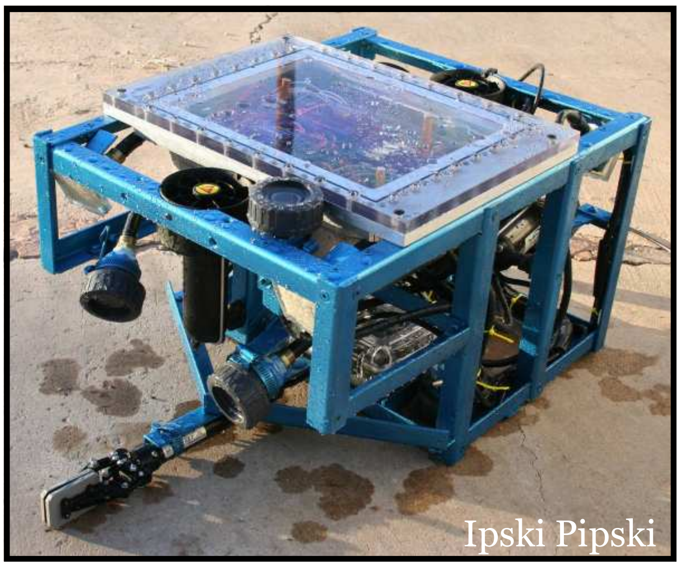
Falcon Robotics

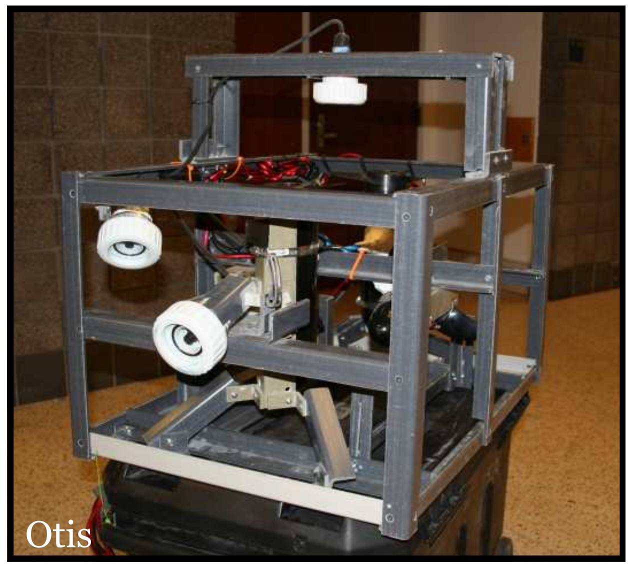
Carl Hayden Community High School Falcon Robotics

Remotely Operated Vehicle Team

MATE National ROV Championships 2006

Project Janus


Ipski Pipski


Otis

Team members:

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Faculty mentors:

Dr. Allan Cameron, Greg Harrison, Jim Haugen, Fredi Lajvardi

Industry mentors:

Jerry Little, Dr. Karen Suhm, Marcos Garcia-Acosta

Prepared by Annalisa Regalado

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Prepared by Annalisa Regalado

Abstract

The Carl Hayden ROV Team has competed in the Explorer Class of the MATE ROV Competition for the past two years. With the experience gained from previous competitions the team has learned much about creating a capable ROV.

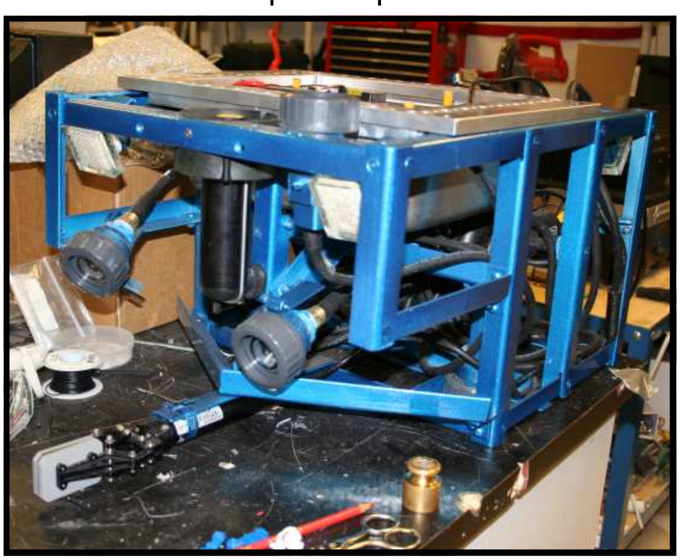
The team has taken a different approach to accomplish the mission scenarios in this year's competition. We have completed two ROVs which will perform simultaneously to complete the mission tasks faster and more efficiently while staying within mission parameters.

The first ROV, named Ipski-Pipski, will utilize an onboard battery and a fiber optic tether which makes it a very maneuverable ROV, ideal for fine turns and precise actions. The second ROV, named Otis, was designed to fully utilize the higher voltage and current that is allowed by using surface power. Its thrusters are more powerful to facilitate the delivery of heavy objects to the pool floor.

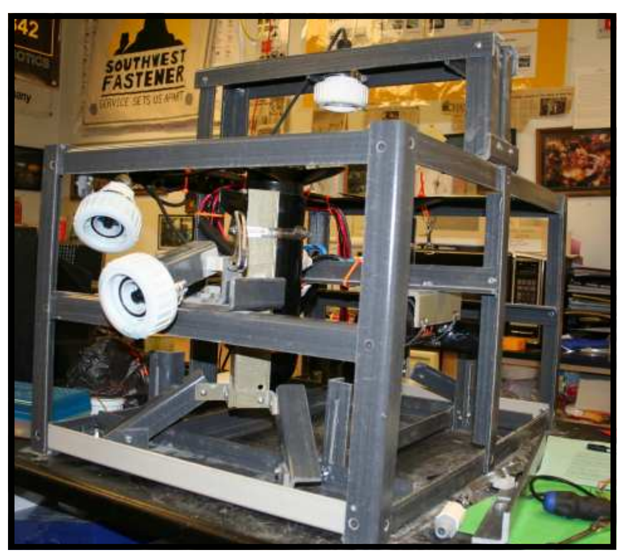
These two ROVs have been designed to complement each other. By splitting up the duties between two ROVs they will individually accomplish the tasks each is better equipped to undertake. By using this strategy the team plans to accomplish all the mission tasks well within the maximum time allotted.

