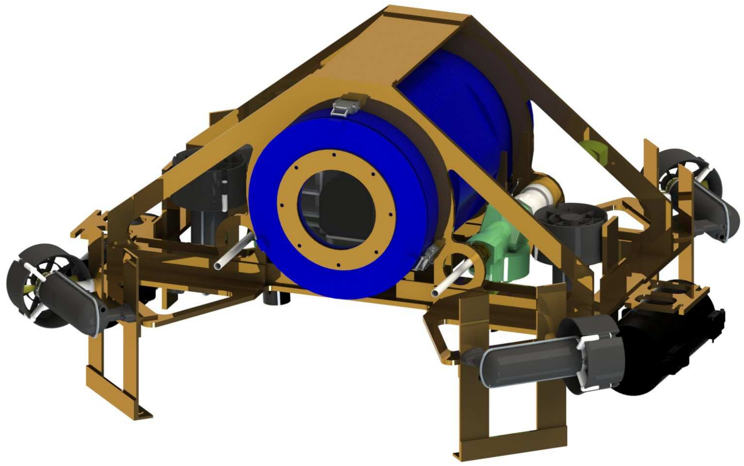
Falcon Robotics AUV Team



Sovereign Falcon

The Falcon Robotics team's maiden voyage to RoboSub 2011 was a successful learning adventure. Beyond competing, it was an ideal research opportunity, with the team particularly drawn to Team Sonia AUV and the Cornell teams. A "to do" list was compiled that would raise the level of the AUV design, components, and mechanical sophistication to equal or approach the top competitors. A three year plan was developed that first focused on building an AUV advanced enough to require only minimal alterations or modifications over the next 3 years. The goal is for only a gap in programming abilities to distinguish the team's AUV from its competitors in the 2012 field. The next two years will be dominated by a focus on programming, which would include seeking opportunities to send team members to Cornell or some other top tier team for an "apprenticeship" period of study to further close the programming gap. The team spent the majority of the past year designing and building this new AUV and preparing to take an "80% approach"to the mission this year, basically earning the maximum number of minimum points. Beyond 2012, the expectation is to bring programming skills to the RoboSub event that will put Falcon Robotics clearly among the top contenders.

Quick Facts

Dry Weight: 65lbs **Dimensions:** 32" x 33"x 16" **Max Speed:** 3 f/s **Max Depth:** 500'	**Thrusters:** 6x Seabotix SBT 150,4.8lb of thrust @ 4.2amps **Cameras:** Allied Vision, 1394b, Guppy **IMUs:** Phidget 3 axis Compass, Gyroscope, Accelerometer **CPU:** EC7-1817LNAR, Mini ITX, 64 Bit, Intel I7, 3GHz

Team Members: *(Students)* Dillon Dayea, John Rangel, Martin Carranza, Isabel Martinez, Joach Avitia, Carlos Ruvio, Ulises Barraza, Jorge Tay, Daisey Fernandez, Sergio Corral, Elizar Diaz, Jesus Meraz, Bianca Rodriguez, Isela Martinez, Quenan Ruiz, Diserae Sanders
(Adults) Faridodin Lajvardi, Ken Whitley, James Haugen, Steve Forbes, Srnka Johnson, Jill Jones
(Alumni) Maria Castro, Elizabeth Perez, John Harris, Eduardo Fernandez

Team background

Carl Hayden Community High School is located in central Phoenix, Arizona. Carl Hayden is an inner city school with many of the common inner city school challenges. Some characteristics that further distinguish Hayden include a student population of which 98% qualify for the federally assisted school lunch program, 97% are Hispanic, and an overwhelming majority are first generation immigrants. Many of the students are the first in their family to graduate from high school.

The Falcon Robotics team was formed in 2001 by Allen Cameron and Faridodin "Fredi" Lajvardi. The club was initially created to show students that science and technology can be interesting and exciting but quickly evolved into something far more powerful. The team is now not unlike a school within a school, a "robotics academy" of sorts. Students and mentors spend an average of 3 hours a day, year round, designing and building robots to compete in various competitions. The competitive spirit, a sense of social responsibility, along with the natural aversion to embarrassment drives the learning experience. The program continues to be a huge success!

Since its inception, the team has won numerous awards in a variety of competitions from FIRST Robotics *(For Inspiration and Recognition of Science & Technology)*, and MATE *(Marine Advanced Technology Education)*, ROV Championships, to Pete Conrad Foundation's Spirit of Innovation Awards. The Falcons are always looking for new and challenging ways to be tested, and AUVSI's RoboSub is the latest iteration.

