Long Beach City College

Viking Explorers – Long Beach, CA

Debonair INDUSTRIES

MATE International ROV Competition 2013 Explorer Class

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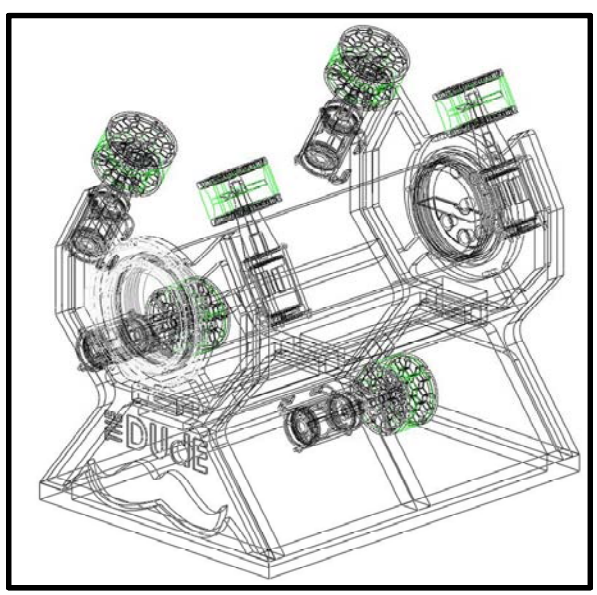

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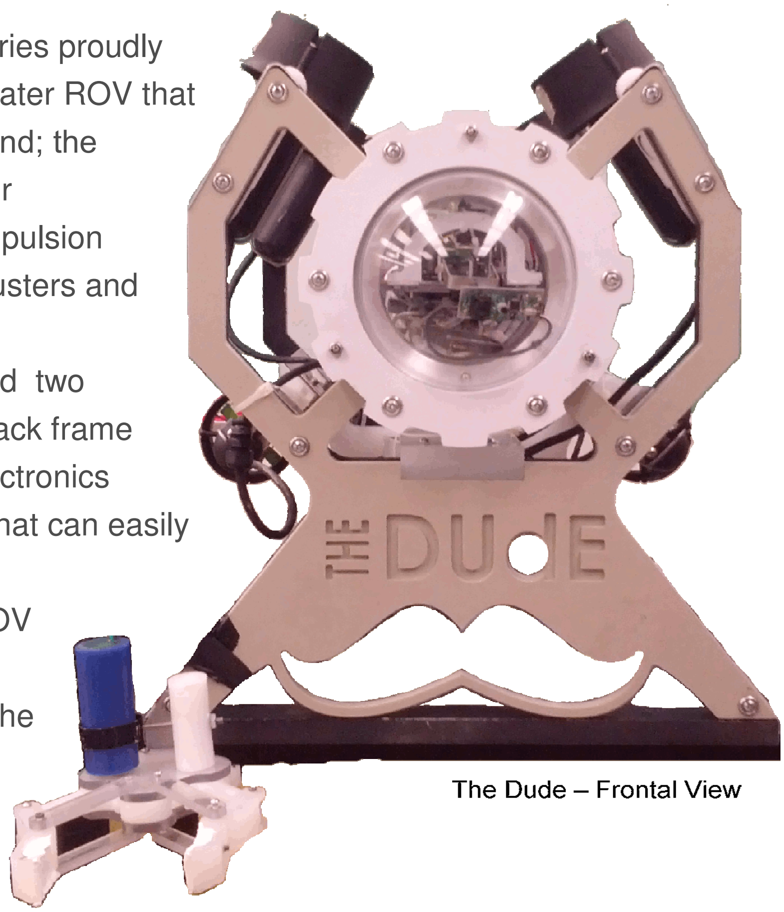
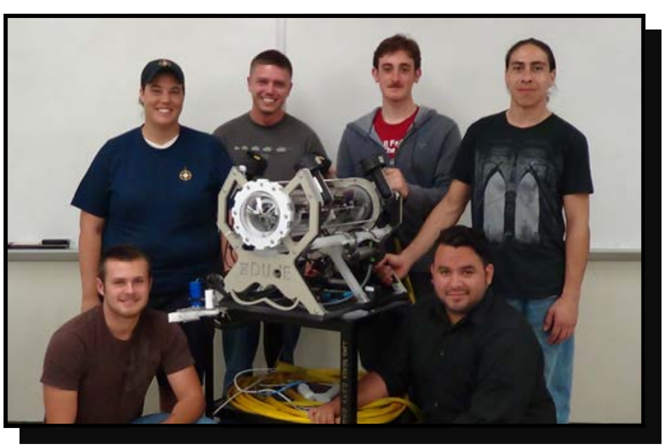
Abstract

Long Beach City College and Debonair Industries proudly presents "The Dude." *The Dude* is an underwater ROV that has been created and built with one goal in mind; the maintenance and data collection of underwater observatories. *The Dude* features a vector propulsion system that consists of four vertical vector thrusters and two horizontal thrusters. The ROV also comes accompanied with a three axis manipulator and two grippers. Allocated in between the front and back frame plates of the ROV is the housing for all the electronics which sit in a watertight clear acrylic cylinder that can easily be disassembled for quick maintenance or troubleshooting. The software used for this ROV is National Instruments LabVIEW used in conjunction with three Arduino Uno's. Two of the Arduinos are accompanied by a custom designed motor control board that utilizes six LMD18200T H-bridges that control the thrusters and the other motors onboard the *The Dude*. The third Arduino is used to control the custom pan and tilt servo and lighting functions. *The Dude* also features a trademark design of Debonair Industries mustache and monocle that double as both logo and water flow channels. The team has, through testing, developed a specific arrangement of multiple cameras for the diverse tasks assigned. The circuitry is designed with efficiency in mind using a relay board to eliminate the need for a third motor control board. Countless hours of research and troubleshooting have resulted in a uniquely maneuverable and adaptable ROV that can easily be maintained and adapted to perform different tasks with minimal adjustments.

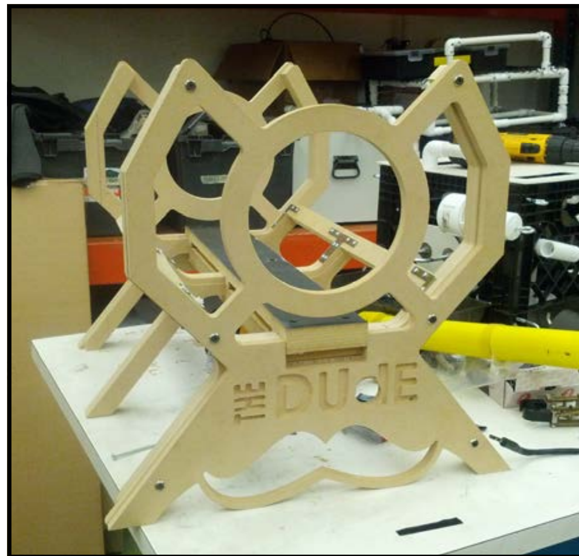


The Dude – Frontal View



Team Members from top left to bottom right:
Tara Willis, Robert Brant, Stephen Estrin, Emanuel Perez, William Courduff, and Michael Marin

Design Rationale



MDF Frame Prototype

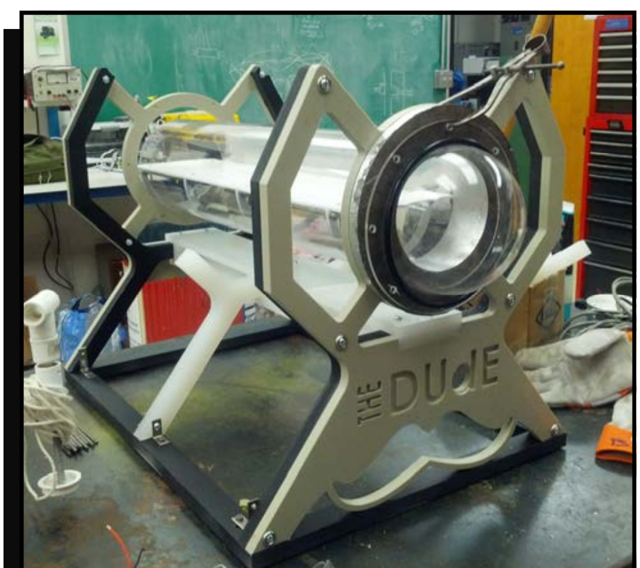
The overall design of *The Dude* was drawn out with pencil and paper as we brainstormed amongst the team members. As our collaborations became more structured we moved to a 3D CAD program to better conceptualize the overall design. We utilized SolidWorks during this process to draw out detailed dimensions that we could not otherwise do with a pencil. With the SolidWorks designs completed, we were able to export them out to our in house CNC machine for fabrication. Every component the ROV was designed and built in house by team members of Debonair Industries.

