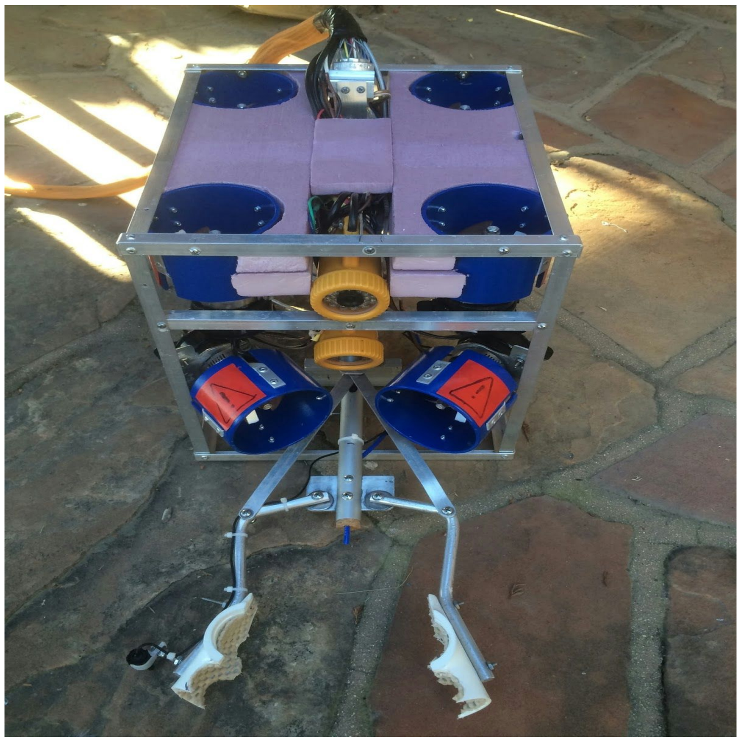
Nautilus 2.0

ROV



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Abstract

The Nautilus 2.0 offers an improved version of the previous ROV(Remotely Operated Vehicle), the Nautilus, that is built to withstand the harsh environments of both deep ocean and outer space.

The Current ROV is equipped to survive transportation to planets as far as jupiter's moons and operate in the ocean under its ice sheets to collect data and deploy instrumentation. Many members of Aptos High Robotics have multiple years of experience under them that they can apply to help differentiate between the best ways to design, build and optimize the ROV to complete the tasks at hand. Planning for the Nautilus 2.0 began in early August and we have been continuously working to ensure the highest quality ROV with new special features to accomplish the proposed Outer Space and Deep Ocean Tasks. The goal of the Nautilus 2.0 is to provide the most accessible ROV for the customer while still maintaining the necessary professionalism able to complete complex tasks. With this goal in mind we aimed to build a simplistic yet sophisticated ROV capable of completing any task.

Design Rationale

Frame

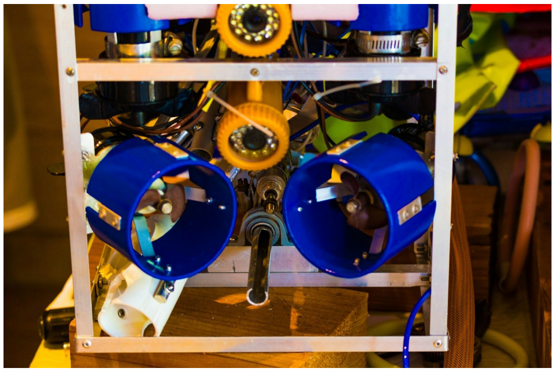
The frame of our ROV was designed to give us a lot of control, speed, and balance while still fitting through a 48cm circle. We created a ¼ inch plywood template before building the frame so it was possible to truly envision what it would look like and how it would work. The frame was made out of half inch aluminum angle because, although we know the benefits of plastic, aluminum is what was available to work with at the time and we found it to be a better alternative to plastic. Aluminum is much lighter allowing us to maneuver easily and complete many of the tasks with ease, compared to some of the struggles encountered when using other materials such as Polyvinyl Chloride which are much bulkier and have a higher weight out of water. Also, many members of the team were experienced at working with aluminum from previous years and we had a large supply. To hold the frame together we used ⅛" rivets.

