T.E.S.S.

Technical Education Structuring System

Bristol Community College (BCC)

Fall River Massachusetts, USA

Team Members:

Chris Green - Mechanical Engineering Technology 2009

Dan Pitrone - Electrical Engineering Technology 2009

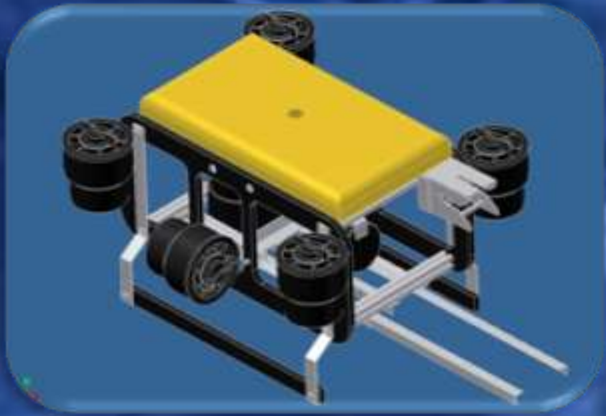
Helder Lobo - Engineering Science Transfer 2010

Don Chapin - AutoCAD Certificate

Mentors:

Dr. Michael Meyers

Mrs. Meghan Abella-Bowen



MATE 2009 International Underwater ROV Competition

Ranger Class **Team Gears – "T.E.S.S."**

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Abstract

Team Gears is one of the teams competing in the Mate 2009 International Underwater ROV Competition from Bristol Community College located in Fall River, Massachusetts, USA. We have designed and built T.E.S.S. (Technical Education Structuring System), an underwater remotely operated vehicle. Our main objective is to accomplish all the mission tasks of the MATE 2009 Competition.

Team Gears is comprised of Chris Green (Mechanical), Dan Pitrone (Electrical), Don Chapin (Team Leader), and Helder Lobo (Communications). We came together in the goal of creating the very best ROV that we could. Every team member has a different and diverse background and by taking advantage of this opportunity we learned and used the engineering process and created T.E.S.S. Although there were times we struggled, through the use of the engineering design process we collaborated to accomplish our goals.

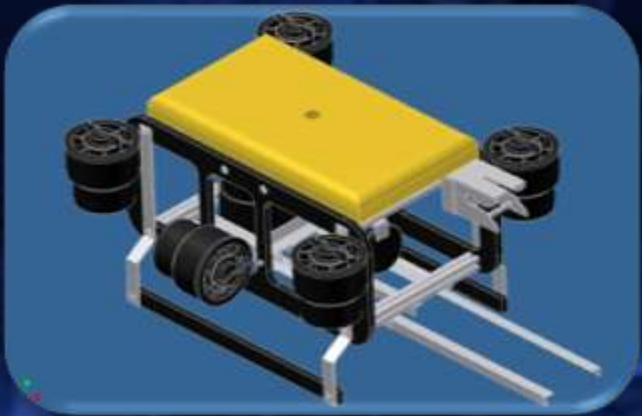
In this detailed technical report we will describe our design rationale, including the schematics we used to create T.E.S.S., major challenges, discuss future improvements, and the lessons we learned throughout the design process. As you will see we conquered many challenges and had to create troubleshooting techniques to solve our challenges. In the end it was all due to team work and dedication. Upon reflection none of this would be possible without the help of our mentors, our school, and MATE.

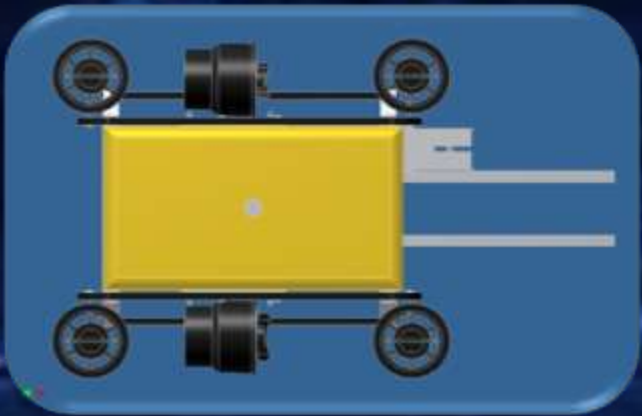
In order to maximize our time efficiently, we have created a website to coordinate events and goals among our team members.

You may log onto our website at:

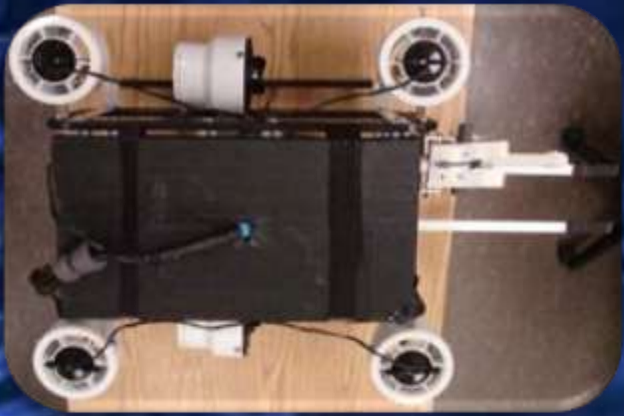
sites.google.com/site/teamgearsproject

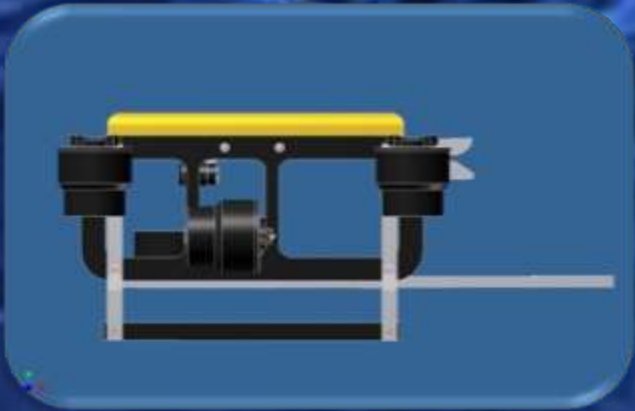
Photo Gallery

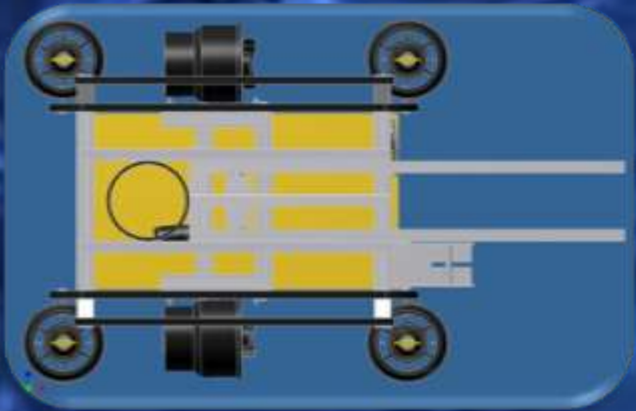

(Figure 1) 3D drawing of completed ROV

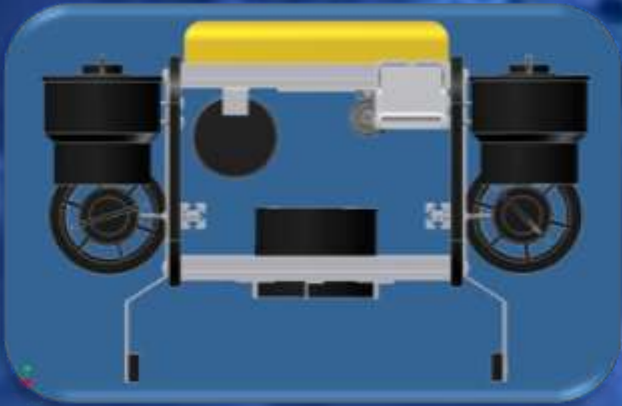

(Figure 2) Top View


(Figure 3) Isometric View


(Figure 4) Top View

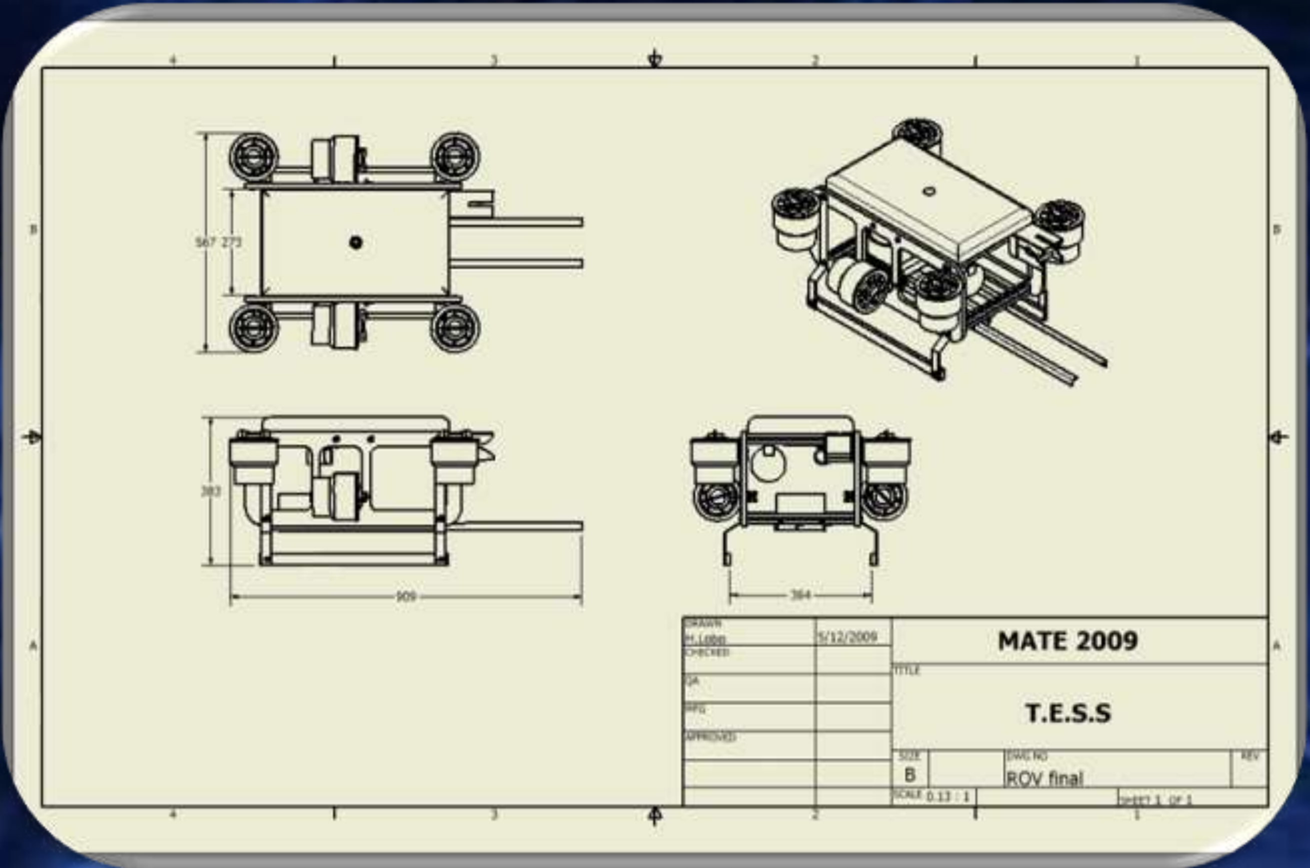

(Figure 5) Right View


(Figure 6) Bottom View

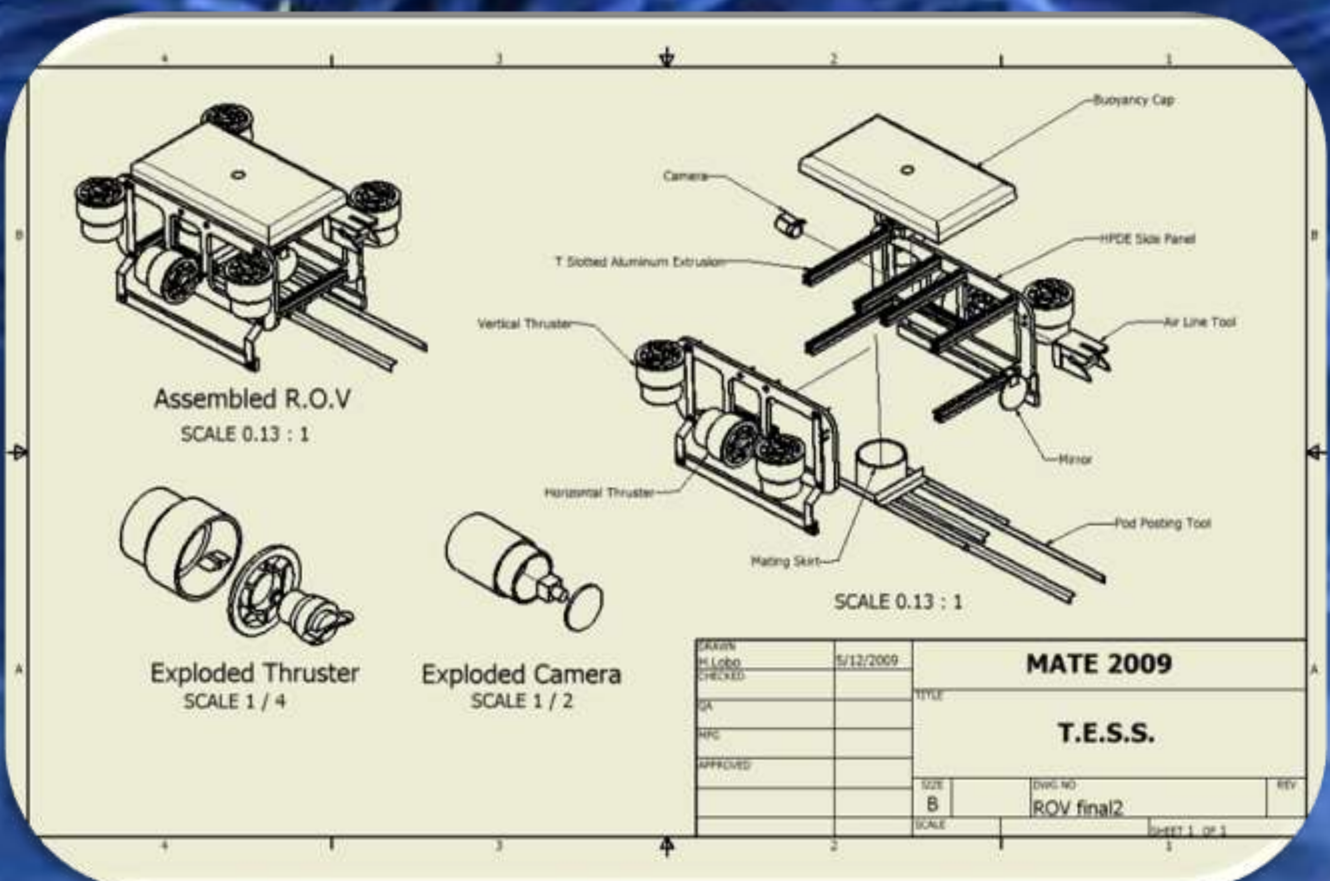

(Figure 7) Front View


(Figure 8) Back View

Photo Gallery



(Figure 9) Dimensions of our ROV



(Figure 10) Exploded view of our ROV

Expense Report

Team Gears Expense Sheet

Body				
Part Description	**Quantity**	**Unit Price**	**Total Cost**	
Seaboard HDPE 12.7mmx1219.2mmx1219.2mm	1	84.36	84.36	
T Slotted Aluminum Extrusion (180cmx25mmx25mm)	1	38.66	38.66	
6.35mmx25.4mm long Stainless Steal Pan Head Philips Machined Screws	16	0.65	10.40	
6.35mmx38.1mm long Stainless Steal Oval Head Philips Machined Screws	12	0.47	5.64	
6.35mmx19.05mm long Stainless Steal Pan Head Philips Machined Screws	9	0.50	4.50	
6.35mmx12.7mm long Stainless Steal Pan Head Philips Machined Screws	9	0.40	3.60	
6.35mm Nylon Stock Nuts	30	0.23	6.90	
6.35mm Finishing Washer	12	0.36	4.32	**Total Body Dollar Cost**
1.58mmx6.35mm Medium Aluminum Rivets	1	4.97	4.97	163.35
Thrusters				
Part Description	**Quantity**	**Unit Price**	**Total Cost**	
Prop Blades (1270 & 1250)	6	3.99	23.94	
3785.412 LPH Bildge Pump Cartridge	6	19.95	119.70	
101.6mmx50.8mm PVC Reducing Bushing	4	6.47	25.88	
101.6mmx7.62cm PVC Reducer	6	3.29	19.74	
