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CAD/CAM Group Sub 1B:

Capstone Report

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Presented by: Group Sub 1B
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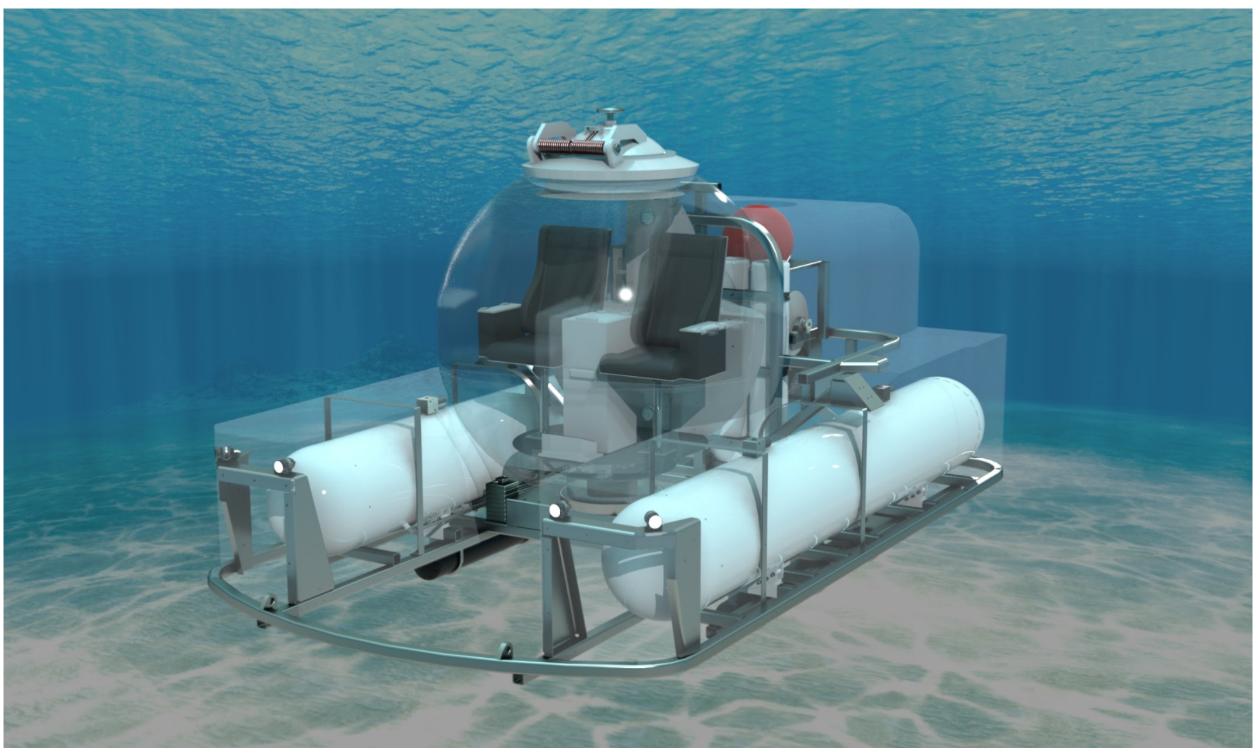
Abstract

The design presented in this report consists of ballast systems and emergency drop weights for a manned submersible capable of diving to depths up 1000m. The MBTs are used for surfacing and allow up to 0.9m of freeboard. The front and rear VBTs permit depth control for ascent and descent with speeds up to 0.5 m/s and 1.79° of trim control to level the submarine horizontally. The release of the drop weights is a fail-free procedure allowing the submarine to surface when solenoid actuators supporting the weights open upon power outage in the event of an emergency. The design is also equipped with enough air bottles to blow the main ballast tanks at any depth up to 1000m, and is used as a second emergency procedure that requires electricity. The maximum payload is assumed to be 250kg. Passengers are weighted before boarding, and Lead weight is added to the submarine's drop weights to meet the set maximum payload. The ballast system is design in a way to permit easy access for both external and internal maintenance and an affordable manufacturing of spare parts. Most of the components of the design are made of 2507 Stainless Steel, which has a PREN number higher than 40 and makes it a very good corrosion resistant metal for seawater applications. The pump, the motor, the valves and the piping as well as other external features exposed to sea pressures are all capable of accommodating pressures up to 1000m. The design solution is shown on figure bellow:

[H]



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Nomenclature

Acronyms and Abbreviations

VBT	Variable Ballast Tank
MBT	Main Ballast Tank
DW	Drop Weight
WHVBS	Water Hydraulic Variable Ballast System
GUI	Graphical User Interface
SUB1B	Submarine team #1 group B
SUB1A	Submarine team #1 group A
PREN	Pitting Resistance Equivalent Number

1 Project Charter

1.1 Mandate

Aquatica Submarines is a Canadian company that provides small submersibles for commercial, scientific,and personal use at lower costs with no compromise to functionality or safety.Currently, the submersibles are unable to sustain depths greater than 330m. The new proposed design of the ballast system and emergency drop weights should allow the submersible to operate at depths up to 1000m.The design should allow an easy parametrization to change mass and buoyancy properties of the submersible to satisfy multiple market demands.

1.2 Requirements

The submarine should be equipped with a soft ballast tank as the principle component providing buoyancy. The variable ballast tanks must be powered electrically. The submersible must be equipped with an emergency drop weight that allows the submarine to rapidly surface. The drop weight mechanism should be fail-free. Additionally, all the components exposed to sea pressures must be designed to resist pressures up to 1000 MSW of depth. The hydraulic system should be protected from exposure to unallowed pressures by using a closed circuit safety valve that directs water to the sea when the pressure indicated is too high. When blowing the air into the ballast tanks, an arrangement should be present to protect these tanks from over pressurization. The compressed air supply used should be sufficient for the intended mission, without any refill during the trip. When the hatch is open to access the entry of passengers and equipment, the submarine should be able to remain floating under normal environment and payload conditions. While ascending and descending, the submersible should be able to maintain an acceptable stability and trim.

1.3 Constraints and criteria

To increase the submersible's freeboard, the soft ballast tanks should be able to provide up to 2200 Kg of buoyancy. The variable ballast tanks should provide up to 50 Kg of controlled depth and trim, operate at depths between 330 and 1000 MSW and provide variable buoyancy between 0 and 50kg. The design criteria of the submersible is to have variable ballast tanks sized as small as possible.

1.4 Design optimization

The GUI is allowing the user to enter 5 different inputs. The first two inputs are a range of temperatures of the surface of sea water a selection of seas or oceans where the submersible will operate.They both determine the critical density of seawater. The third input is the maximum depth at which the submarine is operating, ranging from depths of 330m to 1000m. The fourth input is the normal ascent and descent speed desired ranging from 0.4 m/s to 0.5 m/s. The final input is the minimum desired freeboard.The outputs are displayed on Solidworks through changing the radius and the thickness of the MBTs, the thickness and water capacity of the VBTs, the length and number of solenoid actuators on the drop weights, and finally the number of compressed air bottles used to purge the MBTs.

2 Proposed Design

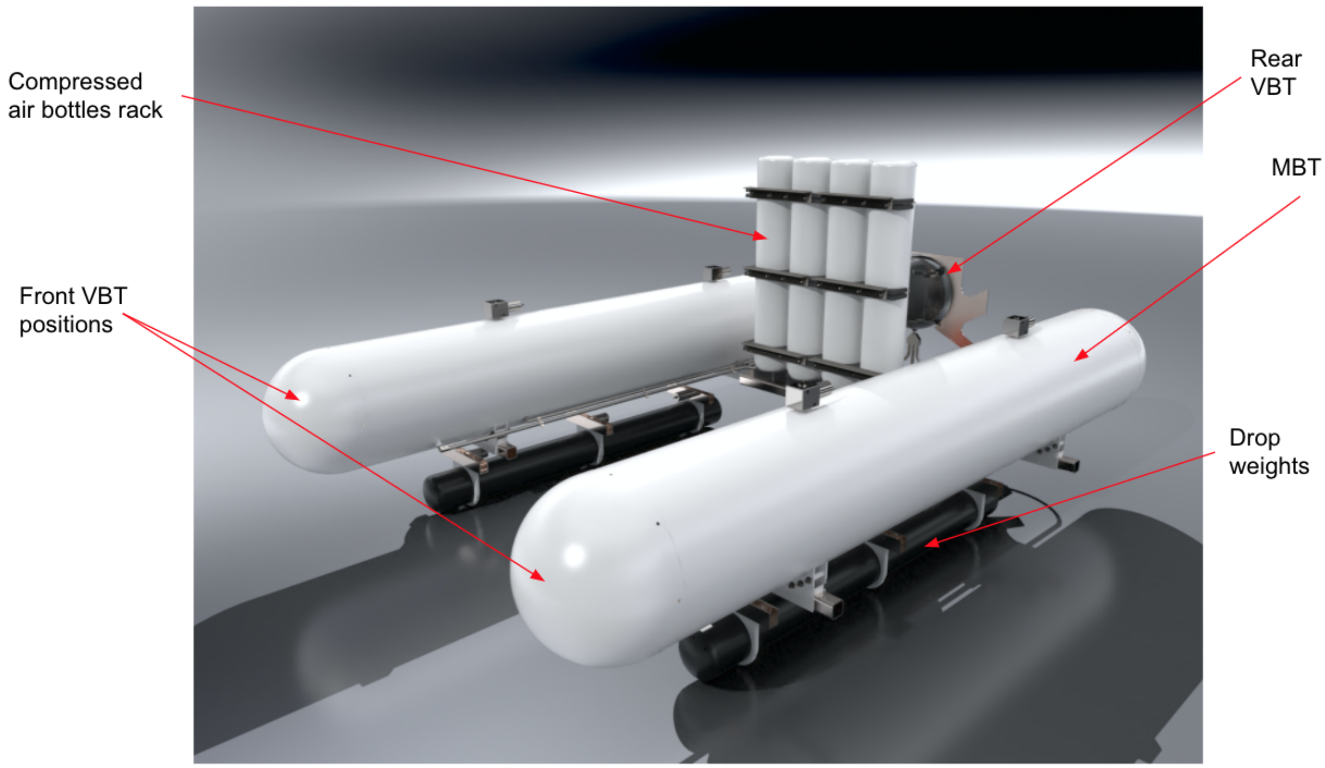

Figure 2-1: Isometric view of the proposed design

2.1 Main Ballast System

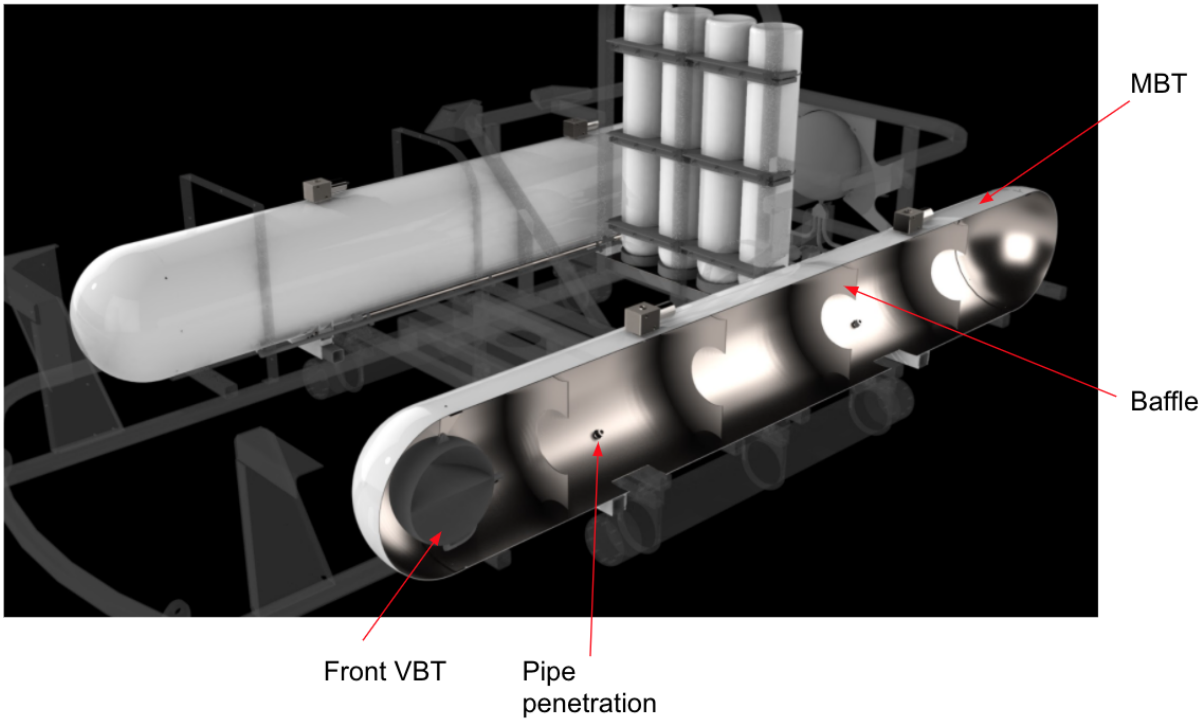

Figure 2-2: Isometric cross section of the MBT

As seen in Figure 2-2, The main ballast tank is divided into 5 sections via 4 equally spaced baffles to prevent sloshing of water during different processes like MBTs purging and submarine pitching. Two solenoid air vents are placed on the top face of the tanks to allow air to vent out at the surface and bring the submarine to neutral buoyancy. Two flood holes are implemented to facilitate MBT flooding.

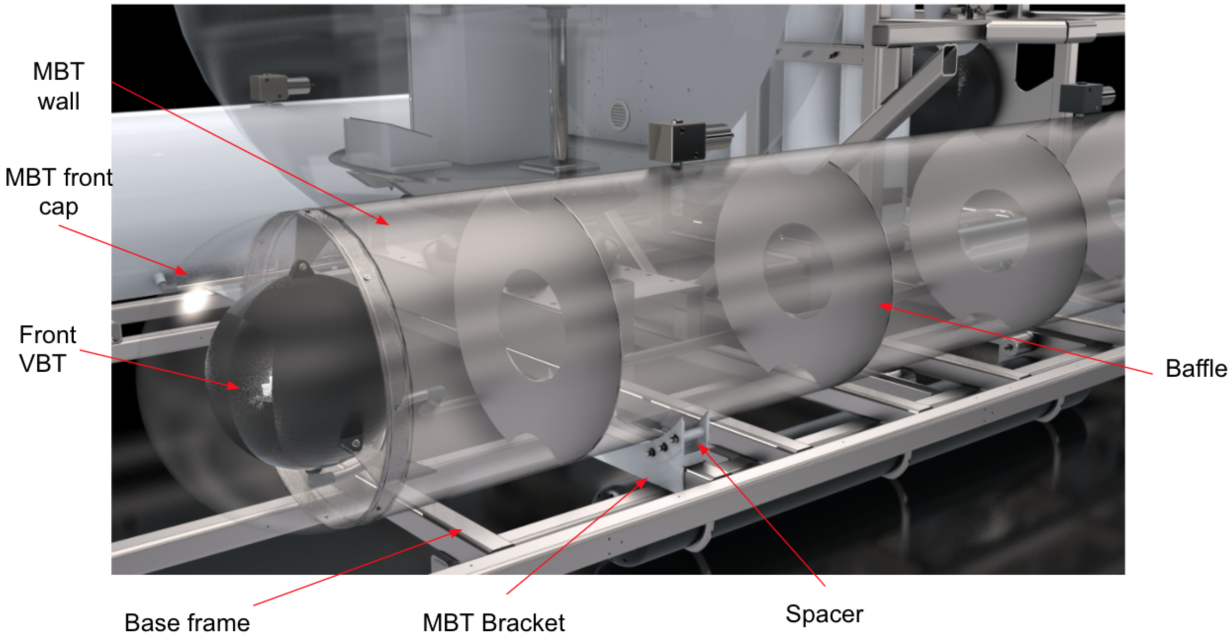

Figure 2-3: MBT Frame Brackets

The MBTs are attached to the main frame using two brackets shown in Figure 2-3. Each bracket it welded to the frame and contains 6 bolts that hold the MBT firmly to the bracket. Solenoid air vents are fitted on top of the MBTs using press fittings.

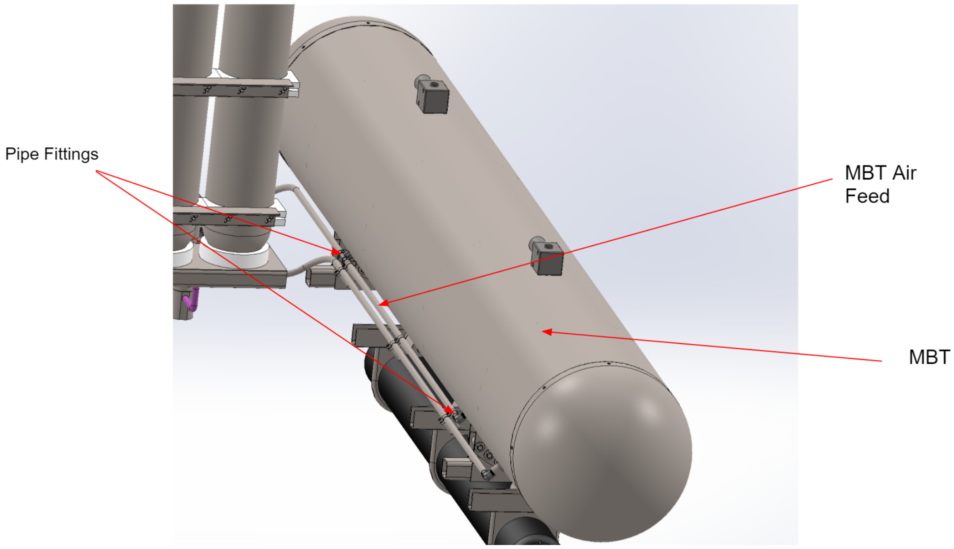

Figure 2-4: Main Ballast Tank Air Feed Pipes

Air feed pipes run along the MBTs lenght connecting the air bottles to the air inlets. Pipes are assembled with the MBT using pipe fittings as shown in Figure 2-4.