Frame

The Dude was designed to accomplish all tasks assigned by the 2013 MATE Competition. With this years emphasis being underwater observatories, the ROV frame design is structured to ensure that it can execute all the tasks at hand. *The Dude* is designed with an extra wide base to accommodate the specific tasks of this years mission. The base is capable of holding the SIA and the secondary node leveling platform within. This design was developed after the prototype was built to properly determine size dimensions. The primary material used is Teflon with expanded PVC and ABS plastic. These positively buoyant materials in addition with the electrical housing warrant the exclusion of any additional foam or tube buoyancy.

The hexagonal shape of the main body serves a dual purpose. The first is that it allows for the mounting of the four vertical thrusters set at a vectored angle of 60 degrees. The vector angle

Tara Willis and Michael Marin constructing the final frame



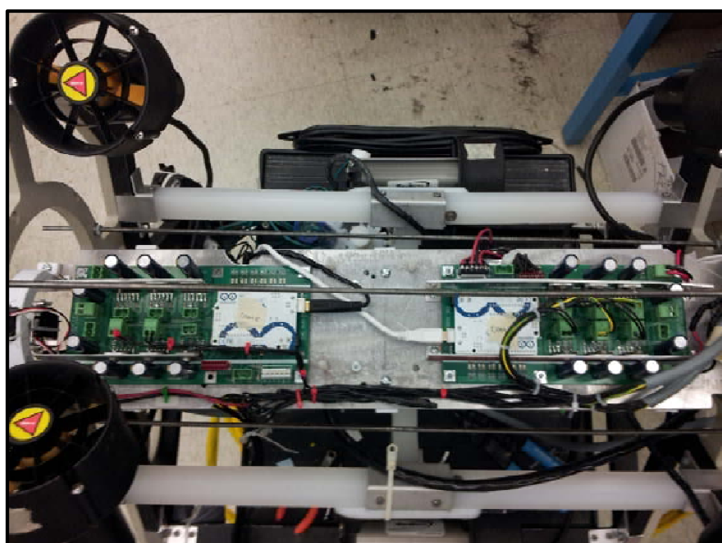
Core frame assembled

not only allows the ROV to ascend and descend but also enables the ROV to crab left and right greatly improving its maneuverability. The second serves as handles for easy transport and recovery from the aquatic environment. Employing this design greatly enhances the safety of the deployment and recovery team members by allowing them to properly secure the ROV.

6 Seabotix Thrusters

Thrusters/propulsion

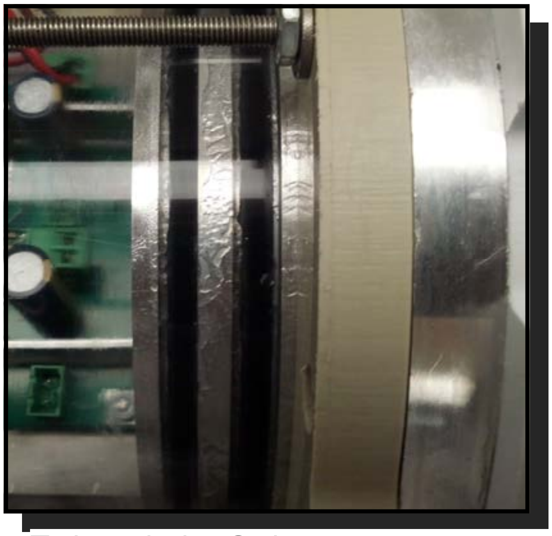
The Dude utilizes six Seabotix 36V brush DC thrusters with each capable of outputting a continuous 2.2 kgf. Every motor is controlled by a 3A H-bridge custom designed circuit board allowing current to flow in either direction for clockwise and counter-clockwise rotation. The configuration of thrusters on The Dude was designed to obtain high levels of control and maneuverability that allows for pulse width modulation (PWM) to each thruster giving speed and control to the pilot. There are four vectored vertical thrusters mounted at 60 degree angles for heave and sway, and two horizontal thrusters for surge and yaw. The horizontal motors are located at the center of mass to prevent unwanted pitch and allow for perfect linear movement.



Twin motor control boards mounted to metallic electronics base plate

Electronics Housing

The electronics housing is designed with an emphasis on redundancy. An acrylic cylinder houses the metallic electronics base plate that holds two motor control boards, a relay board, a pan and tilt servo camera, a USB hub, and a five volt and twenty-four volt DC power supply. The thermic energy is dispersed throughout the metallic base plate that is mechanically mounted to the rear aluminum end cap. This allows heat generated from the circuit boards to dissipate to the rear end cap



Twin cylinder O-rings

thereby essentially providing the electronics with water cooled system.

The cylinder is sealed at each end by a triple O-ring design. The first two O-rings are on the shaft of the aluminum end caps where the cylinder slides over each one creating a watertight seal. The third O-ring resides at the very end of the end cap where the acrylic cylinder butts with the end cap. This design feature allows for a stronger seal as the water pressure outside of the housing increases. The overall electronics housing design is an excellent watertight seal with a multistep failsafe to protect the electronics.

Team members machining end cap from a block of aluminum

A dome on the bow of the ROV is implemented to facilitate a wide viewing range for the main camera that is controlled by pan and tilt servos. This dome is independently sealed with an O-ring to the front end cap and does not rely on the cylinder to hold it in place. This is achieved by utilizing a cog shaped plate ring that

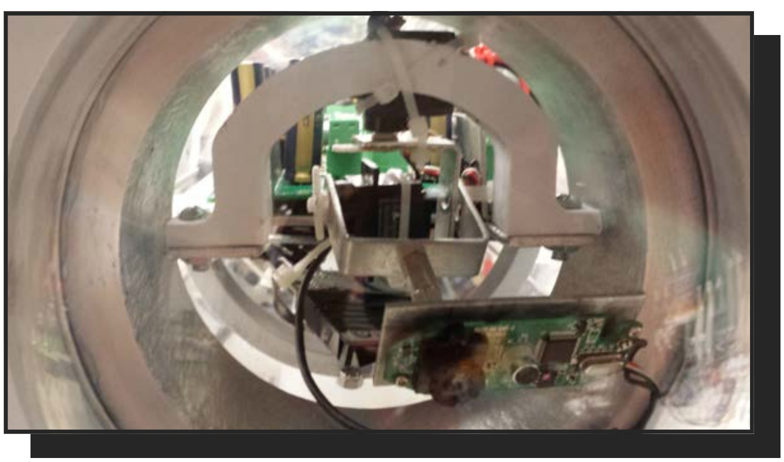
Dome mounted to end cap.

compresses the dome's O-ring to the aluminum end cap. This segregation of dome and cylinder is executed to minimize possible water leaks.

