Title:
Setting the Stage: Upgrage of Existing SSBN Submarine Staging to Conform to the New SSGN Platform

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Senior Engineering Design Project
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Setting the Stage

Upgrade of Existing SSBN Submarine Staging to Conform to the New SSGN Platform

Submitted to
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Abstract

With the end of the Cold War, The United States Navy is seeking to convert its fleet of Nuclear Warhead equipped, Ballistic Submarines to a more useful, more versatile platform. This transformation requires significant changes to the submarine's sail, the topmost structure of a submarine. The sail houses the submarine's compliment of missiles as well as the communication equipment and the periscope. In order to accommodate the new platform, additional access ports are being cut into the sail. The addition of these ports is the impudence to our project.

When a submarine is in port for repairs, a structure call the "staging" is lowered over the sail. This staging acts as a scaffold from which the maintenance crews can easily utilize the access ports and perform their tasks. Once the changes are made to the submarine, the existing staging will need to be modified. Fifteen new access ports are being added to the sail. Of these ports, ten are not accessible from the current staging, and five are actually obstructed by it. Our team's task will be to design the necessary modification to the staging allowing it to adapt it to the new platform, while ensuring that it is still backward compatible with as of yet un-renovated submarines.

Our design will strive to meet the objectives the Navy has set for success. This project is to be a cost effective as possible in order to minimize costs. Any changes we make must be simple enough as to be quickly effective on each of the Navy's current ports. Above all, our design must ensure for the safety of the workers who will be the end users of the staging

Table of Contents

Table of Appendices

I. Introduction

Problem Background:

In 1981 the United States Navy commissioned the first Trident Class Ship Submersible Ballistic Nuclear Submarine (SSBN), the USS Ohio. The Ohio and her sister ships carried twenty-four nuclear missiles and were designed to be a "strategic deterrent." At the height of the Cold War, the Trident Class Submarines carried more than fifty percent of the United State's nuclear arsenal. The ships' sole missions of strategic deterrence were the backbone of our defenses in the Cold War era [3].

The Ohio was scheduled to be decommissioned in 2002 with the remainder of the Trident Submarines following suit in the years to come. However changing world climate and new technologies have breathed new life into these ships. At the direction of Secretary of Defense Donald Rumsfeld, the Navy is converting selected Trident Submarines from the SSBN platform to a more versatile format, Ship, Submersible Guided Missile Nuclear (SSGN). Plans call for the submarines to be stripped of all but two nuclear silos, converting twenty-two of their missile tubes to other uses. The SSGN Submarines will be able to carry up to one hundred fifty-four of the Navy's current weapon of choice, the Tomahawk Missile. Other configurations include controls for and launching of unmanned air vehicles, sensors ranging from anti-submarine to long range mine reconnaissance [4].

These changes require significant modifications to the submarine's sail. The sail is the topmost, fin-like structure, and is the only part of the submarine visible as it puts off to sea. In addition to carrying the ship's payload, the sail serves as the eyes and the ears, and is one of the most crucial structures in a submarine.

Problem Statement:

When the submarine docks for maintenance, much of the work is concentrated on the sail and the equipment within. For this purpose the exterior of the sail contains a number of access ports. Even with the ports, maintenance is no easy task. The top of the sail is twenty feet above the hull of the ship. In order to reach the access ports, workers employ a structure called the "staging." The staging is essentially a scaffold with one difference; instead of being supported from the ground up, it is suspended from the sail down.

Changing the equipment housed in the sail forces changes in the arrangement, location, and number of the access panels. Fifteen new panels are being added to the side of the sail. All fifteen are not accessible from the staging currently in use. Ten are below the staging and five are actually covered by it. Our task is to modify the existing staging to make it compatible with the upgraded submarines.

Problem Constraints:

There are several factors that must be considered in our design. The Navy has put the following criteria on the design:

Maintenance Free – currently no maintenance is performed on the staging. It sits outdoors, exposed to the elements at all times, and still must function properly.

Life – the staging must last as long as the submarine, if not longer.

Weight – the crane used to lift the staging can move a certain load. The submarine must also be able to support the weight of the staging and the personnel.

Simplicity – this modification must be made to multiple stagings, so a simple design with clear and concise instructions is desirable.

Safety – the safety of the workers is a top concern. Any change made to the staging must consider the effect on the workers

Universal – this staging is to be used for the converted SSGN submarines, while still being used for the remaining SSBN submarines.

