ME 423 A – Engineering Design VII – Fall 2008
Senior Design Project

Autonomous Underwater Vehicle

Phase I – Proposal and Conceptual Design

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Due Date:
Thursday, September 25, 2008

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Abstract

Our Project is to create an autonomous underwater robot that competes in the AUVSI competition.

The team competing in the competition consists of the nine Stevens engineers. There are five Mechanical Engineers and four Electrical Engineers. The mechanical team will work on the hull design, propulsion system and the robotic arm design. The electrical team will work on the autonomous part of the project.

This report discusses the competition and our plan to win it.

Objectives

The overall objective for the first phase is to gather data on underwater robots, particularly propulsion systems and hull design. However, the main objective, focus, and responsibility of the mechanical team which is comprised of the five Stevens Institute of Technology students is to quickly develop an autonomous robot which will be tested and improved over the course of the year. The four primary objectives of the mechanical portion of the project are to research current propulsion technology, accurately calculate the forces, velocities, and power consumption, design a functional hull, and to perform simulations that will generate useful information.

The research and calculations will allow the team to create a model of the environmental conditions, which will lead to the development of a technically sound prototype. Once the prototype concept has been created, the entire team will design and validate the guidance and control system. Lastly, simulations will be run multiple times to display uncertainties. These will provide the team with confidence in the final phases of this project.

Other minor goals to be achieved are:

- Knowledge of advanced MATLAB procedures
- Experience in fluid dynamic simulation
- Exposure to automated vehicle technology

Problem Statement

To design, build, and test an AUV to enter the Association for Unmanned Vehicle Systems International (AUVSI) and Office of Naval Research's (ONR) 11th Annual International Autonomous Underwater Vehicle Competition.

Project Background

An autonomous underwater vehicle (AUV) is a robot that can travel underwater with limited human interaction. AUVs primarily used are to make detailed surveys of the seafloor, undersea research, and for object search and detection. AUV are used in situations when the task is very repetitive and human control is not needed for the majority of the task. This should not be confuse with a remotely operated underwater vehicle (ROV) which are similar to an AUV but is directly controlled by a human pilot via an umbilical cable due to the limited range of a wireless signal through water.

Social Impact

Underwater vehicle impact on society is undoubtedly significant. The greatest asset it offers is its ability to perform various tasks autonomously. Thus, it is suitable to be deployed for rescue mission under emergencies such as tsunami where human involvement is limited and dangerous. Under this situation, going underwater is preferable since the water surface is usually filled with floating rubbles that hinder humans to move by boat. The underwater vehicle could be used to carry emergency supplies and tracking devices so that aid could be delivered to victims immediately. Its small size also enables it to locate potential survivors trapped inside tight space underwater.

There is also potential for the underwater vehicle to do deep-sea exploration. This is a relatively new field and many hidden mysteries such as the deep-sea life forms are yet to be unveiled. With its abilities, the vehicle can explore the deep sea where the high pressure and darkness makes it impossible for human to explore. It could also explore underwater caves especially ones that a human could not fit inside, enabling it to give greater insight on a world unknown to human is knowledge.

By adding certain features, the underwater vehicle would be able to complete more tasks. For example, a robotic arm would allow the AUV to collect and bring samples to the surface for analysis. Adding an explosive package would make it a formidable weapon against potential enemies since it small size makes it harder to be detected as threats by radars. Adding sonar would enable it to help accurately draw underwater maps.

With more innovation, the team believes that the underwater vehicle can have a huge impact on society.

State of the Art

Recent advances in technology open a new whole dimension in underwater autonomy. The demand for autonomous underwater vehicles (AUVs) has been rising over years to be utilized for scientific, commercial, and military underwater applications.

Some of the first AUVs were developed at the Massachusetts Institute of Technology in the 80'. Sea Squirt was the first of the MIT AUV Lab's vehicles. It operated inside a long-baseline array, taking measurements of oxygen concentration, turbidity, temperature, and salinity in the Charles River, Boston Harbor and various lakes and ponds. The vehicle also served as a test bed for software and instrumentation.

