Reyer		**Chairperson:** Mihaita Matei Who is organising the meeting?	
Minutes			
During the meeting: 1. Set or obtain project criteria and restrictions 2. Discuss specification changes since the last meeting. 3. Discuss scope of project. 4. Discuss design changes (teams). Meeting minutes content: 1. Summarize specifications 2. Outline design changes 3. List components that are assigned to specific groups	∘ Discussed about sharing documents between groups. Decided we should not. ∘ Initial client meeting (Monday) Q&A		
Next meeting Chairperson: Mihaita Matei	Minute taker: Soras Emeka Chianu	Date & Time: Sept. 18 - 8h30 AM	Venue: CBY Coll.

Group Minutes					
Attendees: SUB1A, SUB2A, SUB3A, SUB1B		**Absent:** N/A	**Date & Time:** 2019-09-30 ; 6:30PM		**Venue:** CRX
Minute taker: Who is filling out this form? Daniel Howard-Lopez		**Chairperson:** Who is organising the meeting? Olivier Reyer			
	Task What has to be done?	**Action** What action is required to get it done?	**Who** Who is responsible?	**Duration** How long will it take to complete?	**Status** Has the task been completed?
1	Hull teams to provide Ballast team with four co-planer connection surfaces to attach a ballast carriage.	Hull teams will include this in there next design iteration.	SUB1A SUB2A SUB3A	To be completed for design dossier	In progress
2					
3					
4					
5					
Next meeting Chairperson: Olivier Reyer		Minute taker: Daniel Howard-Lopez	Date & Time: 2019-10-07 ; 6:30		Venue: CRX

Minutes

During the meeting:
1. Discuss work accomplished since the last meeting.
2. Discuss tasks not-completed since the last meeting.
3. Review action items and tasks to be completed after the meeting

Meeting minutes content:
1. Summarize completed work
2. List previous tasks that have not been completed in the prescribed timeline
3. Specify task reassignments
4. List additional tasks completed but not listed in previous minutes
5. Specify additional out-of-class meeting attendance

Previous Friday lab attendance	**Previous lecture attendance**
2019-09-25	2019-09-20

Team/Partner Minutes

Attendees:	**Absent:**	**Date & Time:**	**Venue:**
All coordinators	No one	Oct. 9 2019	CBY C06

Minute taker: Who is filling out this form? Olivier Royer	**Chairperson:** Who is organising the meeting? Olivier Royer

Minutes

During the meeting:
1. Set or obtain project criteria and restrictions
2. Discuss specification changes since the last meeting.
3. Discuss scope of project.
4. Discuss design changes (teams).

Meeting minutes content:
1. Summarize specifications
2. Outline design changes
3. List components that are assigned to specific groups

- Talked about the Concept merging for Hull teams into Ballast team.
- Ballast team showed drawings, specifications, and dimensions for Hull teams to implement in their design
- Air supply is designed by Hull teams
- Hull team will provide components at the locations dictated in the drawings
- Ballast team will provide minimum specs for air fits

Next meeting Chairperson:	**Minute taker:**	**Date & Time:**	**Venue:**
Olivier Royer	Ruikang	Oct. 23 2019	CBY C06.

Team/Partner Minutes

Attendees:	Absent:	Date & Time:	Venue:
ALL	NONE	10/25/2019	CBY c011

Minute taker: Who is filling out this form?	Chairperson: Who is organising the meeting?
Jonas Emeka Chianu	Ruikang Liu

Minutes

- discuss how ballast system connects with hull
- keep doing analysis calculation and solidworks

Next meeting Chairperson:	Minute taker:	Date & Time:	Venue:
Jonas Emeka Chianu	Jonas Emeka Chianu		

Team/Partner Minutes

Attendees:	Absent:	Date & Time:	Venue:
Everyone	No one	2019-11-14	Site

Minute taker: Who is filling out this form?	Chairperson: Who is organising the meeting?
Olivier Mayer	Olivier Mayer.

Minutes

During the meeting:
1. Set or obtain project criteria and restrictions
2. Discuss specification changes since the last meeting.
3. Discuss scope of project.
4. Discuss design changes (teams).

Meeting minutes content:
1. Summarize specifications
2. Outline design changes
3. List components that are assigned to specific groups

Individual meeting with each Hull group with Ballast group to discuss CoG & CoB

Next meeting Chairperson:	Minute taker:	Date & Time:	Venue:
N/A	N/A	2019-11-20	Site or CBY

Team/Partner Minutes

Attendees:	Absent:	Date & Time:	Venue:
ALL	NONE	10/16/2019	Site comp lab

Minute taker: Who is filling out this form?	Jonas Chianu	Chairperson: Who is organising the meeting?	Jonas Chianu

Minutes

Suba groups and subb group made sure over designs matched

Next meeting Chairperson:	Minute taker:	Date & Time:	Venue:
N/a	Jonas Chianu	10/23/2019	CBY c011

Team/Partner Minutes

Attendees:	Absent:	Date & Time:	Venue:
ALL	NONE	10/30/2019	Site comp lab

Minute taker: Who is filling out this form?	Jonas Chianu	Chairperson: Who is organising the meeting?	Jonas Chianu

Minutes

Suba groups and subb group met to compares values and decide the best place to put ballast and each individuals group's hull.