Our design must encompass all of these constraints to be considered by the Navy.

II. Statement of Work/Methods

Customer Criteria:

Pursuant to the constraints outlined above, United States Navy has requested a sail staging design for the new SSGN class submarines. The existing SSBN class submarine staging is to be modified to incorporate the structural changes involved in the conversion to the SSGN class submarine. Each port that performs maintenance on the Trident class submarines already has an SSBN staging. Building a second staging would come at an unacceptably high cost. The financial consideration not only concerns the material and construction costs of what is essentially a duplicate staging, but each port would then be required to house and maintain two of these structures.

The Department of the Navy has given this group a purchasing budget to provide for all materials needed for prototyping. This budget will be adjusted according to the needs of the group as well as the requirements of the Navy as the final prototype takes shape. In addition a Department Head in the Sail Systems Group has been assigned as an advisor to our team to provide a review of all designs as well as assisting in obtaining necessary documents, materials, and access.

Design Parameters:

In addition to the design constraints involved in adapting the staging to the upgraded SSGN sails, the design must continue to incorporate the basic constraints of any sail. The new staging must grant access to the sail top as the old design did, additionally the new design must allow maintenance crews to reach the new access ports in both the port and starboard sides of the sail. The new staging must not block access to any ports that already exist in the sail. The design team also had to take the diving plane location into consideration when designing the staging modifications. If the existing SSBN structure were lowered onto a renovated SSGN sail, not only would the staging not allow sufficient access to the ports, it would almost completely cover some of the ports. Most likely, the existing staging structure will have to be cut in order to fix this problem. Whether or not it is necessary to cut the structure will be decided by modeling the existing staging structure and the new SSGN sail. This will allow the clearances to be studied and a determination to be made. Schematics of the diving plane and access ports discussed above can be found in Appendix C.

Proposed Design Approach:

In order to achieve the requested requirements of the Navy, the team has designated some details crucial to the new design. The first is the addition of a partial tier below the existing racetrack to provide access to all ports. Once the second tier has been added, the maintenance crew must be able to utilize it. For this purpose a ladder descending to the lower tier must be incorporated into the design. Second, any added structure must be integrated into the existing support system. The new components to the design will be constructed of either aluminum tubing, plate, or beams in order to conform to the existing structure. The actual design will be finalized over the next few months as further studies into existing clearances and load analyses are completed (Appendix B.) The project is a real world engineering project and the design will continue to change as testing, analysis and new information is compiled. A clearer path of the design steps our team plans to take can be seen in Appendix A.

Design Analysis:

The analysis of the design will be done using finite element analysis (FEA.) This will be completed by first modeling the design in a 3-D modeling program such as Pro/Engineer. Once modeling is complete the FEA analysis will be done using an appropriate package such as ANSYS and importing our Pro/E model. This will determine if the structure is capable of supporting a live load as well as if the submarine is capable of supporting the static load of the staging. ANSYS will also provide an analysis of the deformation, bending, and stress distribution due to these loads. The live load will be considered to be a distributed load on the structure, while the structure will be considered a point load on the sail. The decision to treat it as a point load was made because it is supported at three places by cross members resting on the sail.

Manufacturing:

The manufacturing process will require welding of aluminum alloy as well as cutting aluminum with either a torch or grinder. Additionally some mechanical work may be necessary in assembling the new structure, depending on the final design. There will be no uncommon or new techniques involved in assembling the structure. The Navy’s current contractors already have the necessary equipment, so there will be no need to purchase any additional, expensive equipment.

Design Testing & Validation:

Testing the staging in full scale is not feasible for this project. This would require traveling to a location where the existing staging resides and making the modifications necessary. All this would have to coincide with a submarine being in port, which is not a guaranteed occurrence. With the possible exception of a full scale mockup of individual components, the majority of the testing will be simulated electronically and through the use of a scale model. The electronic simulations will include the analysis described above to insure that it can support the required weight along with providing access to the necessary components of the sail.

The validation of the proposed structure will be completed by employees of the Navy. They will examine the structure and, based on their expertise, discuss any issues or concern they have. The scale model will have to be presented including representations of the sail structure and all access ports, the dive planes, and the proposed staging design. This model will allow the team to display the design as well as show that it meets all design criteria.