This scientific endeavor represents another educational "doorway" in our growth as students of science and technology, reminding us of Janus, the mythological guardian of portals. In addition, the use of dual robots reflects the dual face of this Roman god. For these reasons, it was decided that Project Janus best represents the nature of our approach to this year's MATE mission.

Ipski-Pipski



Otis



Design Rationale

Based on last year's mission experience the team decided to make a smaller ROV. The team felt that the ROV last year was too large for onboard power, and we believe that onboard power is the better approach for these particular types of ROV functions under these mission conditions. To accomplish this year's goal, we built smaller cameras and selected smaller thrusters. Basically, we miniaturized the ROV. As we were building the ROV, we realized that this smaller, more compact ROV might not be able to deliver the electronics module down 12.19 meters to the trawl resistant frame in a short amount of time. Furthermore, this year it appears likely that more teams will be able to finish the mission within the 30 minute time period. We concluded that if we had two ROVs, the team would be able to do more parts of the mission simultaneously. We believe that this idea will allow us to complete the mission under the 30 minutes to get additional bonus points. Having two ROVs also allows for each to be specifically designed for certain tasks, making accomplishing the tasks easier.

The first ROV, Ipski Pipski, is designed to be a finesse robot. It will be assigned the task of retrieving the instrument cable connector with its attached cable from the sea floor and lay or weave the cable through 4 waypoints. After having laid the cable through the waypoints, Ipski will then insert the cable connector into the electronics module. To have this maneuverability, this ROV will be small and compact and have 5 thrusters to go in any direction. It will also have on board lithium polymer batteries and will be equipped with a fiber optic tether to the surface for control. The ROV will also have a grabber manipulator to handle objects. One drive camera and 4 auxiliary cameras will be used to show views from various vantage points of the ROV.

The second ROV, Otis, will focus on delivering the electronics module to the trawl resistant frame in the shortest amount of time. It is bigger and more powerful than Ipski because it uses surface voltage of 36 volts for its vertical thrusters. It also has 12 volt thrusters for horizontal direction to allow for finer movements than the 36 volt thrusters are capable of. Its secondary task is to open the trawl resistant frame door that will reveal the ports into which the power and communication connectors must be inserted. The larger 12 volt thrusters on Otis will ensure that opening the door is no problem. Otis will also have a grabber manipulator for opening the door and grasping other objects. The third task is for Otis to retrieve the power connector and insert it into the power port.

Each ROV will require three operators—two pilots and one tether management personnel. The team feels that for this particular mission this design rationale will ensure the best possible chance for success.

An Interesting & Unique Challenge

One challenge that our team overcame was designing an innovative, inexpensive, and reliable housing for our ROV's controls and connections. In previous years we have used a "watertight" case to house all of our electronics. These cases are not 100% reliable to stay sealed. Team members who need to check for a leak had to open the case to verify if there was a problem. Having to break the o-ring seal each time to check our housing contributes to lower reliability and critical time spent opening and closing the case. To overcome this drawback, our team designed a housing made out of a metal serving pan from a restaurant buffet line covered by a transparent sheet of 1.27cm (1/2") thick Lexan (Plexiglas).

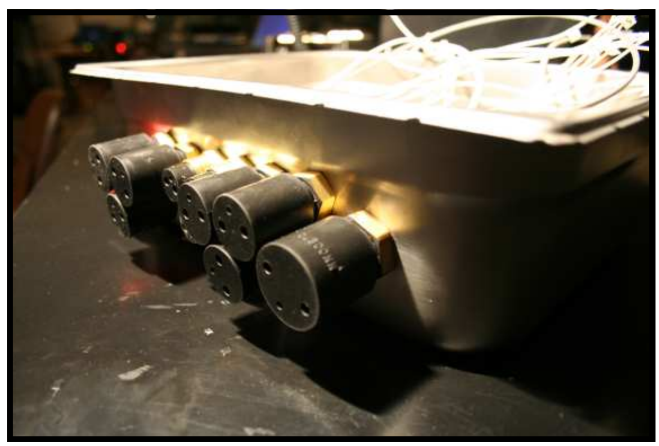
Prior to deciding on the use of a stainless steel serving pan, we considered other options for a reliable and practical material to act as the housing. There are few places that make water proof housings the size we needed. One day while brainstorming, we decided that we were going to use some sort of storage tub with a transparent lid. We had in mind a Tupperware bowl, but even the large ones wouldn't be reliable enough because of their lack of strength and sturdiness. They would flex and the buoyancy would change. One of our mentors, Mr. Harrison, mentioned that his brother worked with carbon fiber that is commonly used on formula-1 cars. We were quickly intrigued. We obtained a sheet of carbon fiber fabric and some resin to bind and solidify the carbon fiber sheet. The Tupperware bowl we used was going to act as our mold to make the housing for a materials test. We mixed the resin and applied it to the Tupperware and waited for it to dry. After about 8 minutes one of the team members, Pablo Santillan, picked up the housing and softly touched the fiber sheet, "Dry," he said. Then he proceeded to test it by slightly tugging on the extra carbon and it easily peeled off. "Well, that didn't work…"

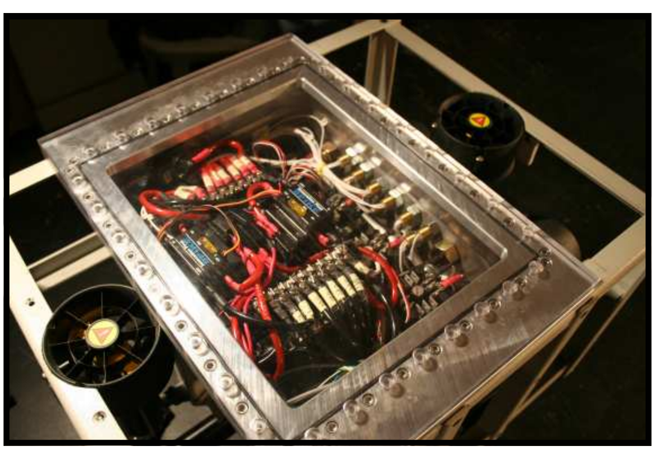
Our test confirmed that using carbon-coated Tupperware was not an option, and we tried to formulate another solution. We learned from our experiment with the Tupperware how well something similar would work for holding our control center. It allowed us to see how much space we needed. We went on to test how a metal serving pan would work.