Direct Drive Propeller Adapter	6	4.99	29.94	**Total Thrusters Dollar Cost**
101.6mm SCH 40 PVC Pipe 60.96 cm section	1	3.48	3.48	222.68
Tools				
Part Description	**Quantity**	**Unit Price**	**Total Cost**	
3mmx19mmx2.4384m Aluminum Angle	3	8.42	25.26	
25.4cm Mini Bungee	1	2.22	2.22	
101.6mm Black ABS Coupling	1	12.18	12.18	**Total Tools Dollar Cost**
				39.66
Controls System				
Part Description	**Quantity**	**Unit Price**	**Total Cost**	
18-2 Stranded Tether Wire 121.92m	1	32	32.00	
Assorted Heat Shrink Tubing	1	1.78	1.78	
3mm Heat Shrink Tubing	1	1.78	1.78	
12.7mm PVC Access Pull Elbow	1	2.05	2.05	
12.7mm PVC Type T Conduit Box	1	2.52	2.52	
12.7mm Flex Blue Conduit	1	2.83	2.83	
203.2mm Zip Tie PKG	1	1.79	1.79	
Relay (DPDT)	8	4.59	36.72	
Switches (SPST)	4	2.25	9.00	
Barrier strip (Connector)	2	2.25	4.50	
Joystick (Arcade Style)	2	11.95	23.90	
Solder-Donated by BCC	1	4	4.00	
Control System Wire-Donated by BCC	1	1	1.00	
Fuses 25A-Donated by BCC	1	1	1.00	**Total Control System Dollar Cost**
				118.87
Camera System				
Part Description	**Quantity**	**Unit Price**	**Total Cost**	
B/W Night Vision Camera-8.46mm LGCCDB/W-420TVLines-100mA(Donated By Chapin Boats)	1	175	175.00	
38.1mm PVC Cap	1	0.77	0.77	
12.7mmx6.35mm PVC Bushing	1	1.47	1.47	
				Total Camera System Dollar Cost
				2.24
Buoyancy System				
Part Description	**Quantity**	**Unit Price**	**Total Cost**	**Total Buoyancy System Dollar Cost**
Hull & Deck PVC Foam Core 453.59g Density Sheet (Donated by Chapin Boats)	1	64.5	64.50	0.00
			Final Dollar Cost	546.80
Donated Items (IN YELLOW) were not included in the final ROV cost				