Cameras

In order to make our ROV as consumer friendly, cost effective and efficient as possible we decide to use pre-manufactured Cameras that we knew would give the consumer optimal vision underwater. The Cameras are equipped with LED lights and they have an angular field of view of 97°. The Cameras are attached to the ROV by adjustable aluminum brackets, making it possible to change the view of the Cameras with ease. The Nautilus 2.0 is equipped with three of these Cameras, one looking down through the General Purpose Manipulator, one at the top of the ROV for forward vision and one in the rear for a general view of what is behind and under you.

Propulsion

The ROV is propelled by 8, 1000 gph bilge pumps equipped with propellers, four of which are vertically positioned motors. The vertical motors are positioned in the corners so that the ROV is able to achieve vertical movement and pitch. The lateral motors are mounted directly in the corners in an "X" configuration. This means that they are at a 45 degree angle to the frame. This maximizes the space inside the frame as well as provides a superb strafing ability. This configuration is key because the robot needs to be able to strafe as well as have a small silhouette to make navigation around the various mission tasks easier. One helpful idea the team has adopted from it's sophomore class was taking the bilge pump impellers and grinding them down until they are one thin plate and then putting them back on the motors before putting the propellers on. This makes it so water isn't being pumped back into the shaft/motor. Surrounding the propellers are shrouds, which allow for a 2 cm buffer for safety around the motor. The shrouds are made out of 3 ½ inch PVC pipe and are 6.5 cm in length.



The 8 ROV propellers have two blades, like airplane propellers. The other option was to use 3 bladed propellers, which resemble boat propellers. We decided to use two blade instead of three blade for many reasons. The three bladed propellers exert a thrust 5.78 newtons, while the two bladed exert a thrust of 5.33 newtons. The three bladed propeller draws 5.8 amp ≈ 12 volts compared to the two bladed which only draws 5.2 amps when running wide open. Our ROV is small, so it doesn't need the extra thrust the three bladed has to

offer. So we chose the two bladed propeller, which has enough amplitude and exerts enough thrust to do the job.

Tools
(Pneumatic measuring system)

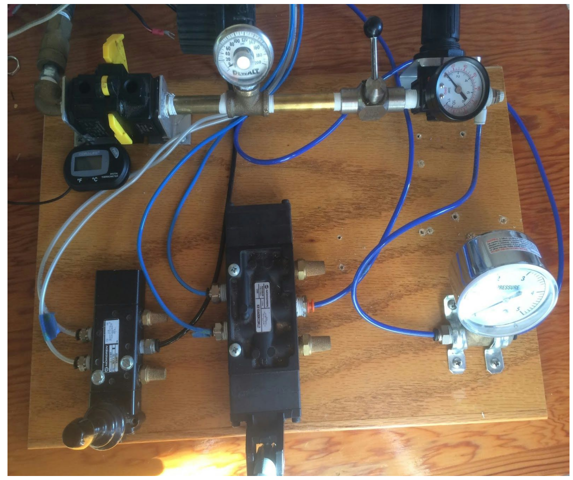
One of the newest introductions to the Nautilus 2.0 is the use of air pressure to determine the depth. Knowing the conversion 1ft=.43 psi we are able to determine the pressure using a 5 psi pressure gage and then take the reading, convert it to feet and finally convert the reading into meters. Using one of our high quality waterproof cameras we watch a ¼” piece of pneumatic tubing until the amount of bubbles is reduced to a small flow. Then one of the team members reads the pressure gage and we begin performing conversions. This is a cheap, simple and very accurate way to determine depth.