Part of the team's success involves sharing what they have learned with others and promoting curricular and extracurricular STEM *(Science, Technology, Engineering, & Mathematics)* education in over 30 presentations annually. In addition, the team hosts STEM competitions such as FIRST Lego League for grade schools, and NURC *(National Underwater Robotics Challenge)* for competitors ranging from grade school to college. The Falcon Robotics team members not only push themselves into STEM but they bring STEM to as many people as possible.

What The Team Learned Last Year

Based on their experiences at the RoboSub competition last year, the team came away from the event having learned a great deal to guide them in preparing for the 2012 competition. The first item identified for improvement was a more simplified hull sealing system that used latches instead of bolts. In addition, an aluminum hull was preferable for its thermal conduction properties. While many teams used acrylic, which is an insulator, for their housing, the team felt that this was a poor choice as they observed cases of overheating problems. It appeared that the acrylic hulls were more of a vanity issue, because the argument that acrylic allowed for better identification of a leak is a weak one since, in reality, it would probably be too late once you were able to see it. Another area needing improvement was the hull size. Last year's hull was too large and required a lot of ballast weight to get the AUV to be neutral due to its excessive positive buoyancy. The team studied how other teams practiced using high density electronic architecture to reduce the hull size. The team set out to develop their own solution to the challenge of taking rectilinear components and fitting them into a curvilinear package, thus creating a hull with less air to ballast out.

Another takeaway from the competition last year was the value of having a tether for programming and one for power. The team had neither last year and it proved very time consuming to develop code and recharge batteries. While they saw many teams using an ethernet tether to develop code at the competition, they did not see a tether for power. It struck the team that it would be wise to have both, thus allowing them to develop code faster and allowing them to do tethered runs at the competition.

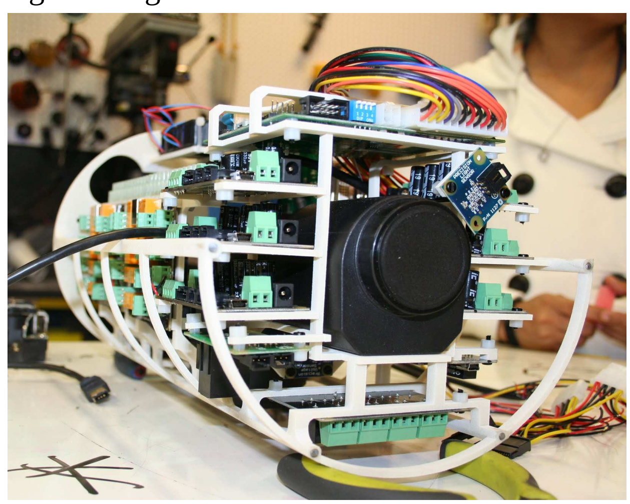
Still another area identified for improvement was the idea remote camera control. Other teams had to manually adjust their camera's focus, iris and zoom. This meant that they had to open watertight compartments to accomplish this. A preferable method would be to give camera control to the on-board computer. Three function motorized lenses became another implementation goal.

The area in greatest need of improvement was programming and, more specifically, software architecture. For all practical purposes there was not structure. From interviewing teams and looking at their journal papers and poster displays, the other teams had far more experience and the Falcons recognized what needed to be upgraded and what skills needed to be developed. It is paramount to design a complete flow chart of all the AUV functions before starting to program. This would help the students to write code with the proper structure and with methods and mission planner all structurally organized for optimal performance.

The last area requiring major improvement was the digital compass. The USB device previously used had a very peculiar property which resulted in getting lost off the registry on USB devices any time the AUV went below two feet. Various efforts to solve the problem failed. After the 2011 competition, the team even tried to simulate the problem in the lab. Nothing seemed to work until the team came up with a new method for connecting to the mesh shielding wire on the USB cabling. It is very resistant to soldiering. This seems to have solved the problem.

Design Rationale

While at the 2011 RoboSub competition, the team took notes on the best concepts and ideas to implement in the next AUV for 2012. The decision was made to build an AUV based on the best ideas demonstrated at the competition, which would then provide a platform for the development of the programming of the AUV over the next two years. The goal was to match the best teams in terms of components and reduce the programming gap estimated to be about six years. The team is looking for the opportunity in the near future to work with one of the top teams in the competition to further develop programming abilities. Following this strategy, the team hopes to avoid building a new AUV for the next two years , thus focusing all resources on programming.