The oil and gas industry uses AUVs to make detailed maps of the seafloor before they start building subsea infrastructure. The detailed maps from the AUVs allow oil companies to install pipelines and subsea completions in the most cost effective manner with the minimum disruption to the environment.

Researches on AUVs use for inspection of in-service transmission mains are still running. Large-diameter water pipes must be inspected periodically to gain information about their current condition and rate of deterioration. Conventional inspection methods require taking the pipes out of service to drain and clean them.

Technology

Propulsion

Most of the autonomous underwater vehicles today use thrusters for propulsion. Thrusters are chosen for the method of propulsion because of their high availability, high efficiency, and ease of control compared to other methods such as fish-like fins, or servo-actuated control surfaces. Fish-like fins or servo-actuated control surfaces require low energy consumption, lightweight and has high mobility compared to AUVs that use thrusters, but it involves many simulations on various moving patterns.

Energy sources

Most AUVs in use today are powered by rechargeable batteries such as lithium ion, lithium polymer, and nickel metal hydride. Some vehicles use primary batteries that provide perhaps twice the endurance at a substantial extra cost per mission. A few of the larger vehicles are powered by aluminum based semi-fuel cells.

Hull Designs

Generally, AUVs have several shapes sphere, cube, or cylinder. Their hull shape influences the maneuverability, drag force, pressure resistance, and durability of AUVs. Sphere shape has high resistance to pressure because water pushes equally from all dimensions of the sphere, thus the sphere shape is. The streamlining hull helps decrease the drag and lowers the amount of power needed to move the vehicle at a certain speed.

Existing Designs/Products/Approaches

2008 Stingray

The 2008 Stingray was constructed by the San Diego iBotics Student Engineering Society for entry in AUVSI and ONR's 11th International Autonomous Underwater Vehicle Competition. The hull design of the underwater robot was inspired by one of the ocean's deadliest animals, the stingray. The streamlined profile and low cross sectional area of the hull provide low drag force, thus improve the robot's maneuverability. High-density polyurethane foam is placed within the hull to trim the vehicle's buoyancy.

Figure: The 2008 Stingray

The 2008 Stingray relies primarily on two Voith-Schneider propellers (VSPs) mounted on the hull bottom to maneuver about the course. VSPs allow thrust of any magnitude to be generated in any direction quickly, precisely and in a continuously variable manner. It combines propulsion and steering in a single unit.

Four thrusters are mounted symmetrically across the longitudinal plane of the boat – with two on the wings and two on the tail. The placement of the thrusters allows for ballast-free depth control when all thrusters generate equal forces with no moments, and roll and pitch attitudes can be controlled by generating moments from differential thrust about the Stingray's center of gravity.

Bearacuda

Bearacuda was designed and constructed by the University of Alberta, Canada. The shape of the hull features a high height to width ratio, which allows for component positioning that increases the distance of the center of gravity (CG) to buoyancy (CB) and thus increases the restoring moment and static stability of the vehicle. A curved surface was added to the front of the vehicle to reduce hydrodynamic drag.

Thrusters were chosen for the method of propulsion because of their high availability and ease of control compared to other methods such as fish-like fins, or servo-actuated control surfaces.