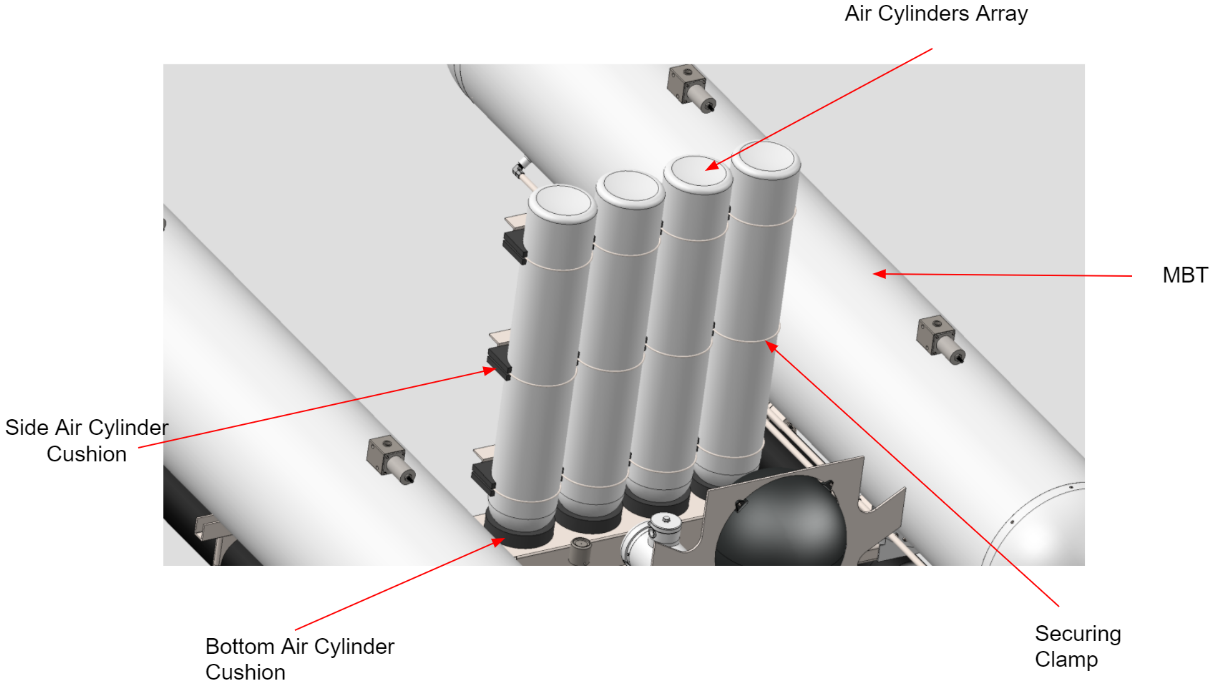

Figure 2-5: MBTs Air Cylinder Array

Compressed air is stored in one to four compressed air cylinders shown in Figure 2-5. This air is used for surfacing and emergency ascent purposes. The air cylinders are secured to the frame through securing clamps and a combination of side and bottom cushions as seen in Figure 2-6

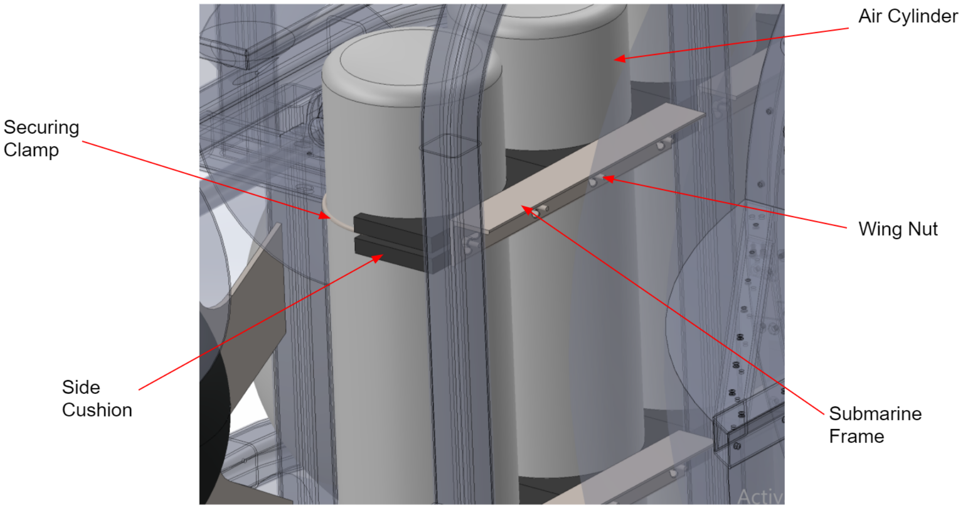

Figure 2-6: MBTs Air Cylinders Frame Attachment

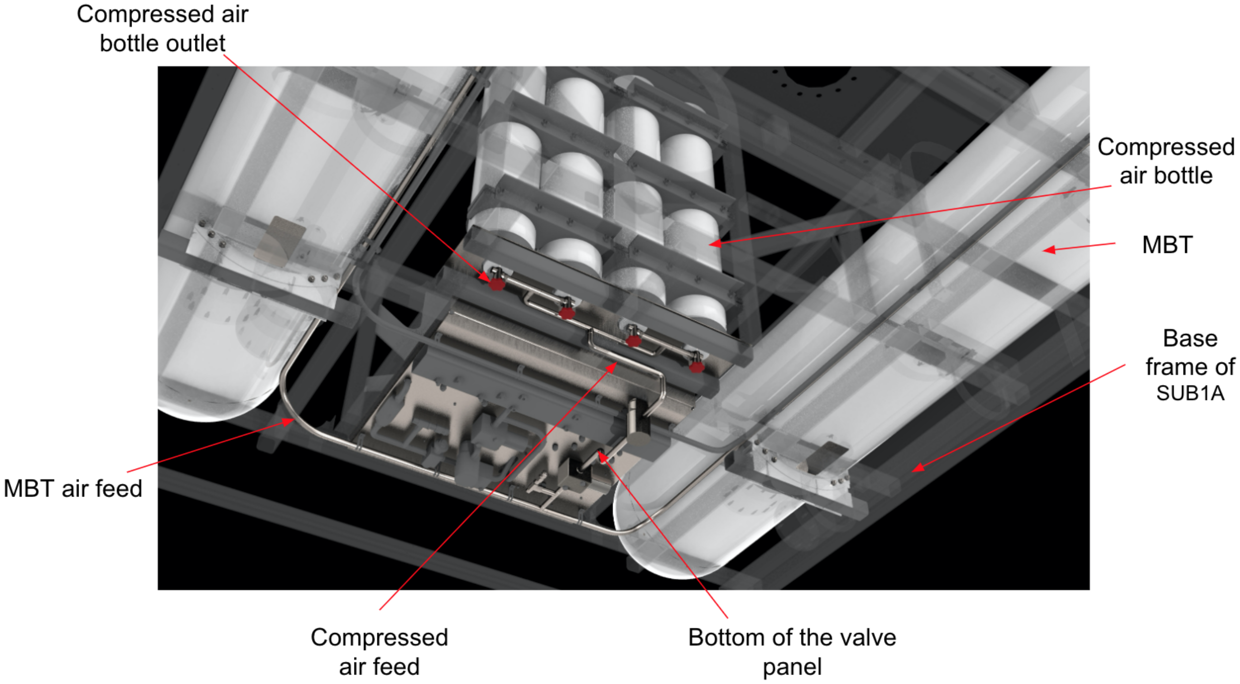

Figure 2-7: Bottom view of the compressed air bottles rack

Figure 2-7 shows the valve circuit of the compressed air. Air is first regulated to $200kPa$ above ambient sea water pressure through the pressure regulator, and then purges the MBT through a pneumatic solenoid valve.

2.2 Variable Ballast System

2.2.1 Rear VBT

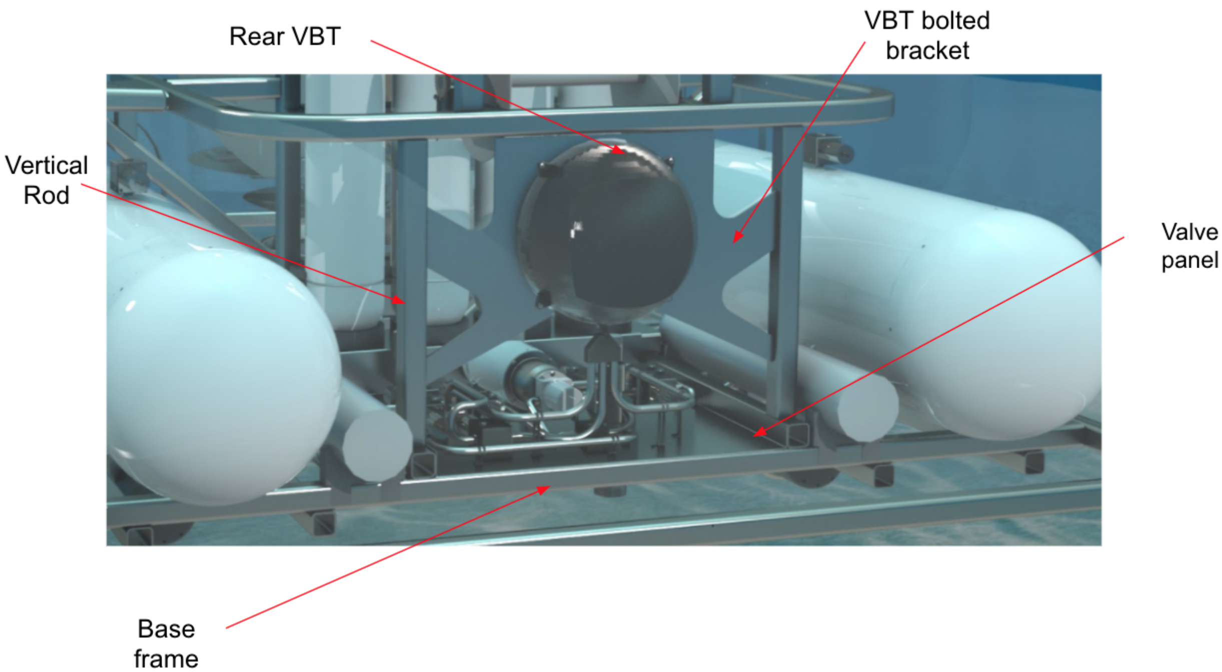

Figure 2-8: Rear variable ballast tank and supports

The figure 2-8 shows the rear VBT, which assures the depth control and trimming. It has a buoyancy of 25 kg (minimum thickness of 2mm). This spherical tank with four brackets and one support, is connected to the depth and pitch panel through hydraulic pipes. The tank is welded at the middle, with a specific welded steam, which supports any over stress due to torsion.

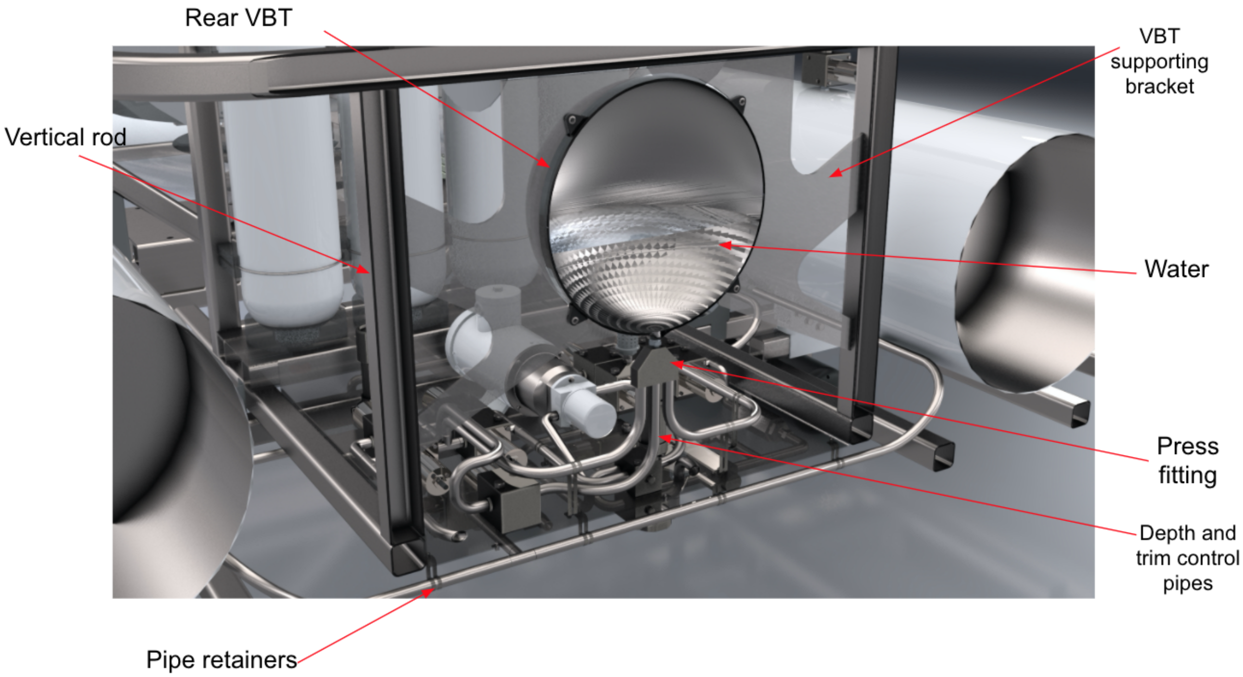

Figure 2-9: Water Level of rear VBT

The figure 2-9 is a cross section that shows the water lever in the VBT. In this situation, the VBT is half filled. The height of water at neutral buoyancy is fixed, and varies to control the ascent and descent speed of the submarine.

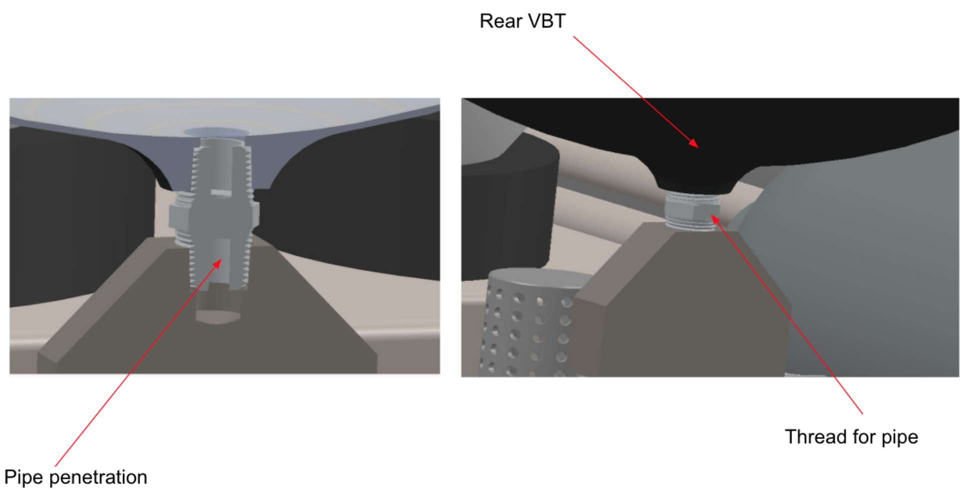

Figure 2-10: Rear VBT pipe penetration and threads

The figure 2-10 shows the connectivity of the pipes in the rear VBT. The pipe is threaded (male threads), to be connected to the pipe penetration which is as well threaded (female thread) to ensure the best connectivity, at a high safety factor. Pipe sealants are added in the threaded joints, to prevent fluid from leaking out.

2.2.2 Front VBT

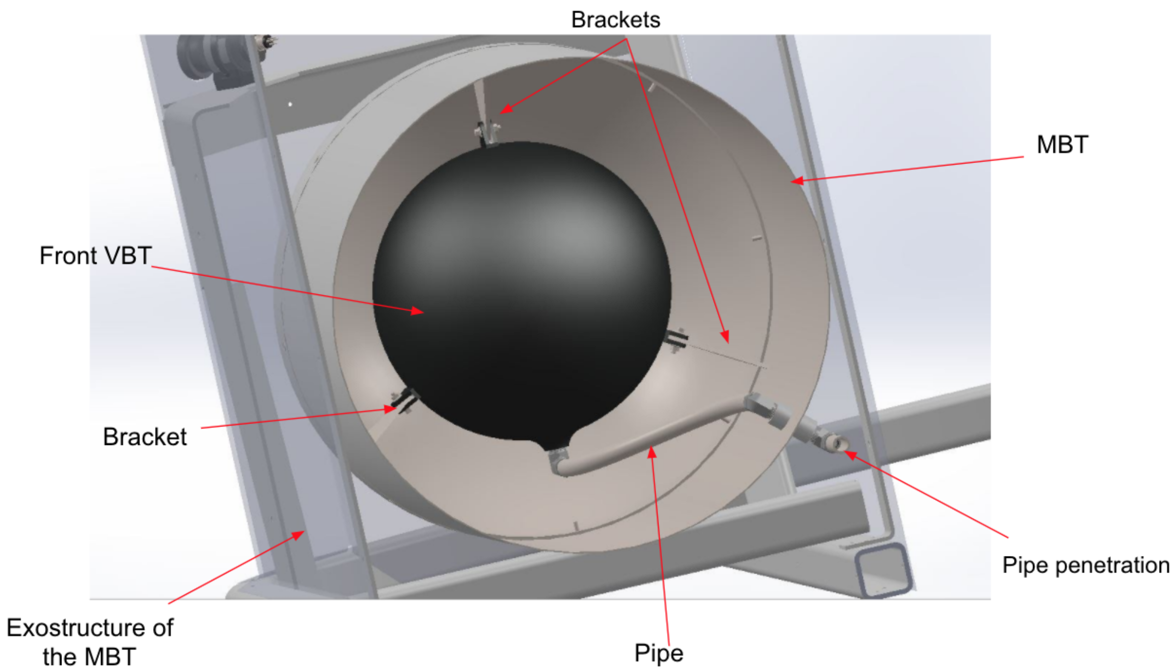

Figure 2-11: Front VBT with supports and brakets

The figure 2-11 shows the front VBT, which along with the rear VBT provides the trimming and depth control systems. Both front VBTs contribute with 25kg of buoyancy. That gives to the total variable system a buoyancy of 50kg. The two front VBTs are in the main ballast tanks. They are stabilized with brackets and supports, which ensures a high safety factor at any internal pressure of the main ballast tanks. The tank is welded at the middle, with a specific welded steam, which is going to support any over stress due to torsion.

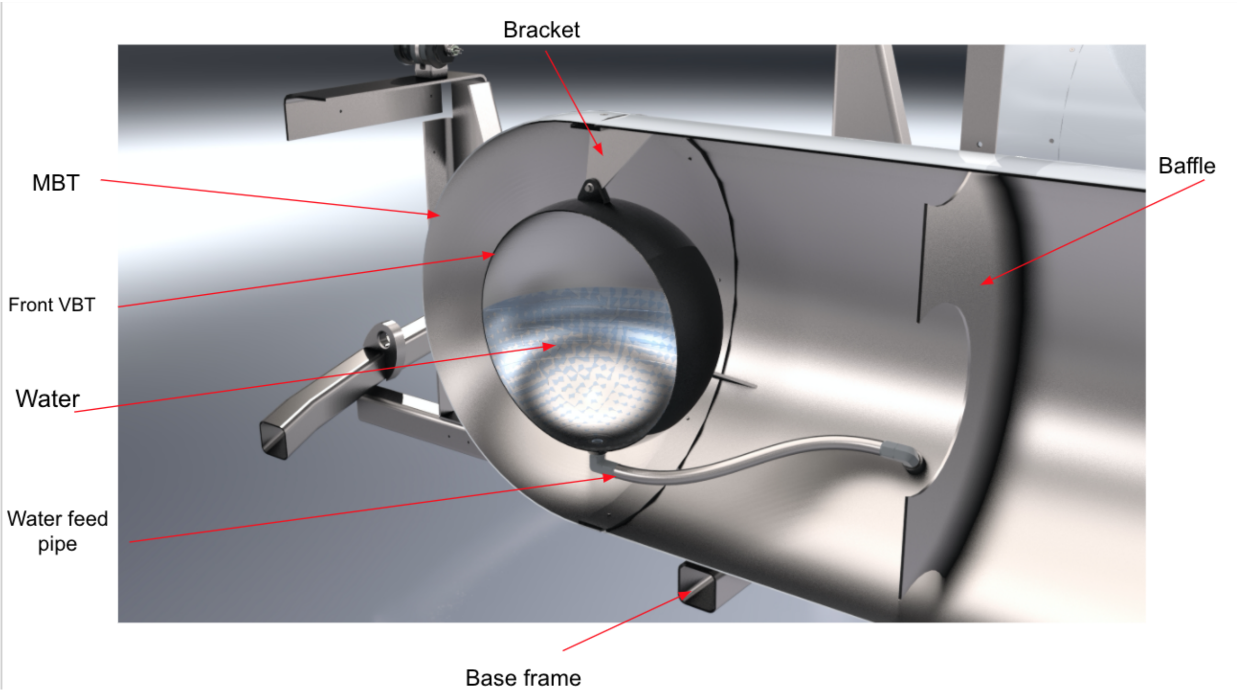

Figure 2-12: Water Level of Front VBT

As shown in the figure 2-12,the front VBTs provide neutral buoyancy. To achieve a maximum pitch, the hydraulic circuit is closed from sea water to allow moving water from one VBT to the other through the closed circuit.