Cameras

There will be a total of eight cameras utilized for the various missions that *The Dude* will execute. The entire camera system is based on a Universal Serial Bus (USB) 2.0 system that utilizes a central hub mounted to the electronics base plate allowing up to eight cameras to be fitted onto *The Dude*. The system power for the cameras is supplied from the central hub which is also used for data transfer. All cameras mounted on *The Dude* will consist of Logitech C110 USB webcams. The cameras hardware specs contain a frame rate of 30FPS, and a resolution of 1024 x 768. The main camera housed in the frontal dome of the cylinder utilizes two 120 degree motion servos which are mounted to the front most section of the electronics baseplate. The servos are mounted to each other in such a way that allows for a pan and tilt function of our main camera. The main camera's bracket as well as the pan and tilt functions hardware was fabricated in shop. Our overall visual configuration allows for stereoscopic vision when the main camera is paired with another camera (for instance, when utilizing the gripper's camera, depth is able to be measured). The gripper camera is mounted on a fixed bracket that is positioned slightly behind the claw. Five cameras will work in conjunction with LABVIEW in our modular grade leveling system. The cameras give visual assistance to adjust the leveling platform according to the position of the leveling platforms central bubble indicator.

Logitech C110 USB webcam



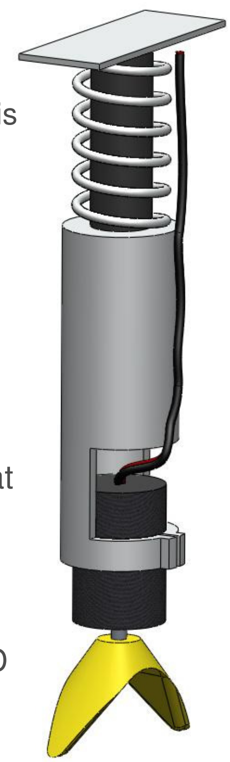
Logitech C110 camera removed from its plastic housing and mounted to a pan and tilt system

Payload

Mounted beneath the frame of the ROV is our modular payload. This payload is where various components are utilized to complete the specific mission tasks of transporting the Transmissometer, the secondary node leveling device, and the SIA to their appropriate locations. All core features of the ROV itself work independently of the payload, allowing it to be disconnected and updated as needed. In addition to the transport ability, the payload comes equipped with four motor control couplers that are used to level the SIA to seafloor.

Secondary Node Leveling Device

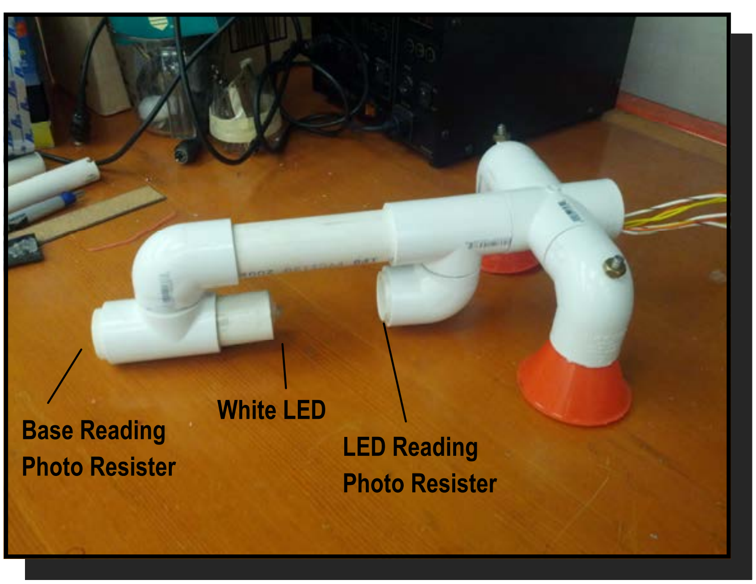
Ensuring the secondary node sits level on the seafloor can be a time consuming task. To increase our efficiency, a leveling device was created. It contains four motors mounted on spring loaded risers to maintain contact with the node while uneven. Attached to each motor is self locating coupler. This ensures a proper connection despite the angle of the handles on the node. A camera mounted adjacent to our latching mechanism monitors the bubble level on the node. After determining the pitch using LabVIEW Vision Acquisition software system we can rotate each motor to its required direction. By utilizing four motors to adjust the platform we greatly increased our efficiency.



Secondary Node Leveling Device

Transmissometer

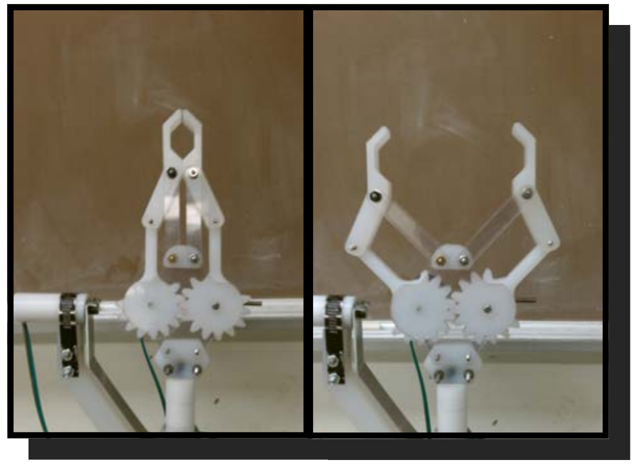
The transmissometer is a separately derived and tethered system than that of the ROV. Controlled by a separate Arduino Uno with a data feed to the surface via a Cat5, this system will graphically map data readings measured. Deployed by the vehicles' gripper to the seafloor platform, the sensor device consists of a white LED with 7.0 cd luminous intensity opposite of a photo resistor. The photo resistor in conjunction with the LED will measure the turbidity of the water around the platform. Due to the effects of ambient light at shallower depths, the device is equipped with another photo resistor mounted on the backside of the LED. This sensor will act as a base measurement of the ambient light and send this information to the surface. This data is inputted to a program that we created using LabVIEW and will subtract the base reading photo resister from the LED reading photo resister. By establishing a baseline to measure the ambient light, we are able to eliminate the effects of the surrounding light, giving us accurate readings of the area being observed. This simplistic approach eliminates the need to construct a large structure that cancels out the ambient light to get a reading.



Transmissometer

Gripper

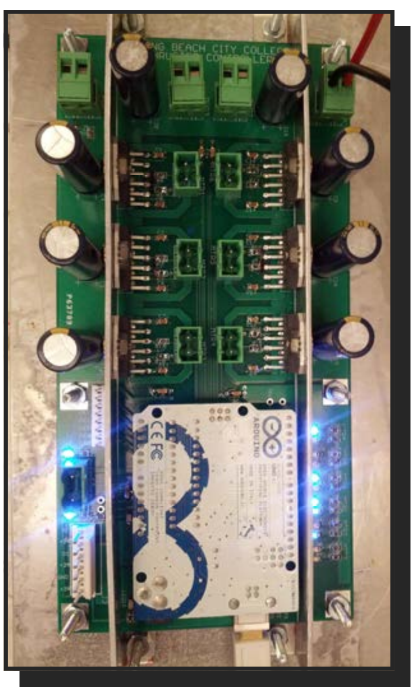
Mounted to *The Dude* is a three axis arm and gripper that is controlled by four bi-directional 24VDC motors that are geared down to decrease the RPM. By utilizing a gear motor it reduces the speed of the motors and we are able to obtain 13.5 kg-cm of torque. These torque specifications are enough to overcome the forces associated with the lifting, twisting, rotating, and closing abilities of our manipulator. A secondary gripper is designed to remove the CTA from the mooring platform that holds it in place. In conjunction our fully articulate manipulators will be able to complete all tasks.