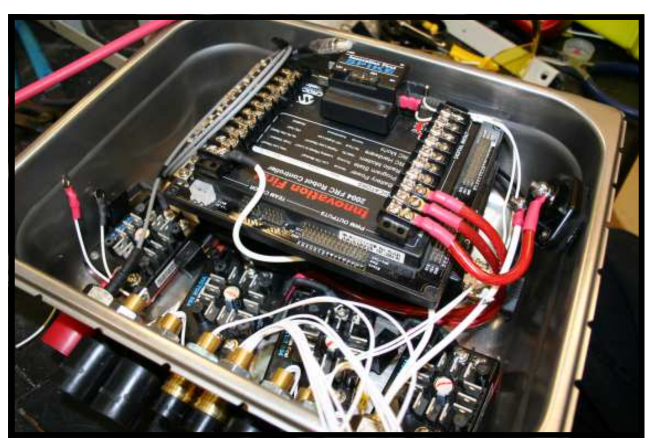
An Interesting & Unique Challenge (Continued)

We used a 29cm x 22cm x 10cm stainless steel serving pan that is .32 cm thick for the housing and a 20cm x 40cm x 1.27cm sheet of aluminum to attach to the pan to make a surface for mounting to the ROV frame and to hold the o-ring to seal against the 20cm x 40cm x 1.27cm sheet of Lexan. It worked great. We tested it in 3 meters of water for 45 minutes with no leaks! A major advantage is that we can see the o-ring seal against the Lexan and we can see if water is leaking into the compartment. We had our electronics housing!

Another benefit to using the metal serving pan was that we could also use Subconn connectors that would mate with the stainless steel pan using an o-ring seal. We wanted the Subconn connectors because we wanted to be able to remove components without too much difficulty, avoiding things like cutting and reconnecting wires. We wanted to able to change components easily.







Troubleshooting Techniques

In the team's history we have always gone the extra step to make sure that all of our equipment is low maintenance, cost effective, easy to operate and easy to repair when needed. The first step is to limit the possibility of a problem occurring. We accomplish this by having as many spare parts as possible, avoiding the use of unique or very expensive parts that are hard to replace, and keeping the workshop clean and organized. The basic approach of our troubleshooting technique is to always start investigating the issue from the macro point of view and then move to the micro point of view. This is an ethic that all of our team members learn from years of building experience. In solving problems we always follow a general algorithm, analyzing the problem and taking the logical steps towards the goal of getting the system back online.

One strategy in attacking problems involves using laptops with a dashboard viewing program that is connected to the Dashboard Viewer port of the operator interface, to view all of the ROV's data. From this laptop the pilot can diagnose many of the problems associated with the ROV. Here the pilots can also see real-time information on the ROV's motors and cameras. Having the ability to see the real-time information about the ROV is crucial in the event that an issue surfaces. From this point the pilots asses their options and they proceed to fix many of the problems.

Often what might seem like a disaster might be caused by something as small as a loose connection somewhere; loose connections are the most common source of problems. Loose connections may be indicated when you start losing control of one of the motors on the ROV or when the video feed starts blinking on and off. The pilot then proceeds to check all of the connections on the robot and operator interfaces to make sure all of the feeds are plugged in and that power is reaching the components. If the problem cannot be found then usually a multi-meter is used to help identify the source of the problem. The team members will then test each connection to make sure the appropriate voltage matches the correct components.

Whether it be a leak in the ROV's electronic housing, or just a loose connection, there is always a solution, whether it be a run to the women's hygiene isle for leak absorption material or replacing a connection. Our team is ready to take on the challenges of running complicated machines under stress, requiring our team to competently assess and troubleshoot in any situation that might arise.

Skills Gained

During this season's build period for our ROV, we learned a skill that is invaluable to our ROV's dependability and simplicity. We learned how to utilize the chemical rubber bonding agent 3m Scotchcast 2130. Using this compound we are now able to join any two cables in a completely water-proof medium.

The complete process takes approximately two hours. We made our own mold for the Scotchcast out of a 1.27 cm (1/2 inch) PVC pipe. In the mold we made a slit with a Dremel with a grinding wheel, to have a place through which we could inject the liquid Scotchcast. Connecting two cables together is simple. First, we put the mold over one of the cables we were working with before soldering the wires together. Second, we connected the other cable with our solder connections staggered with respect to each other to prevent shorting out if the two wires touched. Third, we used the self-vulcanizing tape to hold the mold in place. Next, we took out the Scotchcast package and ruptured the membrane that separates the rubber chemical from the hardening chemical so that they could mix. After about one minute of mixing the two chemicals inside this pouch, we cut open the corner of it and inserted a 100ml syringe, taking up enough of the black rubber chemical to fill it. Once the syringe was full, we injected the compound into the PVC mold and allowed it to dry for about an hour before cutting open the mold with the Dremel using the same grinding wheel used to make the slits in the mold.