One of the upgrades was the packing of the electronics into the main hull. The team designed a lattice structure that would take the rectilinear electronic devices and fit them into a curvilinear housing. This approach was used in order to make the AUV as light as possible. Phoenix Analysis & Design Technologies (PADT) sponsored the team by rapid prototyping the lattice structure composed of duraform PA & GF plastic. This material is a durable, high-quality, rugged thermoplastic used in functional applications that can withstand aggressive handling in both rapid manufacturing and prototyping. After the reduction in hull space and, consequently, a reduction in weight, the next design improvement was to make the opening of the hull simple and easy to seal and unseal. This effort resulted in a spring loaded latching system using an open face o-ring sealing mechanism that uses the water itself as the fourth side of pressure to ensure a watertight fit. This same method of sealing the hull was used for the battery pods.

Some other design features that focus on increasing the programming time on the AUV include the hull completely made of aluminum to increase heat dissipation, remotely controlled motorized lenses, fiber optic tether for teleoperation and programming without opening the hull, and a tethered power system to increase water time.

There was only one thing that the team did not change from the previous year. The team elected to keep their vector drive system because of the huge maneuverability advantage it provides.

The 2012 Mission Strategy

The team's strategy is to maximize the score by completing particular tasks and earning bonus points. The team will clear the gate, touch a buoy, pass through the obstacle course, drop at least one marker in a bin or fire a torpedo through a target, and fully surface within one of the octagons. The plan is to be under 84 lbs to get a weight bonus, as well as complete the minimal number of required tasks to be eligible for the time bonus at the end of the mission.

Mechanical

Hull

For the water-tight electronics compartment, something easy to open and close was desired. The quality of being simple to machine was essential because the team had minimal access to machining equipment. Aluminum was ideal because it is an excellent heat conductor, allowing the electronics to keep cool when the hull is in contact with water. For these reasons the team selected an 8" aluminum pipe, ½" thick, and machined it to meet requirements. Two ½" thick circular lids were machined so that most of the lid fits inside the pipe leaving an 1/8" lip. An o-ring was fitted over the part of the lid that inserts into the hull creating

an o-ring seal against the lip of the lid and the hull face itself. This allows for a larger margin of error, unlike other methods that require accuracy up to a thousandth of an inch. The lids are sealed to the hull using three spring loaded latches. Since our cameras are located inside our hull we needed two light openings, one in front on one of the lids and one facing down into the middle of the main hull. Each opening is then covered by a ¼" thick piece of Lexan. To prevent leakage we put an o-ring groove around the openings to create a seal between the glass and the aluminum. This allows the cameras to be placed in the hull and also negates the need to machine additional water-tight compartments. The hull was then thinned to reduce mass.

Battery Compartments

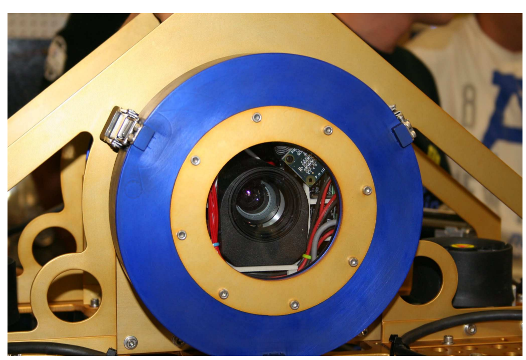
The battery compartments are similar to the hull in structure. They consist of 3" diameter by ¼" thick by 6.5" long aluminum pipes. Like the hull, they have two machined circular lids that are 3" in diameter and ½" thick. Half of the lid is machined down to 2.5" so that an o-ring can be placed around it to create an o-ring seal. Unlike the hull, the battery compartment latches could not be mounted directly onto the compartment because of the sharp curve on the compartment. To compensate for the sharp curve, washers were made out of ABS pipe that had one side flat and the other curved to match the compartment, allowing the flat latches to be mounted to a curved compartment without modifications to either. The center of the compartment was thinned to reduce mass.

AUV Frame

The AUV frame consists of three sections. The main section, which is horizontal, holds everything, and the two minor sections, which are perpendicular to the main section, are used to keep the hull in its proper place. An internal frame was selected in order to reduce weight and retain strength. The main section has six thruster mounts, four of which are mounted horizontally at 45 degree angles to each other allowing for vector drive and two that are mounted vertically for vertical movement.