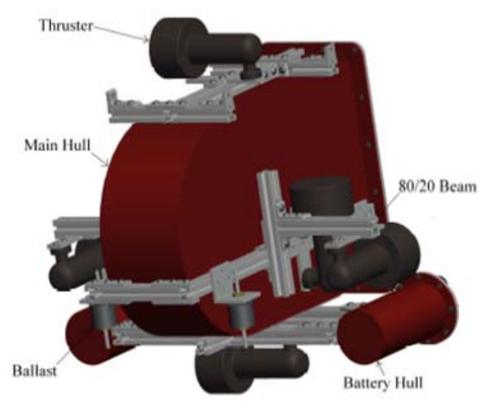
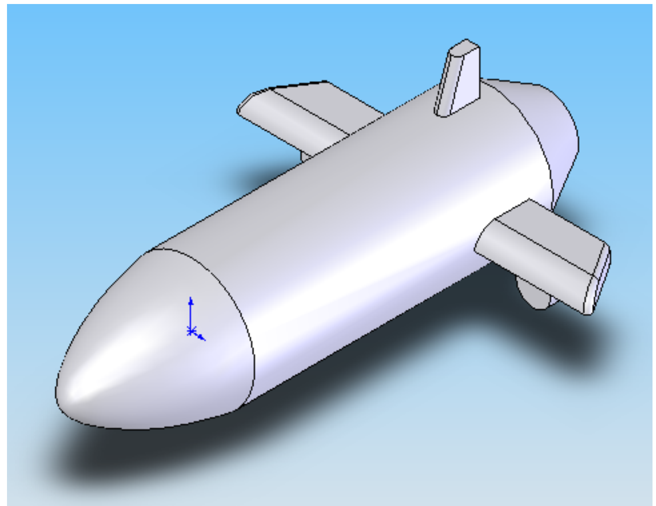


Figure: Bearacuda

Conceptual Designs

Torpedo Design



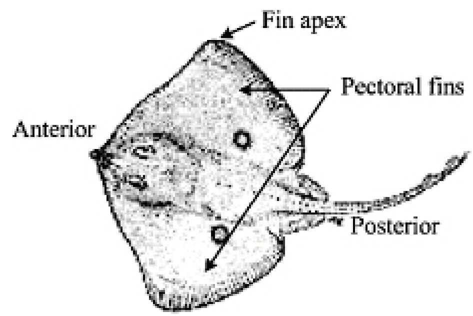
The design is initially modeled after a torpedo, an explosive projectile weapon. A torpedo is essentially a guided missile that happens to move underwater. It therefore has a propulsion system, a guidance system, and a good design that can improve its maneuverability to move underwater: operations that resemble with the team's underwater robot.

The torpedo design is a compromise between endurance, maneuverability, and functionality. It has three main parts: main body, propulsion system, and wings. The main body of the robot is a streamlining horizontal cylinder that cuts down on drag, the resistant force of water pushing against it. The cylinder is divided into two internal sections an upper part and a lower part. The lower part of the main body will be occupied by heavy components like battery and sensors to lower its central of gravity. At the top of the upper body, syntactic foam would be used to provide the necessary buoyancy. By placing the light components on the top and the heavy components on the bottom, the overall system has a large separation between the center of buoyancy and the center of gravity; this provides stability to do work underwater.

At the one end of the streamlining cylinder (the tail), this torpedo-like design has two small symmetrical wings, designed to maintain stability of the vehicle and to hold thruster, one at each wing. The main purpose of having one thruster at both sides is to help the robot to turn left and right. By slowing the left thruster, the vehicle will turn left and so the opposite. There is another thruster at the end of the tail. The holder of the thruster will be designed in such a way that it could guide the thruster to move up and down. This could help the vehicle to move down to the floor, and go up to the water surface.

Overall, this seems to be a promising conceptual design. It is relatively simple, and capable of having good mobility, and similar designs have been shown to work.

Stingray Design



One of the conceptual designs that the team come out with is modeled after stingray fish. This is particularly because stingray's body has a unique aerodynamic feature. Its angled head enables it to deflect water flow smoothly over its body. This feature significantly lower drags force since less surface area is in contact with the water. Thus, it would enable the team's underwater vehicle to move faster and consume less energy. The deflected flow also creates a downward force on top of the body that would prevent the underwater vehicle from unnecessarily going above water under any unforeseen situations.