Next meeting Chairperson:	Minute taker:	Date & Time:	Venue:
N/a	Jonas Chianu	11/6/2019	Site comp lab

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ALL</td><td colspan="2">Absent:
NONE</td><td>Date & Time:
11/6/2019</td><td>Venue:
Site comp lab</td></tr>
<tr><td colspan="2">Minute taker:
Who is filling out this form? Jonas Chianu</td><td colspan="3">Chairperson:
Who is organising the meeting? Jonas Chianu</td></tr>
<tr><td colspan="5">Minutes</td></tr>
<tr><td colspan="5">Suba groups and subb group met to compare COB and COG values and to work on drop weight mechanism positioning.</td></tr>
<tr><td>Next meeting
Chairperson:
N/a</td><td colspan="2">Minute taker:
Jonas Chianu</td><td>Date & Time:
11/13/2019</td><td>Venue:
Site comp lab</td></tr>
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ALL</td><td colspan="2">Absent:
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11/20/2019</td><td>Venue:
Site comp lab</td></tr>
<tr><td colspan="2">Minute taker:
Who is filling out this form? Jonas Chianu</td><td colspan="3">Chairperson:
Who is organising the meeting? Jonas Chianu</td></tr>
<tr><td colspan="5">Minutes</td></tr>
<tr><td colspan="5">Suba groups and subb group met to quickly go over and compare values together before submission.</td></tr>
<tr><td>Next meeting
Chairperson:
N/a</td><td colspan="2">Minute taker:
Jonas Chianu</td><td>Date & Time:
11/27/2019</td><td>Venue:
Site comp lab</td></tr>
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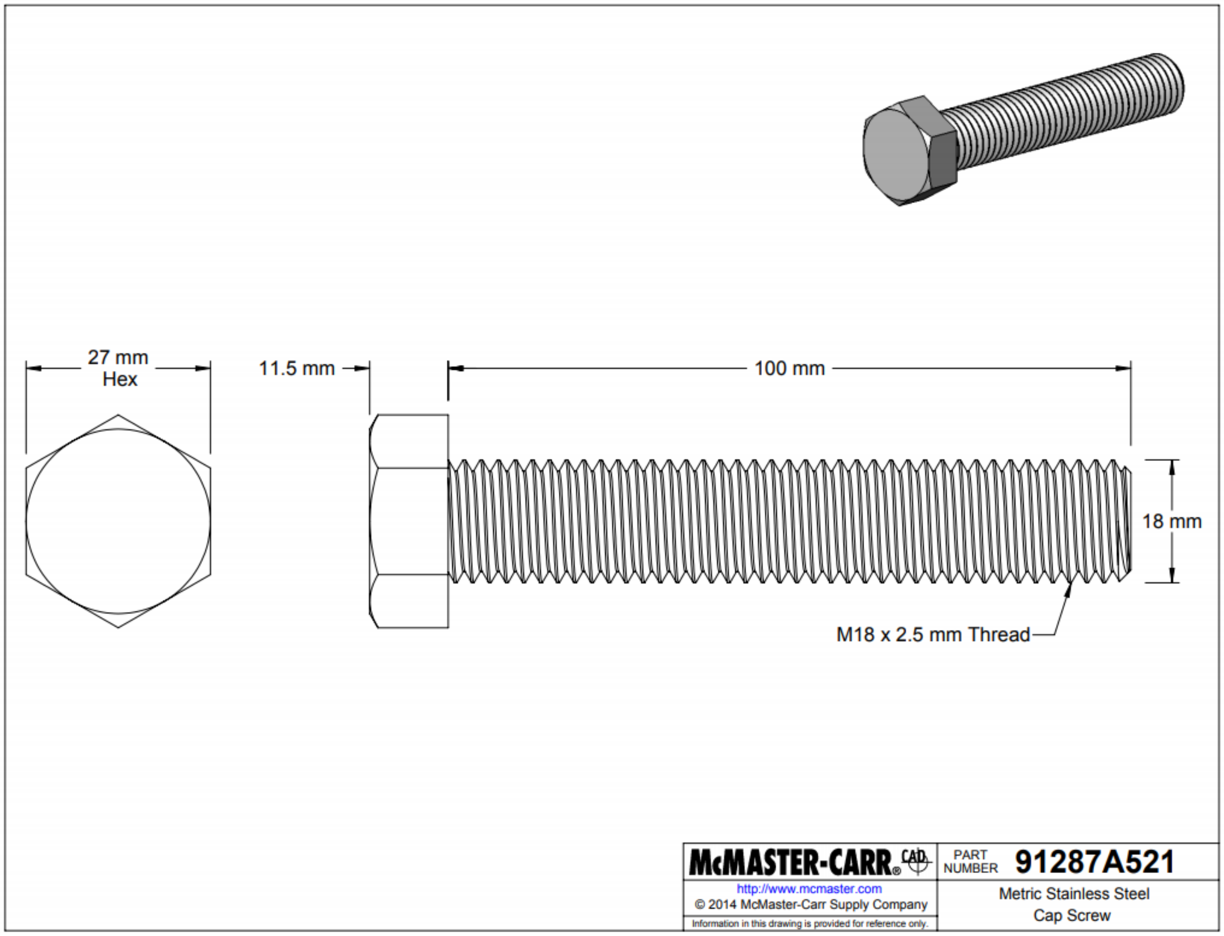
Team/Partner Minutes			
Attendees: ALL	**Absent:** NONE	**Date & Time:** 11/27/2019	**Venue:** Site comp lab
Minute taker: Who is filling out this form? Jonas Chianu		**Chairperson:** Who is organising the meeting? Jonas Chianu	
Minutes			
Suba groups and subb group met to go over how to make parameterization code match.			
Next meeting **Chairperson:** N/a	**Minute taker:** Jonas Chianu	**Date & Time:** 12/4/2019	**Venue:** Site comp lab