Gripper closed and open

Electronics

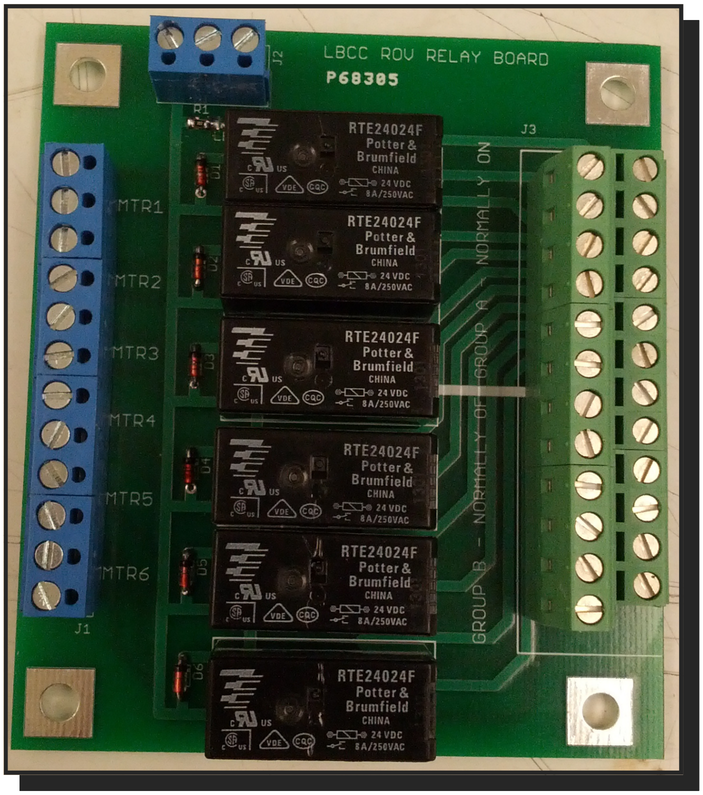
The Dude operates on two custom designed motor control circuit boards and one motor relay board. The relay board and the two motor control boards are located on the top section on the plate. Mounted on the bottom side of the plate is a custom designed 5vdc power supply board and a 24vdc power supply board. The 5 volts is used to power the USB hubs and all the cameras attached. The 24 volts is used to power all motors that are connected to the front motor control board. The rear motor control board is connected to the six thrusters and receives the full 48 volts from the surface. Also included on the boards are two MOSFETs that enable a 24v switch to be utilized for a various purposes. The motor control boards each interface with an Arduino Uno microcontroller. The Arduino is a versatile and inexpensive way to control all systems onboard *The Dude.* This microcontroller is capable of input and output signals. The Uno comes equipped with 14 digital IO pins and 6 analog input pins. Six digital pins are capable of pulse width modulation (PWM) and these are currently set to control the thrusters and motors.



Arduino Uno attached to motor control board

The Dude comes with twin motor control boards. The rear is dedicated to the six thrusters alone but the front motor control board is tied to the motor relay board. This gives the dude the capability to control not six but up to twelve motors. This is achieved by utilizing the MOSFETs. When the relay board is not engaged, the normally closed (NC) contacts are connected to Motor Group A which control six motors. When the MOSFET is engaged, the normally open (NO) contacts are closed,

MOSFET



Motor Relay Board

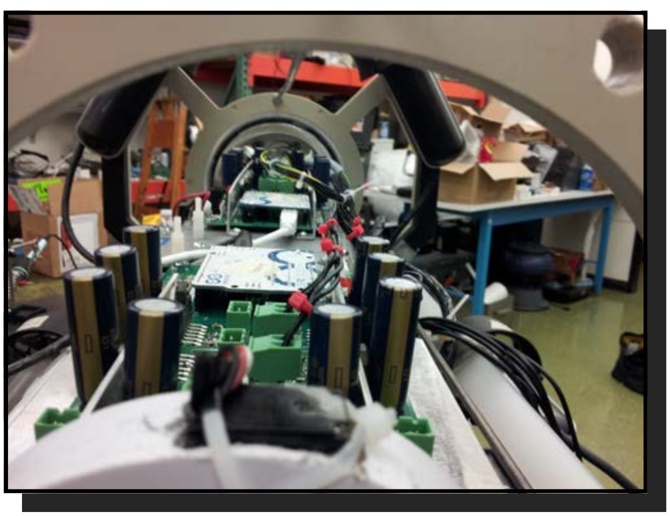
thereby engaging Motor Group B.

Currently Motor Group A connects to the port arm and the starboard arm. The port arm contains four motors that control open/close gripper, rotation, reach, and pivot. The starboard arm contains two motors that function as a swing and open/close gripper. This is a total of six motors.

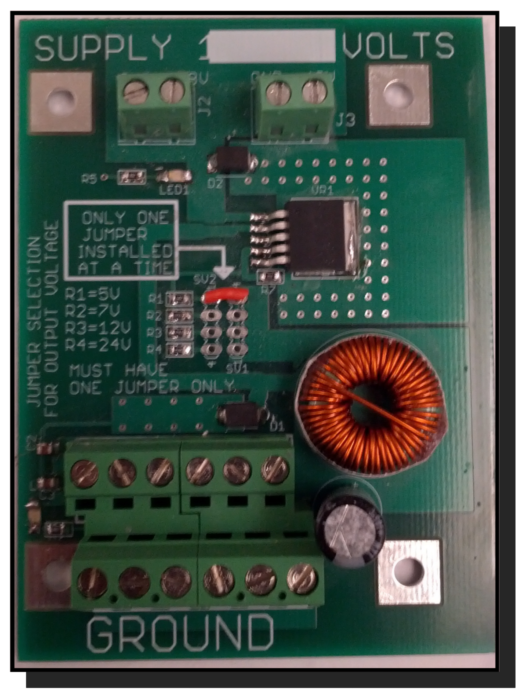
Motor Group B connects to the payload motors and the center clamp motor. This is a total of five motors but it is capable of controlling a total of six motors as well.

This design was incorporated because Motor Group A will not be used when Motor Group B is being utilized and visa versa. This ingenuity removes the need for a third motor control board and Arduino Uno.

The power supply board is located on the underside of the base plate. It receives 48v from the surface and depending on which jumper is installed, it is capable of supplying 5v, 7v, 12v, and 24v. This allows for the possibility of adding new equipment on board *The Dude* that may require different voltage supply. Currently there are two that supply 5 volts and the other supplies the 24 volts. The 5 volt supplies power to the USB hub which in turn powers the USB web cameras. The 24 volt powers the eleven motors that are equipped on *The Dude.*