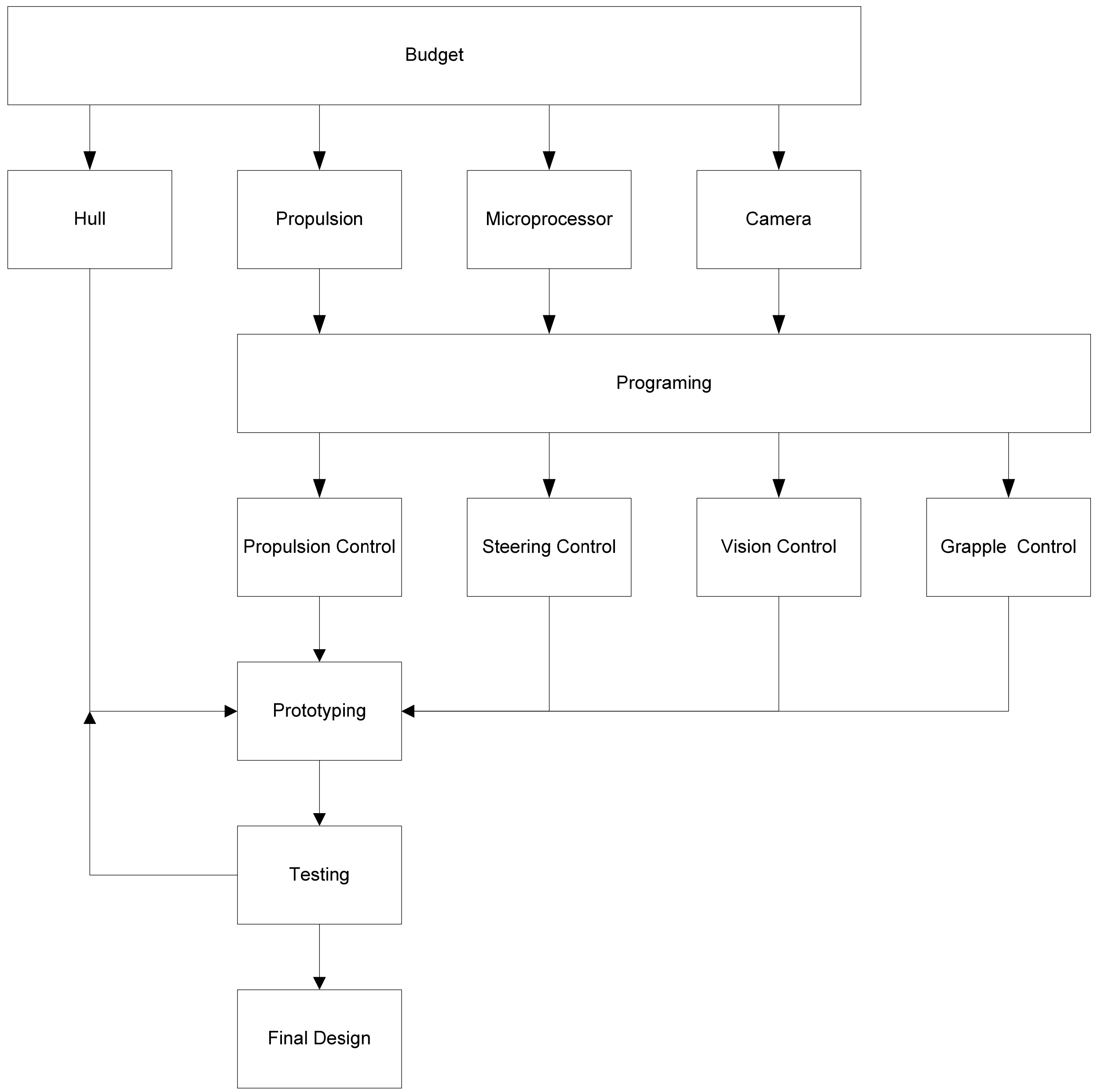
Another important feature about stingray's body is its role on stability. Typical stingray has very low center of gravity that would provide good maneuverability. Lower center of gravity also shortens the distance between the center of gravity and the center of buoyancy. A good design requires the center of buoyancy to be closely below the center of gravity, creating a situation called "metastable". A metastable situation allows the underwater vehicle to correct itself into upright position whenever it has tilted. This is because both the center of gravity and center of buoyancy creates a "righting moment" that would oppose the direction the underwater vehicle tilted into and would return to its original position. A large distance between center of gravity and center of buoyancy is undesirable since it would create larger moment that would make it easier for the underwater vehicle to flip over.