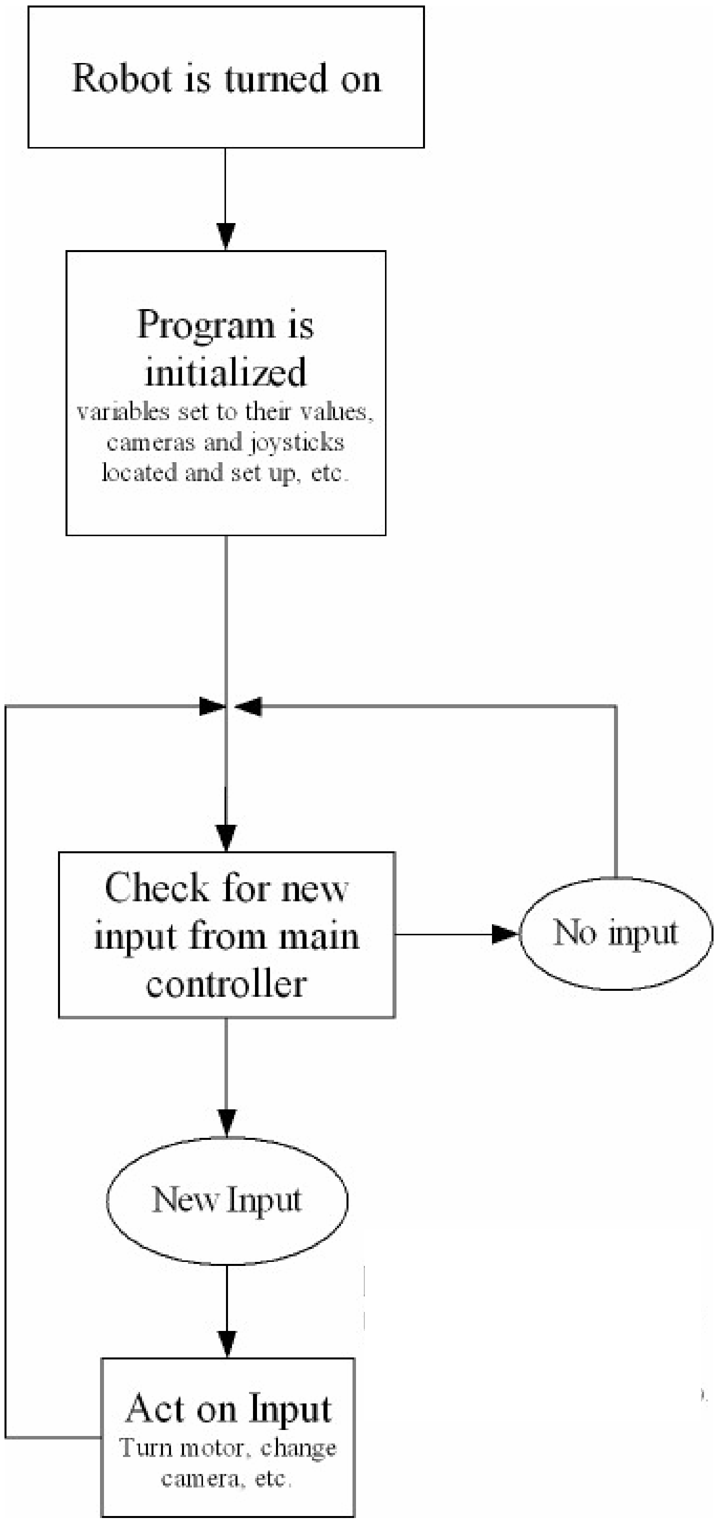
This method is now the first choice to any situation in which we have to bond any two cables or wires, whether it be motor controls or camera feed; we can connect them and know that they will remain 100% waterproof.

Expenditures

Expense Sheet two Rovs and controls				
Item	**Quantity**	**Price each**	**Total**	
5v power chip	1	$ 20.00	$ 20.00	
ABS plastic	1 sheet	$ 40.00	$ 40.00	
bolts 3/16	1 kilo	$ 6.00	$ 6.00	
camera wide angle lens	1	$ 40.00	$ 40.00	
CCD cameras	8	$ 90.00	$ 720.00	
Tri grabber	1	$ 1,200.00	$ 1,200.00	
Flat Grabber	1	$ 300.00	$ 300.00	
control boxes	4	$ 5.00	$ 20.00	
control case	1	$ 223.00	$ 223.00	
fiber optic cable	40 m.		$ 400.00	donated
fiberglass	30 m.	$ 100.00	$ 100.00	
fiberglass floaties	40 pcs.	$ 3.00	$ 120.00	
FIRST operator interface	1	$ 850.00	$ 850.00	
FIRST robot interface	1	$ 700.00	$ 700.00	
hose clamps	4 x 5 packs (20)	$ 10.00	$ 40.00	
hotel pan	1	$ 20.00	$ 20.00	
IFI receiver	1	$ 1,000.00	$ 1,000.00	donated
IFI transmitter	1	$ 1,000.00	$ 1,000.00	donated
LED clusters	4	$ 21.25	$ 85.00	
lithium-ion batteries w/charger	2 sets	$ 1,215.00	$ 1,215.00	
monitors	4	$ 180.00	$ 720.00	
Motor guide 12v	2	$ 150.00	$ 300.00	
Motor guide 36v	2	$ 200.00	$ 400.00	
motor speed controllers	6	$ 158.50	$ 951.00	
nuts 3/16	1 kilo	$ 6.00	$ 6.00	
parallel head for claw	1	$ 600.00	$ 600.00	
PVC Camera housing	8	$ 6.25	$ 50.00	
relay chip	1	$ 20.00	$ 20.00	
rotary joint	1	$ 500.00	$ 500.00	
Scotch-case mold	5	$ 30.00	$ 150.00	
Seabotix thrusters	5	$ 393.00	$ 1,965.00	
spikes	3	$ 70.00	$ 210.00	
Subconn connectors	assorted sizes	$ 1,000.00	$ 1,000.00	donated
switches and dials	assorted	$ 50.00	$ 50.00	
wire	assorted	$ 750.00	$ 750.00	
Donated total				$ 3,400.00
Total			$ 15,771.00	

Prepared by Annalisa Regalado

Software Flow Chart



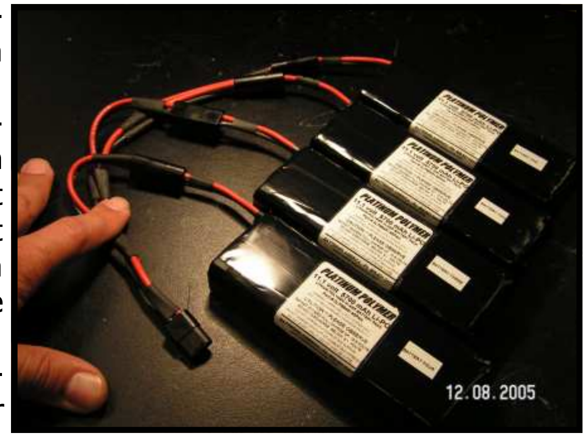
While at first, the programming portion of the robot seemed daunting, the actual execution was remarkably simple. The programming language is C. The program initiates when the robot is first turned on. After all the cameras and joysticks are located, the program then assigns them values, each joystick getting two variables, one for the x-axis, and one for the y-axis. (e.g.: joystick_1_y corresponds to the first joysticks y-axis) Subsequently, the program enters an infinite loop, where it is constantly checking for new input from the Operator Interface. This loop executes every 28.8 milliseconds.