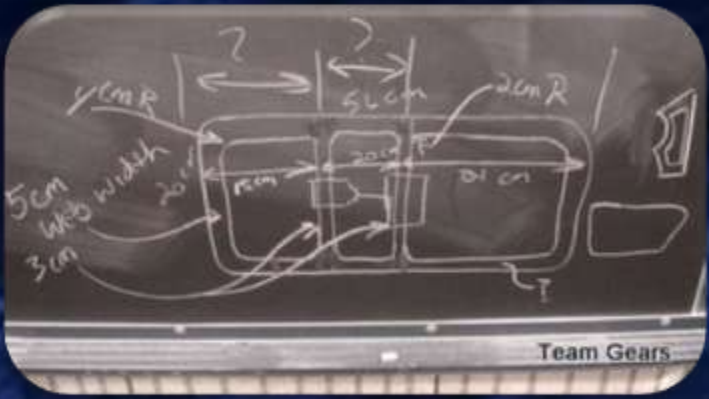
(Figure 11) Expense Report

Design Rationale

Frame:

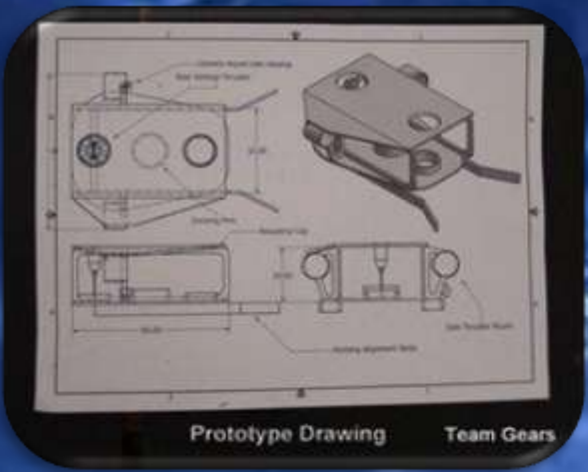
When the team first came together and brainstormed we came to the conclusion that we wanted to create a simple yet modular design. Our first discussion was centered on the frame characteristics and dimensions. We wanted the basic frame to be light, robust, and affordable. Our frame was designed to take the abuse of performing difficult tasks in a harsh environment without sustaining damage. It consists of two Black High-density polyethylene (HDPE) side panels, six horizontal aluminum extrusions (for structural rigidity and modularity) with stainless steel machine screws holding it all together. We determined the width of T.E.S.S. based on the fourth mission task of docking; allowing TESS to be able to “straddle” the submarine in order for alignment and docking onto the escape hatch.

We started by first drawing the ROV by hand on a black board. Then Don took the lead to draw up two prototype designs in inventor to give us a 3D drawing that we could discuss further. Once we were satisfied with one of the prototype designs we started to build the frame and adjusted the design as we saw fit.



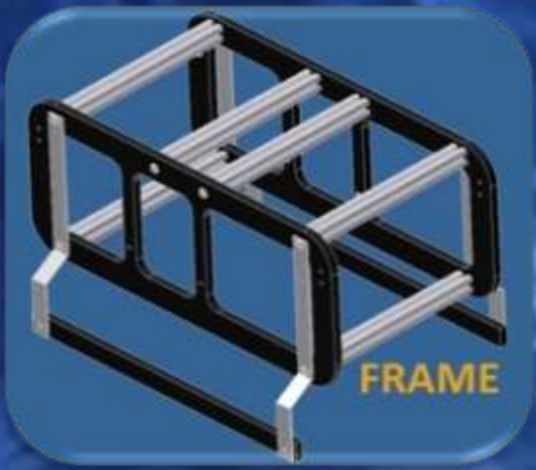
(Figure 12) Our first frame dimension drawing

(Figure 13) Don drawing the first prototype



(Figure 14) Our second prototype drawn by Don

(Figure 15) Chris marking the HPDE



(Figure 16) This is the final frame design drawn by Helder

Control System & Tether:

Our control system went through many generations. The original design of the control system was greatly over-engineered for this project. Originally, we use digital logic, controlled by a joystick, but found it rather difficult to implement. Our system also featured a variable speed control system that was achieved using Pulse Width Modulation or P.W.M. However, after a few tests in the pool, the variability in the speed proved to be unnecessary because the ROV preformed well at the maximum setting. Therefore the operating system needed to be redesigned with a simpler control system.

The new design would use only a single speed to control all movement. The system uses two multi-directional joysticks that control the horizontal and vertical movement separately. Moving the joysticks closes different electrical switches mounted to the base. The closing of these switches activate different relay coils connecting the 12 volt power supply to the ROV Thruster motors. When activated these relays engage these motors in the proper direction to achieve the desired movement.

The tether of T.E.S.S. is a custom designed tether. A professional tether was offered to our team, however, after a long discussion, and the use of a engineering decision matrix, we decided that the tether was not going to fit our needs. We measured out six lengths of 24.384 meter, 18 AWG wire and a single video cable, and the tether was bundled together at every meter. The tether was made neutrally buoyant by attaching buoyancy foam every few decimeters .

(Figure 17) Control System used for the New England Regional (Currently being cosmetically improved)

(Figure 18) Dan displaying our tether

Video System:

We originally designed our ROV to have three cameras, but after some of the cameras failed we rethought our "keep it simple stupid" strategy and quickly realized we had made the ROV more complicated than it needed to be. By using one strategically placed camera and a mirror we found that we could replace all three cameras with just one, and still be able to guide our ROV through the various mission tasks. We have positioned the camera to guide us in travel mode, flipping open and closing the escape hatch, picking up and posting the pods, inserting and turning the air valve, and docking with the submarine. The mirror is utilized only during the docking portion of the mission. Our camera is a water proof black and white camera with 420 lines of resolution providing an analog signal, connected through a RCA connector and with a current requirement of approximately 100 mili amps. Both the camera and mirror are bolted onto the T slotted aluminum extrusion.