THE GENERAL PURPOSE MANIPULATOR (THE CLAW) or GPM

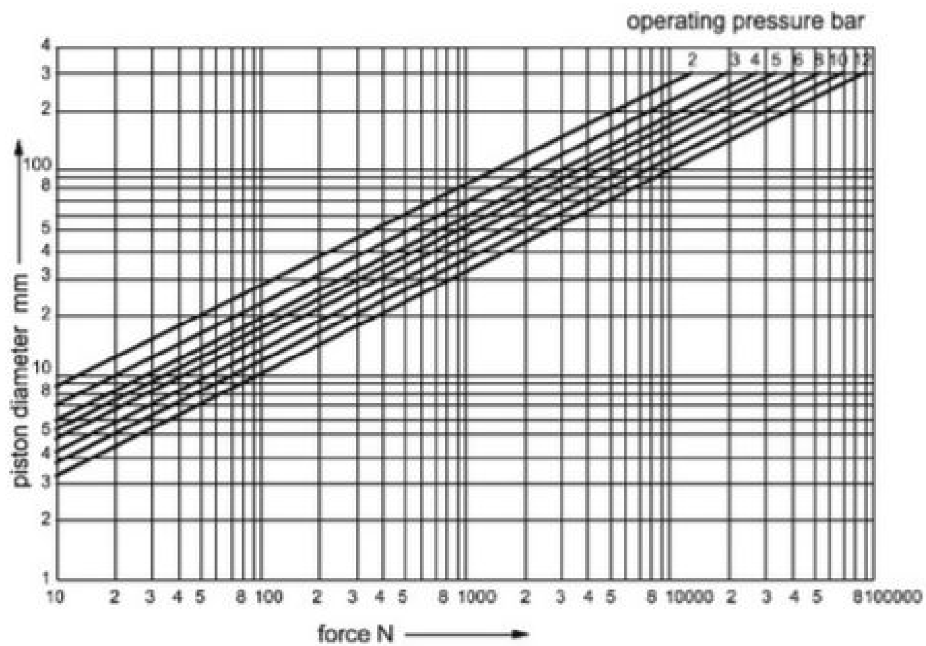
The claw was designed to accomplish a number of important tasks. These tasks were:

- To open the door to the port on the power and communications hub
- To insert the cable connector into the port on the power and communications hub
- To rotate or flip the CubeSats to read their numbers
- To recover the mission-critical CubeSats
- To collect one sample of each of the two oil mats
- To return two coral samples to the surface
- To install the flange to the top of the wellhead and secure it with a bolt

- To install the wellhead cap over the flange and secure it with a bolt



In addition to these tasks, the claw needed to be able to fit a temperature sensor to measure the temperature of the venting fluid and an air tube in order to determine the thickness of the ice crust and depth of the ocean under the ice. It was also necessary that the claw was able to be added to the ROV without making its size greater than 48 cm in diameter and its weight no greater than 11 kg. With all of these constraints in mind, the team decided upon designing a new claw for this year's ROV. One of the major issues with using the claw mounted on last year's ROV on the new ROV was that it was large and was very hard to fit onto an ROV without making it longer than 48 cm. To fix this, the new claw is designed to be detachable so that it can be put in the ROV while it is being sent into space. The claw is connected to the ROV with just one screw and one nut so that it is easy to remove and reattach quickly. The claw's shaft is made of lightweight aluminum with a PVC cross covered with anti-slip PVC foam at the end. The top of the PVC cross was cut out, making it into a PVC T with a hole in the top to improve vision underwater. A ½ inch hole was drilled on the bottom front of the PVC cross in order to be able to get a better grip on smaller items underwater. The temperature sensor can be attached to the bolt at the front right of the PVC cross with two nuts (refer to Temperature Sensor below). The pneumatic measuring system is also a part of the claw, with its pneumatic tubing fitting inside the hollow shaft. A piece of cork with a hole in the center for the pneumatic tubing is fitted in the end of the hollow shaft. The piston used for opening and closing the claw has a ¾ inch bore and a 1 inch throw, allowing for the claw to open to 25 cm. Another piston is located on the shaft of the claw to allow for it to be rotated 90° in order to grab or manipulate anything necessary.