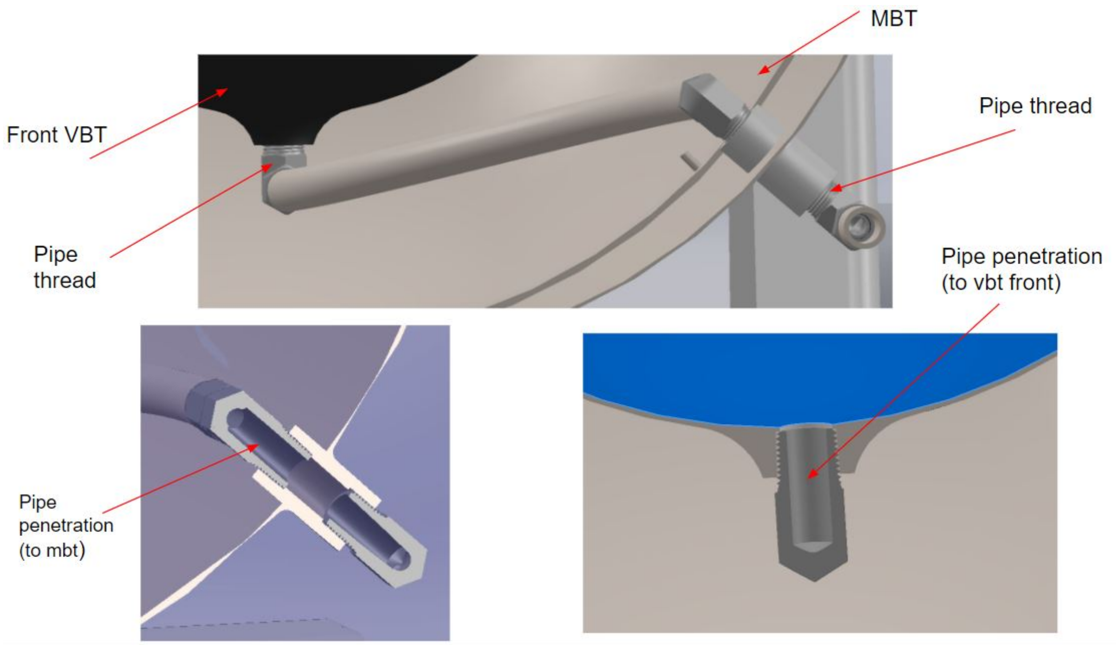

Figure 2-13: Front VBT pipe penetrations and threads

The figure 2-13 above shows the pipe entrances of the Front VBT and their fittings: the first entrance is from depth or pitch panel to the MBT, and the second entrance is to the VBT. For the fitting of the pipe, the pipe is threaded at the two entrances. Like the rear VBT, pipe sealants are used, on the threaded penetrations, to prevent fluids from leaking out.

2.3 Valve panel, pipes pump and motor

2.3.1 Valve panel

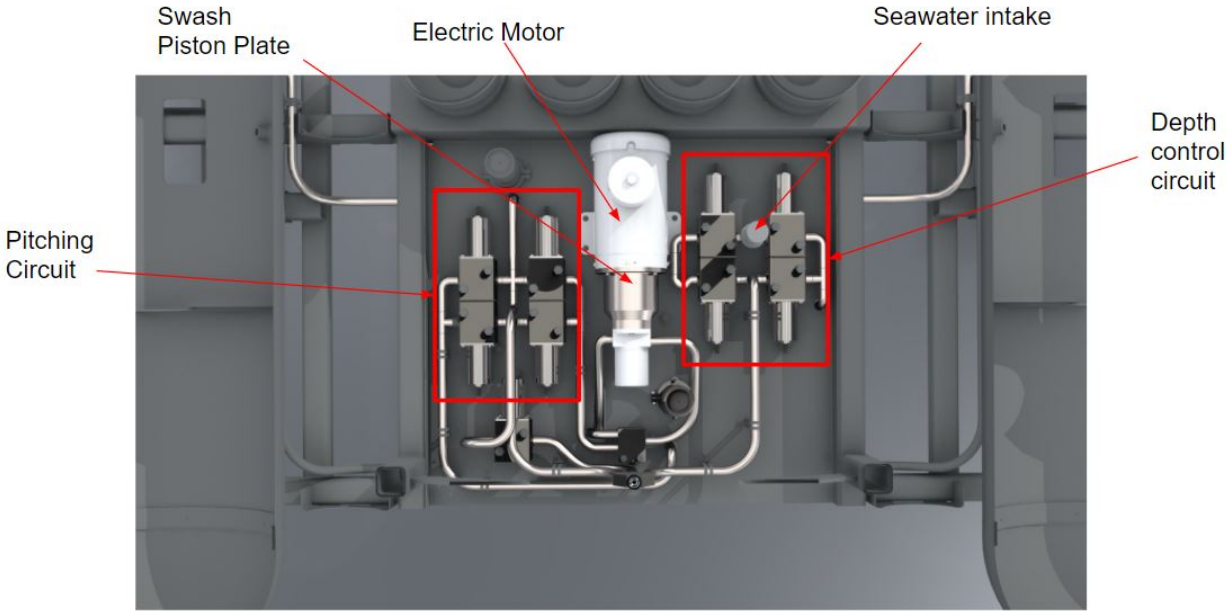

Figure 2-14: Top view of the valves panel with depth control and pitching circuit

The figure 2-14 shows the valve panel, with the two circuits: the depth control circuit, and the pitching circuit. Both circuits are related to the front and rear vbt. The depth control circuit controls the height of the water inside of the vbt, depending on the depth where the submarine is operating. the pitching circuit moves water from fronts VBTs to rear VBT, or the inverse. The maximum pitching angle obtained is 1.5°, since the buoyancy given by the VBTs is very small (50kg).

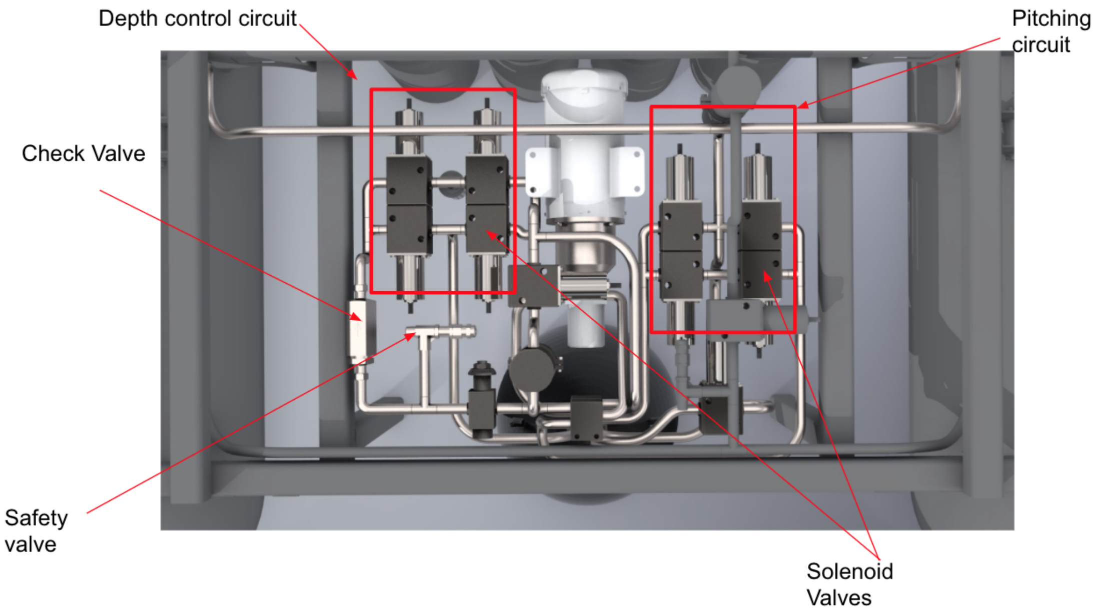

Figure 2-15: Bottom view of the valves panel with depth control and pitching circuit

As we can see on this figure 2-15, for both the depth control and the pitching control circuits, pipes are connected to solenoid valves, controlled automatically by the pilot, with the control panel in the pressure hull. The check valve provides back pressure surge protection to the pressure balance valve. The safety valve prevents over pressure of the seawater pump [7].

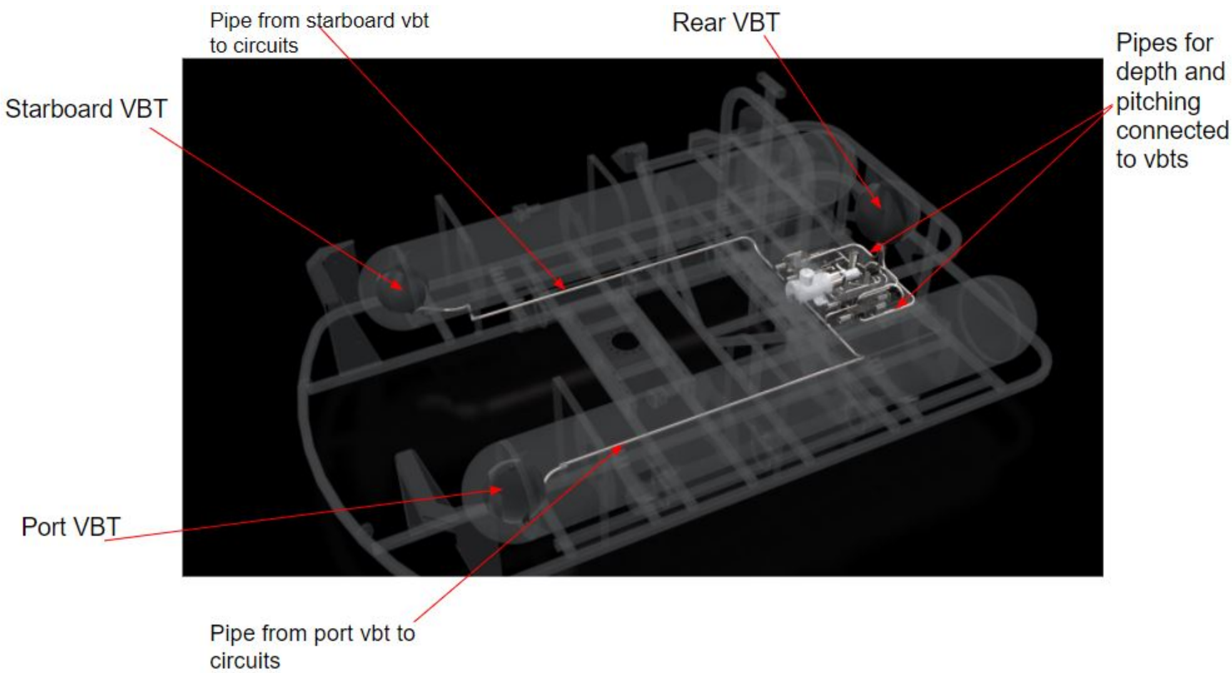

Figure 2-16: Pipes connections from VBTs to circuit

The figure 2-16 shows how the pipe is connected from the rear VBTs and Front VBTs to the circuits. The functionality of the circuit is on the appendix E.1.

2.3.2 Pump and Motor

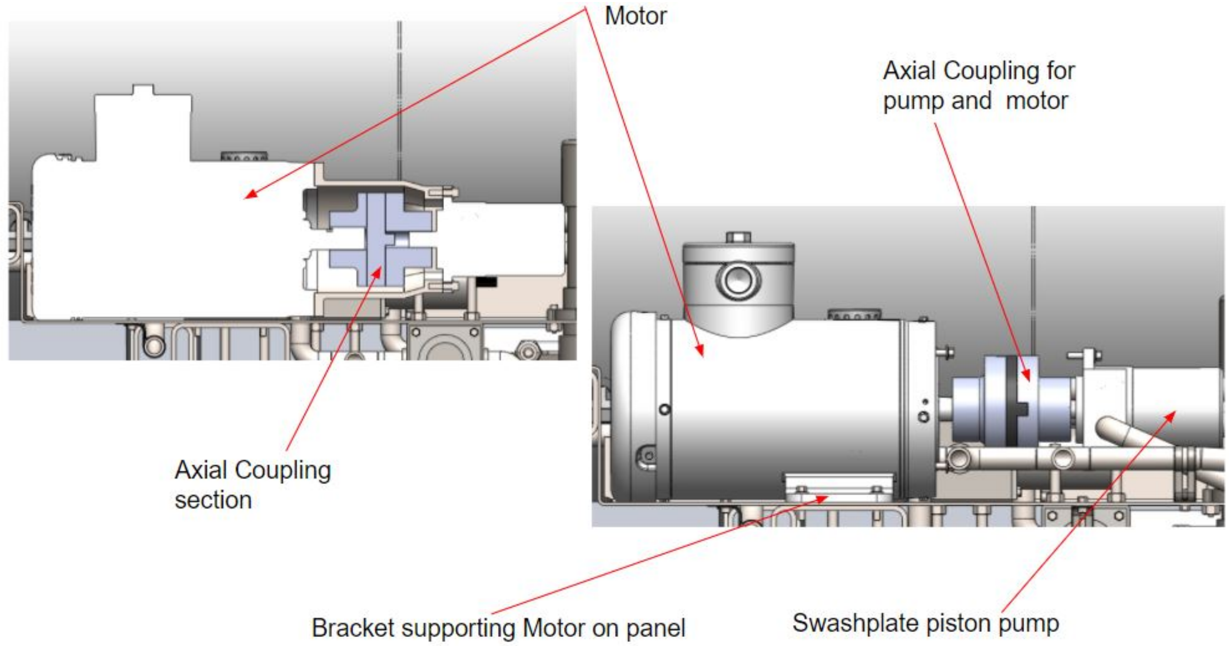

Figure 2-17: Pump and motor, with axial coupling

The figure 2-17 shows the pump and the motor from Danfoss (Appendix E). They ensure depth and pitching control.This pump is chosen by considering to satisfy maximum and minimum outlet and inlet pressures respectively. They work at any depth between 330m and 1000m. The axial coupling ensures a good connectivity and transmission between the pump and motor.

2.4 Drop Weights

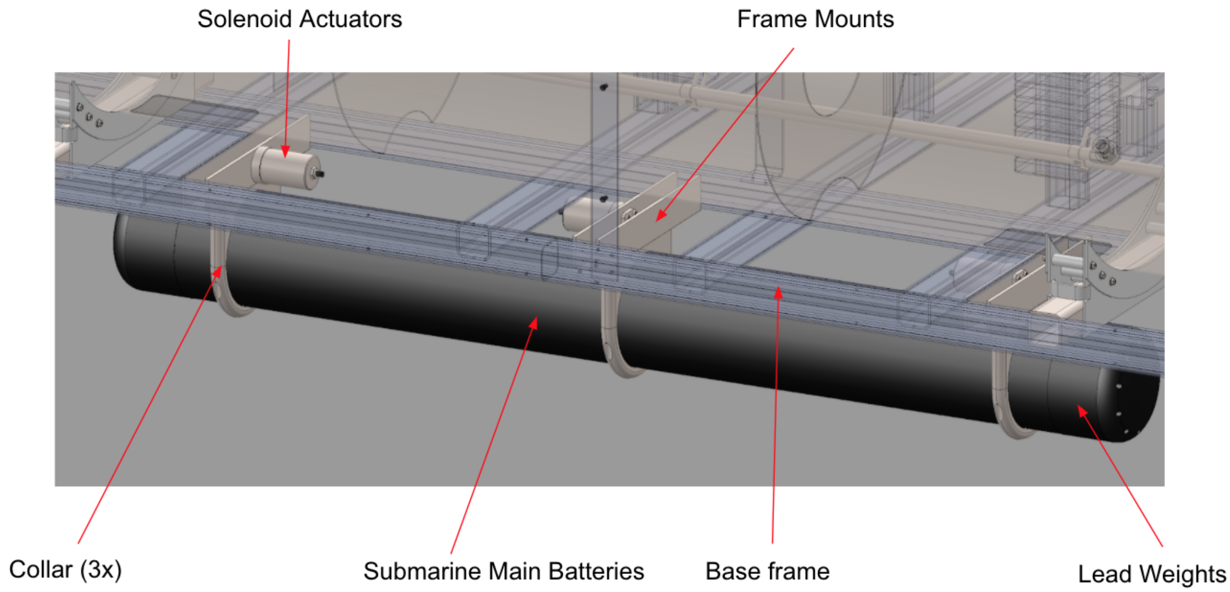

Figure 2-18: Drop Weights Assembly

Drop Weights are the primary safety feature of the design. Upon release, the sub is guaranteed to jettison to the surface. Figure 2-18 shows the Drop weights assembly. The middle of the weights is reserved for the main submarine batteries, if the design determines that more weight is needed then solid lead is added on both ends as needed. The weights are supported by three collars that are held in place with the frame mounts via solenoids actuators.

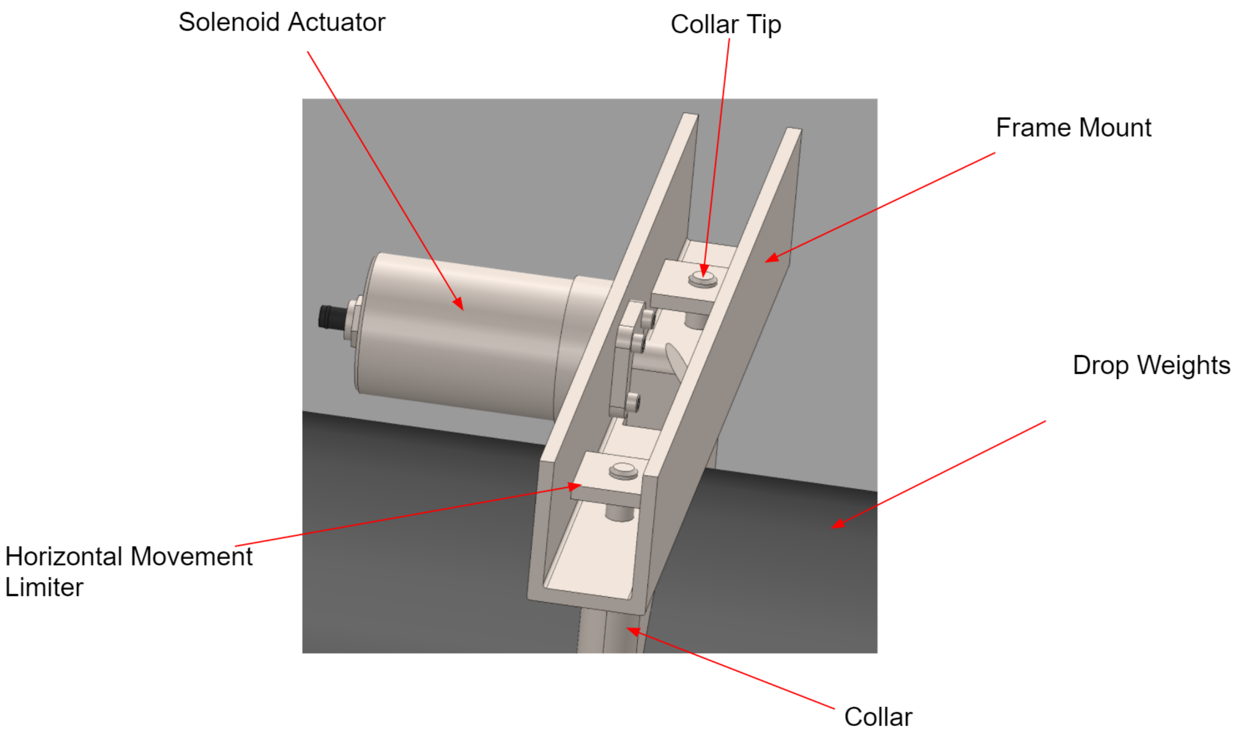

Figure 2-19: Drop Weights Mounts

The frame mounts has two horizontal movement limiter to restrict the movement drop wieghts in the horizontal plane. This can be seen in Figure 2-19.