(Figure 19) The camera and mirror combination allows us to see when we are docked onto the escape hatch

(Figure 20) Our water proof camera is incased in a protective PVC housing

Tools:

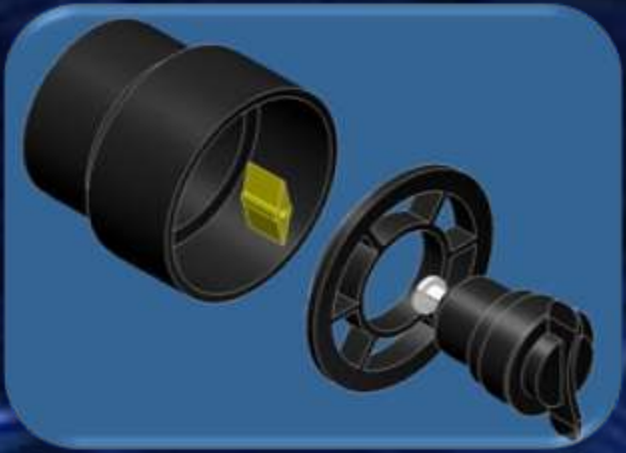
The over-all design guidance we established as a team for tool development was simplicity and modularity. Rather than develop complicated systems we opted to tackle each mission task with function specific "Dumb" tools. We used the ROV dimensions and design characteristics to simplify the completion of each mission task. This includes a video inspection camera that is best placed to take advantage of the mobility of the ROV, static tools designed to turn valves, open hatches, and handle the PODS. Our only tool that has movable components (snap and release) is the vent tool used for carrying, releasing, and recovering the air valve in mission #3.

(Figure 21) Pod Tool

(Figure 22) Vent Tool

Propulsion:

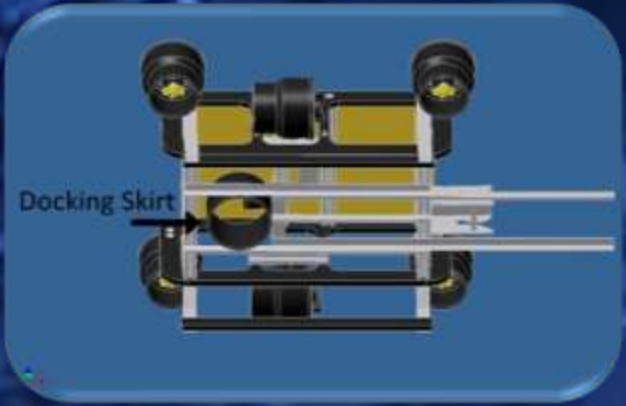
We have chosen to use a total of six 3785.4 liters per hour, twelve volt bilge pump cartridges with two Octura 1270 and four Octura 1250 model boat dual blade propellers. Each *bilge pump* cartridge motor, in their *protective* PVC housing and with the Octura 1270 Propeller, creates a total of ten (10) newtons of force while the use of the Octura 1250 propellers gave us six (6) newtons of force. There is one thruster on each side, which provides us with forward, reverse, left, and right movements, and four vertical thrusters on the four top corners of the ROV. These four dive motors allow us to dive and ascend as well control the pitch of our ROV. Each prop is connected using a MA 3200 propeller adapter connected to it's respective motor. Our total motor draw test determined a maximum of 10 amps above the surface (unloaded) and 23.6 amps submersed. (loaded)



(Figure 23) Exploded view of our completed motor housing

Docking Skirt:

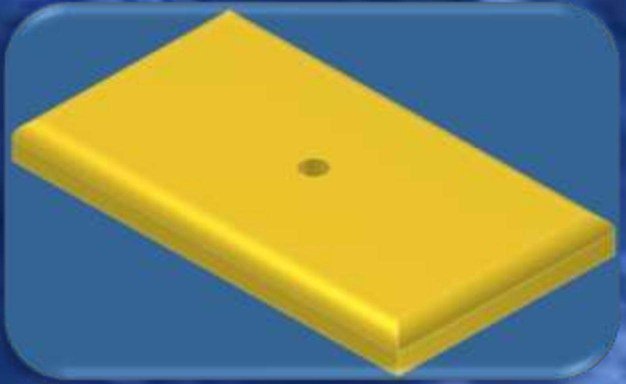
The docking skirt is a simple 10.16 cm hub to hub PVC coupling mounted rigidly to the underside of the ROV flush with the bottom runners. The side rails of the skids are positioned to straddle the sub and handle the side to side alignment.



(Figure 24) Docking Skirt

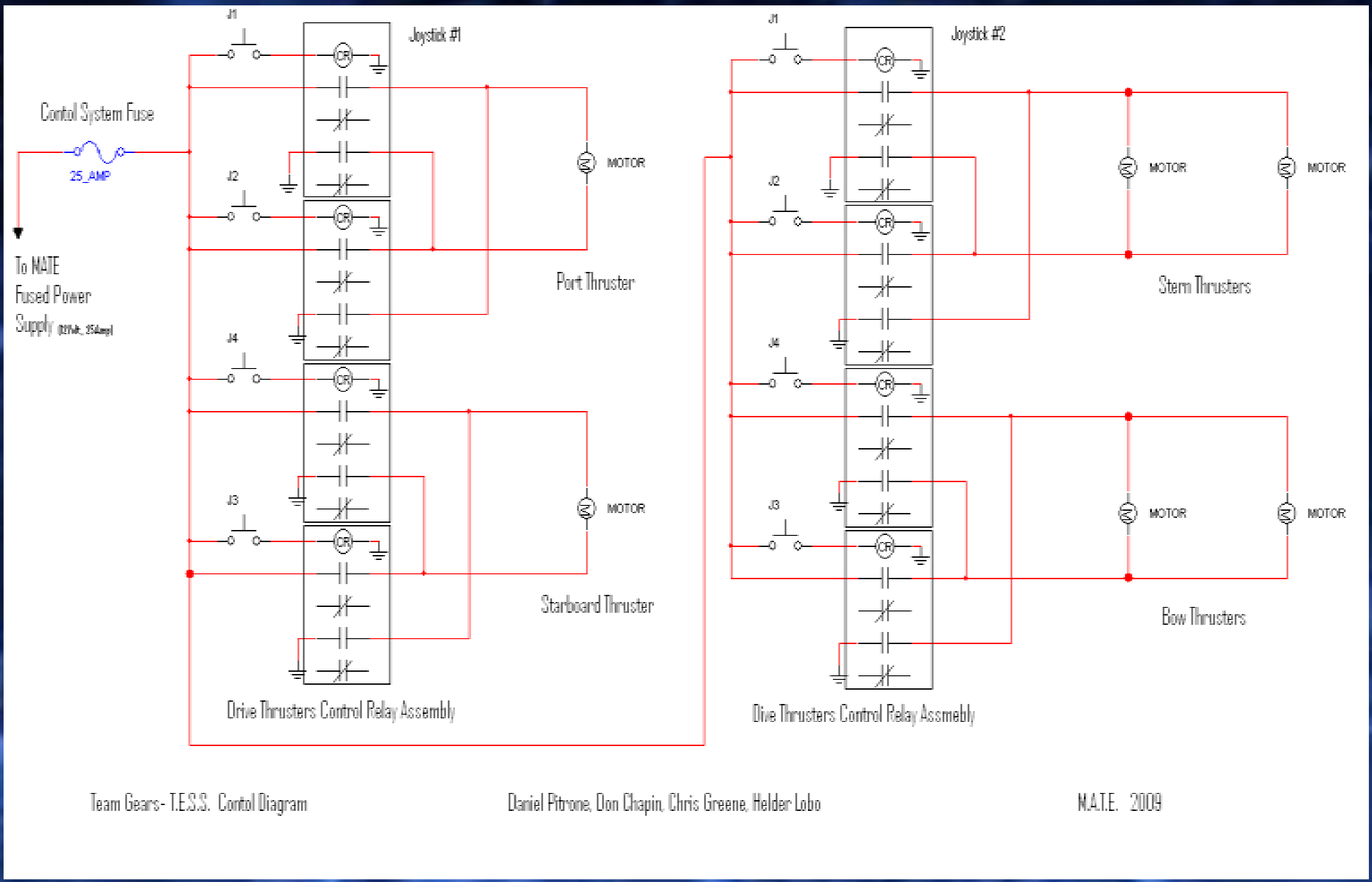
Buoyancy Cap:

The buoyancy of the ROV is slightly positive to allow for recovery to the surface if catastrophic failure such as severance of the ROV from the tether occurs. The Cap volume has been determined to allow for positive buoyancy with minimum additional ballast added to the ROV. The cap is cored with closed cell boat deck and hull coring. It has been built up of 1 cm layers bonded with hot melt adhesive. We weighed the ROV in the water and then calculated the required volume of the buoyancy cap. Water testing confirmed the volume adjustments required. Once all water testing was complete the buoyancy cap received final shaping and was covered in fiberglass to improve structural integrity and durability.



(Figure 25) Buoyancy Cap

Electrical Schematic



(Figure 26) Please see control system section for detailed explanation

Major Challenges

As a team, we faced many challenges and one of the most difficult ones was the design and positioning of the static "Dumb" tools. We developed a design rational that initiated with the examination of the specific task, considered the mobility of the ROV, and the relationship to both previous and subsequent tasks in the expected mission strategy. Our goal was to develop the method a mission task strategy that resulted in the least amount of specific actions required to accomplish tasks and to travel between tasks. For example, being able to pick up all five pods in one trip reduces the travel time to accomplish that mission task. The team determined that carrying the airline nozzle throughout the mission tasks would eliminate the need to return to the surface and back to the mission area, thereby saving time. Positioning of the Airline nozzle at the left front top corner of the ROV reduced the potential for entanglement in the mock submarine apparatus while completing the other mission tasks. Additionally it reduced the potential that the airline nozzle would be knocked loose while completing the other mission tasks.

In one of our first designs, we placed the vent tool in the rear of our ROV. When some of our cameras malfunctioned, and we decided to use only one camera, we positioned the vent tool on the right, front, top section of the ROV. Upon testing our ROV in the pool we quickly realized that the position of the vent tool on the right side conflicted with the ability of accomplishing mission task #3. By placing the vent tool of the left side, the ROV would be positioned on the outside of the submarine and the pod tool can't interfere when inserting the airline nozzle.

There were many instances that we decided to use a decision matrix to resolve a challenge. For example, the team needed to decide whether or not to use a donated professional tether. The main points of this decision matrix were number of conductors, buoyancy, and adaptation of electrical connectors. All members of the team had different opinions on whether or not to use the professional tether, therefore we used the decision matrix to reach a consensus on how to best address our tether dilemma. By using the decision matrix we came to the conclusion that we should not use the donated tether but make our own.

Another instance where we used a decision matrix was in strategic mission planning. The goal of this particular matrix was to decide the proper order to complete the missions to minimize time usage and maximize time efficiency. The matrix allowed us to narrow our decision from six possible combinations to two. Then through further pool test we decided on the stronger of the two. (Please see appendix) Another challenge we faced was when we were designing our control system. Deciding how sophisticated our design should be was very difficult. At first we wanted to maximize the mobility of the ROV however after testing we decided maximum maneuverability was unnecessary and are new control system was limited to a few fixed movements. Our final challenge proved to be the most difficult. For the MATE regional's we used all 1270 propellers with our bilge pumps. This caused a major problem with the MATE 25 Amp current usage requirement, we were drawing an excessive amount of current. To correct the problem we added four switches that disengaged the individual thruster motors. This was a band aid solution that needed to be repaired if we to continue at the International level. As you can see we conquered many challenges and in the end it was all due to team work and dedication to ourselves and each other.

Troubleshooting Techniques

Structural:

We determined from the start that we wanted to create an ROV that was as close as possible to a commercially viable ROV yet was able to complete all the missions of the MATE 2009 Competition. We used High-density polyethylene (HPDE) because it does not degrade when submersed in water, it is sufficiently strong, commercially available, and affordable. Throughout testing it became clear that our HPDE side panels were a perfect selection. The frame repeatedly took hits on objects in the testing pool yet the HPDE was able to absorb the energy and no damage took place.

Buoyancy:

To create our buoyancy cap several layers of foam core materials were constructed with hot melt glue and covered in Duct tape for early trials of buoyancy. As the ROV construction continued through testing the cap volume was adjusted until appropriate buoyancy levels were almost reached. The final “sweet spot” was reached by adding one lead weights until we reached neutral Buoyancy.

Tools:

The most complicated “Dumb” tool to develop was the airline tool. . The true challenge was maintaining a firm grip on the airline nozzle throughout the missions while having the ability to release and recapture the nozzle in completion of the mission task. The team brainstormed numerous possibilities to address this this task. In the end, an open/close passive gripper with adjustable tension allowed us to adapt the tool to the mission task.

Electrical:

The electrical control configuration was designed to work as simply as possible. The simple design worked fine but to give the motors the power they needed to operate, the design had to be re-engineered. The lack of availability of parts also led to last minute design changes in the controls. One challenging event that we needed to troubleshoot was when we transitioned from four motors to six, when we expressed all the motors we were blowing the 25 amp fuse.

The problem was solved by replacing the four up/down propellers from the larger 1270 to the smaller 1250. This change in size reduced the drag on the propeller therefore reducing our thruster current draw. The cumulative effect of reducing the sizes of all four propellers, maintained a safe current draw of 23.6 amps (measured with a Elenco VOM) with all six thrusters in the on position under full load.