Redesign:

The most critical step in the design is the stress and structural analysis. After that the Navy's reviewing team will have an opportunity to call out any potential problems. Finally the maintenance crews would identify any problems prior to installation, or during use. If problems arise at any of these steps, redesign will be necessary. The problem areas will have to be addressed and the problem will need to be corrected. As stated earlier, the design process will be an ongoing event, since this is a real world project. The actual design will be continually modified as testing and analysis are completed, and feedback is received from the customer. The design will only be complete when all these factors are taken into account and all users satisfied.

III. Project Management Timeline

The timeline can be found in the form of a Gantt chart in Appendix B.

IV. Economic Analysis

The budget for this project was created assuming that the project would take one year to finalize. The start up costs included a background check for all of the engineers. A background check, including a drug test and proof of citizenship, is required in order to have access to any Navy drawings and designs. Initial costs also include office equipment and supplies for all of the engineers. The required software includes Pro\Engineer, ANSYS, and MSOffice, all of which are considered in start-up costs. This software will be used in designing and drawing the racetrack, performing the stress analysis on the racetrack, and completing any project documentation.

Yearly costs include rent for the engineers' office, which has been estimated at $500.00/month, utilities estimated at $150/month, and the payroll for each of the engineers. Each engineer will have an estimated yearly salary of $50,000, and will cost the Navy $50,000/year for benefits. This gives a total cost of $100,000/year, per engineer. There are four engineers working on the project. It is estimated that each engineer will work 8 hours/day, 20 days/month, for the 12 months in the year. The cost per engineer is about $52/hour.

Aluminum has been selected as the material used to modify the racetrack. This is the material of the existing structure, and it has been assumed that the same material will be deemed the most appropriate for our design. Different materials for construction will be evaluated as alternative solutions. Aluminum has been found to cost an estimated value of $1.02/lb [1]. The existing structure weighs 6000 lb, and it has a volume of about 130 cubic feet made up of one level with an average perimeter of 87 ft, an average width of 3 ft, and an average thickness of .5 ft. Our modified design will include adding a section to the lower level of the racetrack which will be about 30 ft long, 3 ft wide, and .5 ft thick. We are estimating that we will be adding an additional 45 ft^3 of aluminum. This will involve purchasing an additional 2080 lb of aluminum. Aluminum costs about $47/$ft^3$. Therefore, we estimate the cost for the additional aluminum will be around $2115.

Current plans call for a wooden prototype to be constructed as a scale model. We anticipate using a one foot equals one inch scale. This will allow the prototype to be detailed as well as transportable. Following completion of this project, the Navy will use our prototype in their demonstrations. This scale is acceptable to them for their needs. We will require an estimated 130 in^3 for existing staging, 45 in^3 for new staging, and 1740 in^3 for the sail itself. Lumber cost can be estimated at $.008/$in^3$ based on standard 2"x4"x8' lumber [2]. We applied a multiplier of three to account for specific pieces of wood being more expensive. This gave us a rough wood cost of $46.875 or roughly fifty dollars. We have budgeted an addition fifty dollars for miscellaneous items such as glue, nails, and paint. We feel that a $100 estimate is reasonable for the prototype, though it may change as the final design takes shape.

V. Social and Environmental Analysis

Since the staging will only be used by the Navy, and only while the submarine is in port, there will be no societal impact. Also, the staging is currently being used, and any modifications of the current structure would not affect society any more than it does now. The environmental impact will also be negligible, since we plan on using the same materials used in the current staging and no additional harm will come to the environment.