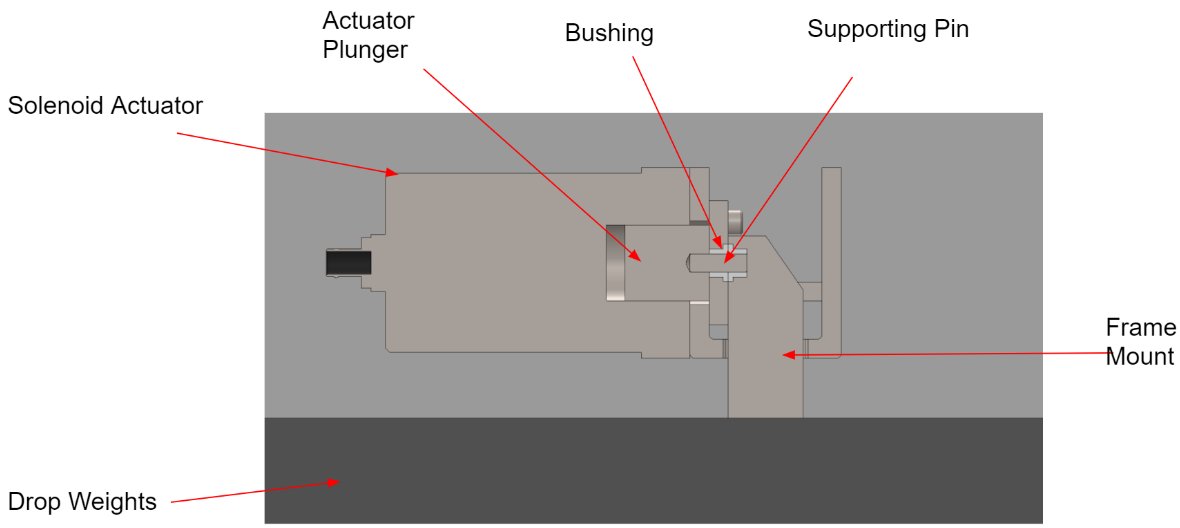

Figure 2-20: Drop Weights Actuator Cross Section

Figure 2-20 shows how the solenoid actuators are used to release the drop weights. Upon emergency, the plunger is pulled back sliding the pin out of the bushes and releasing the drop weights.

2.5 Interconnectivity

- Design

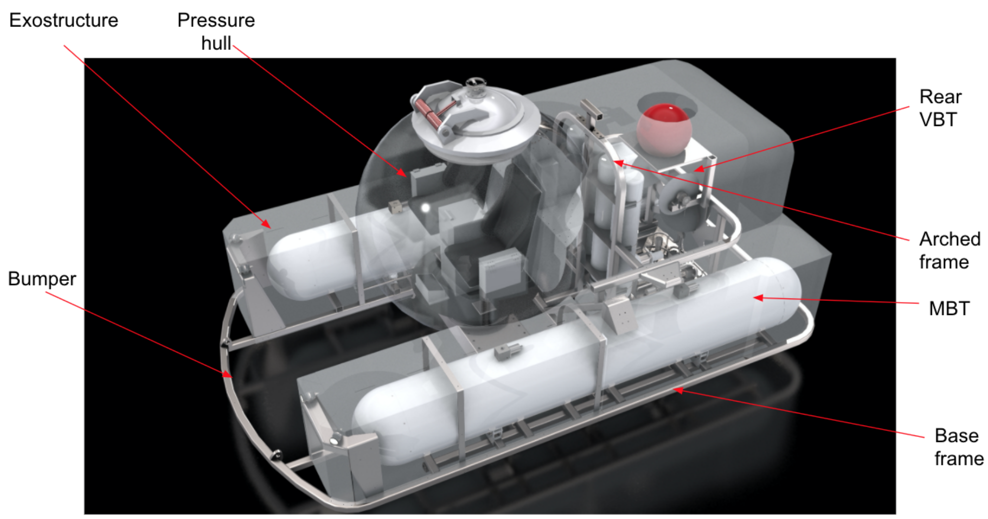

Figure 2-21: Interconnectivity of SUB1A and SUB1B designs

Team SUB1A is responsible for building the exostructure the hull, frame, hatch, seals and access mechanisms, as well as other other internal features. The MBTs have two brackets as seen on Figure 2-3, each one welded to a support beam. The support beams are welded to SUB1A's front base structure. The compressed air bottles rack is supported by three horizontal rear beams, which are welded to the arched structure of SUB1A behind the pressure hull in Figure 2-7.Three solenoid actuators mounts supporting the length of the drop weights. These mounts are welded to the base frame of SUB1A's design. The radial bracket of the VBT is welded the stern frame and the valve panel is also welded to the stern base frame as seen in Figure 2-8.

- Functionality

  Initially, the overall design of the submarine with the exostructure and the ballast system combined, was not horizontally leveled. The center of gravity and buoyancy were not vertically aligned, which was causing the submarine to have a default pitch that can not be canceled by trim control alone. After bringing up the issue to SUB1A's team, it was agreed that the MBT's center of mass needs to be vertically aligned with the center of mass of the submarine. Additionally, a volume of at least $2.2m^3$ of foam placed at the rear of the submarine is needed to drag the center of mass of the submarine horizontally and align it with the center of buoyancy. The second issue brought up related to the overall mass of the submarine that was too high relative to its buoyancy. Consequently, both SUB1A and SUB1B had to shed as much weight as possible to make the submarine positively buoyant upon releasing the drop weights. Finally, Sub 1A team needed to store 250 kg of batteries on board. Consequently, It was agreed to store the batteries in the drop weights to avoid unnecessarily increasing the weight of the submarine.

3 Parameterization

3.1 Outline

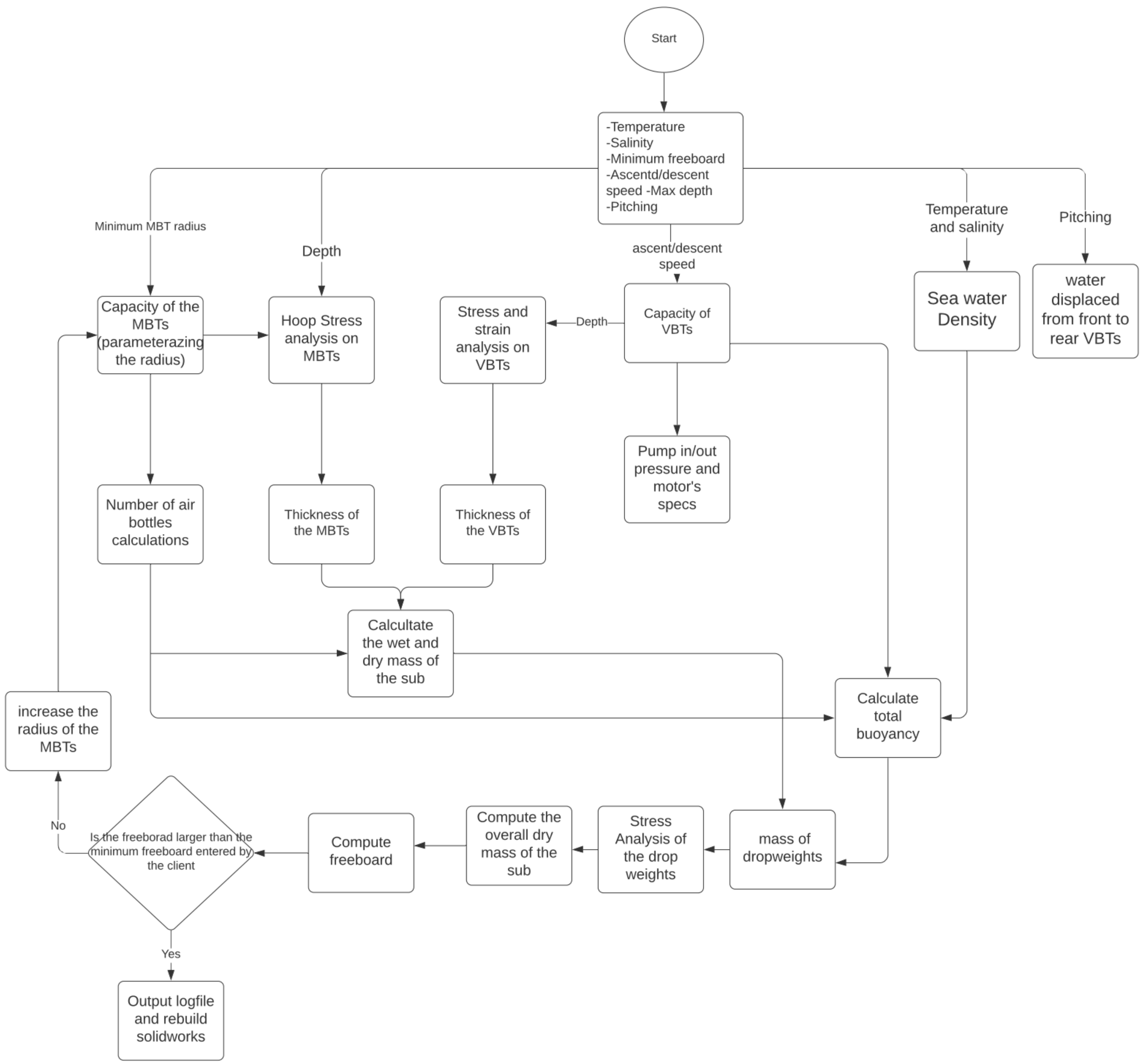

Figure 3-1: Parameterization outline

3.2 Component optimization and discussion on results

Table 3-1: Structural optimizations of the MBTs, VBTs and drop weights

Assembly	Components	Optimization
MBTs	Radius	0.24 m<Rmbt<0.3 m
	Thickness	1.4 mm< t_{mbt} <1.7 mm
	Number of air bottles	1< $N_{air.b}$ <4
Fronts VBTs	Capacity	6.25 < $M_{water.f}$ <12.5 kg
	Thickness	2.001 mm< $t_{vbt.f}$ <3.428 mm
Rear VBT	Capacity	12.5 < $m_{water.vbt}$ <25 kg
	Thickness	2.001 < $t_{vbt.r}$ <4.241
Drop weights	length	1.659 m< L_{dw} <2.371
	Number of solenoid actuators	1< $N_{airbottles}$ <4

The parameterization of the components above on table 3-1 allows to determine an optimized range of values depending on the desired inputs by the user. The range range of depths from 330m to 1000m effects primarily the thickness of the the MBTs and the VBTs. The shallower the maximum depth is, the lower the thicknesses needed to overcome Hoop stresses and the lower the number of air bottles needed for emergency surfacing on air. The submarine therefore becomes lighter. Consequently, this increases the mass of the drop weights, hence their length and the number of solenoid actuators needed for their release. On the other hand, decreasing the radius of the MBTs decreases the freeboard of the submarine, but also decrease the number of air bottles needed to blow the MBTs. The density of water is a key factor in determining the buoyancy of the submarine. If the user inputs the lowest temperature and the highest salinity, this will allow the highest buoyancy and therefore a higher value for the mass of drop weights needed to keep the submarine neutrally buoyant. Additionally, the fastest emergency ascent is achieved when the drop weights are the heaviest. At neutral buoyancy, the MBTs are completely submerged with water and the front and rear VBTs are half filled with water. For ascent and descent control, 25kg of buoyancy is added or subtracted from the VBTs and 500N of upward/downward force of the thrusters to a reasonably good ascent and descent time. The figure bellow shows two extreme of cases parameterization

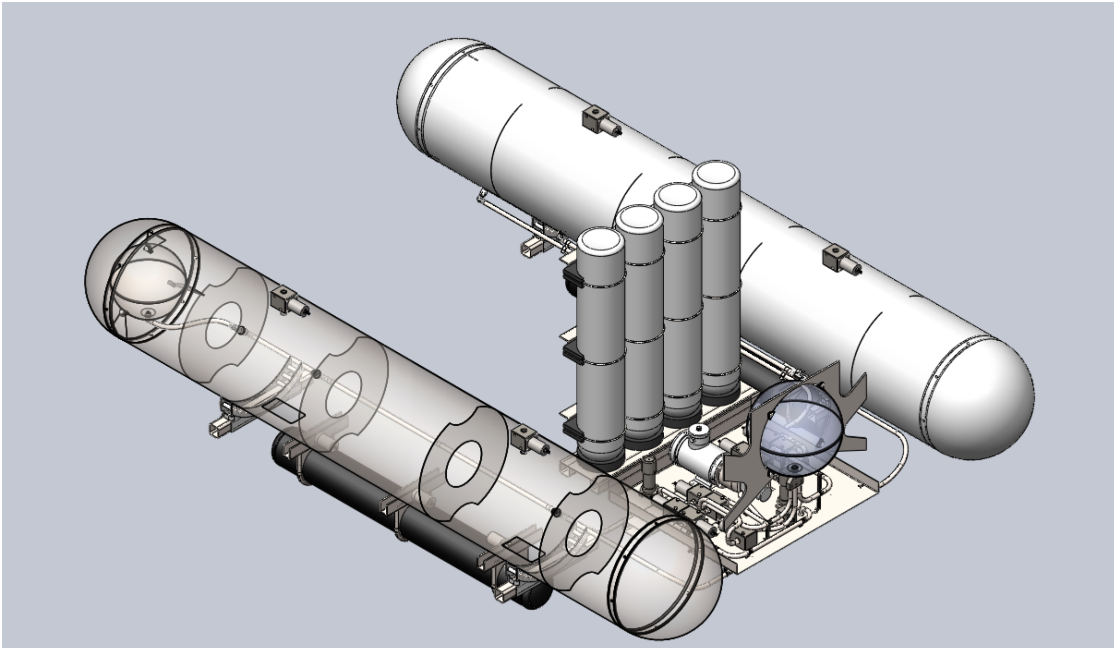

Figure 3-2: Assembly showing Maximum MBTs Size, VBT Capacity and Number of Air Bottles

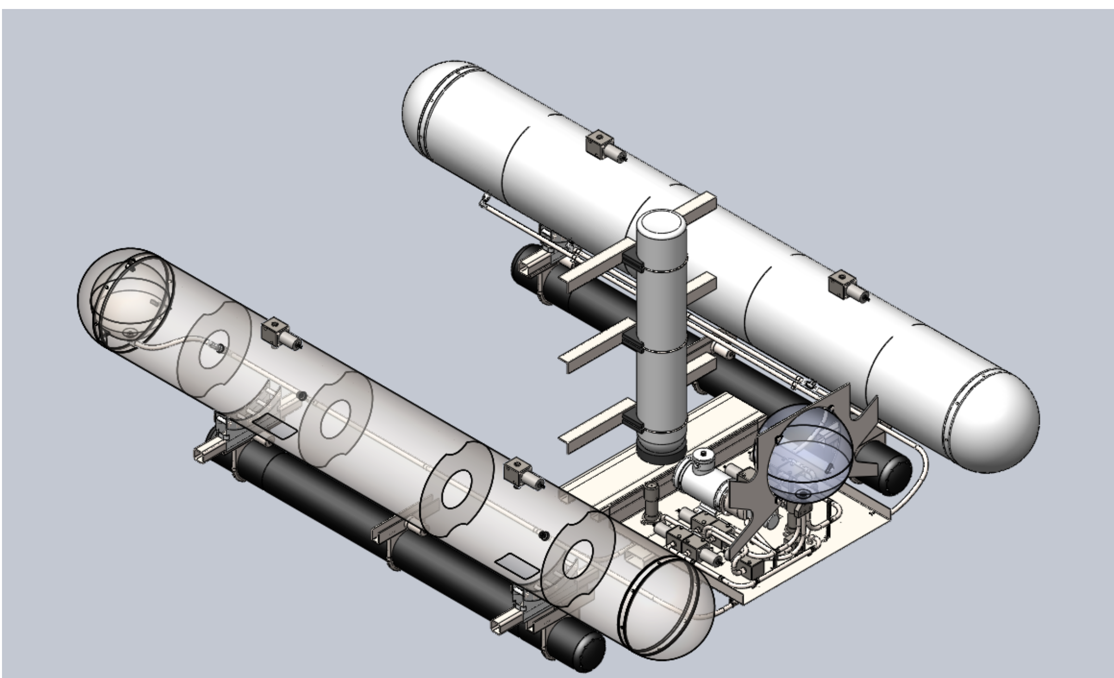

Figure 3-3: Assembly showing Minimum MBTs Size, VBT Capacity and Number of Air Bottles

The first case shown on Figure 3-2 is under conditions of highest maximum depth (1000m), lowest buoyancy (highest temperature and lowest salinity), and highest freeboard (highest MBT radius and number of compressed air bottles).This results in having the smallest length for the drop weights due to the heavy mass of the submarine. The second case, Figure 3-3 presents opposite conditions that showcase the smallest depth depth at 330m, highest buoyancy and lowest freeboard (smallest MBT radius and number of air bottles). This results in having the largest and heaviest drop weights.

4 Discussion and critical review of the solution

The ballast systems and drop weights of this design are capable of satisfying the the required functionalities of the submarine. The MBTs are capable of contributing 2200 kg of buoyancy for surfacing purposes and acheiving enough free board to allow passengers to enter the the hatch. The saddle design of the MBTs also contributes to stabilizing the submarine on the surface during passengers and equipment's entry. The MBTs are completly vented and filled with water to initiate the descent. At neutral buoyancy, the MBTs remain flooded and the VBTs are at 50% of their capacity. Flooding the MBTs solves a major issue of the compressibility of air inside the MBTs. If the MBTs were not completely vented, the air will compress more the deeper the submarine dives. Air bubbles will start forming trapped inside the MBT's water and will be difficult to vent for ascent. Using VBTs and thrusters only for depth control makes this design simple, cost efficient and adjustable to different applications that can suit different market demands.

Paramterization allowed evaluating the design's performance under different conditions, under the constraints of a 1000m maximum depth, 2200kg and 50kg maximum buoyancy from the MBTs and VBTs respectively. The VBTs design is capable of affording speeds up to. The MBTs parameterization allows a minimum freeboard ranging from $0.5m$ to $0.95m$. The VBTs alllow an ascent and descent up to $0.5m/s$ while only using a 6th of the thrusters maximum power, which saves on energy consumption and cost. In any case of outage of power, the submarine is capable of surfacing at $12.6mins$ from a maximum depth upon releasing the drop weights. the submarine is also equipped with enough compressed air bottles to afford a second emergency procedure that consists of blowing the air in the MBTs at any maximum depth if there is no outage of power. This procedure permits costs less than releasing drop weights which are storing batteries, is fast enough to accommodate an emergency event (13 mins from maximum depth).