Electronics board—looking in

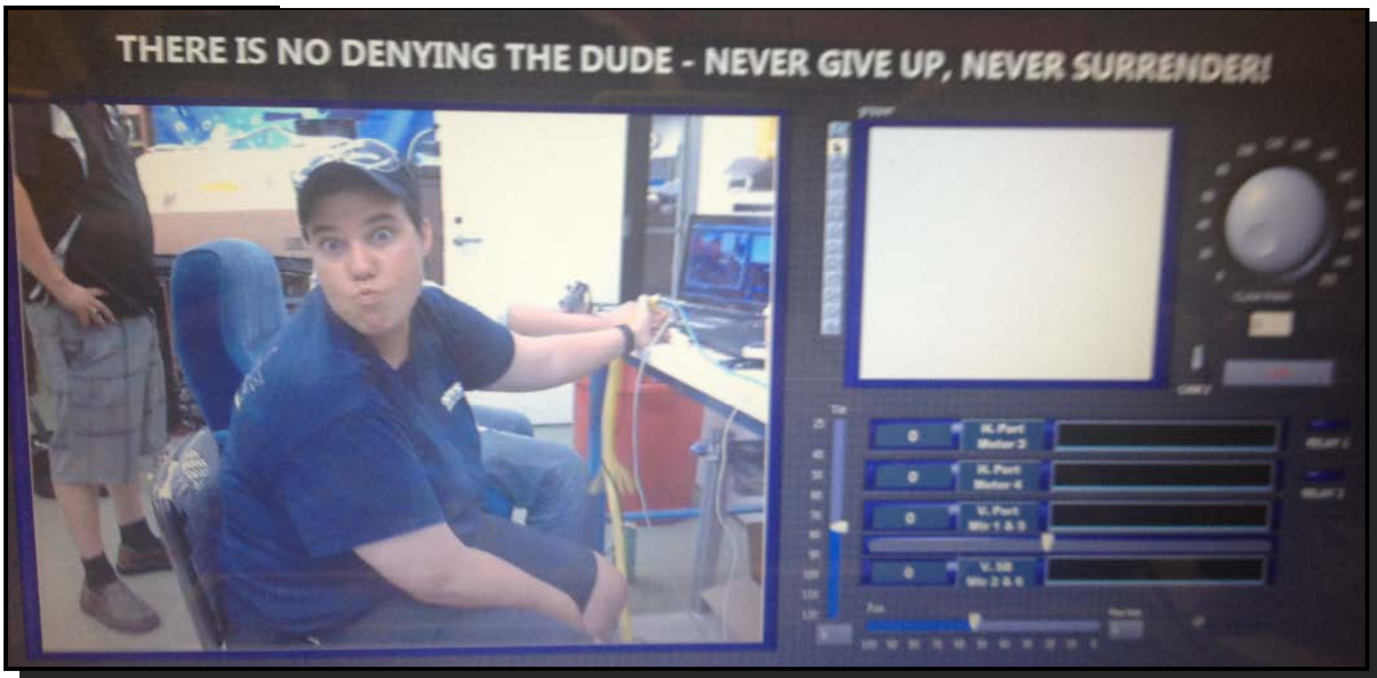


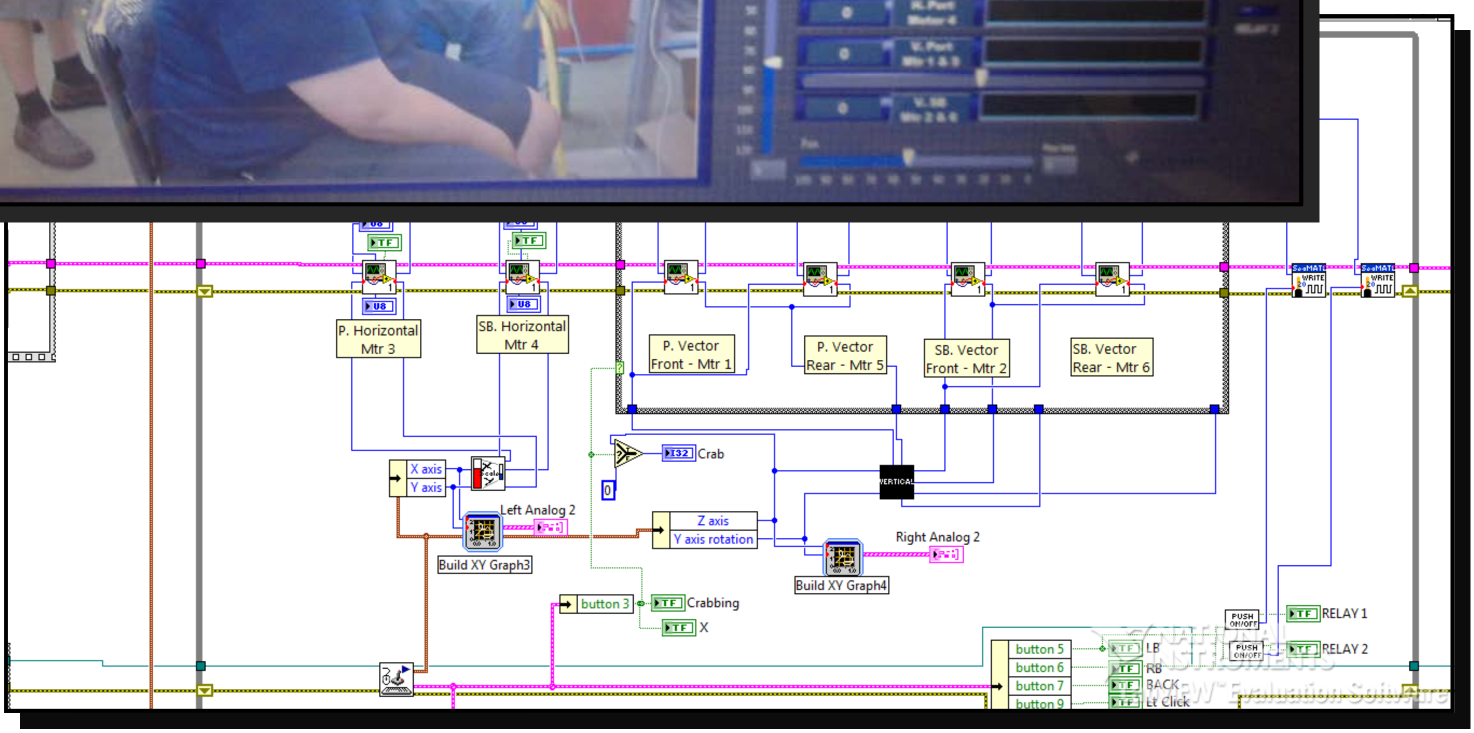
Power Supply Board

Programming

The software used to control *The Dude* is written using National Instruments LabVIEW graphical programming language. LabVIEW is a completely different form of programming in that it is not dependent on using a programming language such as C++ or Java. Instead it utilizes a graphical system design software that integrates with various data acquisition devices. LabVIEW is able to communicate with the Arduino Uno and display a graphical representation of the information the Arduino Uno is sending and receiving.