VI. References

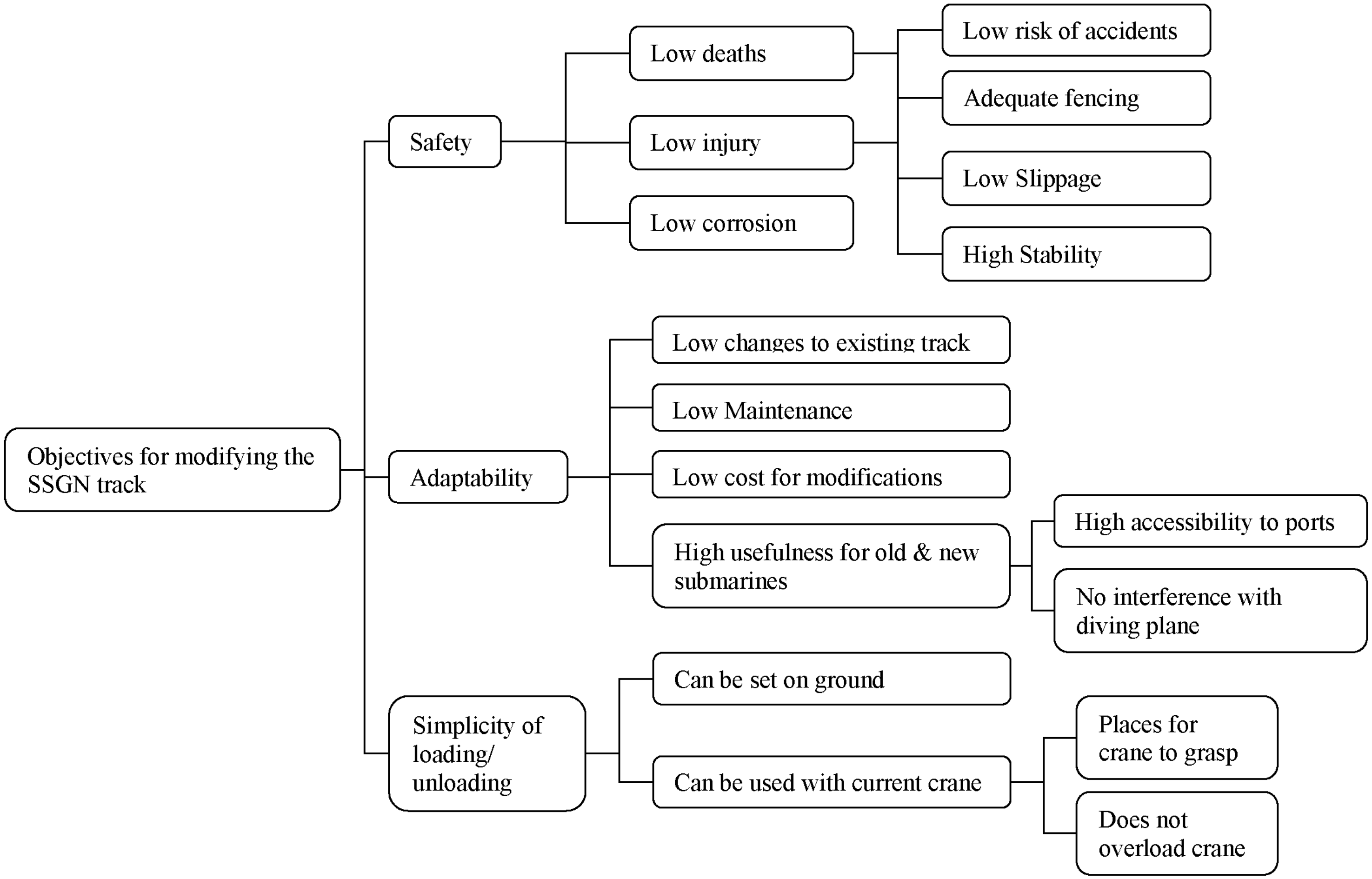
[1] Callister, William D. Jr. Fundamentals of Materials Science and Engineering/An Interactive eText. 5th Edition. New York: John Wiley and Sons, Inc., 2001. 19 Nov. 2003. <http://ecal-admin.mme.tcd.ie/MSEInteractive/frontmatter.pdf>.

[2] Lowe's. Top Choice KD Fir Dimensions. 18 Nov. 2003. 18 Nov. 2003. <http://www.lowes.com/lkn?action=productList&catalogId=TOP_CHOICE_KD_HEM_FIR_DIMENSION>.