The front and rear VBTs are connected to a closed loop circuit that allows trim control at neutral buoyancy. However, the constraint of $50kg$ of buoyancy from the VBTs restricted the range of trim control to 1.37°to 1.79°.To accommodate this constraint on the capacity of the VBTs, a parameterization of the position of the rear VBTs was initially tested to attempt optimizing the maximum pitch. However, only a maximum pitch of 2° was obtained obtained upon translating the rear VBT further away from the front VBTs by $0.8m$. After further calculations, the results demonstrated that ideal trim angle ranges of 5°to 10°can only be achieved with VBTs with capacities of at least 100kg. This design would have been able to afford the ideal trim range for no additional cost if the mandate allowed $100kg$ buoyancy from the VBTs.

References

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A Instructions for installing and running the GUI

To run the GUI, open the main.m file available in SUB1B directory and click on Run as shown below

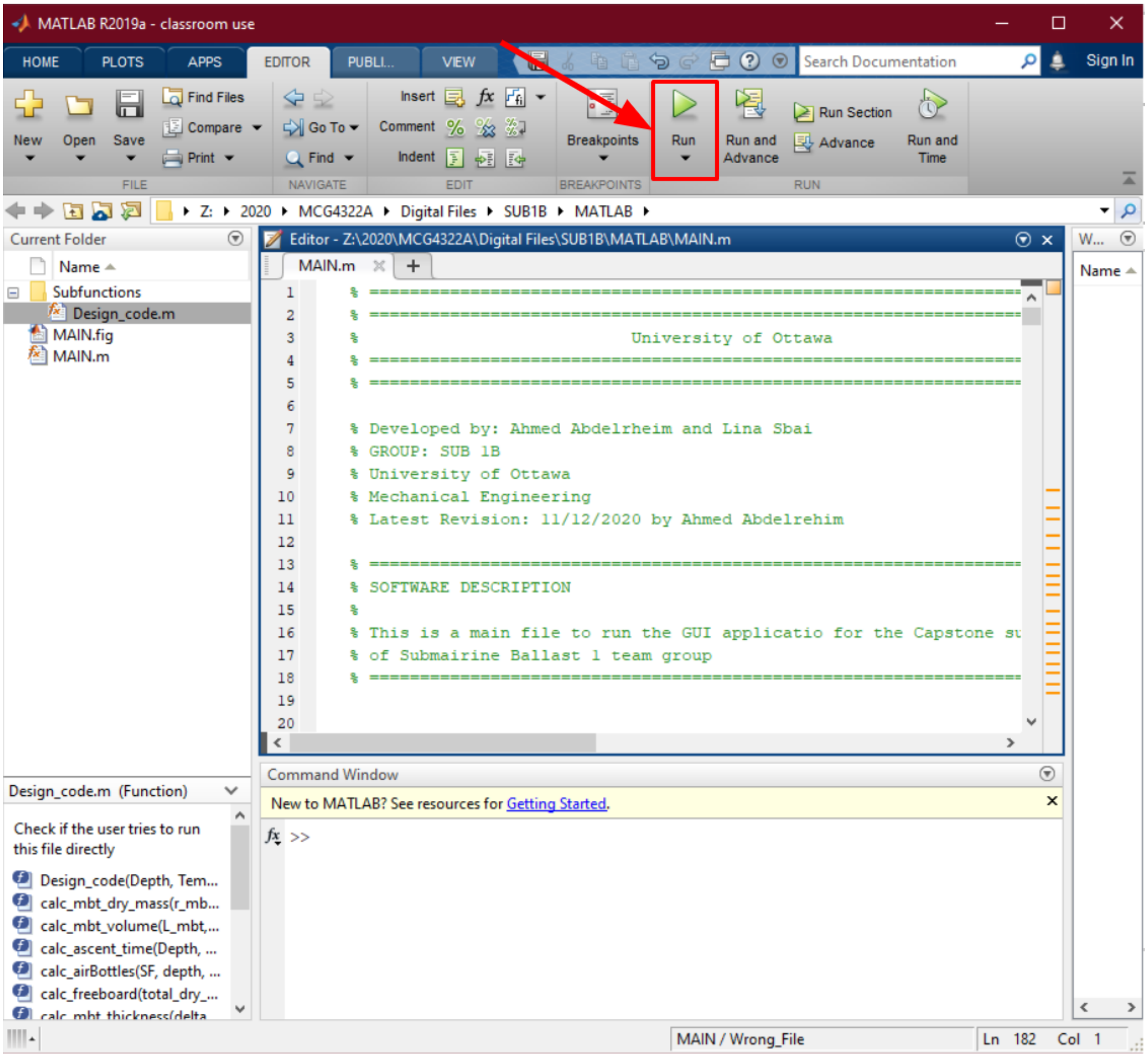


Figure A-1: Clicking Run to start the GUI application

Once you click on Run, the following GUI should pop up.

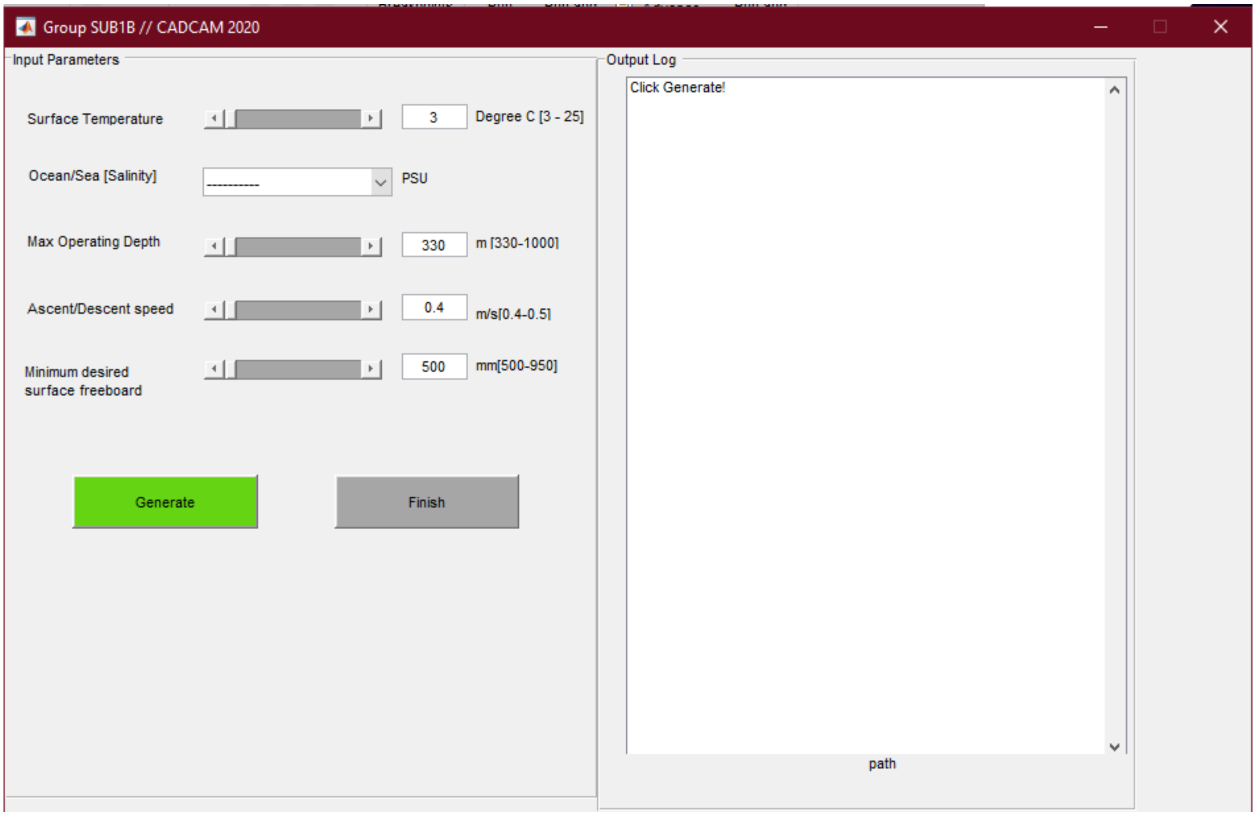


Figure A-2: The Parameterisation GUI Upon Startup

You can now set the input parameters that fit your requirements. Once the inputs are in, click on the green button Generate to see the result of the right panel on the GUI as seen below