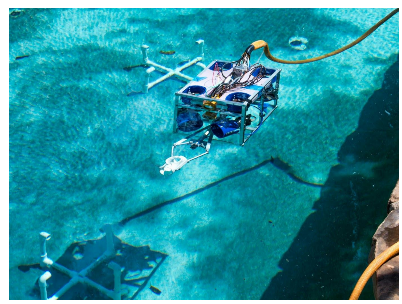


Temperature Sensor

For measuring the temperature of the venting fluid the team decided it was best to use a pre manufactured temperature sensor and make some modifications to it. The sensor is 4cm in length and .5cm in diameter. The team extended the wire by 17 Meters and added a small fuse to it for the consumer's safety. On the surface there is a digital readout that will display the temperature reading in either Celsius, or Fahrenheit. The sensor only takes about 15 seconds to adjust to the venting fluid temperature and is very accurate. The sensor itself is very easy to place in the hole where the venting fluid comes out because of its small design and because of the way it is mounted to the claw. The sensor sticks out 5 cm from one side of the claw and can be rotated to make it parallel with the claw when not in use, so it doesn't get in the operator's way.

Buoyancy

At first, we were planning to use PVC pipes to control the buoyancy of the ROV. Nonetheless, we opted to choose a closed cell foam buoyancy system because we felt that it was effective with the given missions at hand. In this, we used 1 inch thick, closed-cell Foamular R-5 Insulation and carefully attached it to the top of the ROV in order to create a neutrally balanced ROV. We chose to use this material because it was cost-effective, durable, easy to work with, and very effective in creating a buoyancy level that was needed for our small ROV Through calculations and trial and error, we positioned the Foamular R-5 Insulation equally on the top of the ROV and covered up the top wiring with a small rectangle of the material. Additionally, due to the tether slot on the ROV being placed on top, there was a tendency for the tether to dip and pull the ROV in an awkward way. We combated this with cutting out 8 small blades of the Foamular R-5 insulation, which was attached in equal intervals along the tether, thus creating less of a drag on the ROV.



Challenges

To find the depth of the ROV in the water we were originally going to use a pressure gage, with a camera looking directly at it. We found that although the pressure gage was accurate the pressure acting on the gage from the pool was affecting the accuracy of the reading. The delta of the gage in water was about 2 psi less than when out of the water. In order to fix the problem we attempted to make a plexiglass case for the gage. We originally thought the issue lied within the pressure upon the front and the back of the gage thus we came up with the idea to form a case to alleviate the pressure placed upon it. To create this case we used ¼ inch plexiglass and cut two 9 cm squares. To attach these squares we placed bolts in all four corners. We then put silicone around the plexi glass and the gage. Unfortunately it failed and the pressure reading was still inaccurate. We finally overcame this challenge by using a pressure gauge and converting the pressure (Psi)into depth (meters). This method allows the team to quickly get a reading on the pressure gauge and continue onto the next task while the mathematician calculates the depth.

Pricing

Category	Description	Budgetary Estimates	Actual Cost
Mission Props	PVC Parts J-Bolts, Screw Hooks Acrylic Sheets	$250 $10 $30	$256.75 $9.86 $31.08
ROV Structure	1/2” Aluminum Angle Buoyancy Materials Rivets Zip Ties Misc. Construction Materials	$75 $15 $3.50 reused $46	$60.75 $13.50 $3.50 reused ($1.50) $45.00
Pneumatics	Pipe Fittings Solenoids Cylinders	$0 $30 $100	$0 $18.00 $57