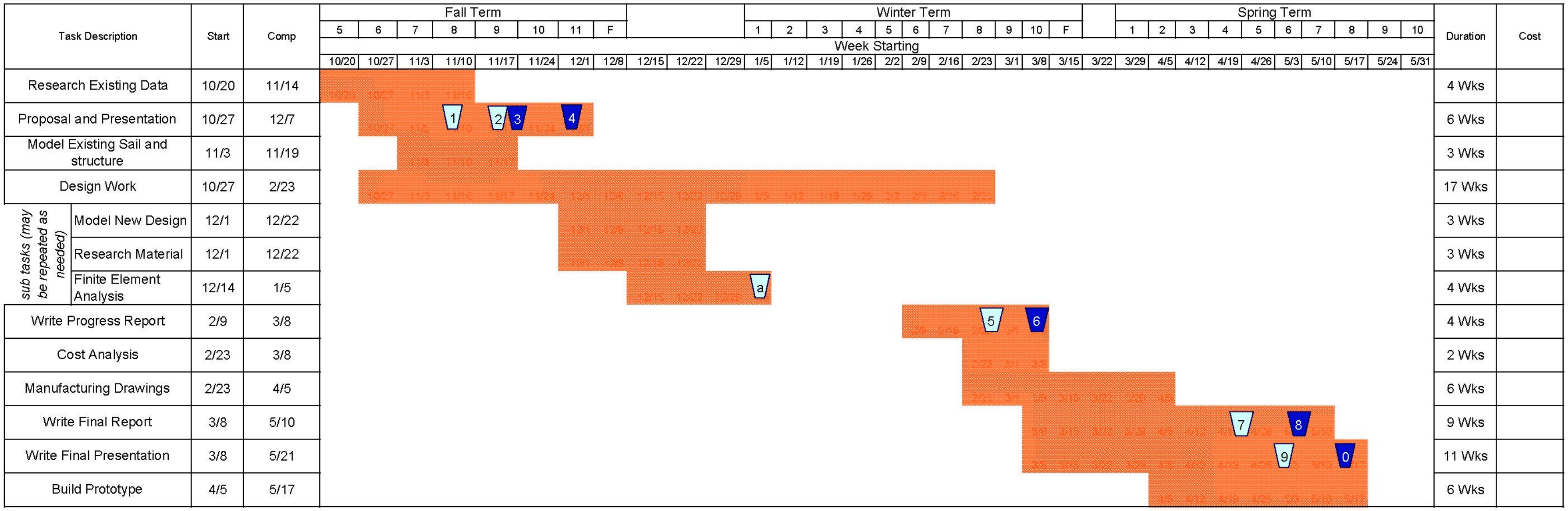
[3] Submarines: History – The US Navy's First Submarine. 10 Oct. 2003. 11 Nov. 2003 <http://www.onr.navy.mil/focus/blowballast/sub/history4.htm>.

[4] Wikipedia. Ohio Class Submarine. 16 Oct 2003. 11 Nov. 2003. <http://en2.wikipedia.org/wiki/Ohio_class_submarine>.

Appendix A – Objective Chart



Appendix B - Gantt Chart



Task Description		Start	Comp	Duration	Cost
Research Existing Data		10/20	11/14	4 Wks	
Proposal and Presentation		10/27	12/7	6 Wks	
Model Existing Sail and structure		11/3	11/19	3 Wks	
Design Work		10/27	2/23	17 Wks	
sub tasks (may be repeated as needed)	Model New Design	12/1	12/22	3 Wks	
	Research Material	12/1	12/22	3 Wks	
	Finite Element Analysis	12/14	1/5	4 Wks	
Write Progress Report		2/9	3/8	4 Wks	
Cost Analysis		2/23	3/8	2 Wks	
Manufacturing Drawings		2/23	4/5	6 Wks	
Write Final Report		3/8	5/10	9 Wks	
Write Final Presentation		3/8	5/21	11 Wks	
Build Prototype		4/5	5/17	6 Wks	

Milestones Key

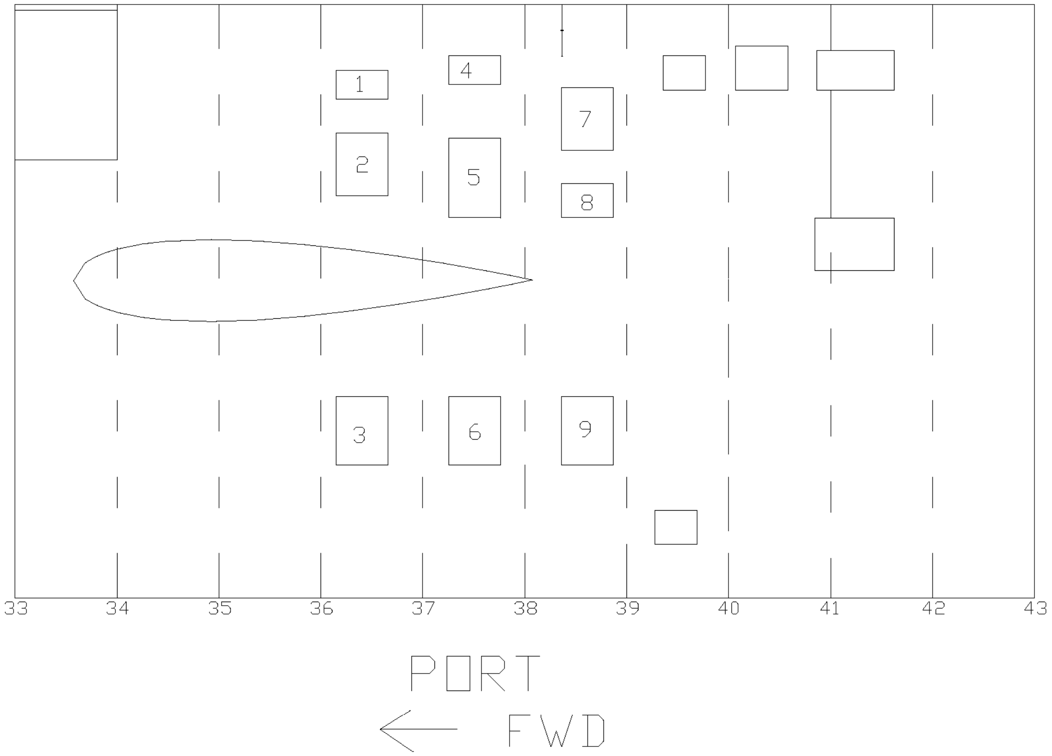
▽	Marks a due date with advisor
▼	Marks a due date for Senior Design Class