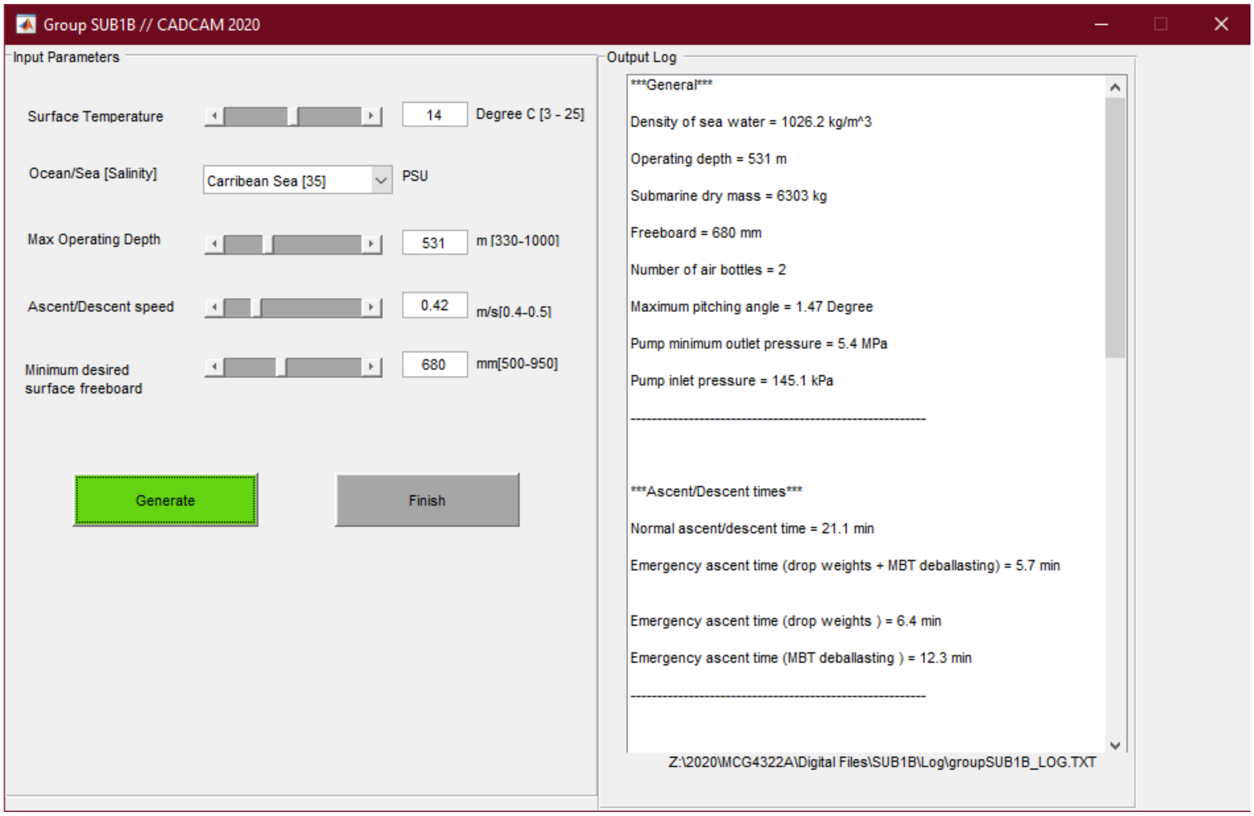


Figure A-3: The Results of Parameterisation After Clicking Generate

B Component parameterization flowcharts

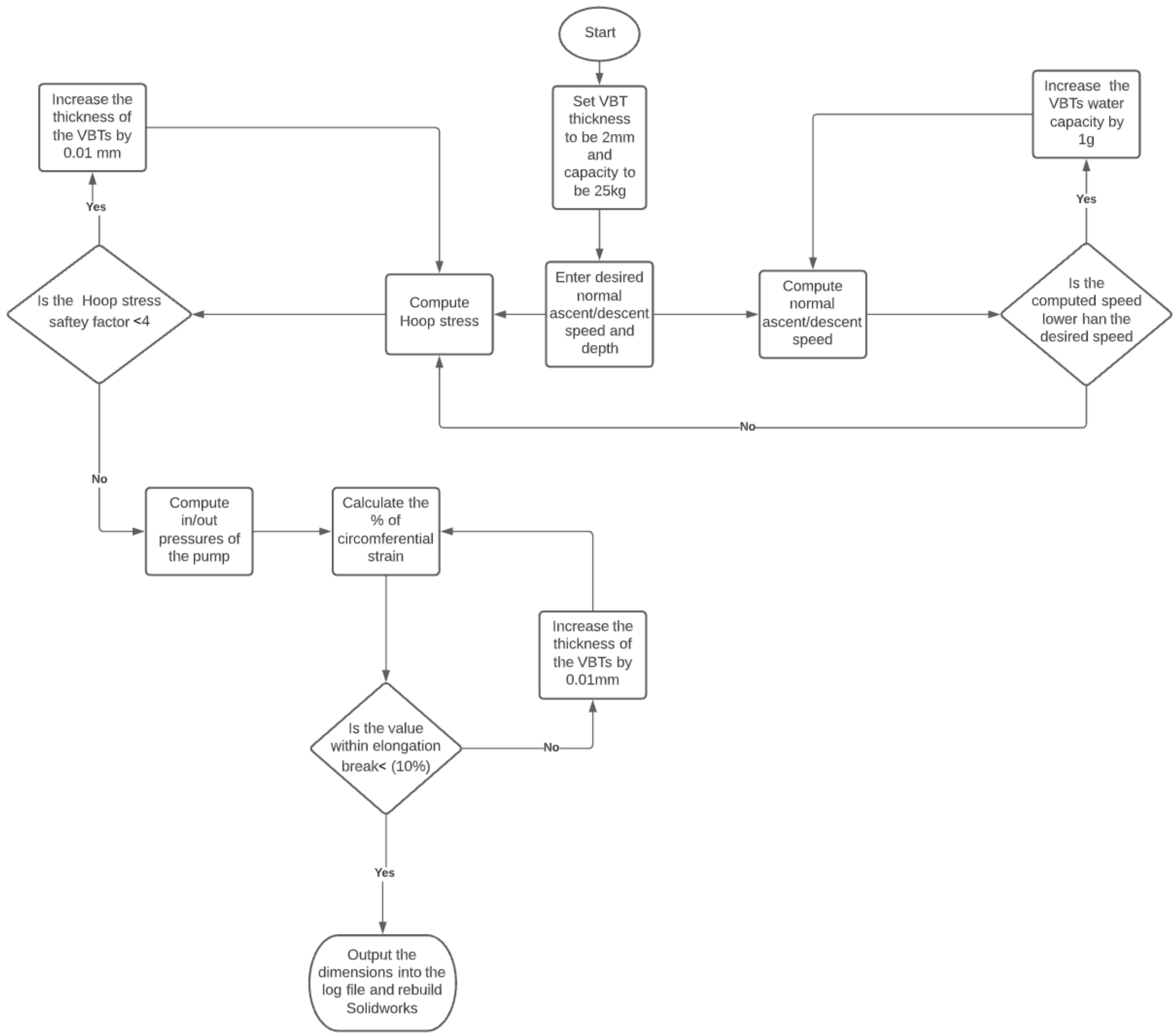


Figure B-1: VBT Parameterization outline

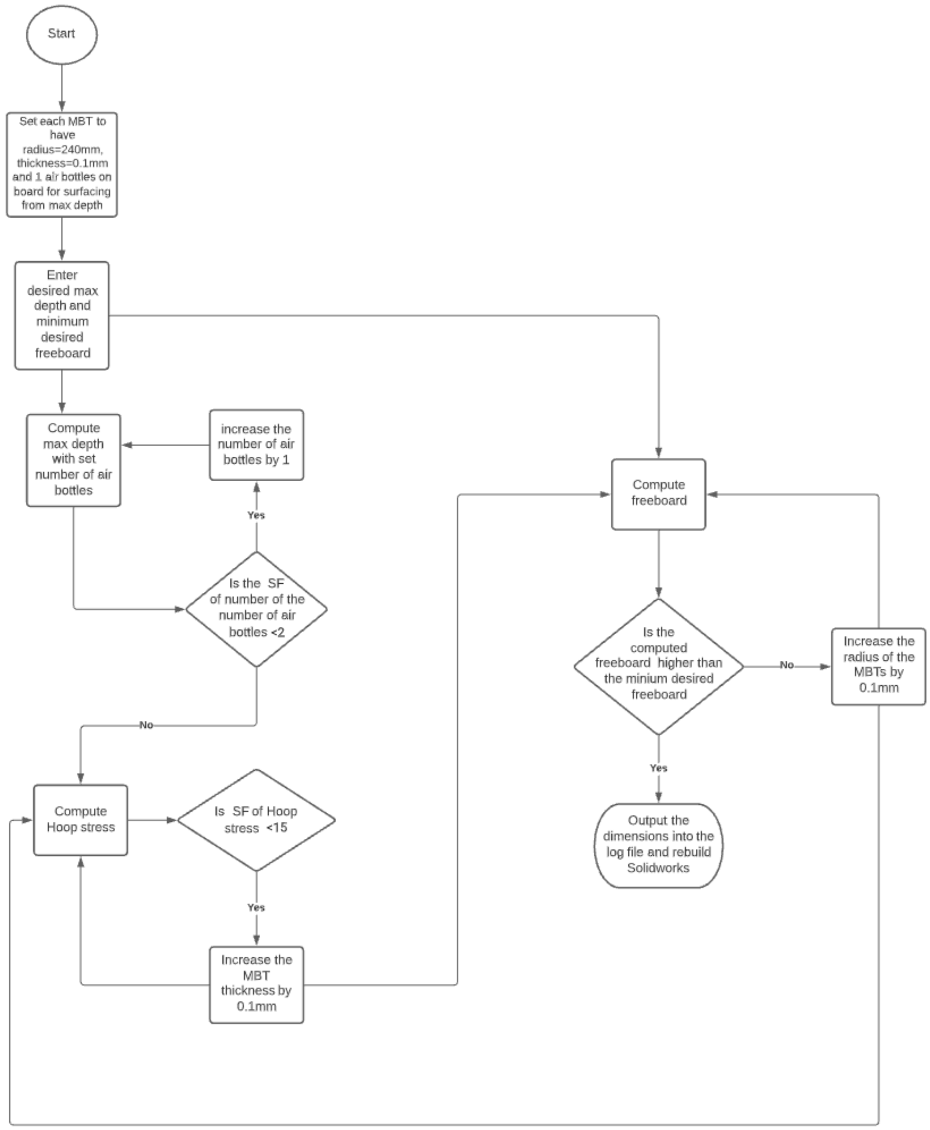


Figure B-2: MBT Parameterization outline

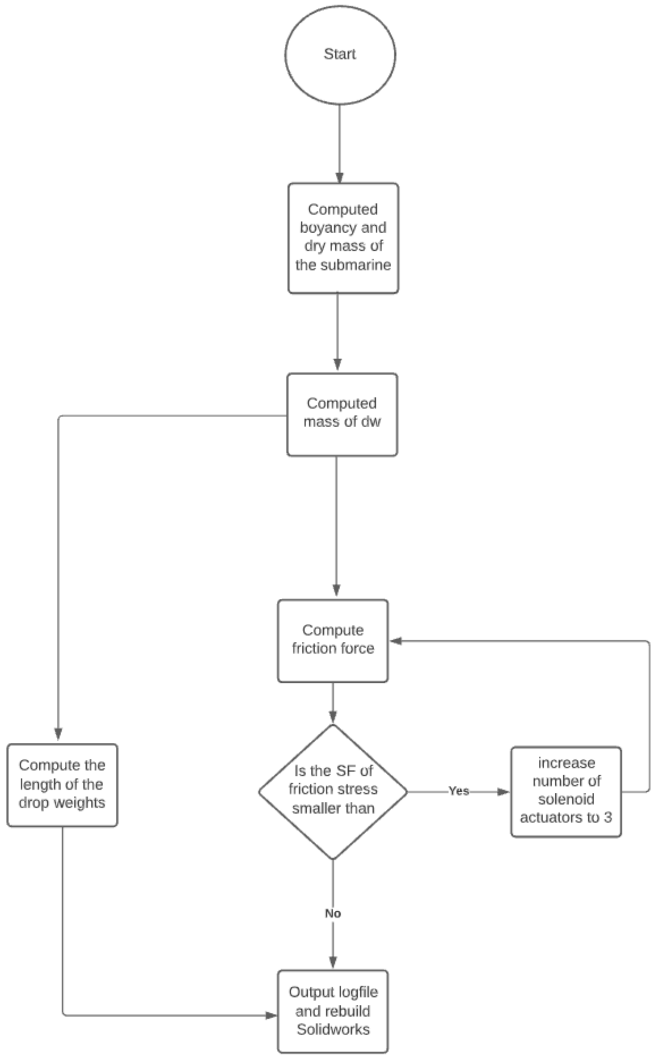


Figure B-3: Drop Weights Parameterization outline

C Design code

```
function Design_code(Depth,Temperature,Freeboard,ADspeed,Salinity)
    %Check if the user tries to run this file directly
    if ~exist('Depth','var')
        cd H:\groupSUB1B\MATLAB\
        run H:\groupSUB1B\MATLAB\Main.m; %Run Main.m instead
        return
    end

    log_file = 'Z:\\2020\\MCG4322A\\Digital Files\\SUB1B\Log\\groupSUB1B_LOG.TXT';
    fid = fopen(log_file,'w+t');



    %% constants to be used
    rho=calc_density_seawater(Temperature,Salinity);%Units (kg/m^3), density of the sea water at a given temperature and salinity
    g=9.81; %(N/Kg) gravitational acceleration constant
    P_atm=101325; %Units (Pa), atmospheric pressure
    mbt_delta_pressure = 200E3; %(Pa) Pa),regulators of the MBTs insure that the pressure difference between the inside and outside of the MBTs is always 200kPa
    %%

    %%%%%%%%%%%%%%%%%%%%%
    %%VBT Calculations%%
    %%%%%%%%%%%%%%%%%%%%%

    %safety factors
    vbt_Hs_SF=4; % Hoop stress

    %The following is a list of constants and calculations of masses, volumes and dimensions of the front and back VBTs

    V_vbt_r=0.048; %Units (m^3), Volume of the rear VBT
    V_vbt_f=0.024; %Units (m^3), Volume of front VBTs
    R_vbt_r=0.226; %Units (m), outer radius of the rear VBT
```

```
R_vbt_f=0.179; %Units (m), outer radius of front VBTs
vbt_cap_neutBuoy=25; %(kg) amount of water in VBT to get sub to neutral
    bouyancy

%The following are function calls to calculate the new water capacity of
    the VBTs
vbt_capacity=calc_VBT_capacity(rho,ADspeed, vbt_cap_neutBuoy);


%The following are calculations of pressures inside the VBTs due to the
    the mass of water inside


P_rear=(P_atm*V_vbt_r)/(V_vbt_r-((0.5*vbt_capacity)/rho)); %Units (Pa),
    pressure of the air inside the rear VBT when compressed by water
P_front=(P_atm*V_vbt_f)/(V_vbt_f-((0.25*vbt_capacity)/rho));%Units (Pa),
    pressure of the air inside the front VBT when compressed by water
P_sea=P_atm+rho*g*Depth; %Units (Pa), sea water pressure at a chosen depth
     entered by the client
P_out_front=P_sea+mbt_delta_pressure;

%The following are function calls to calculate the new optimized thickness
     of the rear and front VBTs at a given depth with a safety factor of 2
vbt_r_thickness=calc_VBT_thickness(R_vbt_r, P_sea, P_rear, vbt_Hs_SF);%
    Units (m),new thickness of the rear VBT
vbt_f_thickness=calc_VBT_thickness(R_vbt_f, P_out_front, P_front,
    vbt_Hs_SF);%Units (m),new thickness of the front VBT
%Displaying the new values of the thickness of the rear and front VBTs


f_vbt_water_height = calc_VBT_water_height(rho,0.25*vbt_capacity,(R_vbt_f-
     vbt_f_thickness));
r_vbt_water_height = calc_VBT_water_height(rho,0.5*vbt_capacity,(R_vbt_r-
    vbt_r_thickness));




%The required inlet and outlet pump specifications for pitching and depth
    control purposes
```

```
    P_out_pump=P_sea;
    P_in_pump=P_rear;

 %Displaying pump and motor specs

 %fprintf(fid,sprintf('The motor specifications are:\n',);

 %The following are function calls to calculate the new optimized masses of the rear and front VBTs at a given depth with a safety factor of 2
 m_dry_vbt_r=calc_mass_material(R_vbt_r,vbt_r_thickness); %Units (kg), new dry mass of the rear VBT
 m_dry_vbt_f=calc_mass_material(R_vbt_f,vbt_f_thickness); %Units (kg), new dry mass of the front VBTs


 %%%%%%%%%%%%%%%%%%%
 %%MBT Calculations%%
 %%%%%%%%%%%%%%%%%%%


 mbt_length = 3.44;%(m^3)
 mbt_min_radius=0.24; %(m)minimum radius of mbt due the front vbt
 sub_area_projected = 7.543; %(m^3)



 %%foam%%
 V_foam=2.21; %(m^3)
 rho_foam=385; %(kg/m^3)
 m_foam = V_foam*rho_foam; %(kg)


 %submarine constant masses
 m_sub1A=3755;%(kg)given to us by sub 1A team
 m_payload = 250;%(kg) payload is kept constant at 250 by adding tungesten weights, taken care of by sub 1A
 m_valve_panel = 212.37;%(kg)
 m_air_bottle = 137.44;%(kg)

 m_vbt_total = 2*m_dry_vbt_f+m_dry_vbt_r; %(kg) we have 2 front and 1 rear
```

```
    vbt
V_pressureHull=(4/3)*pi*0.97^3; %(m^3) volume of the pressure hull
V_air_bottle = 0.043; %(m^3) volume of one air bottle


%safety Factos
air_bottles_SF=2;
mbt_thickness_SF=15;



%%now we optimise everything until we get a suitabe freeboard
flag=false;
computed_freeboard=0;
mbt_diameter = 2*mbt_min_radius; %(m) minimum starting diameter due the
    presence of front VBT
while(computed_freeboard<Freeboard/1000)
        %skip increasing the diameter in the first loop
        %to see if the starting diameter will
        %work for freeboard
        if(flag)
            mbt_diameter=mbt_diameter+0.0001;%(m)
        end

        %maximum MBT capacity of 2200kg as entitled in the project mandate
        if(mbt_diameter>0.6)
            fprintf(fid,sprintf('Maximum allowable freeboard with this
                combination is %0.0f mm. Please try different inputs\n\n',
                 computed_freeboard*1000));
            break;
        end
    flag=true;

    %find MBT volume
    mbt_volume = calc_mbt_volume(mbt_length, mbt_diameter/2); %(m^3)

    %optimise number of air bottles based on current MBT diameter and
    %desired depth
    Num_air_bottles=calc_airBottles( air_bottles_SF,Depth,mbt_volume,279,
        rho);
```

```
    %optimise mbt thickness based on MBT diameter and desired depth
    mbt_thickness=calc_mbt_thickness(mbt_delta_pressure, mbt_diameter/2 ,
        mbt_thickness_SF);%(m)

    mbt_dry_mass=calc_mbt_dry_mass(mbt_diameter/2,mbt_length,mbt_thickness
        ); %(kg)

    %find current total submarine masses (dry and wet)
    sub_dry_mass = m_sub1A+m_payload+m_valve_panel+m_air_bottle*
        Num_air_bottles+m_foam+m_vbt_total+2*mbt_dry_mass; %(kg)

    %note that the wet mass is with VBT partially filled with water to get
         neutral
    %buoynacy
    sub_wet_mass = sub_dry_mass+(2*rho*mbt_volume)+vbt_cap_neutBuoy; %(kg)

    % main volume contributing to the buoyancy of the sub
    buoyant_volume = V_foam+(2*mbt_volume)+V_vbt_r+V_pressureHull+(
        Num_air_bottles*V_air_bottle); %(m^3)

    %force calculations
    F_gravity = sub_wet_mass*g;%(N) % weight of the sub without the drop
        weights

    F_bouyancy = buoyant_volume*rho*g; %(N) % maximum buoyancy of the
        submarine

    F_net = F_bouyancy-F_gravity; %(N) delta  force


    %find drop weights to get the sub to neutral buoyancy at partially
    %filllled VBTs as discussed
    m_drop_weights=F_net/g; %(kg)

    % total mass with drop weights
    sub_dry_mass_total = sub_dry_mass+m_drop_weights; %(kg)


    %compute freeboard based on new total mass. If less than desired,
```

```matlab
        %increase MBT diameter and loop back
        computed_freeboard= calc_freeboard(sub_dry_mass_total, rho, mbt_diameter/2); %(m)
    end

    %pitching

    Pitching_angle = calc_trim_angle(m_drop_weights,mbt_volume,Num_air_bottles,rho,mbt_dry_mass,m_dry_vbt_r,m_dry_vbt_f,sub_wet_mass,R_vbt_r);%(degrees)
    %%%%%%%%%%%%%%%%%%%%%%%%
    %%Emergency Calulation%%
    %%%%%%%%%%%%%%%%%%%%%%%%

    %emergency happends when you drop the drop weights and deballast the
    %MBT

    ascent_time_total = calc_ascent_time(Depth, sub_area_projected, rho, mbt_diameter/2, m_drop_weights);
    ascent_time_dw = calc_ascent_time(Depth, sub_area_projected, rho, 0, m_drop_weights);
    ascent_time_mbt = calc_ascent_time(Depth, sub_area_projected, rho, mbt_diameter/2, 0);
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %%Drop Weights Calculations%%
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%


    %safety factors
    dw_sol_SF=2;

    %getting the length of every drop weight based on their masses
    dw_length = calc_length_dw(m_drop_weights/2); %(m)
    %Function call to calculate the number of solenoid actuators needed to be attached on the drop weights
    num_sol=calc_num_sol(dw_sol_SF, m_drop_weights);
    %Displaying the number of solenoid actuators



```

```
    fprintf(fid,sprintf('***General***\n'));

    fprintf(fid,sprintf('Density of sea water = %0.1f kg/m^3\n', rho));
    fprintf(fid,sprintf('Operating depth = %0.0f m\n', Depth));
    fprintf(fid,sprintf('Submarine dry mass = %0.0f kg\n',sub_dry_mass_total));
    fprintf(fid,sprintf('Freeboard = %0.0f mm\n',computed_freeboard*1000));
    fprintf(fid,sprintf('Number of air bottles = %0.0f\n',Num_air_bottles));
    fprintf(fid,sprintf('Maximum pitching angle = %0.2f Degree \n', Pitching_angle));
    fprintf(fid,sprintf('Pump minimum outlet pressure = %0.1f MPa\n', P_out_pump/1000000));
    fprintf(fid,sprintf('Pump inlet pressure = %0.1f kPa\n',P_in_pump/1000));
    fprintf(fid,sprintf('--------------------------------------------------------------------\n'));
    fprintf(fid,newline);

    fprintf(fid,sprintf('***Ascent/Descent times***\n'));
    fprintf(fid,sprintf('Normal ascent/descent time = %0.1f min\n',Depth/(ADspeed*60)));
    fprintf(fid,sprintf('Emergency ascent time (drop weights + MBT deballasting) = %0.1f min\n\n',ascent_time_total));
    fprintf(fid,sprintf('Emergency ascent time (drop weights ) = %0.1f min\n', ascent_time_dw));
    fprintf(fid,sprintf('Emergency ascent time (MBT deballasting ) = %0.1f min\n',ascent_time_mbt));
    fprintf(fid,sprintf('--------------------------------------------------------------------\n'));
    fprintf(fid,newline);

    fprintf(fid,sprintf('***MBT***\n'));
    fprintf(fid,sprintf('MBTs capacity = %0.1f kg\n', 2*rho*mbt_volume));
    fprintf(fid,sprintf('MBT dry mass = %0.1f kg each\n',calc_mbt_dry_mass(mbt_diameter/2,mbt_length,mbt_thickness)));
    fprintf(fid,sprintf('MBT length = %0.1f mm\n',mbt_length*1000));
    fprintf(fid,sprintf('MBT radius = %0.1f mm\n',mbt_diameter*1000/2));
    fprintf(fid,sprintf('MBT Thickness = %0.1f mm\n',mbt_thickness*1000));
    fprintf(fid,sprintf('--------------------------------------------------------------------\n'));
    fprintf(fid,newline);
```

```
    fprintf(fid,sprintf('***VBT***\n'));
    fprintf(fid,sprintf('VBTs capacity = %0.1f kg\n', vbt_capacity));
    fprintf(fid,sprintf('Thickness of rear VBT is=%0.2f mm\n', vbt_r_thickness*1000));
    fprintf(fid,sprintf('Thickness of front VBT  is=%0.2f mm\n', vbt_f_thickness*1000));
    fprintf(fid,sprintf('------------------------------------------------------------\n'));
    fprintf(fid,newline);

    fprintf(fid,sprintf('***Drop Weights***\n'));
    fprintf(fid,sprintf('drop weights mass = %0.1f kg\n',m_drop_weights));
    fprintf(fid,sprintf('drop weights length = %0.1f mm\n',(dw_length*1000)+1655));
    fprintf(fid,sprintf('The number of solenoid actuators = %i\n',num_sol));
    fprintf(fid,sprintf('------------------------------------------------------------\n'));
    fprintf(fid,newline);

    fprintf(fid,sprintf('***Net forces at diffeernt states***\n'));
    fprintf(fid,sprintf('Buoyancy Force = %0.1f N\n',F_bouyancy));
    fprintf(fid,sprintf('Gravitatinal Force(without dropweights) = %0.1f N\n',-F_gravity));
    fprintf(fid,sprintf('Net Force (without dropweights)= %0.1f N\n', F_bouyancy-F_gravity));
    fprintf(fid,sprintf('Gravitatinal Force(with dropweights) = %0.1f N\n',-F_gravity-m_drop_weights*g));
    fprintf(fid,sprintf('Net Force (with dropweights i.e neutral buoyancy)= %0.1f N\n',F_bouyancy-F_gravity-m_drop_weights*g));
    fclose(fid);

   %Declaring text files to be modified
   %Files

    equations_file = 'Z:\\2020\\MCG4322A\\Digital Files\\SUB1B\\Solidworks\\equations.txt';


        %Write the equations file(s) (FILE(s) LINKED TO SOLIDWORKS).
```

```
        %You can make a different file for each section of your project (ie
            one for steering, another for brakes, etc...)
        %or one single large file that includes all the equations. Its up to
            you!

    fid = fopen(equations_file,'w+t');
    fprintf(fid,strcat('"r_o"=',num2str((mbt_diameter+mbt_thickness)*1000/2),'
        \n'));
    fprintf(fid,strcat('"t"=',num2str(mbt_thickness*1000),'\n'));
    fprintf(fid,strcat('"t_vbt"=',num2str(vbt_f_thickness*1000),'\n'));
    fprintf(fid,strcat('"vbt_water_height"=',num2str(f_vbt_water_height*1000),
        '\n'));
    fprintf(fid,strcat('"t_vbt_rear"=',num2str(vbt_r_thickness*1000),'\n'));
    fprintf(fid,strcat('"vbt_water_height_rear"=',num2str(r_vbt_water_height
        *1000),'\n'));
    fprintf(fid,strcat('"numBottles"=',num2str(Num_air_bottles),'\n'));
    fprintf(fid,strcat('"dw_len"=',num2str(dw_length*1000),'\n'));
    fprintf(fid,strcat('"num_solenoids"=',num2str(num_sol),'\n'));
    fclose(fid);


end

%function to calculate the dry mass of the MBT
function mbt_dry_mass = calc_mbt_dry_mass(r_mbt,L_mbt,t_mbt)

    %Eq.(1)

    %mbt are made from stainless steel
    rho_ss=7800; %(kg/m^3)

    m_mbt_peripherals=98.6; %air vents, baffles, mounting brackets

    mbt_material_volume=pi*(L_mbt*(r_mbt+t_mbt)^2+(4/3)*(r_mbt+t_mbt)^3-L_mbt*
        r_mbt^2-(4/3)*r_mbt^3);%(m^3)
    mbt_dry_mass=(mbt_material_volume*rho_ss)+m_mbt_peripherals;%(kg)
end

%function to calculate the volume of the MBT
function mbt_volume = calc_mbt_volume(L_mbt, r_mbt)
```

```
    %Eq.(2)
    mbt_volume = pi*r_mbt^2*L_mbt + (4/3)*pi*r_mbt^3;
end

%function to calculate the ascent time by equating vertical forces
function ascent_time = calc_ascent_time(Depth, area_proj, rho, mbt_radius, drop_weight_mass)
    %Eq.(3)
    mbt_length=3.44;%(m)constant length to enable max pitching
    C_d = 0.8;%found by looping over renolds number

    mbt_volume = calc_mbt_volume(mbt_length, mbt_radius);%(m^3)

    %the net force is only coming from MBTS, assuming the average displaced
    %volume to be 20%, because the 10% purge will keep expanding as the
    %submarine move up, this is combined with the upward force from
    %dropping the drop wights
    Net_upward_force=0.2*mbt_volume*rho*9.81+ drop_weight_mass*9.81;%(N)

    %ascent speed can now be calculated by equating the upward force to
    %drag force

    ascent_speed = sqrt((2*Net_upward_force)/(area_proj*C_d*rho));%(m/s)

    %finding time
    ascent_time = Depth/(ascent_speed*60); %(min)

end

%funcrion to find number of air bottles based on depth and MBT volume
function new_num_airbottles = calc_airBottles(SF, depth, mbt_volume,Temp,rho)

        %Eq. (4)

    P_atm = 101325; %(Pa)
    R_air = 287;% (J/(kg*K)) air ideal gas constant
    P_bottle = 41.4e+6 ;%(Pa) air pressure in bottle
    V_bottle = 0.043; %(m^3) volume of air
    %calculte pressure at max depth