Stingray design is also desirable since it provides a good platform for the propulsion system. Its fin provides space to equip thrusters that could propel it forward and backward. Its tail can also be used to install thrusters to push it upward and downward. This would prevent the underwater vehicle from having too many parts piled at the center body. Having too many parts at one closed space caused overheating and affects the vehicle's stability.

The typical shape of stingray can be modified to improve its efficiency. The fin's length can be reduced so that less surface area is exposed. The head could also be redesigned to be aerodynamic so that it could deflect more flow and reduce drag.

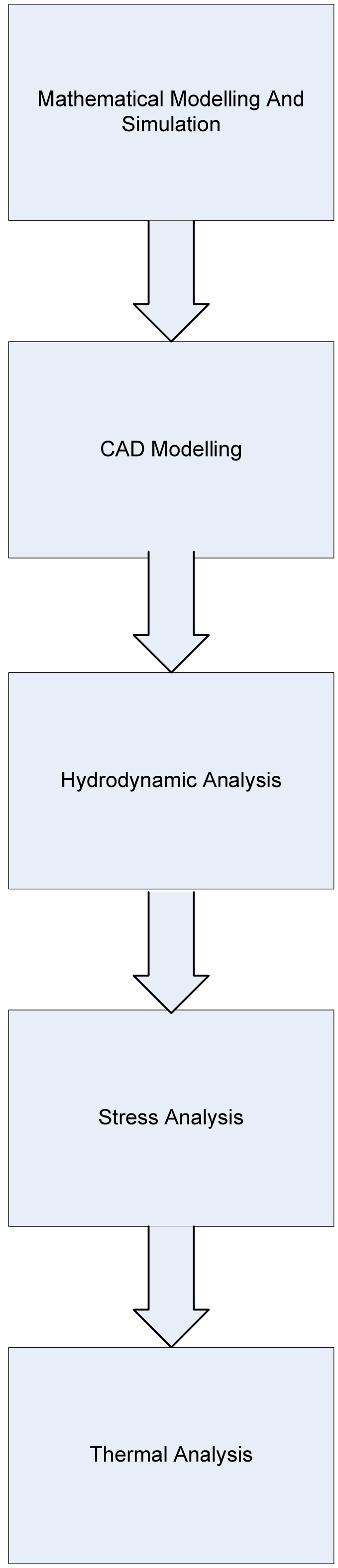
Overall, the team believes that stingray design is a worthy design to be considered for this project.

Plan of Engineering Design



Visions rarely become a reality without implementation of a plan. A plan provides the framework in which the company will operate. The plan will help team members stay on task and perform as efficiently as possible. There will be a six-phase plan with subtasks in each phase. Within each phase, tasks are assigned according to each member's strengths. Throughout the process, we will all communicate our progress, as to ensure we all stay on the same page.

Plan of Technical Analysis



Deliverables

The goal of the project is to compete in the AUVSI competition. By the end of Senior Design, we hope to have a completed Autonomous vehicle that is ready to win the competition.

By the end of the Fall Semester, we will have completed the design phase of the project. Deliverable by then will be a CAD model and results of the stress, hydrodynamic and thermal analysis.

In addition, we will give three presentations, as required by the school, in the Fall Semester. In these presentations, we will to show our progress.