	Pneumatic Tubing	$160	$172
Propulsion	8 Bilge Pump Motors PVC Motor Shrouds 8 rolls 20 gauge wire	Reused Reused $20	Reused ($258) Reused($25) $20
Control System	Motor Control Boards Wires 3 cameras with ??? tether	$60 $30 reused	$25 $22 Reused ($100)
Misc Supplies	Business Cards T-Shirts Food for Meetings Misc nuts bolts, etc	$45 $50 $175 $20	$55 $40 $126 $23.38

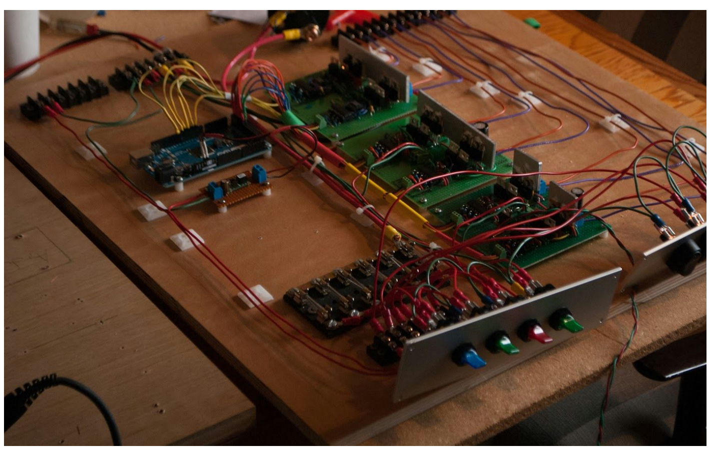
The Nautilus 2.0 reused a lot of materials from the original Nautilus that were used in the 2015 competition. This greatly cut down on our expenses for this year. The team also constructed many of the parts by hand when possible. The company received a $1000 donation from the Aptos High booster club.

Electronics

Two years ago, the team chose to pursue electronics that were mounted on the ROV. This proved problematic as we struggled to shove our circuit board and arduino into a small tube. After doing an Failure Mode Effects Analysis FMEA (Appendix) we chose not to reproduce last year's electronics design as there were many factors that could lead to failure.

The main feature of our electronics box are the six handmade motor controllers. Four of them control a single lateral motor while two other control a pair of up-down thrusters. The motor controllers receive a PWM signal which actually opens the circuit and does not let current through. The controllers also receive a forward control line and a reverse control line to specify which direction the motors will run.

We ran into a multitude of problems while building these boards, but we thankfully solved everything. The most common difficulty was overheating of the N channel FETs we used. One of the first problems we encountered was cold solder joints, which led to high resistance and high power consumption. Another problem was in the speed that the FETs switched from off to on. Because we had a resistor in front of the gate pin, it slowed down the speed that the FET turned on. This increased time that the transistor was floating, which caused the FETs to heat up to 180˚F. In our first design we used a combination of P channel and N channel FETs to create the H-Bridge. This was another flaw as there is an extremely small time difference between the P channel turn on time and the N channel turn on time. To fix all these problems, we practiced soldering, removed the resistors that came before the gate pins on the FETs and also slightly altered our layout to include only N channel FETs.