```

```
    P_max =  P_atm+ rho*9.81*depth;

    %calculate the mass of air needed to fill 10% of the mbt volume at
    %max depth
    mass_air_mbt = (2*P_max*mbt_volume*0.1)/(R_air*Temp);%(kg)

    %air is going to get out of the bottle until the inside pressure is
    %equal to ambient pressure P_max

    %so the mass of air to get out of one bottle is
    mass_air_bottle_out = ((P_bottle - P_max)*V_bottle) / (R_air*Temp);%(kg)

    %optimise number of air bottles
    num_bottles = 0;
    n=0;
    while(n<SF)

        num_bottles = num_bottles+1;
        %new safety factor
        n = (num_bottles*mass_air_bottle_out)/mass_air_mbt;

    end

    new_num_airbottles = num_bottles;
end

%Finding freeboard based on net weight and surface buoyancy
function new_freeboard = calc_freeboard(total_dry_mass, rho, r_mbt)

    %Eq. (5)
    %solidworks dimensions
    %foam
    L_foam=2.6; %(m)
    W_foam=0.83; % (m)
    H_foam= 1.16; % (m)

    %pressure hull
    r_pressureHull = 0.97; %(m)

    L_mbt=3.44; %(m)mbt length
```

```
    %equating submaine weight to bouyancy at surface, then solving for
    %displaced volume gives


    V_displaced = total_dry_mass/rho; %(m^3)


    %submarine submerged volume at surface needs to be found using the
    %following geometry equations
    V_total_submerged=0;
    h_submerged = 0;

    %find water height at sea surface
    while(V_total_submerged<V_displaced)

        %fprintf('here\n');
        h_submerged = h_submerged + 0.00005; %(m)

        %if the mbt is partially submerged
        if(h_submerged<(2*r_mbt))
            %finding volume of partially filled cylinder with spherical
            %caps, (m^3)
            V_mbt_submerged = 2*((r_mbt^2*acos((r_mbt-h_submerged)/r_mbt)-(
                r_mbt-h_submerged)*(sqrt(2*r_mbt*h_submerged-h_submerged^2)))*
                L_mbt+((pi/3)*h_submerged^2*(3*r_mbt-h_submerged)));

        else
            %mbt fully submerged
            V_mbt_submerged = 2*(pi*r_mbt^2*L_mbt); %(m^3)

        end

        %if foam is partially submerged
        if(h_submerged<H_foam)
            V_foam_submerged = L_foam*W_foam*h_submerged;%(m^3)
        else %foam is fully submerged
            V_foam_submerged = L_foam*W_foam*H_foam;%(m^3)
        end

```

```

        if(h_submerged<0.354 )
            %water level is below pressure hull
            V_pressureHull_submerged =0;%(m^3)
        elseif(h_submerged<2.294)
            %water level is within the pressure hull
            V_pressureHull_submerged = (pi/3)*(h_submerged-0.354)^2*(3*r_pressureHull-(h_submerged-0.354));%(m^3)

        else
             %pressure hull is fully submerged
            V_pressureHull_submerged =(4/3)*pi*r_pressureHull^3;%(m^3)
        end

        V_total_submerged = V_mbt_submerged+V_foam_submerged + V_pressureHull_submerged;%(m^3)

    end

    %submarine height
    H_sub = 2*r_pressureHull+2*r_mbt-0.354;%(m)

    %freeboard height is simply then the total height minus the water
    %height
    new_freeboard = H_sub-h_submerged;%(m)
end

%funtion to find MBT thickness MBT geomtry and pressure difference
function new_mbt_thickness=calc_mbt_thickness(delta_P, mbt_radius, SF)
    %Eq. (6)
    Sigma_y = 551E6; %(Pa) of 2507 stainless steel
    thickness =0;
    n=0;
    %optimise thickness based on hoop stress
    while(n<SF)
        thickness = thickness+0.0001;
        Hoop_Stress = (mbt_radius*delta_P)/thickness; %(Pa)
        n=Sigma_y/Hoop_Stress;
    end
    new_mbt_thickness=thickness;%(m)
```

```
end

%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%VBTs%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%

%Find the VBT capacity to get to the desired vertical speed
function new_vbt_capacity=calc_VBT_capacity(density, desired_speed,
    vbt_cap_neutBouy)
   %Eq. (7)
   capacity=0;% Units (kg), the mass of water that the VBT can contain
   A_cc=7.543; %Units (m^2), The longitudinal cross section area of the
       submarine
   C_d=0.8; %Drag coefficient
   F_thrust=500; %Units (N); The force genenerated by the verstical thrusters
   v=0;
   %At neutral bouyancy, the VBT are half filled
   while (v<desired_speed) && (capacity<=25)
       capacity=capacity+0.0001;
       F_net=F_thrust+capacity*9.81;%Units (N), the net force applied on the
           submarine during ascent and descent
       v=sqrt((2*F_net)/(A_cc*C_d*density));%Units (m/s);ascent and descent
           speed
   end
   new_vbt_capacity=vbt_cap_neutBouy+capacity;% Units (kg), the mass of water
       that the VBT can contain
end

%function to find the water height at VBT
function VBT_water_height=calc_VBT_water_height(rho,capacity,radius)
   %Eq. (8)
   water_level=0;
   mass_cap=0;
   while (mass_cap<capacity)
       water_level=water_level+0.0001;
       mass_cap=rho*(((4/3)*pi*radius^3)-(pi*((2*radius- water_level)^2)*(3*
           radius-(2*radius- water_level)))/3);
   end
   VBT_water_height=water_level;% Units (m), the height of water that the VBT
       can contain
```

```

end

%function to find VBT thickness given VBT geomtry and pressure difference
function new_vbt_thickness=calc_VBT_thickness(radius,P_out,P_in,SF)
   %Eq. (9&10)
   n=0;%setting the safety factor to a value of 0
   thickness=0.002;%setting the thickness to a value of 0.001m
   strain=0;%setting the circumferential strrain to a value of 0
   sigma_yield_Tit=1100E6; %Units (Pa), yield strength of Titanium
   Young_Tit=114E9; %Units (Pa), Young modulus of Titanium
   %Increasing the thickness of the VBTs until n=SF
   while (n<SF)
       thickness=thickness+0.00001; %Incrementing the thickness by 0.000001 m
       Hoop_stress_VBT=((radius^2)*P_in-((radius+thickness)^2)*P_out)/((2*radius+thickness)*thickness);%Units (Pa), Hoop stress on the walls of the VBTs
       n=sigma_yield_Tit/abs(Hoop_stress_VBT); %Safety factor of Hoop stress
       strain=(100*(-Hoop_stress_VBT+0.33*Hoop_stress_VBT))/Young_Tit;% Units (%), Cicumferential strain
   end
   stress_thickness = thickness;
   new_strain=strain;%Units (%); Strain applied of the walls of the VBT due to Hoop stress
   %Evaluating if the thickness computed in the first loop accomodates a strain lower than 10%
   while (new_strain>10)
       stress_thickness=stress_thickness+0.00001;
       Hoop_stress_VBT=((radius^2)*P_in-((radius+stress_thickness)^2)*P_out)/((2*radius+stress_thickness)*stress_thickness);%Units (Pa)
       new_strain=(100*(-Hoop_stress_VBT+0.33*Hoop_stress_VBT))/Young_Tit;
   end

   new_vbt_thickness=stress_thickness;%Units (m)
end

%The following are the functions called for calculations of the volume and mass

function mass_hollow_sphere=calc_mass_material(radius,thickness)
```

```
    %Eq. (11)
    rho_Tit=4430; %Units (kg/m^3),density of Titanium
    volume=(4/3)*pi*((radius+thickness)^3-(radius^3));%Units (Kg/m^3), Volume
        of the material of the VBTs
    mass_hollow_sphere= rho_Tit*volume;%Units (kg), mass of a hollow Titanium
        sphere
end

%function to find density of sea water based on salinity and water
%temperature
function rho_sea_water= calc_density_seawater(Temperature,Salinity)
    %Eq. (12)
    T=Temperature;
    S=Salinity;
    C=999.83;%Units(kg/m^3), density of pure water
    Beta=0.808; %Units(kg m^-3 psu^-1), saline contraction
    alpha=0.0708*(1+(0.068*T)); %Units(m^3. C ^-1), coefficient of thermal
        expansion
    gamma=0.003*(1-0.012*T); %Units(kg.m^-3. C ^-1.psu^-1), compressibility
        coefficient
    rho_sea_water=C+Beta*S-alpha*T-gamma*(35-S)*T;%Units (kg/m^3), density of
        sea water at the surface of seawater at a given temperature and
        salinity
end

%function to calculate the pitching angle given the total mass and buoyancy
%of the submarine
function angle=calc_trim_angle(m_drop_weights,mbt_volume,Num_air_bottles,rho,
    mbt_dry_mass,m_dry_vbt_r,m_dry_vbt_f,sub_wet_mass,R_vbt_r)
       %The maximum pitch angle is calculated by assuming that 12.5 kg is
       %displaced from the front VBTs to the rear VBT at neutral buoyancy
       rho_lead=11340;%Units (kg/m^3), dentisty of Lead
       volume_dw=m_drop_weights/rho_lead;%Units (m^3),Volume of drop weights
       rho_foam=385;%Units (kg/m^3), density of foam
       V_foam=2.21;%Units (m^3), volume of foam
       m_foam=rho_foam*V_foam;%Units (kg), mass of the foam

       y_B=((2.21*0.735-0.40185*volume_dw)+(2*0.14515*mbt_volume)
           -(0.41373*0.048)+(1.018*3.82)+(Num_air_bottles*0.6665*0.043))/(2.21+
           volume_dw+2*mbt_volume+0.048+0.048+3.82+Num_air_bottles*0.043);%
```

```
    Units (m), y coordinate of center of buoyancy
    z_B=((-0.735*0.735-0.5*volume_dw)-(2*0.500*mbt_volume)-(0.41373*0.048)+(Num_air_bottles*-1.1661*0.043))/(2.21+volume_dw+2*mbt_volume+0.048+0.048+3.82+Num_air_bottles*0.043);%Units (m), z coordinate of center of buoyancy

    m_water_r=25;%Units(kg/m^3), the final mass of water at the rear VBT after maximum pitching
    h_r_new=R_vbt_r;%Units (m),height of water inside the rear VBTs

    y_Gr_water=(3*(2*R_vbt_r-h_r_new)^2)/(4*(3*R_vbt_r-h_r_new));%Units (m), center of mass of the diplaced water
    y_G=((m_foam*0.735)+(-0.40185*m_drop_weights)+(0.70104*4390.14)+(2*0.14515*(mbt_dry_mass+rho*mbt_volume))+(0.41373*m_dry_vbt_r)+(2*0.11218*m_dry_vbt_f)+((y_Gr_water+0.18773)*m_water_r)+(Num_air_bottles*0.6665*137))/(sub_wet_mass+m_drop_weights);%Units (m), y coordinate of the new center of gravity

    z_G=((-2.220*m_foam)+(-0.500*m_drop_weights)-(2*0.500*(mbt_dry_mass+rho*mbt_volume))-(2.047*4390.14)-(2.04774*(m_dry_vbt_r+m_water_r))+(-Num_air_bottles*1.1661*137))/(sub_wet_mass+m_drop_weights);%Units (m), z coordinate of the new center of gravity
    angle=(180/pi)*atan((12.5*3.9)/((sub_wet_mass+m_drop_weights)*abs(y_G-y_B)));%Units (degrees),maximum pitch angle

end


%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%DWs function calls%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%

%function to find the number of solenoids supporting the drop weights
 function new_num_sol=calc_num_sol(SF, m_drop_weights)
    %Eq. (13)
    mu=0.1; %Friction factor of PTFE-Steel
    F_sol=177.93; %Units (N),linear force generated by the solenoid actuotor
    num_sol=1;
    n=0;
    while (n<SF) && (num_sol<3)
```

```
            num_sol=num_sol+1;
            F_N=(1/num_sol)*m_drop_weights*9.81; %Units (N), normal force applied
                on each pin
            F_f=mu*F_N;%Units (N), frcition force applied on the pin
            n=F_sol/F_f;
       end
           new_num_sol=num_sol;
  end

 %function to find the length of drop weights given its mass
function length_dw=calc_length_dw(mass_dw)
     %Eq. (14)
     lead_mass = abs(mass_dw-125); %(kg) taking away the mass of batteries
         located inside the drop weights
     r_dw=0.1;%Units(m);radius of one drop weight(dw)
     rho_lead=11340;%Units (kg/m^3), dentisty of Lead
     length_dw=(lead_mass/rho_lead)/(pi*r_dw^2);%Units (m), length of one dw
 end
```

D All minutes (team/partner and group)

Group Minutes

Attendees:	**Absent:**	**Date & Time:**	**Venue:**
Jeromy, Osman, Lina, Ahmed, Fanta	None	Meeting 1: 09/14/20 4:30pm Meeting 2: 09/16/20 8:30am	Discord/MS Teams

Minute taker: Who is filling out this form?	Lina	**Chairperson:** Who is organising the meeting?	Jeromy

	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	Literature Review: Broad Research	- Understanding of the literature review and its required contents - Each member is to carry out broad and individual investigations and research about the SUB B task	Entire Team	2 Days (48 Hours)	Yes
2	Literature Review: Division of Tasks	- Share collected research for the literature review - Divide literature review tasks among team members with deadlines - Discuss task requirements with the professor and TA	Entire Team	3 Days (72 Hours)	No
3					
4					
5					

Next meeting **Chairperson:**	**Minute taker:**	**Date & Time:**	**Venue:**
Osman	Lina	09/19/20	Discord/MS Teams

Minutes

09/14/20
During the meeting:
1. Discuss work accomplished since the last meeting (No work assigned)
2. Discuss tasks not-completed since the last meeting (No work assigned)
3. Review action items and tasks to be completed after the meeting
   - Understanding of the literature review and its required contents
   - Each member is to carry out broad and individual investigations and research about the SUB B task

Meeting minutes content:
1. Summarize completed work (Each member successfully completed a broad research of the entire lit review)
2. List previous tasks that have not been completed in the prescribed timeline (No previous work assigned)
3. Specify task reassignments (No reassigned tasks)
4. List additional tasks completed but not listed in previous minutes (None to be listed)
5. Specify additional out-of-class meeting attendance (Discussions via group text chat on messenger)

09/16/20

During the meeting:
1. Discuss work accomplished since the last meeting (Each member successfully completed a broad research of the entire lit review)
2. Discuss tasks not-completed since the last meeting (Proper review of ballast and hull integration)
3. Review action items and tasks to be completed after the meeting
   - Each member now has an assigned portion of the literature review to be completed in depth)
     -Osman/Jeromy = VBT
     -Ahmed/Lina/Fanta = Soft Ballast/Drop Weight
   - Keep literature review design oriented
   - Use a higher ratio of academic journals rather then general google links

Meeting minutes content:
1. Summarize completed work (Discussion with prof/TA - designation of tasks for final lit review - discussion of proper hull/ballast integration)
2. List previous tasks that have not been completed in the prescribed timeline (None)
3. Specify task reassignments (No reassigned tasks)
4. List additional tasks completed but not listed in previous minutes (None to be listed)
5. Specify additional out-of-class meeting attendance (Discussions via group text chat on messenger)

Previous Friday lab attendance	**Previous lecture attendance**
All group members attended	All group members attended

Figure D-1: Week1st minutes

Group Minutes					
Attendees: Jeromy, Lina, Ahmed, Fanta		**Absent:** N/A	**Date & Time:** 22/09/2020		**Venue:** MS Teams
Minute taker: Who is filling out this form? Lina		**Chairperson:** Who is organising the meeting?			
	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	Discuss the concept report requirements	Meeting through MS teams	All	1 day	yes
2	Sketching solutions	Drawing rough sketches then clean ones	All	2 days	in progress
3	Distributing report sections among team members	Meeting through MS teams	All	1 hour	yes
4	Finalize drawings	using drawing software	Jeromy	3 days	no
5	Finalize the report	Meeting through MS teams	Ahmed, Lina, Fanta	3 days	no
Next meeting **Chairperson:** Jeromy		**Minute taker:** Lina	**Date & Time:** 24/09/2020		**Venue:** MS Teams

Minutes

Minutes

During the meeting:
1. Discuss work accomplished since the last meeting.
- Rough sketches finalized

2. Discuss tasks not-completed since the last meeting.
-Clean drawings in process

3. Review action items and tasks to be completed after the meeting
-Editing of final drawings.
-Working on cost assessment and decision matrix.
-Working on discussion.

Meeting minutes content:
1. Summarize completed work.
- Each member completed rough sketches.
- Distribution work load between member.

2. List previous tasks that have not been completed in the prescribed timeline
-None
3. Specify task reassignments
- Lina and Fanta will work on main ballast sketches + drop weight sketches
-Ahmed and Jeromy will work on variable ballast sketches.

4. List additional tasks completed but not listed in previous minutes
-None

5. Specify additional out-of-class meeting attendance
- Meeting at SITE to discuss tasks distribution

Previous Friday lab attendance	Previous lecture attendance
Lina, Ahmed, Jeromy, Fanta	Lina, Ahmed, Jeromy, Fanta

Figure D-2: Week2nd minutes

Group Minutes						
Attendees: Jeromy, Lina, Ahmed, Fanta, Mihaita Matei, Nathaniel Mailhot		**Absent:** N/A		**Date & Time:** 30/09/2020		**Venue:** MS Teams
Minute taker: Who is filling out this form? Ahmed			**Chairperson:** Who is organising the meeting?			
	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	Requiring feedback from professor and TA about the concept report	Meeting through MS teams	All	15 min	yes	
2	Editing concept report	Drawing rough sketches then clean ones	All	2 days	in progress	
3	Importing document into Laitex	Meeting through MS teams	Ahmed/Jeromy	1.5 hour	no	
4	Finalize report	using drawing software	All	1 hour	no	
5						
Next meeting **Chairperson:** Jeromy		**Minute taker:** Ahmed		**Date & Time:** 30/09/2020		**Venue:** MS Teams

Minutes	
-Feedback was given to us about the concept report. -Ahmed showed the drawings in the report and asked if we need a sketch that involves all the subsystems together. -The professor inquired about the software used to developed the drawings -Nathaniel mentioned that our drawings are not what is required in this report, pointing that they are more of a schematic than mechanical drawings. -Nathaniel suggested that we should not worry about this at this point in time but rather focus on submitting it in the best way possible and implement the changes in the modeling report. -The Professor asked to meet on us on Friday to give us critical feedback on the concept report so we can implement the changes in the modeling report	
Previous Friday lab attendance Lina, Ahmed, Jeromy, Fanta	**Previous lecture attendance** Lina, Ahmed, Jeromy, Fanta

Figure D-3: Week3rd minutes

Group Minutes			
Attendees: Lina, Ahmed, Fanta, Mihaita Matei, Nathaniel Mailhot	**Absent:** Jeromy	**Date & Time:** 7/10/2020	**Venue:** MS Teams
Minute taker: Who is filling out this form? Ahmed		**Chairperson:** Who is organising the meeting? Ahmed	

	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	Requiring feedback from professor and TA about the Modelling report	Meeting through MS teams	All	15 min	yes
2	Editing modelling report	Drawing rough sketches then clean ones	All	2 days	yes
3	Importing document into overleaf	Meeting through MS teams	All	1.5 hour	yes
4	Finalize report	using overleaf	All	1 hour	yes
5					

Next meeting Chairperson:	**Minute taker:**	**Date & Time:**	**Venue:**
Jeromy	Ahmed	7/10/2020	MS Teams

Minutes	
-Ahmed started by sharing the report and asking for feedback from the professor and the TA -Professor pointed out that the shape of the MBT might need some modifications to withstand high pressure - Professor liked that we have error percentage for our calculations -Ahmed asked the professor for feedback about the buoyancy convention. - Professor answered accordingly -Modelling report feedback meeting was scheduled on Tuesday at 8:50 am.	
Previous Friday lab attendance	**Previous lecture attendance**
Lina, Ahmed, Fanta	Lina, Ahmed, Jeromy, Fanta

Figure D-4: Week4th minutes

Group Minutes

Attendees:	Absent:	Date & Time:	Venue:
Lina, Ahmed, Fanta, Jeromy, Mihaita Matei, Nathaniel Mailhot		13/10/2020 14/10/2020	MS Teams

Minute taker: Who is filling out this form?	Chairperson: Who is organising the meeting?
Lina	Ahmed

	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	Requiring feedback from professor and TA about the Modelling report	Meeting through MS teams	All	15 min	yes
2	Discussing possible solutions for the VBTs	Meeting through MS teams	All	1h	yes
3	Discussing how to divide tasks regarding drawings of the design dossier	Meetig through MS teams	All	1h	yes
4					
5					

Next meeting Chairperson:	Minute taker:	Date & Time:	Venue:
Jeromy	Lina	14/10/2020	MS Teams

Minutes

-The professor and TA gave us an elaborate feedback of our modelling report

-Professor pointed out that the shape of the MBT might need some modifications to withstand high pressure

-There are some mistakes in calculations that need to be corrected

-All group members discussed the number of VBTs and their locations with regards to the pressure hull.