Budget

Systems	
Microprocessor	260
Inertial Navigator	1500
Imaging Sensor	200
Pressure Sensor	100
Heading Sensor	150

Propulsion	
Underwater Thrusters	3000

Hull	700

Robotic Arm	200
Robotic Arm Motors	300

Power Systems	
Batteries	300
Charger	40

Travel Expenses	
Flight to San Diego (10 people) ($400 as of 9/25/08)	4000
Car Rental (2 Cars and Gas)	700
Hotel - 2 rooms 5 nights	1000
Food	400

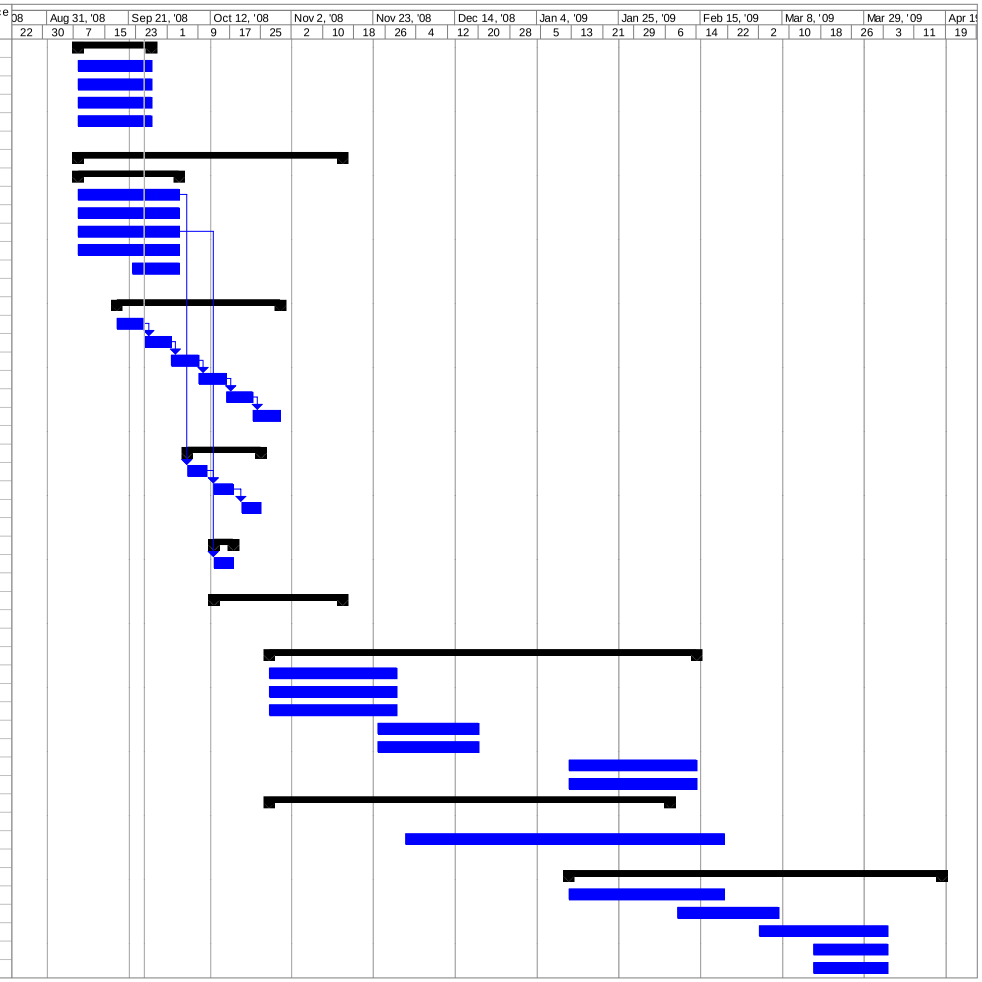
Misc. Hardware	2000

Total Costs	14850

Note: Costs are approximated, as a finalized bill of materials is still to be determined. The final cost will likely be larger than it currently is.