1	Proposal Rough Draft to Advisor	11/12/2003
2	Mock Proposal Presentation with Advisor	11/19/2003
3	Proposal Due	11/24/2003
4	Proposal Presentation Due	12/1/2003
5	Progress Report Rough Draft to Advisor	2/23/2004
6	Progress Report Due	3/8/2004
7	Final Report Rough Draft	4/26/2004
8	Final Report Due	5/10/2004
9	Final Presentation Rough Draft	5/3/2004
0	Final Presentation Due	5/17/2004
a	First Run Design work finished to Advisor	1/5/2003

Appendix C - Figures

Figure 1:

SSGN Sail Port Side Layout

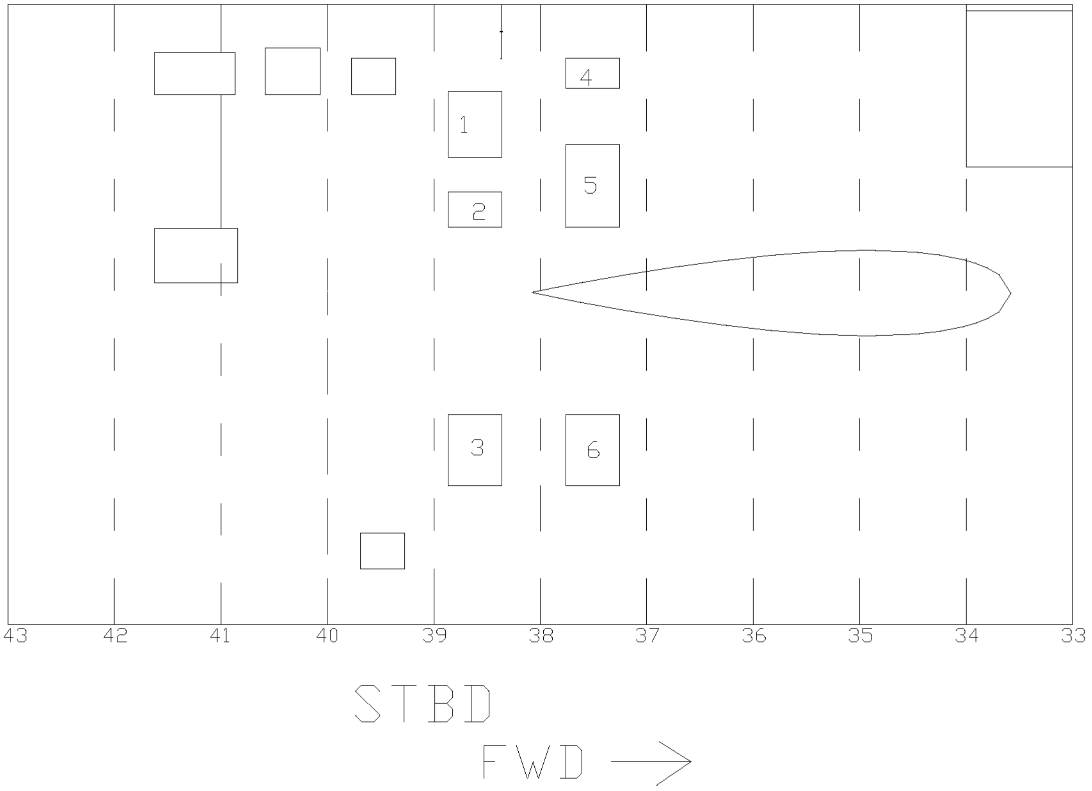


The numbered holes represent the new access holes in the sail. There are nine new holes on the port side allowing access to three UMMs (Universal Modular Mast) including the PMP (Photonics Mast) ports 1-3, HDR (High Data Rate Antenna) ports 4-6, MFM (Multi-Functional Mast) ports 7-9. Access holes 3, 6, 9 have no effect on the design, since they will be access from staging on top of the submarine hull.

Appendix C (continued):

Figure 2:

SSGN Sail Starboard Side Layout

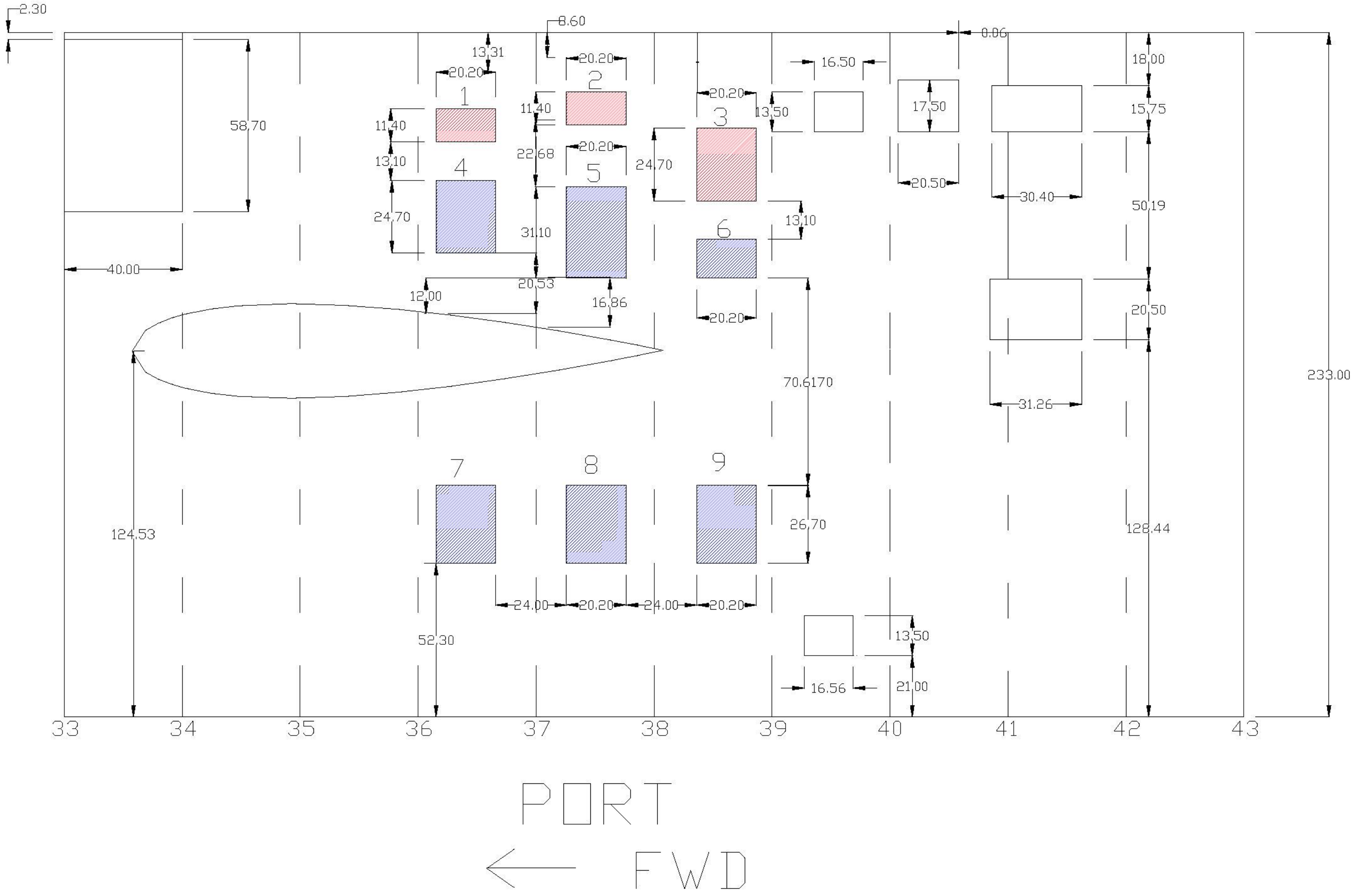


Layout of SSGN starboard side of the sail with new access holes. The numbered holes represent the new access holes in the sail. There are six new holes on the port side allowing access to two UMMs (Universal Modular Mast) including the HDR (High Data Rate Antenna) ports 1-3, MFM (Multi-Functional Mast) ports 4-6. Access holes 3, 6 have no effect on the design, since they will be access from staging on top of the submarine hull.

Appendix C (concluded):

Figure 3:

SSGN Sail Port Side Dimensional Constraints



The above figure represents the dimensional tolerance on the port side of the SGGN sail structure. The hatched access holes represent the new access holes. The red (1-3) hatching represent the access holes that are covered by the existing sail staging denying access to them. As mentioned in earlier it is not at this point clear whether there is enough room to access these ports by reaching behind the existing structure. This will become clear once the sail and existing staging are model, as well as visiting the submarine to examine this first hand. As depicted in the drawing there is a maximum clearance between the lowest access hole and the diving plane which will be a major constraint in the design process. The blue (4-9) are below the staging. Ports 4-6 will have to be accessible through our design, while ports 7-9 can be accessed through standing on the hull, and therefore have no effect on our design.

The starboard side of the sail has the same dimensions, with the exception that the PMP (1, 4, and 7) is only on the port side and no new ports were created on the starboard side for it. (Figure 2) This grants more clearance with respect to the sail plane, but in order to balance the structure the new design will probably need to be symmetrical.

Appendix D - Budget Worksheet