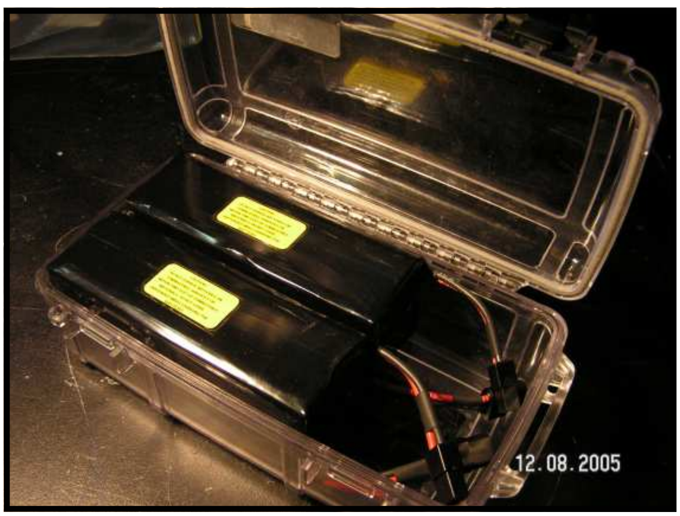
If any input is received, then the program acts upon it, turning on motors, turning off motors, etc. If no input is detected, then the program does nothing and the loop starts again. The loop will only end if the robot is turned off.

Prepared by Adam Burch

Lithium Polymer Batteries

Lithium Polymer batteries are rechargeable batteries that have evolved from lithium ion batteries. The lithium electrolyte is not in a liquid state but in a paste or solid. This has many advantages in that each cell is made into a foil form and this allows the batteries to be made to fit whatever shape is needed. This advancement also makes the batteries non-flammable, which makes them safer. Another benefit is that the energy density of these batteries is very high. This high density allows us to use a smaller battery pack with the same total amount of power as our previous battery pack.





We were using a standard 12 volt, 17 amp/hour dry cell, that weighed 5.4 kg. The lithium polymer pack consists of four 5.7aH units that each put out 12.6 volts. Each unit is made up of three cells that put out 4.2 volts. When the four units are connected in parallel they effectively produce a battery that is 12.6 volts with a 22.8 aH capacity. Not only do we get more aH from this configuration, but it weighs only 1.8 kg and takes up less than half the volume of the standard battery. Lithium polymer batteries can discharge at four times the aH rating. In our case we can safely draw 91.2 amps at one time!

There is a drawback in that charging lithium polymers is a little more difficult than standard dry cells. A special charger is required. Each unit of three cells must be charged separately. Each unit also must be charged at a one C rate, or equal to its aH rating. Once connected to the charger, the charging goes through three phases. The first is a three minute “dumb” charge, the second is a controlled charge of one minute intervals until each cell reaches 4.2 volts, and in the third the charger is turned on and off periodically. Despite this cumbersome charging of individual units, the advantages of the lithium polymer make them clearly worthwhile.

Fiber Optic System

Based on the success of last year's fiber optic system, the team decided to continue using it for this year's ROV, Ipski Pipski. Because this ROV uses onboard power, the tether is used for control purposes only. We are using the International Fiber Systems VR7220-2DRDT which has 2 unidirectional video channels and two bi-directional data channels. This allows us to have two camera views at one time, and the Innovation First robot and operator controls can communicate back and forth to each other. The data and the video can travel in the same fiber optic cable because there are two different colors of light (1310/1550 nm). One carries the two video signals and the other carries the two data channels.

The video signals are put into the onboard fiber optic system in NTSC format and are transmitted to the surface where the fiber optic system receives the video signal and then sends the signals to video monitors. The data from the Innovation First robot controller is sent to the onboard fiber optic system in RS232 format where it is digitized and sent to the surface fiber optic system where the data is retransmitted in RS 232 format to the Innovation First operator interface. The data travels in the reverse order from the surface to the ROV.

Tether management is always an issue even with a 5mm fiber optic cable due to the 30 meter length. The team is making use of a fiber optic rotary joint (FORJ) to allow the team to use a standard backyard garden hose reel to manage the fiber optic tether. The FORJ is connected in the rotating portion of the hose reel. One end of the FORJ is connected to a 30 meter fiber optic cable which can travel in and out of the hose reel, and the other end is connected to a short 2 meter long cable linked to the control panel.

Pilot Control Panel

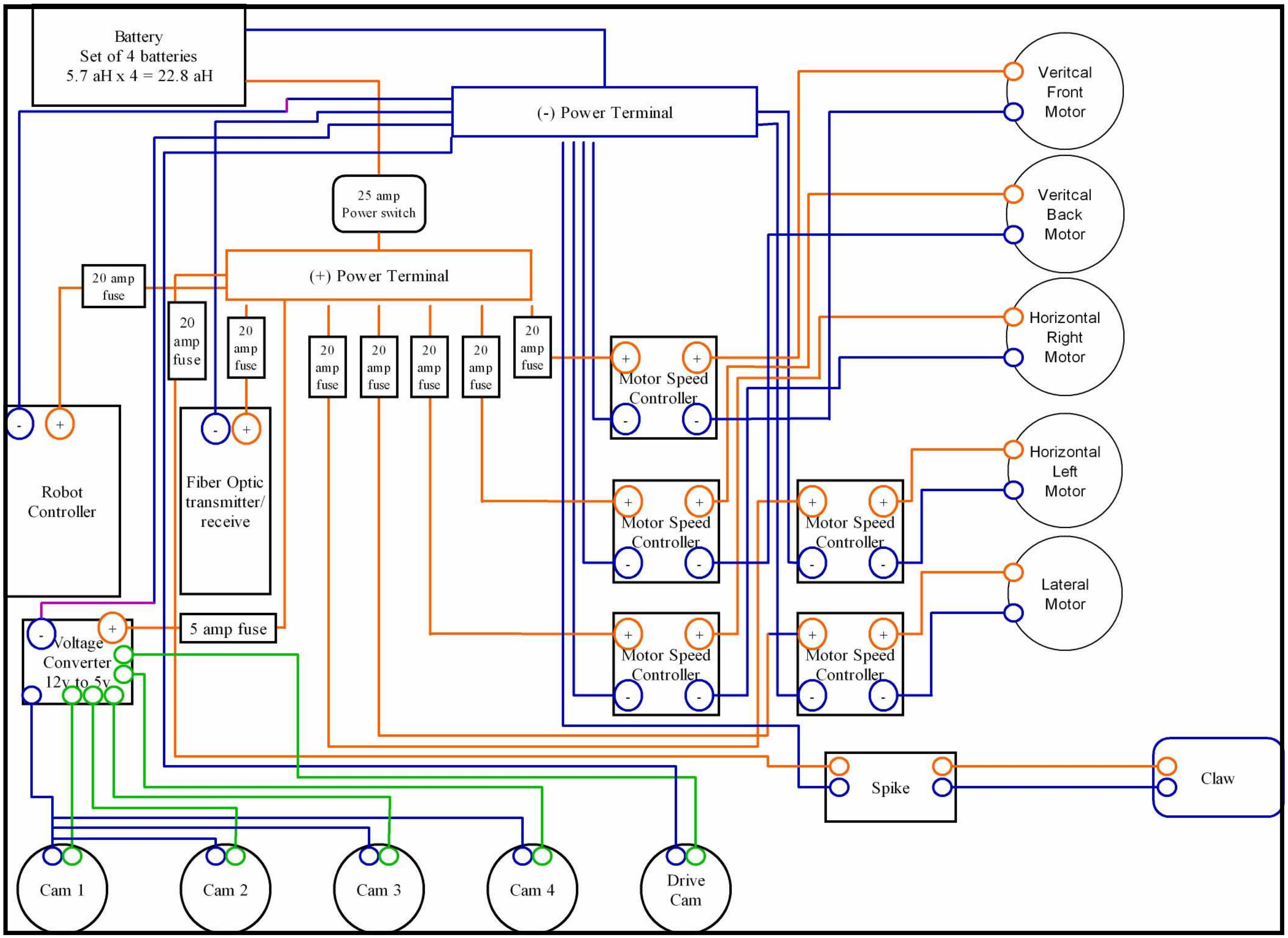
The control panel controls both Ipski and Otis. Otis's power comes from the surface batteries through the control panel and the tether is a set of standard trailer hookups.