Screen shot of LabVIEW User Interface with Tara Willis posing for the Dude

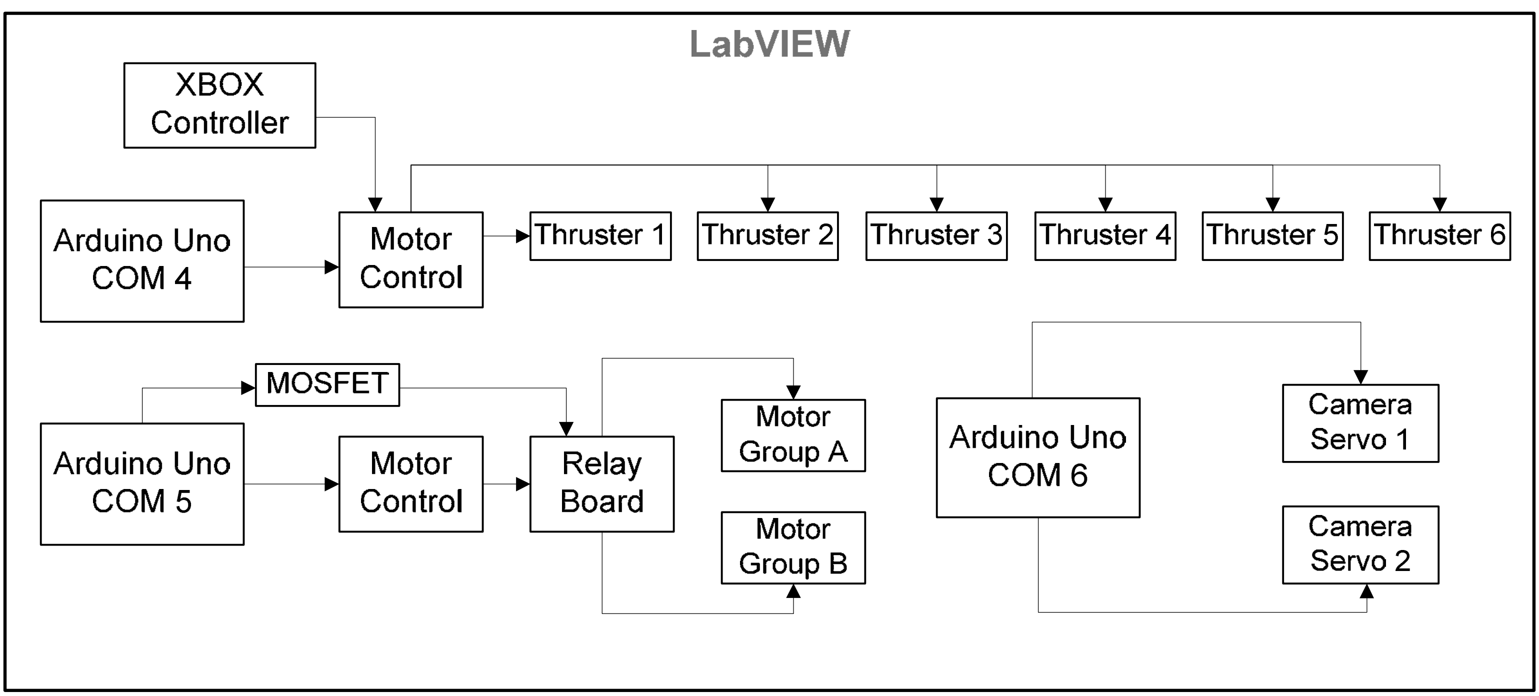




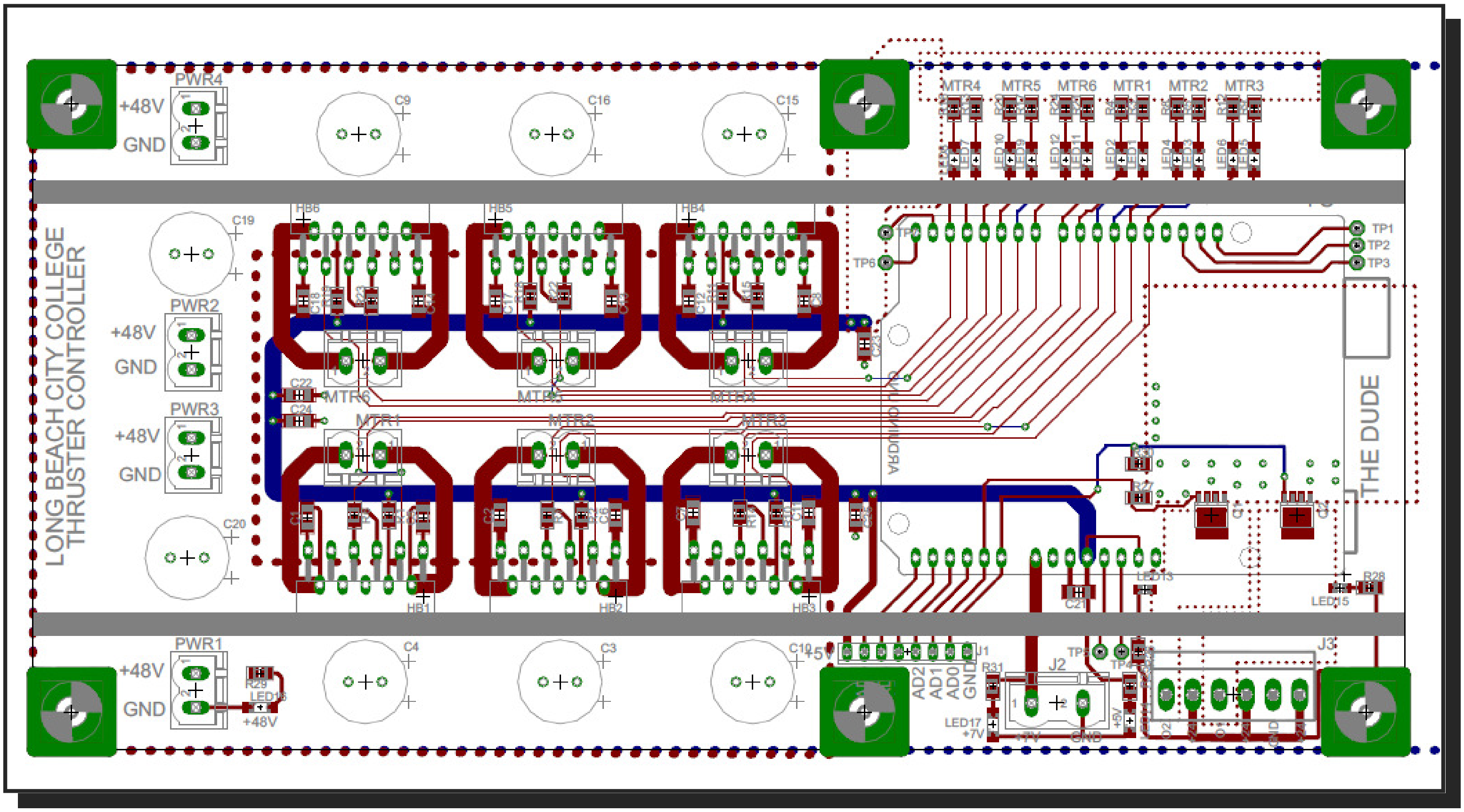
Screen shot of LabVIEW Block Diagram—Thruster Control