Previous Friday lab attendance	Previous lecture attendance
Lina, Ahmed, Fanta, Jeromy	Lina, Ahmed, Jeromy, Fanta

Figure D-5: Week5th minutes

Group Minutes

Attendees:	Absent:	Date & Time:	Venue:
Lina, Ahmed, Fanta, Mihaita Matei, Nathaniel Mailhot, Jeromy		19/10/2020	MS Teams

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

	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	Requiring feedback from professor and TA about the Design Dossier	Meeting through MS teams	All	15 min	yes
2					
3					
4					
5					

Next meeting Chairperson:	Minute taker:	Date & Time:	Venue:
Jeromy	Ahmed	19/10/2020	MS Teams

Minutes

-Professor mentioned that it is really important to consider where the submaine subcomponents are mounted on the main structure. That includes MBTs, air tanks, valve panels and pipes.

- Professor expressed some concerns about the back plate of the MBTs. Preferring to give them a spherical shape to withstand hydrostatic pressure.

- Nathaniel mentioned a question about the safety valve, recommending to use it as an active safety mechanism rather than passive one.

- Nathaniel mentioned the importance of figuring out the force used at the air-water interface as this would be the main element of stress on the MBT structure.

- Nathaniel emphasized on the fact that the team need to analysis the shafts of the pumps and motors, to be able to produce the required flow rate at the maximum given pressure.

- Lina asked if we can use the ideal gas law, Professor approved using it with the MBTs.

-Nathaniel expressed some improvments on how to mount the front VBTs. recommending that we take into consideration easy installation and accessibility

Previous Friday lab attendance	Previous lecture attendance
Lina, Ahmed, Fanta, Jeromy	Lina, Ahmed, Jeromy, Fanta

Figure D-6: Week6th minutes

Group Minutes					
Attendees: Lina, Ahmed, Fanta, Mihaita Matei, Nathaniel Mailhot, Jeromy	**Absent:**		**Date & Time:** 06/11/2020		**Venue:** MS Teams
Minute taker: Who is filling out this form? Fanta		**Chairperson:** Who is organising the meeting? Fanta			
	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	Feedback from professor and TA about the Analysis Dossier	Meeting through MS teams	All	25 min	yes
2					
3					
4					
5					
Next meeting **Chairperson:** Jeromy	**Minute taker:** Fanta		**Date & Time:** 06/11/2020		**Venue:** MS Teams

Minutes

- Professor mentionned that we were supposed to write everything on world.
- He mentionned that we should complete more the analysis
- Professor mentioned that we only have to o calcuation that make sens
- He said that we had to check again ascending, pitching, descending and rolling situation
- The professor said that we don't need to consider forces with a small intensity
- He advices us the start doing programmation, and to finish by manufacturing
- Nathaniel said that we have to make very clean FBD
- Nathaniel said that we have to focus first on pump an motor
- He said as well hat we shoul be able to determine how deep the submarine ca go

Previous Friday lab attendance	Previous lecture attendance
Lina, Ahmed, Fanta, Jeromy	Lina, Ahmed, Jeromy, Fanta

Figure D-7: Week7th minutes

Group Minutes

Attendees:	**Absent:**	**Date & Time:**	**Venue:**
Lina, Ahmed, Mihaita Matei, Nathaniel Mailhot	Fanta, Jeromy	11/11/2020	MS Teams

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

	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 feedback about the progress of the Analysis report	Meeting through MS teams	All	15 min	yes
2					
3					
4					
5					

Next meeting **Chairperson:**	**Minute taker:**	**Date & Time:**	**Venue:**
Jeromy	Ahmed	11/11/2020	MS Teams

Minutes

- Lina mentioned that we are adding foam to increase buoyancy to help determine the drop weights mass

- Lina mentioned that foam will also be used to induce more pitching angles caused by the VBTs

- Professor Mihaita liked the idea that several aspects are being taken into consideration regarding foam, and that is an optimisation problem

- Nathaniel asked about the reason behind the absence of the two team members

Previous Friday lab attendance	**Previous lecture attendance**
Lina, Ahmed, Fanta, Jeromy	Lina, Ahmed, Jeromy, Fanta

Figure D-8: Week8th minutes

Group Minutes					
Attendees: Lina, Ahmed, Fanta, Mihaita Matei, Nathaniel Mailhot		**Absent:** Jeromy	**Date & Time:** 18/11/2020		**Venue:** MS Teams
Minute taker: Who is filling out this form? Ahmed			**Chairperson:** Who is organising the meeting? Ahmed		
	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	Discussing the issue of centering the center of mass and buoyancy	Meeting through MS teams	All	15 min	yes
2	Discussing the specification of the pump used for trim and depth control	Meeting through MS teams	All	15 min	yes
3					
4					
5					
Next meeting **Chairperson:** Fanta		**Minute taker:** Ahmed	**Date & Time:** 25/11/2020		**Venue:** MS Teams

Minutes	
-Lina mentioned that we are adding foam to increase buoyancy to help determine the drop weights mass -Ahmed explained the method used to calculate the drop weight's mass. -Lina mentioned that foam will also be used to induce more pitching angles caused by the VBTs. -Fanta asked about the lack of online resources to find a sea water pump. -Nathaniel suggested to increase the volume of the VBTs to increase the buoyancy.	
Previous Friday lab attendance	**Previous lecture attendance**
Lina, Ahmed	Lina, Ahmed, Jeromy, Fanta

Figure D-9: Week9th minutes

Group Minutes

Attendees:	Absent:	Date & Time:	Venue:
Lina, Ahmed, Fanta, Mihaita Matei, Nathaniel Mailhot	Jeromy	18/11/2020	MS Teams

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

	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	Discussing the issue of centering the center of mass and buoyancy	Meeting through MS teams	All	15 min	yes
2	Discussing the specification of the pump used for trim and depth control	Meeting through MS teams	All	15 min	yes
3					
4					
5					

Next meeting

Chairperson:	Minute taker:	Date & Time:	Venue:
Fanta	Ahmed	25/11/2020	MS Teams

Minutes

-Lina mentioned that we are adding foam to increase buoyancy to help determine the drop weights mass

-Ahmed explained the method used to calculate the drop weight's mass.

-Lina mentioned that foam will also be used to induce more pitching angles caused by the VBTs.

-Fanta asked about the lack of online resources to find a sea water pump.

-Nathaniel suggested to increase the volume of the VBTs to increase the buoyancy.

Previous Friday lab attendance	Previous lecture attendance
Lina, Ahmed	Lina, Ahmed, Jeromy, Fanta

Figure D-10: Week10th minutes

Group Minutes					
Attendees: Lina, Ahmed, Fanta, Mihaita Matei, Nathaniel Mailhot	**Absent:** Ahmed		**Date & Time:** 25/11/2020	**Venue:** MS Teams	
Minute taker: Who is filling out this form? Fanta		**Chairperson:** Who is organising the meeting? Fanta			

	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	Discussing quickly about the capsone	Meeting through MS teams	All	15 min	yes
2					
3					
4					
5					

Next meeting Chairperson:	Minute taker:	Date & Time:	Venue:
Jeromy	Fanta	25/11/2020	MS Teams

Minutes

-The prof give us some advices about the capstone

- The prof recommand us to do a Video for our presentaion, in case we loose our connexion

-Lina asked if we have to combine our solidworks with SUB1A's solidworks to do our parametrization

- Jeromy asked how we can do the piping connexion

- The prof explain us how they are going to correct the Analysis Report, and said that he will give us a feedback, even without marks.

Previous Friday lab attendance	Previous lecture attendance
Fanta, Jeromy, Lina, Ahmed	Fanta, Lina, Jeromy, Ahmed

Figure D-11: Week11th minutes

Group Minutes						
Attendees: Lina, Ahmed, Fanta,Jeromy, Mihaita Matei, Nathaniel Mailhot		**Absent:**		**Date & Time:** 02/12/2020		**Venue:** MS Teams
Minute taker: Who is filling out this form? Fanta			**Chairperson:** Who is organising the meeting? Ahmed			
	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	Discussing about the capstone report	Meeting through MS teams	All	15 min	yes	
2						
3						
4						
5						
Next meeting **Chairperson:** Jeromy		**Minute taker:** Fanta		**Date & Time:** 02/12/2020		**Venue:** MS Teams

Minutes	
- Jeromy asked if we have to consider the fitting of all the piping - And Matei said that we should'nt consider the fitting of the pipes - Ahmed asked if we can invite people to assist the presentation, like the president of Aquatica - Ahmed asked if we have to redo the analysis report, or if we have only to upload what we had, and the prof said that we have only to upload the past reports on the file, and to only focus on the capstone report - Fanta asked if we have to do the parametrization of the depth - Nathaniel suggests us to choose a range of depth, and to do the parametrization for that range	
Previous Friday lab attendance Fanta, Ahmed, Lina, Jeromy	**Previous lecture attendance** Fanta, Ahmed, Lina, Jeromy

Figure D-12: Week12th minutes

E Additional material

E.1 VBT Hydraulic Circuit PID

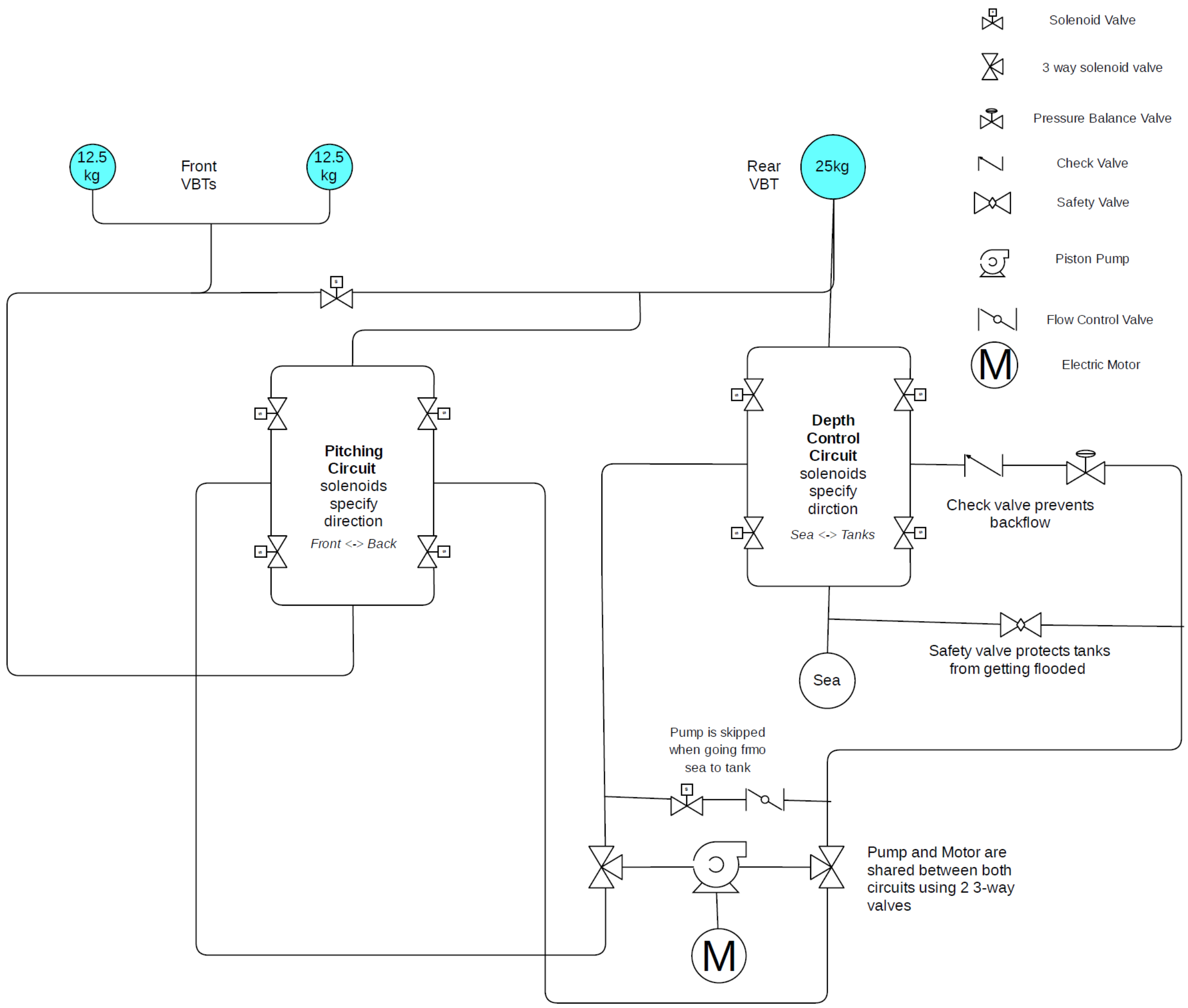


Figure E-1: VBT circuit including pitching and depth control

E.2 Data sheets

Data sheet — **PAH 2/4/6.3, PAH 10/12.5, PAH 20/25/32 and PAH 50/63/70/80/100 pumps**

4. Technical data

4.1 PAH 2-12.5

Pump size		2	4	6.3	10	12.5
Code number		180B0024	180B0022	180B0023	180B0008	180B0007
Code number ATEX[2)]		180B6124	180B6122	180B6123	180B6108	180B6107
Housing material		AISI 304	AISI 304	AISI 304	AISI 304	AISI 304
Geometric displacement	cm^3/rev	2	4	6.3	10	12.5
	in^3/rev	0.12	0.24	0.38	0.60	0.75
Pressure						
Min. outlet pressure	barg	30	30	30	30	30
	psig	435	435	435	435	435
Max. outlet pressure	barg	140	140	140	160	160
	psig	2030	2030	2030	2320	2320
Inlet pressure, continuous	barg	0-4	0-4	0-4	0-4	0-4
	psig	0-58	0-58	0-58	0-58	0-58
Speed						
Min. speed, continuous	rpm	700	700	700	700	700
Max. speed	rpm	1800	1800	1800	1800	1800
Typical flow - Flow curves available in section 5						
1000 rpm at max. pressure	l/min	1.0	3.2	5.6	8.4	11.0
1500 rpm at max. pressure	l/min	2.0	5.2	8.7	13.4	17.2
1200 rpm at max. pressure	gpm	0.4	1.0	1.8	2.7	3.5
1800 rpm at max. pressure	gpm	0.7	1.7	2.8	4.3	5.5
Typical motor size						
1500 rpm at max. pressure	kW	0.9	1.7	2.6	4.5	5.6
1800 rpm at max. pressure	hp	1.5	2.7	4.2	7.3	9.0
Torque at max. spec.	Nm	5.9	10.9	16.7	29.0	35.8
	lbf-ft	4.4	8.0	12.3	21.4	26.4
Media temperature	°C	2-50	2-50	2-50	2-50	2-50
	°F	36-122	36-122	36-122	36-122	36-122
Ambient temperature	°C	0-50	0-50	0-50	0-50	0-50
	°F	32-122	32-122	32-122	32-122	32-122
Sound pressure level [1)]	dB(A)	76	76	76	75	75
Weight	kg	4.4	4.4	4.4	7.7	7.7
	lbs	9.7	9.7	9.7	17.0	17.0

Figure E-2: Danfoss Pump

SUBSEA SOLENOID VALVE

Oil Spill Containment System

Features:

- FULL FLOW - 1/2" NPT
- DIRECT SOLENOID OPERATED
- BUBBLE-TIGHT CLOSURE
- CONTAMINATION TOLERANT
- SEAWATER SUBMERSIBLE
- UNDERWATER CONNECTOR
- HERMETICALLY SEALED SOLENOID
- SHOCK RESISTANT
- LONG CYCLE LIFE
- LOW POWER CONSUMPTION
- **NO ADJUSTMENTS NEEDED**

Specification:

1. 2-way, 2-position, normally closed
2. Ocean Submersible
3. Fluid Pressure: 3,000 psid Operating
4. Ocean Ambient to 4,500 psi
5. Fluids: hydraulic or pneumatic
6. Ports: ½” NPTF
7. Zero Leakage
8. Electrical: 1.85 amps @ 24vdc
9. Corrosion Resistant Stainless Steels
10. Weight: <15 lbs.
11. Size: 3.25" sq x 8"+ subsea connector

MODEL NO.
1723-100

Submersible solenoids meet IPX8 of IEC 529 for protection against the effects of continuous water submersion.

Figure E-3: Hydracon solenoid valve

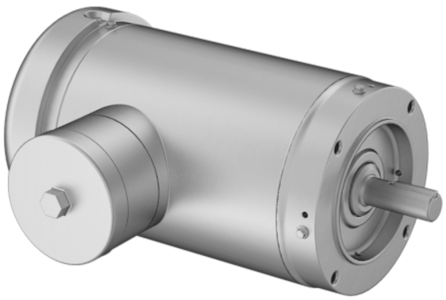
11/23/2020 Sanitary Washdown Face-Mount AC Motor, 230/460V AC, 3-Phase, NEMA 145TC, Totally Enclosed Fan-Cooled, 2 hp, 1800 rpm | McMaster-Carr

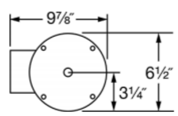
McMASTER-CARR®

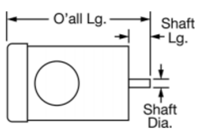
Sanitary Washdown Face-Mount AC Motor

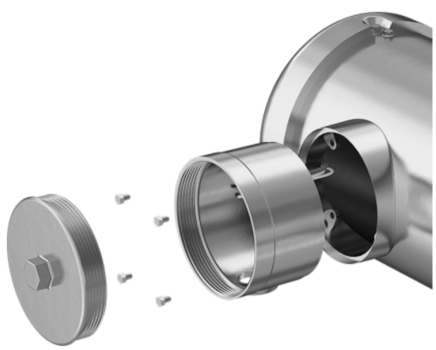
230/460V AC, 3-Phase, NEMA 145TC, Totally Enclosed Fan-Cooled, 2 hp, 1800 rpm

$1,632.27 Each
3540N26









Rotatable Conduit Box

Power Source	Electric
Mounting Style	Face
Voltage	230V AC/460V AC
Electrical Phase	Three
Motor Frame Size	NEMA 145TC
Power	2 hp
Maximum Speed	1,800 rpm
Full Load Current	5.6/2.8 A
Frequency	60 Hz
Electrical Connection Type	Hardwire
Wire Connection Type	Wire Leads
Inverter Rated	Yes
Duty Cycle	Continuous
Service Factor	1.15
Efficiency	86.5%
Motor Enclosure Type	Totally Enclosed Fan Cooled (TEFC)
Enclosure Material	304 Stainless Steel
Overall	
Length	14"
Width	9 7/8"
Height	6 1/2"
Mounting Orientation	Any Angle, Horizontal, Vertical
Bearing Type	Ball
Shaft	
Diameter	7/8"
Length	2 1/8"
Center to Base (A)	3 1/4"

https://www.mcmaster.com/3540N26/ 1/4

Figure E-4: Sanitary Washdown Face-Mount AC motor