The fiber optic tether for Ipski also goes to the pilot control panel after it has passed through the tether reel with the fiber optic rotary joint. The pilot control panel can be closed like a suitcase and it has wheels for ease of transport.

Ipski's controls

Otis's controls

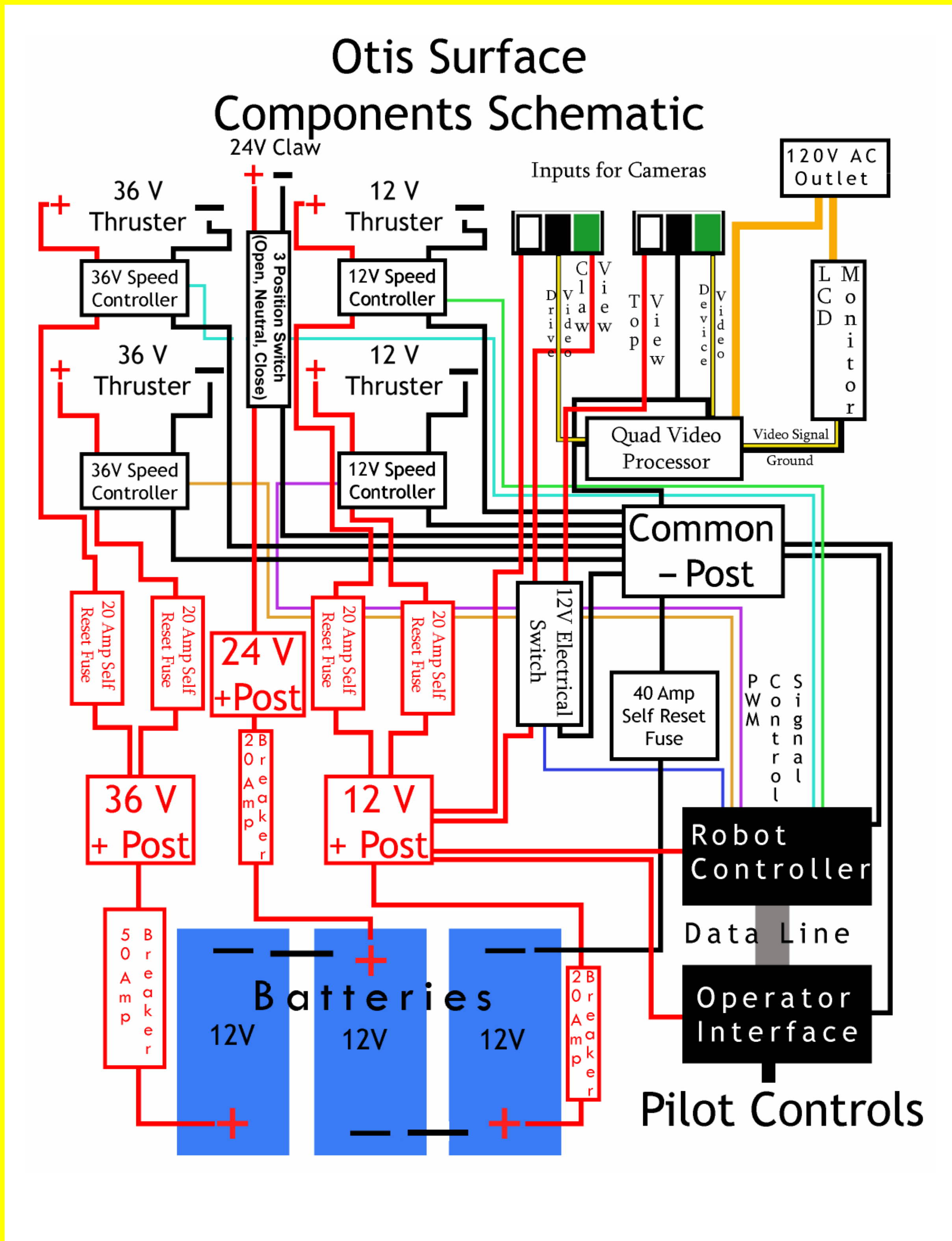
Ipski-Pipski Onboard components



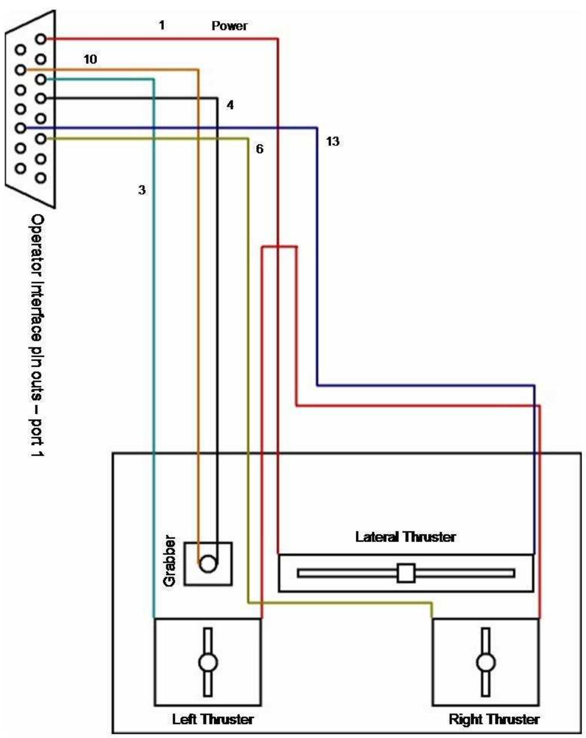
Prepared by Luis Gutierrez

Electrical Schematics

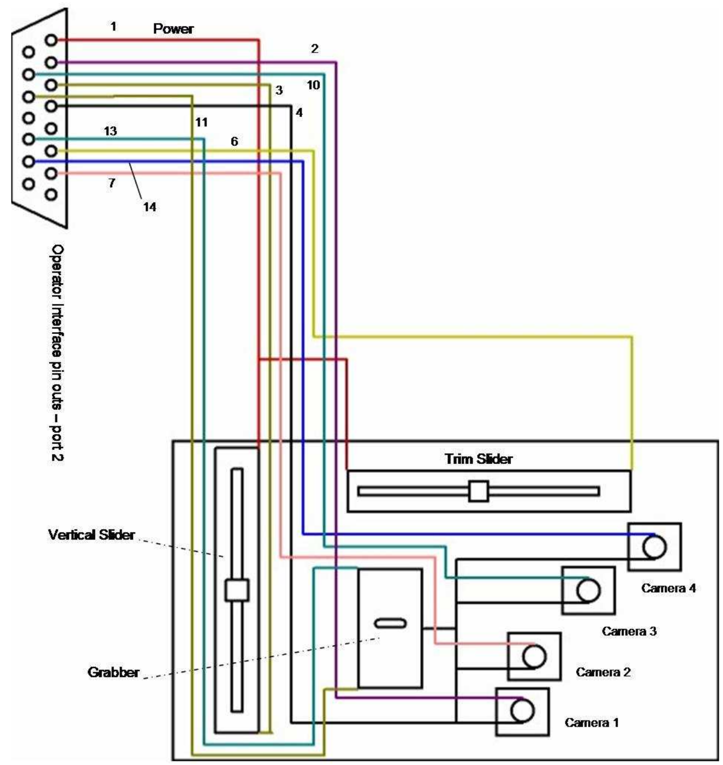
Electrical Schematics



Pilot controls for Ipski Pipski



Horizontal Joystick Controls for Ipski Pipski

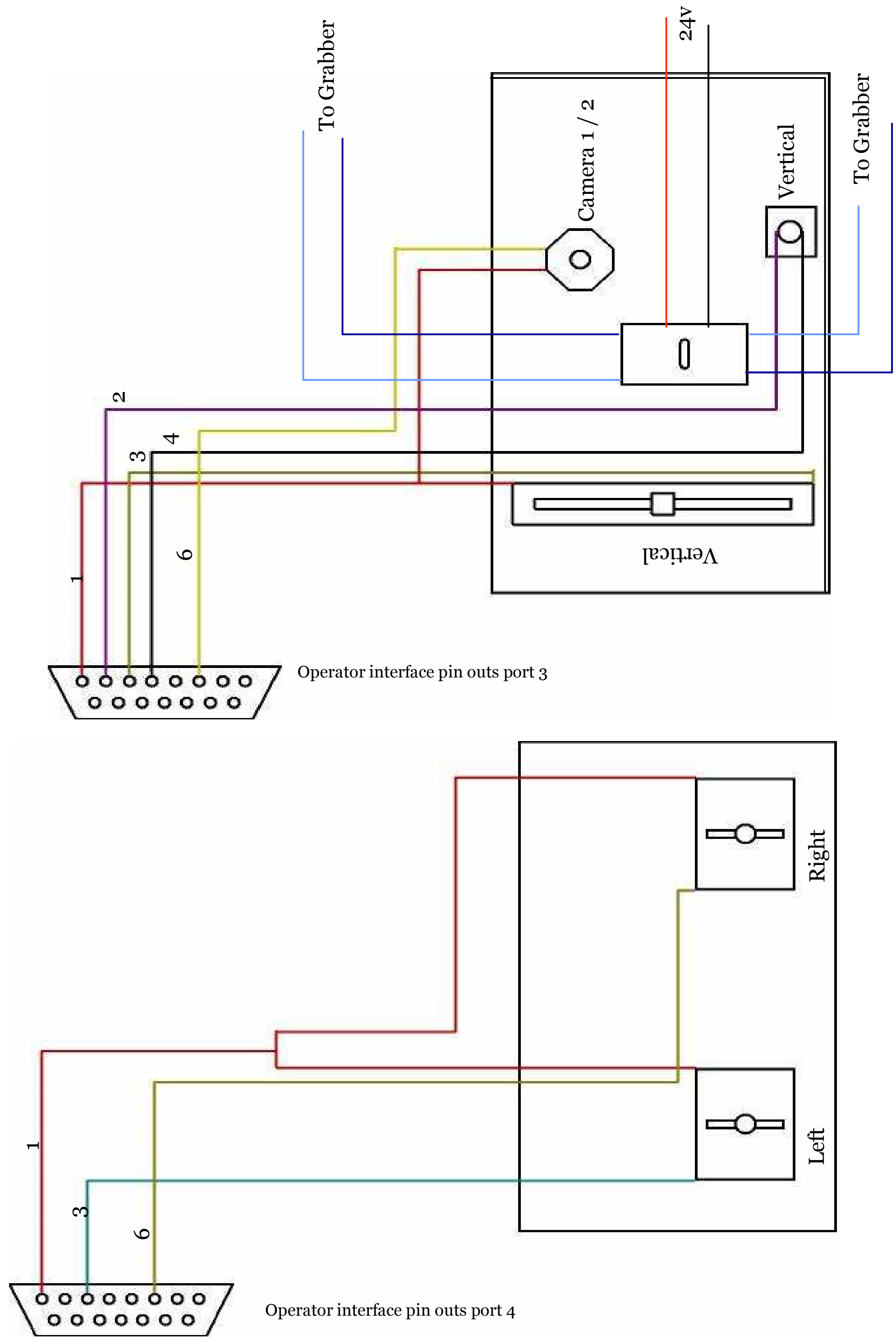


Vertical Slider controls for Ipski Pipski

Prepared by Luis Gutierrez

Electrical Schematics

Pilot controls for Otis

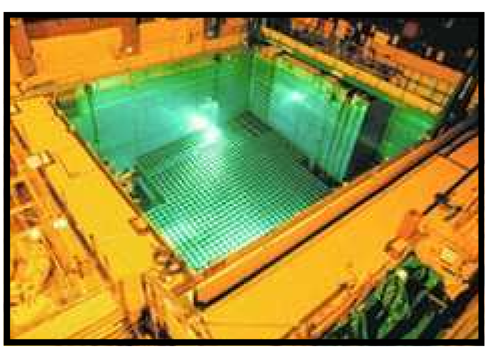


Future Improvements

The Carl Hayden Falcon Robotics Team strives to use innovative improvements to create better ROVs. A large portion of the team's success in performing mission tasks in previous years is due to the use of the smallest tether available. A tether has potential drawbacks on any ROV. Improvements in data communication technology has enabled the team to use a single fiber optic cable to relay information between the user and ROV, however any tether is still cumbersome. As a tether, fiber optic cables have minimal drag, but can get caught on objects in the environment or other ROVs nearby. In many cases, if the tether were to become severed or damaged the ROV would be lost without a possibility of retrieving it.