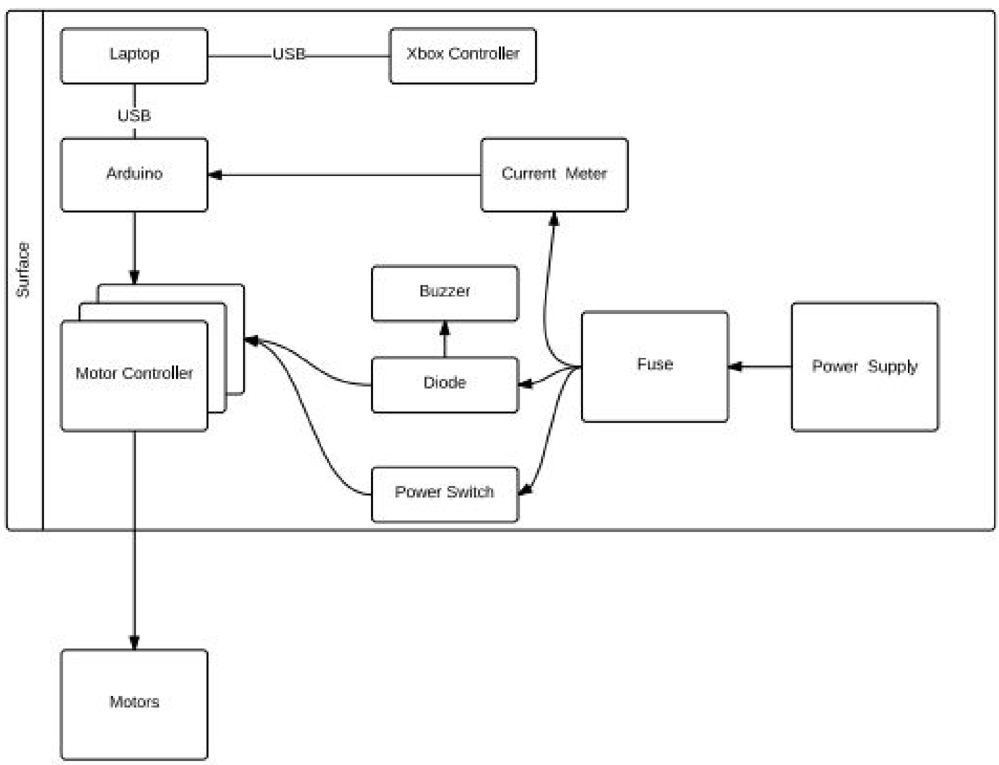


PC Software

The ROV software is made to be as versatile as possible but still be simple and quick to setup and use. All the code on the computer is written in C#, and Arduino code is written in Arduino's variation of C. The motor control software on the computer runs via a main loop, which first checks the state of the Xbox controller, and calculates the desired values for each motor based on the positions of the joysticks. It then sends that data over the serial interface to the Arduino. After it has taken care of the mission-critical tasks, the software uses a few CPU cycles to draw the graphs on the screen which represent motor states. While processing and sending commands down to the Arduino, we simultaneously listen for error codes from the Arduino.

Arduino

We employ the use of one Arduino Mega TM in our control box on the surface to run our robot. There is a single USB cable that connects the Arduino to the ROV. Our priority for communicating over the serial connection is to ensure the motor commands are received. For this reason, we have minimized the amount of cross communication that the Arduino will send backup to the computer, so that the USB Serial link will primarily be used in one direction to reduce interference and errors. The one event where the Arduino will send a message back up to the computer is when the computer requests a status update or when an error occurs. The Arduino code also features several failsafes to allow us to continue to compete, even in the event of a failure of one of our systems. The Arduino is capable of reading current sensors and constantly monitors the power consumption of the motors. If the Arduino receives a request to increase power to a motor at a time when the power draw is already too high, it will not complete the action, but instead sound an alarm and alert the pilot to the situation. We are also protected in the case of the computer failing, as the Arduino code is capable of interpreting a directly connected Xbox controller and controlling the motors without a laptop connected at all.



Tether

The tether of the Nautilus 2.0 is designed to allow the ROV to maneuver as easily as possible. It is equipped with eight 20 gauge wires, two 16 gauge speaker wires, five ¼” pneumatic tubing lines and one 24 gauge speaker wire for the temperature sensor. The team used charts to determine voltage drop and the correct wire size to use. The tether is then wrapped in bright orange spiral wrap. This protects the wires and keeps them tightly bound. The tether also has flotation strategically placed along it to help it from dragging on the bottom and becoming tangled.