Triplex Anodization

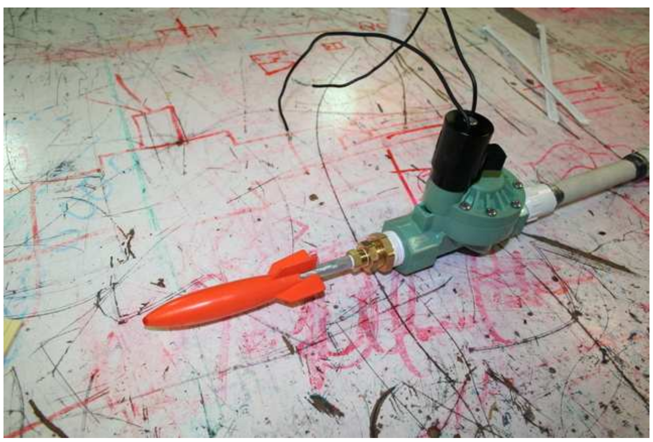
Triplex is a new and recently patented anodization process that was designed to be used on metal in air and underwater. This new process was discovered by Michael Beaver who was approached by Walt Ahland who needed a stronger and more durable anodization process for products that were exposed to a nuclear environment submerged underwater. The standard MIL-A-8625 was easily scratched compared to this new triplex process and is approximately 10 time more durable. Michael and Walt were then joined by Mike Adams and formed the company called Triplex, LLC in order to do further research. This new process prevents the



material from getting scratched as easily and will prevent any chipping of the anodization from expanding. It also prevents material like steel and aluminum from corroding, even in harsh salt water environments.

Torpedoes

The torpedo launching mechanism uses compressed air to fire the torpedo. The compressed air is stored in a 1" diameter, 4" long PVC pipe on the input side of a 24 volt activated inline sprinkler valve, and a ¼" hollow tube is attached to the output side of the valve. The torpedo itself is a modified child's pool toy that fits over the ¼" tube awaiting the instant release of the compressed air to fire it. This is a low cost and simple system that was easy to design and construct and is already watertight. The system can be charged with compressed air using a portable compressor via the Schrader valve on the PVC pipe.



Marker Droppers

Again, our solution for the marker droppers, as in the case for the torpedo launcher, came from the gardening world. Using the 24 volt solenoid from a sprinkler valve as the device that holds the marker in place until power is cut

from it, the team created a marker out of ferrous metal that could be inserted inside the solenoid, and, with the magnetic field created by the solenoid, hold the marker in place until the power was cut by a relay.

Tether

The tether utilizes a fiber optic system created by IMC Networks that communicates at 100 Mbps. It is a bidirectional dual frequency system that communicates via one fiber. The team has 100' of fiber optic tether and Seacon connectors to get inside the main pressure hull.

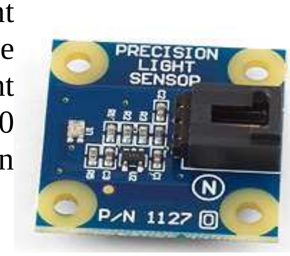
Sensors

Compass

The compass used is a Phidget Spatial 3/3/3 1056. It is a combination compass, gyroscope and accelerometer. It connects to the main computer using a USB cable running through a Phidget USB Isolator to increase stability by eliminating ground voltage differences.

Light Meter

The light meter is a Phidget Precision Light Sensor and can measure human perceptible light levels in lux, from 1-1000 lux. The sensor is non ratiometric.

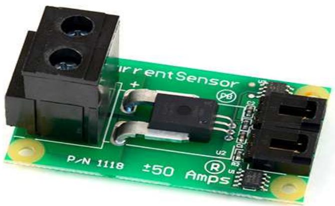


Voltage Sensor

The voltage sensor is a Phidget Precision Voltage Sensor 1135 and can measure voltage from -30V to +30V. The sensor is non ratiometric.

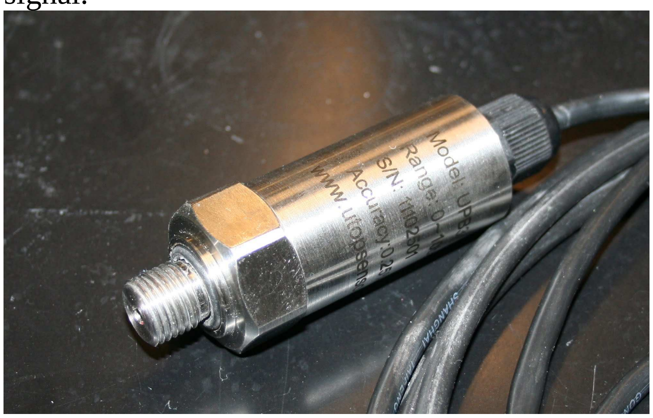
Current Sensor

The current sensor is a Phidget 0-30 Amp Current Sensor 1122. The sensor in this case is ratiometric.



Pressure Sensor

The pressure sensor is a UTOP Sensor ceramic pressure transmitter that can measure from 1 bar to 200 bar. It puts out a 0-5 volt signal.