XBOX Controller Mapping

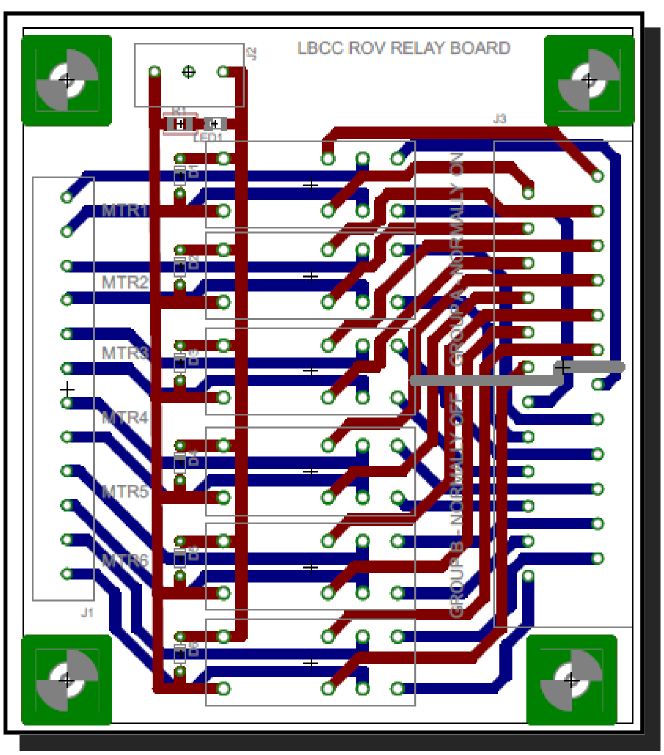
Software Flow Chart



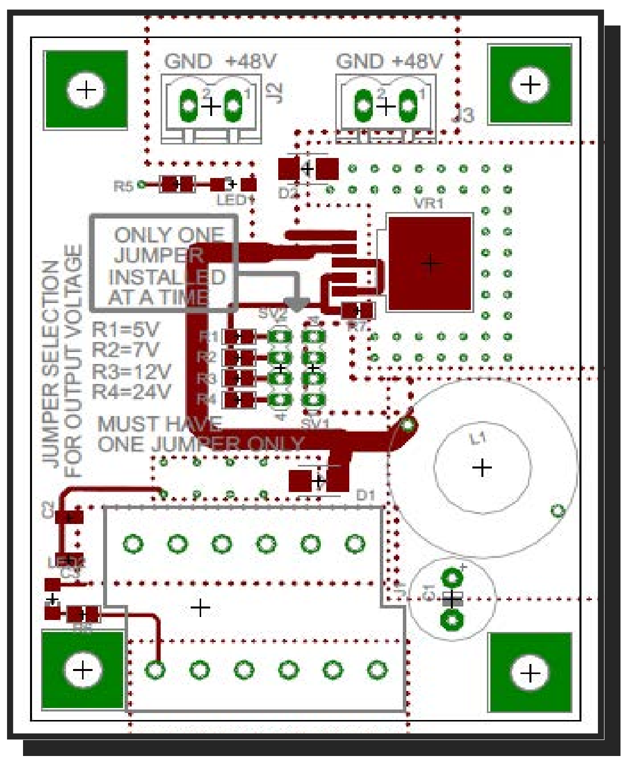
Schematics



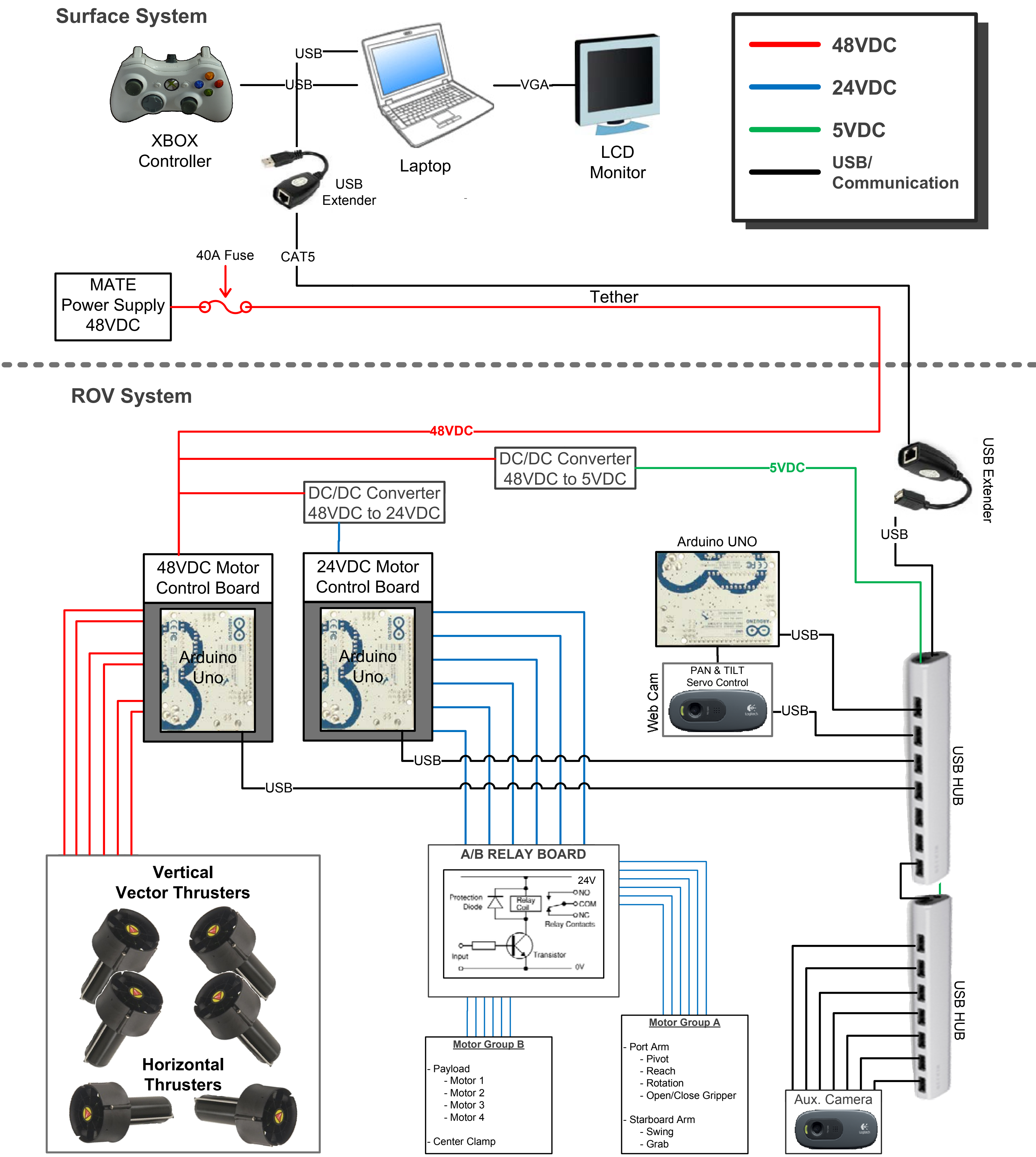
Eagle CAD drawing of custom designed motor control boards



Eagle CAD drawing of custom designed motor relay boards



Eagle CAD drawing of custom designed power supply board


Surface System
USB
USB
VGA
XBOX Controller
Laptop
LCD Monitor
USB Extender
48VDC
24VDC
5VDC
USB/ Communication
40A Fuse
CAT5
MATE Power Supply 48VDC
Tether
ROV System
48VDC
DC/DC Converter 48VDC to 5VDC
5VDC
DC/DC Converter 48VDC to 24VDC
USB Extender
USB
Arduino UNO
48VDC Motor Control Board
24VDC Motor Control Board
Arduino Uno
Arduino Uno
USB
PAN & TILT Servo Control
Web Cam
USB
USB HUB
USB
USB
A/B RELAY BOARD
24V
NO
COM
NC
Protection Diode
Relay Coil
Relay Contacts
Input
Transistor
0V
Vertical Vector Thrusters
Horizontal Thrusters
Motor Group B
- Payload
- Motor 1
- Motor 2
- Motor 3
- Motor 4
- Center Clamp
Motor Group A
- Port Arm
- Pivot
- Reach
- Rotation
- Open/Close Gripper
- Starboard Arm
- Swing
- Grab
Aux. Camera
USB HUB

Safety

The safety policy of Debonair Industries is always enforced. It is the responsibility of everybody involved to look out for one another's safety. In order to maintain safe practices there are safety requirements that must be maintained. A startup procedure has been placed so when we decide to test run *The Dude*, we will minimize potential hazards.

Seabotix Thruster shrouds with hazard sticker

The vehicle has multiple safety features that were designed with the user in mind. All electrical connections are sealed so water will not interfere, the thrusters have shrouds so the propeller will not be exposed, and there are no sharp edges that may cause an injury. Warning signs have been placed on the outside of the thrusters to make users take notice to the propeller. This is useful not just during testing but also for when the ROV is handled and operated. It is important to realize the hazards at all points in time so when operated, repaired, maintained, or at all used everybody knows what is the standard procedure and the possible hazards. This is the reason the safety startup procedure has been created. The startup procedure has been broken down into a checklist to ensure nothing is overlooked (See appendix 1).

Seabotix Thruster shrouds with hazard sticker

Future Improvements

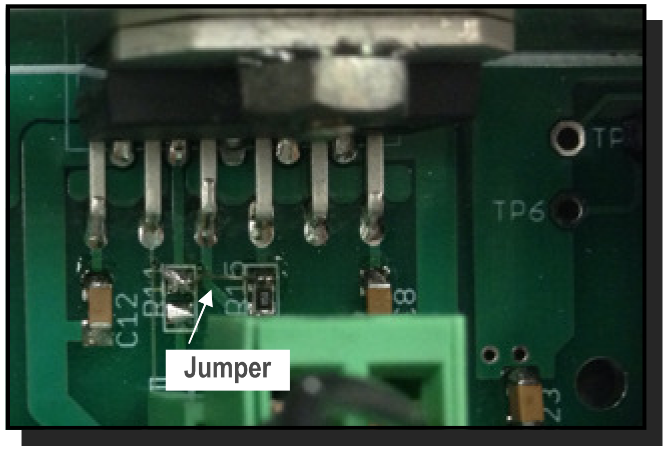
Although The Dude was designed per our specifications, all businesses are faced with improvements they wish to make for future endeavors. There were of course time and cost constraints that played a factor to this current design, however, one major design that we wish to feature in our future product line is that of an industry standard single multi-pin bulkhead connector for the end cap. By limiting the amount of connections through the end cap, you limit the amount access points for potential water leaks. This feature will also allow for easier connection and disconnection access to the electronics housing via the end cap. It is our hope that, although very versatile and modular in its current phase, this future improvement will be implanted as Debonair Industries rolls out future designs.