Initial Items	**Cost Per Person**	**Cost Per Group (4 Members/Group)**
Background Check	$750.00	$3,000.00
Office Equipment	$3,000.00	$12,000.00
Software:		
MSOffice	$150.00	$600.00
Pro-Engineer	$20,000.00	$80,000.00
ANSYS	$20,000.00	$80,000.00
Total:		**$175,600.00**
Yearly Cost (12 Months)	**Cost Per Person**	**Cost Per Group (4 Members/Group)**
Rent ($500.00/month)	$6,000.00	$24,000.00
Utilities ($150.00/month)	$1,800.00	$7,200.00
Payroll ($6666.67/month)	$80,000.00	$320,000.00
Total:		**$351,200.00**
Manufacturing Costs	**Cost Per Unit**	**Total Cost**
Materials:		
Aluminum	$1.02/lb (1035 lbs)	$1,055.70
Fencing		
Construction	$75.00/hour per person (4 people, 8 hours/person)	$2,400.00
Total:		**$3,455.70**
Total Cost of Project		**$530,255.70**

COOLING SYSTEM TEST RIG - DATA SHEET

Description of Unit____
Purpose of Test____
Nozzle Coefficient____
Date_______________ **Location**_____________________ **Observers**_______________________

Test Time (minutes)	5	10	15	20	Average
Readings/Computations:					
COOLANT					
1. Flow Coolant-lb/min					
2. DPw thru core-in Hg					
3. Tin-°F					
4. Tout-°F					
5. Heat Transfer-Btu/h					
AIR					
6. T dry bulb-°F					
7. Corrected Barometer-Hg					
8. Density-Inlet Air-lb/ft3					
9. Density-Chamber Air-lb/ft3					
10. Ta(Nozzle)-°F					
11. DPa-At nozzle-in H20					
12. Air Flow (actual) Outlet-cfm					
13. Air Flow (actual) Outlet-lb/h					
14. Air Flow (standard)-Outlet-cfm					
15. Tin (average) of Core-°F					
16. Tout (average) of Core-°F					
17. Heat Gained (actual)-Btu/h					
18. Heat Dissipation-Btu/h/150°FDT					
19. DPa-across unit-in H20					
20. Fan-volts					
21. Fan-amps					
22. Fan-rpm					

Note 1: All pressure measurements, except ΔPw , accurate to within 0.005 in H20. ΔPw accurate to within ± 0.2 Hg.

Note 2: All temperature measurements accurate to within 0.5°F for air and coolant.