Safety

The enforcement of safety has been taken very seriously since the first day of work on the ROV. For example, all meetings have included adult supervision and a first aid kit has been readily available whenever work was being done. A dress code for all members has also been imposed during all working meetings; No baggy clothes, sleeves must be rolled back, closed toe shoes must be worn, preferably long pants. For girls in particular, hair must be tied back and all loose jewelry must be taken off to avoid tangles in equipment.

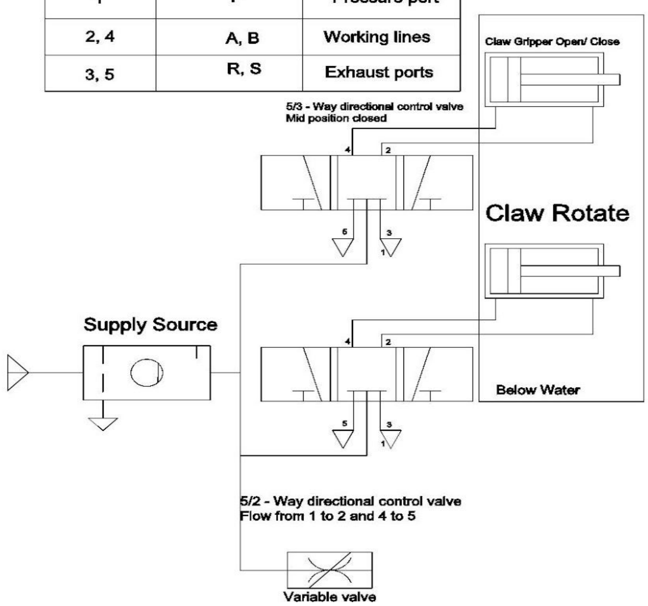
The Nautilus itself also has a multitude of safety precautions and features. All electronics have been fused individually, so that if one feature fails, the rest will still continue to function normally. There is also one main power switch so if total power shut off is necessary, a complete power down may occur. There is also an automatic shut off for the pneumatics which allows air to bleed out accordingly. The air pressure is regulated to 40 psi. Simpler features such as shrouds on the motors also add on to the level of safety, as they protect the propellers and provide a cleaner propulsion experience. Also, all exposed components on the ROV such as the cameras, motors, and wires are waterproofed to prevent any malfunctioning.

A safety checklist is also always present to ensure complete reassurance when working on the ROV;

- Ensure equipment is properly grounded
- All parts of robot are securely attached and no wires are exposed
- No hazardous objects are in the vicinity
- Power supplies are protected from water
- All personnel are wearing proper attire
- Announce prior to running ROV
- Proper communication is maintained

CAD Drawing of Pneumatics

ISO 5599-3	Lettering System	Port of Connection
1	P	Pressure port
2, 4	A, B	Working lines
3, 5	R, S	Exhaust ports



FAILURE MODE & EFFECTS ANALYSIS (FMEA)

981-0035-01-

FMEA NUMBER:		RESPONSIBLE ENGINEER: Quality Manager	Date:
PART NUMBER:			Date
PRODUCT DESCRIPTION:	The Nautilus		Date
PROJECT MANAGER:	Michael Heffner	Date::	Date
OUTSIDE SUPPLIERS AFFECTED?	YES ☐ NO ■		DATE COMPLETED:

POTENTIAL HAZARD	POTENTIAL CAUSE OF VARIATION (FAILURE) (rating documented in Occurrence column)	POTENTIAL EFFECTS OF VARIATION (rating documented in Severity column)	SEVERITY S1	OCCRNCE O1	DETECTN D1	RISK PRIORITY NUMBER (RPN) 1	CURRENT CONTROLS - MEANS OF RISK DEDUCTION (rating documented in Detection column)	RECOMMENDED ACTION(S)	RESPONSIBILITY & TARGET COMPLETION DATE	ACTION RESULTS: ACTIONS TAKEN	SEVERT S2	OCCRNC O2	DETECT D2
Loss of electronics	Flooding of enclosure	Failure	8	6	10	480	Design- moved to above water	none					
Pneumatics fail	Seal failure	slowing of actuator(s)	7	5	7	245	?						
Tool malfunction	poor design	mission abort	6	2	4	48	design review, testing	none					
Tool malfunction	wear failure	mission abort	4	2	4	32	silicone lubed before mission	write into checklist					
Tool malfunction	over extension	mission abort	6	2	4	48	none	put limiters					
Solenoid failure	Flooding of enclosure	?	5	7	8	280							
blown fuse	motor overdriven	mission delay	6	7	6	252	training	software limits					
blown fuse	shorting due to salt water	mission delay	6	5	7	210	testing						
blown fuse	shorting due to mech fail of wire/connect	mission delay	6	4	7	168	testing						
poor visibility	camera flooded	mission abort	8	3	4	96	testing	soak					
poor visibility	camera immobilized	mission slowed	6	4	5	120	testing						

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See work instruction 952-0008-01 Risk Analysis Checklist 981-0037-01

Reflection

Throughout the process of designing, building, testing, and developing our ROV, our team achieved a great victory. We were successful in meeting all of the requirements given to us by MATE, and we are also successful in the water. This process has not been easy; there have been many challenges in creating the ROV, however the finished product is something we are all proud of. A big part of this project was not only the mechanics of building the ROV, but also the software and computer programming. Most of us are more educated on the engineering part of the ROV process, so all of the wiring and electrical work was something we had to work on and learn about. We have learned that the ability to learn about a new topic and being able to apply it to this project is a very important skill. We have also learned many lessons of teamwork and thoroughness, and how it is very important to be certain of everything. This experience and these lessons will not be taken for granted and can be applied in future projects and ROV creations.

Lessons Learned and Gained Skills

One of our most repeated problems was our control board. We had some continuous issues with short circuits, and so we brought in Pete Burnight, who is a friend of our mentor and an ex-Apple engineer. He helped us find the problem with the electronics by showing us how to isolate the system and determine what part of the board was having problems. We found that the wires were working fine, it was our H-bridges that weren't working. There was one H-bridge in particular that we had to replace, but from this experience we learned the importance of isolating a system to find the problem. By testing out everything and taking parts out of the system, it became clearer what parts weren't working. This method will be helpful in future projects that deal with electronics and computers.

Future Improvements

As we were working on the Nautilus 2.0 we made a lot of improvements this year from last years model. Some of our improvements included aspects such as the pneumatic measuring system, and a newly adjusted propulsion system. Along with many new improvements this year we still have new ideas of the future consisting of some changes to the frame. We have always used an aluminum frame due to its robustness and light weight. However, next year we would like to look into a laser cut plastic frame in order to cut down the in water weight and allow for custom designs. Another improvement we would like to make is to adjust the software by making it more user friendly. We would like to improve the software which controls our ROV by adding comments to improve readability for team members who have not written the software.

References

- Festo's Introduction to Pneumatics 1990, Hauppauge, N.Y.
- Quality System Requirements QS 9000 First Edition Issued August, 1994 Second Edition, February, 1995 Third Edition, March, 1998, Second Printing, June, 1998, Third Printing, October, 1998 ISO 9001:1994 (in italics) Copyright © International Organization for Standardization Remainder Copyright © 1994, © 1995, © 1998 Chrysler Corporation, Ford Motor Company, General Motors Corporation
- 2016 Ranger Competition Manual
- IT Professionals. "Voltage Drop Calculator." Voltage Drop Calculator. N.p., n.d. Web. 15 Apr. 2016.

Acknowledgements

- MATE Center for making this event possible
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- Mr. Slyder for helping the club coordinate with ASB and for helping get a room devoted to the club
- Norm Black, Larry Bird, Pete Burnight, Simon Cassar, Greg Rudd for mentoring us to success when trying to accomplish the task at hand
- MATE Center for making this event possible
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