Project Plan

ID	Task Name	Duration	Start	Finish	Predecessors
1	**Requirements Analysis**	**15 days**	**Mon 9/8/08**	**Fri 9/26/08**	
2	AUV	15 days	Mon 9/8/08	Fri 9/26/08	
3	Sensors	15 days	Mon 9/8/08	Fri 9/26/08	
4	Thrusters	15 days	Mon 9/8/08	Fri 9/26/08	
5	Microprocessor	15 days	Mon 9/8/08	Fri 9/26/08	
6					
7	**Design**	**50 days**	**Mon 9/8/08**	**Fri 11/14/08**	
8	**Concept**	**20 days**	**Mon 9/8/08**	**Fri 10/3/08**	
9	Hull Design	20 days	Mon 9/8/08	Fri 10/3/08	
10	Propulsion Design	20 days	Mon 9/8/08	Fri 10/3/08	
11	Arm Design	20 days	Mon 9/8/08	Fri 10/3/08	
12	Sensor Selection	20 days	Mon 9/8/08	Fri 10/3/08	
13	Sensor Positioning	10 days	Mon 9/22/08	Fri 10/3/08	
14					
15	**Hull**	**30 days**	**Thu 9/18/08**	**Wed 10/29/08**	
16	Mathematical Model	1 wk	Thu 9/18/08	Wed 9/24/08	
17	Hull CAD Model	1 wk	Thu 9/25/08	Wed 10/1/08	16
18	Component CAD Model	1 wk	Thu 10/2/08	Wed 10/8/08	17
19	Hydrodynamic Analysis	1 wk	Thu 10/9/08	Wed 10/15/08	18
20	Thermodynamic Analysis	1 wk	Thu 10/16/08	Wed 10/22/08	19
21	Redesign	1 wk	Thu 10/23/08	Wed 10/29/08	20
22					
23	**Propulsion**	**15 days**	**Mon 10/6/08**	**Fri 10/24/08**	
24	Component Selection	1 wk	Mon 10/6/08	Fri 10/10/08	9
25	CAD Model	1 wk	Mon 10/13/08	Fri 10/17/08	24
26	Thermodynamic Analysis	1 wk	Mon 10/20/08	Fri 10/24/08	25
27					
28	**Robotic Arm**	**5 days**	**Mon 10/13/08**	**Fri 10/17/08**	
29	CAD Model	5 days	Mon 10/13/08	Fri 10/17/08	11
30					
31	**Software**	**25 days**	**Mon 10/13/08**	**Fri 11/14/08**	
34					
36					
37	**Develop\Build**	**80 days**	**Mon 10/27/08**	**Fri 2/13/09**	
38	Hull	25 days	Mon 10/27/08	Fri 11/28/08	
39	Control Loop	25 days	Mon 10/27/08	Fri 11/28/08	
40	Propulsion	25 days	Mon 10/27/08	Fri 11/28/08	
41	Inertial Navigation	20 days	Mon 11/24/08	Fri 12/19/08	
42	Robotic Arm	20 days	Mon 11/24/08	Fri 12/19/08	
43	Camera	25 days	Mon 1/12/09	Fri 2/13/09	
44	Hydrophone	25 days	Mon 1/12/09	Fri 2/13/09	
45	**Programming**	**75 days**	**Mon 10/27/08**	**Fri 2/6/09**	
49					
50	Integrate	60 days	Mon 12/1/08	Fri 2/20/09	
51					
52	**Testing**	**70 days**	**Mon 1/12/09**	**Fri 4/17/09**	
53	Submerge	30 days	Mon 1/12/09	Fri 2/20/09	
54	Move	20 days	Mon 2/9/09	Fri 3/6/09	
55	Track Object	25 days	Mon 3/2/09	Fri 4/3/09	
56	Robotic Arm	15 days	Mon 3/16/09	Fri 4/3/09	
57	Hydrophone	15 days	Mon 3/16/09	Fri 4/3/09	



Nugget Chart

Title: Autonomous Underwater Robot

Team Members: Abdul Qayyum Abdul Halim, Wan Ahmad Fauzan Wan Jusoh, Venkat Rao, Michael Trent, Jonathan Yao

Advisor: Shi, Yong

Due Date: September 25, 2008

Project Objectives	Conceptual Designs and Highlights
Why This Project and State-of-the-art	Drawing and Illustration of Promising Concepts See attached sheet
What Are the Key Areas/Aspects to Solve	

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