ROV Motor Draw Test

3785.41 Liters Per Hour Bilge Pumps
Unloaded - with 1270 & 1250 propellers

Single Motor Current Draw	Six Motor Current Draw
1.4 Amps	10 Amps

3785.41 Liters Per Hour Bilge Pump
Loaded - with 1270 & 1250 propellers

Single Motor Current Draw	Six Motor Current Draw
3.9 Amps	23.6 Amps

Lessons Learned

Helder:

Creating T.E.S.S. was a challenge. I have been involved in many team oriented competitions but unlike other events, this time it was truly a team effort. It would have been impossible to have built T.E.S.S. alone. I'm not the most talented of engineers and I only know basic electrical principles. Although I'm not a gear head or great with tools what I lack in pure engineering ability ,I make up in my unwavering persistence to keep moving forward. I had to use all my computer, AutoCAD, troubleshooting, and management skills in order for us to stay on schedule. I learned when it was acceptable to keep pushing my team forward. There were times where they were upset up with me but it was for the greater good of the team that we work as hard as we could. I must say all our hard work paid off. T.E.S.S. is one complicated creature and I have truly realized that Team Gears is just that, a gear. Without one part, the machine stops functioning.

Our team is incredibly balanced. Our team members include Don, an experienced designer, Chris, a mechanical engineer, Dan, an electrical engineer, and me (Helder), the team coordinator and website designer. I learned that time management was extremely important. Early on I resolved to set dates ahead of time instead of the actual due date. This came in handy when we fell behind in manufacturing all the necessary tools. I also discovered the effectiveness of the internet. I used our website and e-mail to coordinate all our actions and goals. In the end our website was a blessing. There were times when I forgot something and because I had placed that information on our website, all I had to do was look at our site. I'm proud to be a part of this team; I have learned the importance of leadership and teamwork.

Future Improvements

In future designs we would like to further enhance all tools and better video placement with mobile video mounts to allow for increased redundancy of systems. We currently have static video cameras that are properly positioned in order to best guide us through all the missions. In future designs we would include a camera system that we can control and pivot by joystick control to better guide us throughout our missions. We would also like to mount the control system in a professional metal brief case.

Research

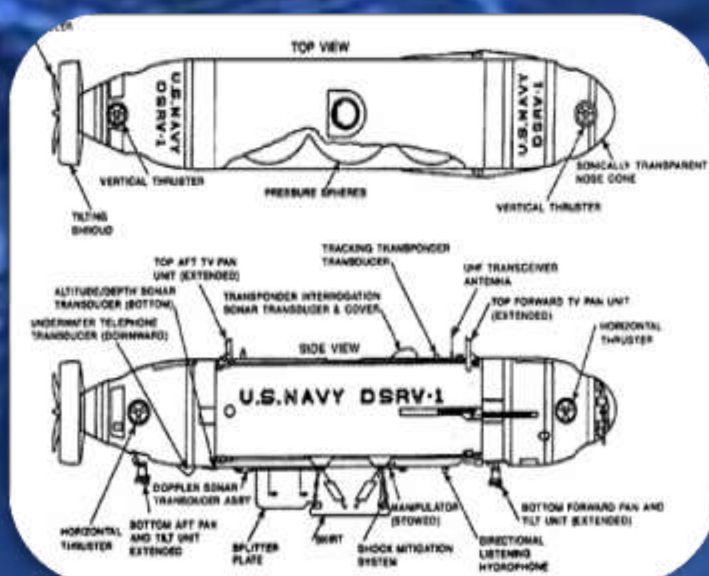
Deep Submergence Rescue Vehicle (DSRV)

The Deep Submergence Rescue System was developed in the mid-1960s after the USS Thresher tragedy in April 1963. The Mystic (DSRV 1) and Avalon (DSRV 2) were built by the Lockheed Missile and Space Company, and designed to rescue personnel from disabled submarines. They have been in service since 1971. The DSRV's are transported to the downed submarine in an efficient manner. It is carried by aircraft, truck, ship, or by another submarine down to the disabled submarine. After they attach themselves to the submarines recue seat, it can introduce emergency supplies or the crew can safely board the DSRV. It can accommodate up to 1905 kilograms of recovered personnel. Both DSRV's can rescue a crew in a disabled submarine at a depth of 610 meters with a maximum operating depth of 1524 meters. The DSRV then detaches itself from the submarine and docks back onto the mother submarine or is can surface to the top of the ocean. There the personnel are taken aboard the rescue vessel.

DSRV's are full of cutting edge technology. They use sonar to detect the downed submarine, and an underwater telephone system to keep constant contact with the distressed submarine. They have a 35mm still camera, five black and white video cameras, and one color video camera in the bow. The DSRV's rescue skirt is centrally located underneath it where it can properly mate with a submarine, with an angle up to 45 degrees, to create a water tight seal. It has one arm to open hatches of disabled submarines and a gripper and cable cutter combined that is able to lift 454 kilograms. It's propelled by battery operated electric motors which turn the fifteen horsepower single shaft, to turn the propeller. It runs off of silver/zinc batteries and it has both a vertical and horizontal thruster located in the nose and rear.

The DSRV's were specifically designed to rescue personnel trapped in a real Submarine and our ROV was designed to successfully accomplish the MATE 2009 Competition. Yet, there are some parallels between the DSRV and TESS. Our ROV is remotely operated and the DSRV are controlled by internal pilots yet we are both electrically controlled. We both use batteries for our main power supply. Even thought T.E.S.S. can't do what the DSRV's can, we have designed T.E.S.S. to accomplish all the missions at the Mate 2009 competition and just like the DSRV's we can accomplish our mission objectives and that's the most important correlation.

(Figure 27) The Mystic (DSRV 1) attached to a submarine
Source: http://www.dsu.navy.mil/mystic.htm



(Figure 28) Mystic (DSRV-1) Overview
Source: http://www.fas.org/programs/ssp/man/uswpns/navy/submarines/dsrv.html

Reflection Statements

Helder Lobo:

I had a great time creating T.E.S.S. I learned much more than I originally thought I would, when signing up for this class. I never used Inventor before, yet I quickly learned , and I drew all the final Inventor drawings that you see in this report. Chris and Don took the lead in building TESS but I also helped by providing assistance when it was needed . After months of hard work I have a much better understanding of machining tools and how to properly use them to build a product. I not only learned engineering principles but I learned the values of true team work. Nothing was ever easy and without my teammates T.E.S.S. would never have come to fruition. Now it's on to the internationals. I can't wait to see what other creative students accomplished. If all goes to plan, T.E.S.S. will perform exceptionally well.