E. Additional Material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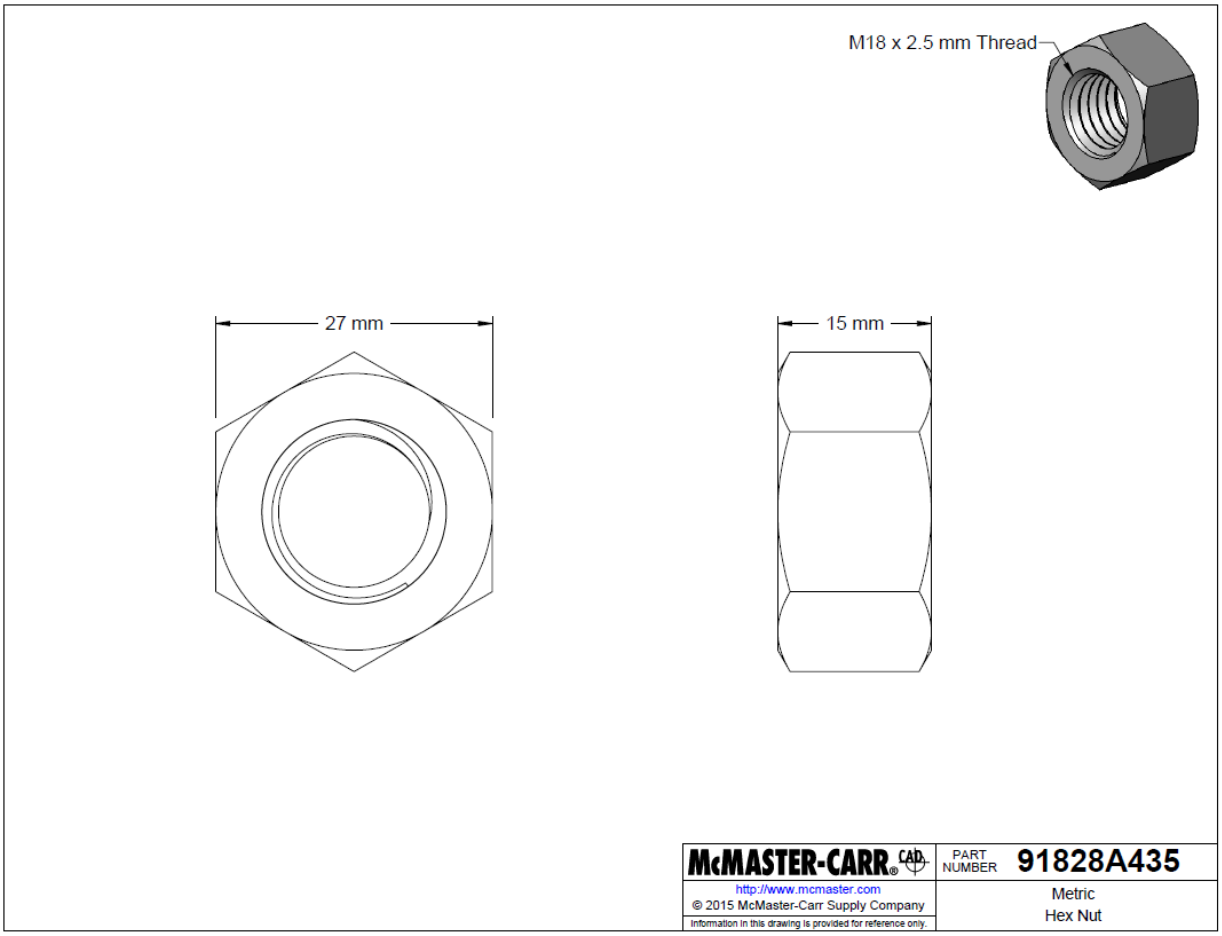
http://www.mcmaster.com
© 2014 McMaster-Carr Supply Company
Information in this drawing is provided for reference only.
Metric Stainless Steel
Cap Screw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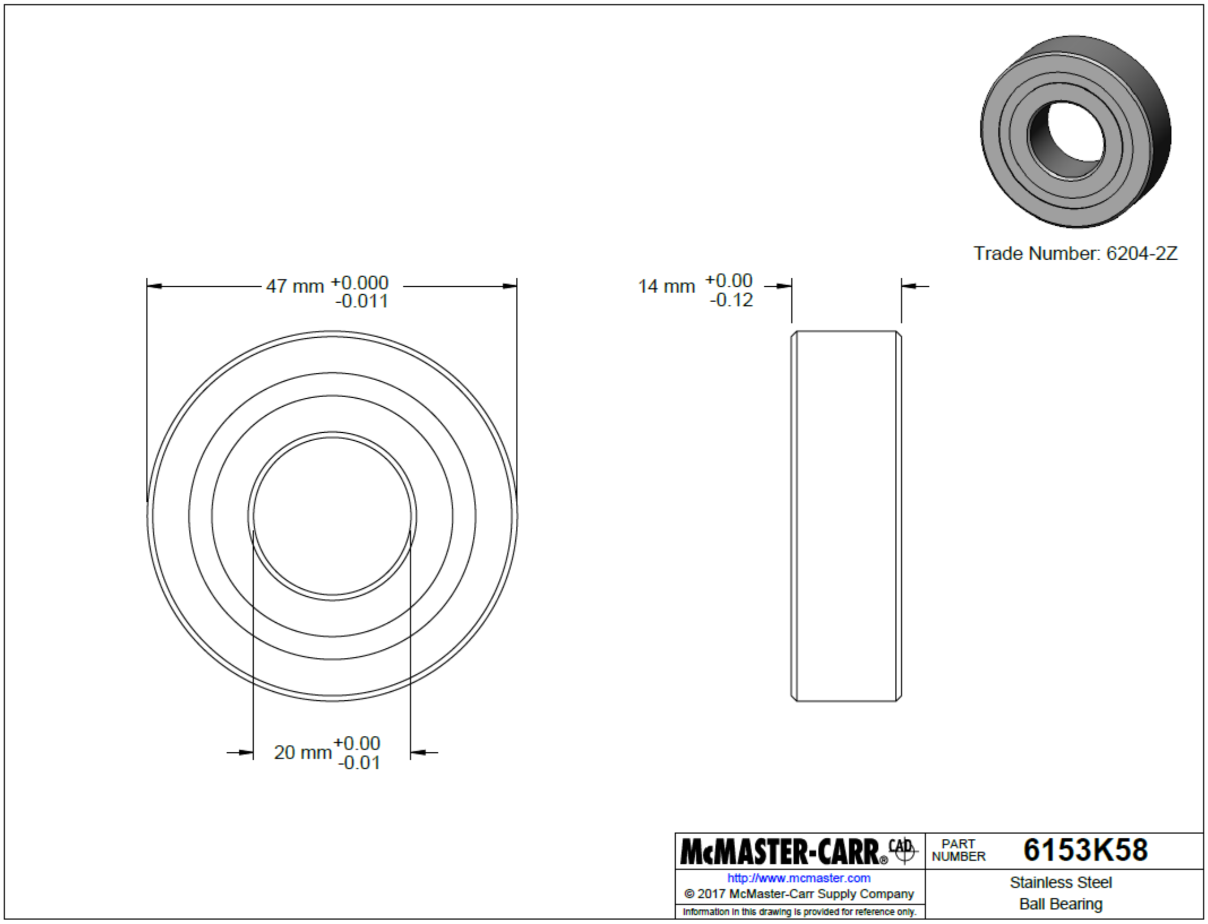
15 mm
McMASTER-CARR CAD
PART NUMBER
91828A435
http://www.mcmaster.com
© 2015 McMaster-Carr Supply Company
Information in this drawing is provided for reference only.
Metric
Hex Nut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McMASTER-CARR CAD
PART NUMBER
6153K58
http://www.mcmaster.com
© 2017 McMaster-Carr Supply Company
Information in this drawing is provided for reference only.
Stainless Steel
Ball Bearing