With this in mind, the team is attempting to utilize high intensity LEDs of a cyan hue to transmit data wirelessly between two sources—the ROV and operator. A buoy stationed above the general position of the ROV will act as a transmitter and data receiver and video at the surface of the water while communicating with the submersed ROV. However, in order to ensure communication between the two sources a CMU camera would be mounted to the ROV. This CMU Camera can be pre-programmed to track the desired light source, in this case the transceiver at the surface. Onboard processors and servos would keep the ROV's transmitter and receiver of data pointed at the correct direction to keep contact between the two systems. While this way of keeping in contact with the surface is more delicate than a standard tethering system, it would alleviate the risk of entanglement of the ROV as well as remove any drag from the tether line.

Despite its advantages, this system is in its initial stages with several problems needing to be solved before it can be relied upon. Current technology keeps the bandwidth of the system very limited. It is enough to transmit packet data for movement but not enough to provide quality video feed from the ROV. Therefore, any ROV using this method would have to be driven with a poor video feed. Another drawback pertains to the method of communication. Since data would be transmitted visually, the ROV must always stay within the acceptable range and position in order to maintain visual contact with the surface. Objects that obstruct their visual contact can disrupt communication and the ROV could be lost. Visibility in water also differs greatly depending on the environment. Light emitted from communication would affect marine life in the light beam's path. Any fish that swim into the beam of light would be blinded.



Animal life would be disturbed and possibly scared away, so the process would not be practical for sea life observation. However, there are circumstances in which the system could be a benefit. This technology, once perfected, could be used to inspect water cooling tanks at a nuclear power plant where the visibility is exceptional and there is obviously no animal life to bother or damage. Generally, any controlled or semi controlled environment might make better use of this system as opposed to a tether system.

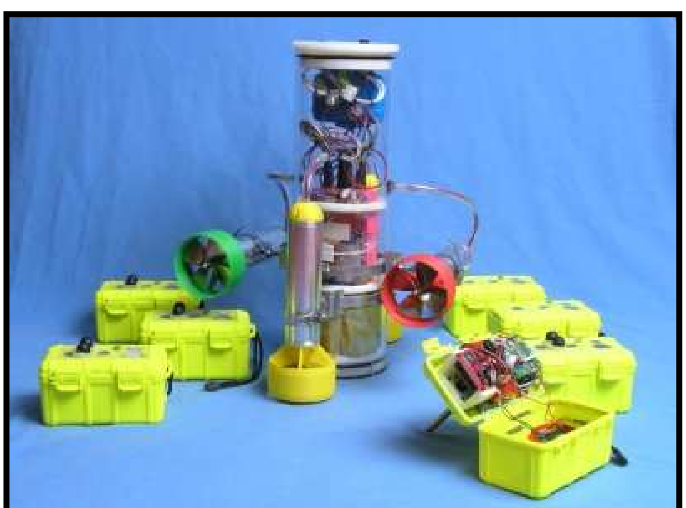
Ocean Observing Systems

One of the greatest limitations to underwater exploration involves the link used to retrieve data from the environment being studied. Transmission lines can easily get tangled or damaged and can severely limit the range of motion of an exploring ROV. Improvements in underwater robotics technology have enabled scientists to explore greater water depths more effectively, but ROV systems are still highly dependent on their ties to the surface, where researchers observe what the ROVs are doing.

One group of researchers from the Research School of Information Sciences and Engineering at the Australian National University has been working to find a more effective way to connect ROVs to their users. This project is called AMOUR, autonomous modular optical underwater robot. This group has succeeded in establishing communication between ROVs and top-side users not by attaching tethers to their ROVs, but rather by sending pulses of light from the ROVs to a stationary data transceiver. Their research shows that the wireless communication between the ROVs and the central transceiver can work over short distances and even with multiple ROVs at one time.

In the Australian group's design, both the central transceiver and the operating ROVs have the ability to transmit and receive data to and from each other through the use of high intensity LEDs. The central device, the only machine tethered to the surface, remains stationary and serves as a data transmit and receive post for the ROVs. This transceiver sends orders to the ROVs, which gather the desired data and then transmit the data back to the central data post, which feeds it to the surface via the tether -- in this case, a fiber optic cable which transmits data using a fiber optic multiplexer. The ROVs themselves can also be used as relay stations to transmit information to other ROVs that may be out of range or out of the line of sight of the detector on the central transceiver.

This method of retrieving data has several advantages. Multiple ROVs can operate while the data transceiver keeps track of them, ensuring that they don't interfere with each other. Also, while the main purpose of this system is to facilitate the retrieval of data from ROVs, the transceiver and ROVs can be used to change the operational parameters of a mission already in progress without having to return to the surface to reconfigure the control systems. The signal sent from the surface to the transceiver has the ability to transmit data between the transceiver and the ROVs it monitors and controls without the need for multiple connections.



Several sensor nodes and AMOUR (Autonomous Modular Optical Underwater Robot) mobile node

Prepared by Cristian Arcega

Acknowledgements

Supporting Ocean Observation Systems:

- http://groups.csail.mit.edu/drl/underwater_robotics/amour/amour.html
- Visible Spectrum Optical Communications and Distance Sensing for Underwater Applications. www.araa.asn.au
- http://users.rsise.anu.edu.au/~trumpf/schill_zimmer_trumpf_ACRA2004.pdf
- http://www.spawar.navy.mil/depts/d70/d74/AdvancedConcepts.html
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- http://www.stanford.edu/class/cs344a/papers/p154-vasilescu.pdf

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