Don Chapin:

What an outstanding experience this has been. I am taking a couple classes each semester to improve my design and engineering skills. I have a background in prototyping and design but it has all been through non-formal education. Being twice the age of the other students on the team has provided me some unique learning opportunities and a great new perspective on the strength of young people. The development of the engineering notebook concept will benefit me greatly in my civilian work with boat design. Having the team relying on me for various design and construction tasks definitely increased my understanding of the team concept. Amazing how education often comes from the unintentional parts of the experience. Great class!

Chris Green:

Preparing for the MATE competition and building our ROV was a great opportunity. Team work was critical to building our ROV. Each team member has their own strengths and weaknesses, in different fields and disciplines, yet in the end we are a very balanced team. While working with my other team mates, I learned many new types manufacturing techniques. I also learned how to use wood templates and a router table. While creating T.E.S.S. I sharpened my manufacturing and mechanical skills. As a team, the experience of competing in the ROV competition allowed us to learn and embrace the engineering design process. We got a taste of what designing solutions in a real world engineering team is like. The MATE ROV competition is a great opportunity. I hope I'll be able to compete next year, and I hope we do well at the internationals. I 'd like to thank MATE for giving me and my team this opportunity to show everyone the end result, T.E.S.S.

Dan Pitrone:

Creating T.E.S.S. was one of the most involved challenges I have ever undertaken. The combination of the engineering work, teamwork, and the class work was very stressful at times. However, the stress was a great tool to learn great lessons such as the importance of team communication and the idea, that your first idea is not always the best. This experience allowed me to dive deeper into the world of digital and analog circuits and sharpen necessary skills to continue my electrical engineering goals. T.E.S.S.' electrical designs went through countless revisions as the project progressed. The demand of this project was a lot higher then I originally thought. This project showed me exactly how much work is required to accomplish your goals and bring your ideas to life.

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Appendix

Engineering Design and Development

Decision Matrix

* Problem Statement Below: What is the best order to complete the mission?

Specifications

Alternatives (order)	[illegible]	Maximum [illegible]	[illegible]	[illegible]									Totals
① 1,2,3,4	0	0	1	0									1
② 1,3,2,4	0	1	1	0									2
③ 1,2,4,3	0	0	1	0									1
④ 1,3,4,2	0	0	1	1									2
⑤ 1,4,3,2	1	0	1	1									3
⑥ 1,4,2,3	1	1	1	0									3 ☆

* Define a clear and concise Problem Statement here:

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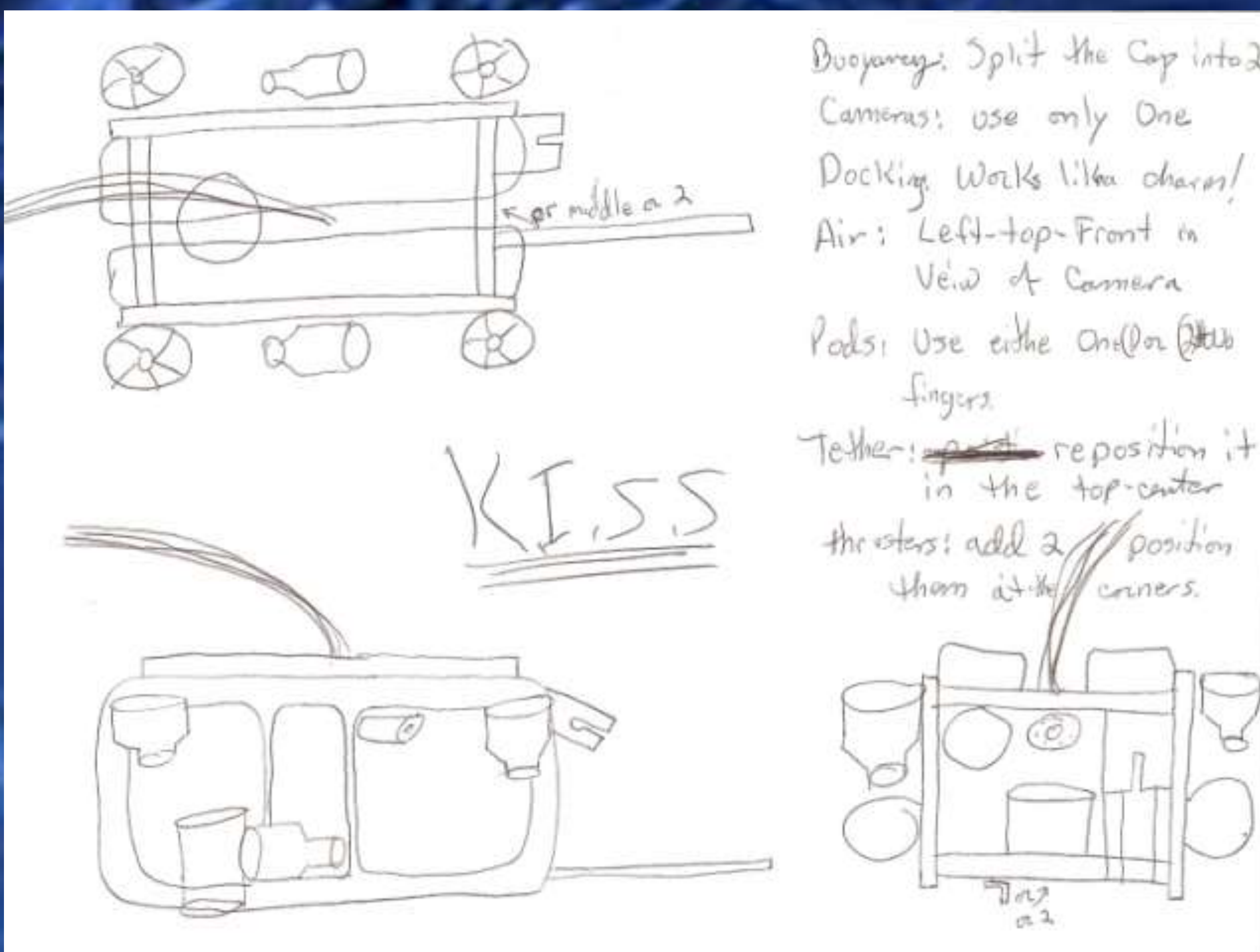
(Figure 29) Decision matrix used to decide the mission order



(Figure 30) When we had to redesign T.E.S.S. this was our first free hand sketch