Budget/Expense Report

Item	Code	Vendor	Expense	Qty	Total Cost
Xbox controller	B	GameStop	29.00	1	29.00
Aluminium Stock	D	Donation from Boeing	325.00	1	325.00
Expanded PVC Stock	D	Donation from MesaWest	150.00	1	150.00
Teflon Stock	D	Donation from MesaWest	200.00	1	200.00
VideoRay Tether	D	Donation from Video Ray	500.00	1	500.00
Logitech USB Cameras	D	Ebay (donation)	8.50	8	68.00
Motors	D	Ebay (donation)	14.25	12	171.00
USB Extenders	D	Ebay (donation)	6.50	2	13.00
USB Hubs	D	Ebay (donation)	7.75	3	23.25
Acrylic Dome	D	Global Plastics (donation)	32.00	1	32.00
Circuit Boards	E	4pcb.com	45.00	4	180.00
Electronics for Boards	E	Digikey	387.45	1	387.45
Funnels	E	Harbor Freight	1.25	2	2.50
Hardware	E	Home Depot	275.00	1	275.00
Tool Box Control Housing	E	Home Depot	25.00	1	25.00
1"PVC Connectors	E	HomeDepot	1.75	7	12.25
1"x 1' PVC Pipe	E	HomeDepot	2.50	1	2.50
28" All-thread Rod	E	McMaster Carr	6.15	3	18.45
Acrylic 24"x 6" Cylinder	E	McMaster Carr	35.00	1	35.00
Gland Connectors	E	McMaster Carr	3.72	4	14.88
O-Ring	E	McMaster Carr	2.30	6	13.80
Arduino Uno	E	Sparkfun	25.34	4	101.36
Servos	E	Sparkfun	22.00	2	44.00
LCD Monitor	L	LBCC	200.00	2	400.00
Misc. Cable / wires	L	LBCC Electrical Stock Room	100.00	1	100.00
Stainless Steel Hardware	L	LBCC Electrical Stock Room	35.00	1	35.00
Metal 8 Pin Connectors	R	Reuse from Previous ROV	225.00	1	225.00
Seabotix Thrusters	R	Reuse from Previous ROV	750.00	6	4,500.00
Whip Connectors Rubber Block‹	R	Reuse from Previous ROV	95.00	2	190.00
			Subtotal		8,073.44
			Taxes		726.61
					$ 8,800.05

Budget Breakdown	
(B) Budget Items	31.61
(D) Donated Items	1,261.40
(E) LBCC Electrical Dept	1,212.29
(L) Borrowed items from LBCC	583.15
(R) Reused items from Previous ROVs	5,357.35
Balance of $1500 LBCC Budget	287.71

Challenges



Motor Control board with jumper installed.

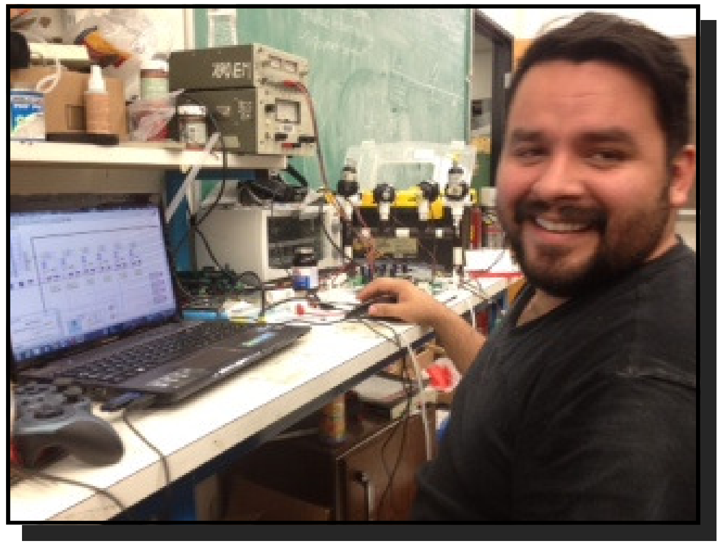
We ran into a number of technical challenges throughout the designing process. One of the most prevalent examples of this is our motor control board. We began the testing of the board and none of thrusters would respond. After verifying it was not a soldering issue we checked our programming to determine the signals were in fact being sent to the correct pins, which they were. Our next step in the troubleshooting process was to verify our circuit. Using our schematic and an oscilloscope we determined that everything seemed to be in order. It wasn't until we crossed referenced our schematic with the LM18200 H-bridge chip datasheet that we realized that the initial circuit board design was using a different H-bridge chip as reference. The H-bridge reference we used to design our board called for a pull down resister but the LM18200 requires a pull up resister. Once the problem was identified it was easily fixed by wiring a jumper to a nearby pull up resistor. Once all the jumpers were soldered on, we fired up the boards and success!

ROV in water tank checking for leaks

Troubleshooting

Once *The Dude* was sealed up it was time to test for leaks. Our initial step was to create a vacuum by pumping out the air and verifying that it holds the vacuum for a set period of time. When we did this, we were losing vacuum which meant we had a leak somewhere. We then pumped air in the cylinder and used Snoop Liquid Leak Detector on all possible points of leakage. We quickly found that one of the gland connectors O-ring had bulged out was leaking air. Once the O-ring was replaced we repeated the process and we where able to hold the vacuum. It was time to put it in the tank and verify that the ROV was indeed watertight. We have to this day never had a leak (knock on wood).

Technical Lessons Learned



Michael Marin programming on LabVIEW

We were introduced to National Instruments LabVIEW in October 2012. It was a steep learning curve for us because we have never been exposed to graphical programming. Fortunately, some members have been studying C++ for a few semesters. This proved useful because a great deal of the core concepts in C++ are translated to LabVIEW but instead of writing code, you draw the pictorial representation. What we have learned in the last seven months has been amazing. We were able to create the program and the GUI for *The Dude* entirely without the help of an official class. We did however spend many many hours on YouTube and the web looking up how-to videos and documentation on LabVIEW. We honestly don't think we would be where we are in our understanding of LabVIEW if not for YouTube. :)

There is still so much more to learn with LabVIEW and we would absolutely love to take an actual class some day when the price is right. What we find fascinating and challenging right now is the Vision Assistant module of LabVIEW. With this module, you can use a camera to track any object in the environment. Currently we are working on a program that can track a location and automatically adjust the thrusters to keep the object centered in the screen. This would greatly increase efficiency and control of the ROV.

Interpersonal Lessons Learned

Donald Kahl, Joshua Reyes, Michael Marin, Stephen Estrin, and Billy Courduff

The most cumbersome was scheduling working time with team members so that we could all collaborate on specific projects. Since each team member is a full time student at Long Beach City College our schedules varied, creating a unique challenge. To overcome this we utilized the program Microsoft Project. We organized all of our individual projects within this program incorporating each member's schedule and creating deadlines. This kept us organized, and on schedule.

Reflections

Debonair Industries is a team made up a many walks of life whose journey has converged on a single path, ROVs. Coming from varying backgrounds and skills, our team operates as a cohesive unit, supporting each other through each challenge that we faced. Not only do we spend long hours in our shop/lab designing, fabricating, assembling, troubleshooting, etc., we take the time to tutor each other in our other coursework. Many calculus and chemistry equations have been written and solved on the chalkboard alongside our gripper designs and software flow diagrams. Knowing that this competition in conjunction with our education will get us far in the industry we have all found our paths to belong. The patience, understanding, and mutual respect we have for one another, allows us to work in sync. Showcasing our individual skills all the while supporting each other, Debonair Industries is a team in balance. Although we all may not be on the same skill or knowledge level as individuals, as a team we each know the ins-and-outs of The Dude. Showing the dedication to the tasks at hand, "There's no denying The Dude".

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Appendix 1

Safety Checklist

Debonair INDUSTRIES

Safety Checklist

Date: ____________

1. Before start, check everybody is wearing necessary PPE
   (Glasses, closed toe shoes, etc.) ____________ ☐
2. Check that there is no power to the ROV ____________ ☐
3. All bolts and fittings are tight ____________ ☐
4. Thrusters are properly protected ____________ ☐
5. Any other unforeseen hazards ____________ ☐
6. Check all wiring connections are sealed ____________ ☐
7. Pull vacuum to ensure electronics housing is water tight ____________ ☐

Once all items in the list have been checked and approved, then ensure everybody is clear of the ROV and it is safe to operate.