Cameras

The cameras are Allied Vision Guppy Firewire machine cameras. They were chosen for their small size and high quality performance as well as their high data rates of up to 400 Mb/s. They have a 696 x 494 resolution at 58 fps. The cameras are fitted with Computar T6Z5710M motorized lenses. They can provide remote control of the focal length, the iris, and the focus through the use of a controller. The Computar lens provides a 6x zoom, and a 5.7-34.2 mm capability.

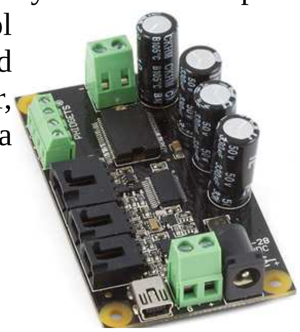
Controls

Motorized Lenses

The motorized lenses are controlled by Phidget InterfaceKit 0/0/8 set of relays Double-Pole Double-Throw. They can handle 60 Watts.

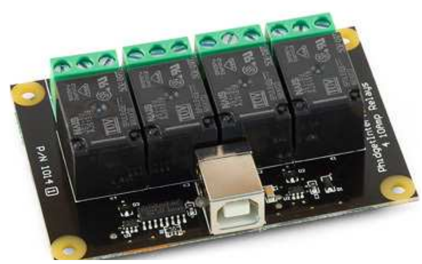
Motor Speed

The thrusters are controlled by Phidget Motor Controls 1065. They can handle up to 28vdc and let you control the direction, velocity and acceleration of a DC motor, and they are connected via USB.



Marker Droppers

The marker droppers are controlled by a Phidget Interface Kit 0/0/4 1014. It has 4 relay outputs for switching up to 5 Amps.

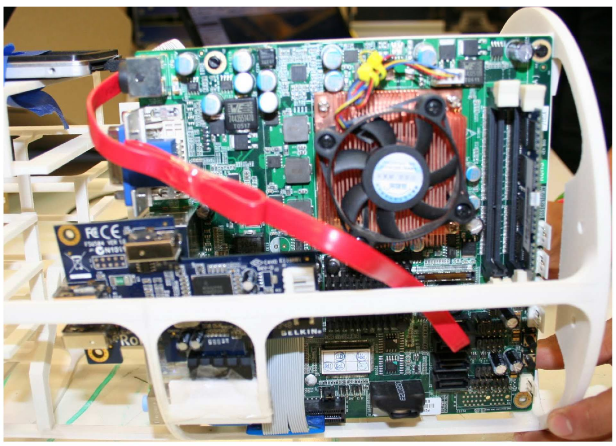


Thrusters

The thrusters are Seabotix SBT 150. It provides a Bollard thrust of about 5pd f at 4025 amps running at 25 volts. The team had these thrusters on another ROV at the time of last year's competition and they used bilge pumps motors to save money. Now they are really happy to be using these on the AUV. It would be nice to have brushless thrusters to reduce emf noise, but the cost was prohibitive and we were unable to get them donated, so we were went with SBT 150.

Computer

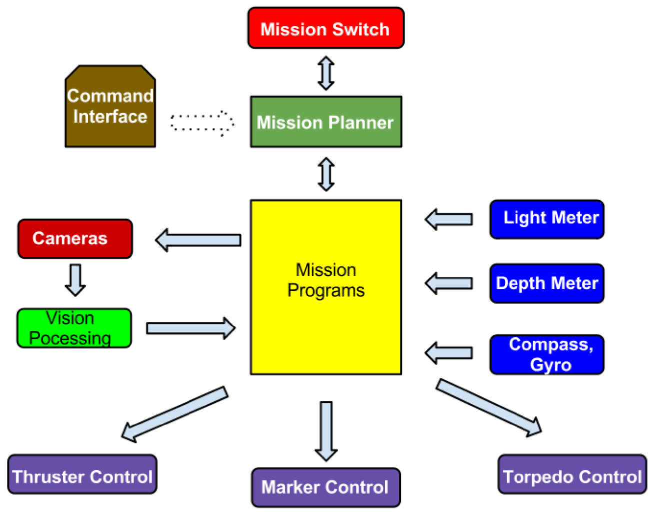
The computer is an EC7-1817LNAR Mini-ITX SBC with Intel 17 Sandy Bridge 64 bit processor operating at 3.0 gHz. It is loaded with 16GB of memory and internally integrated graphics controller. The small form factor of the Mini-ITX allows the team to have a powerful full-functioning computer, but in a size that allows the team to incorporate it into their AUV without having to make a larger hull to house it.



Software

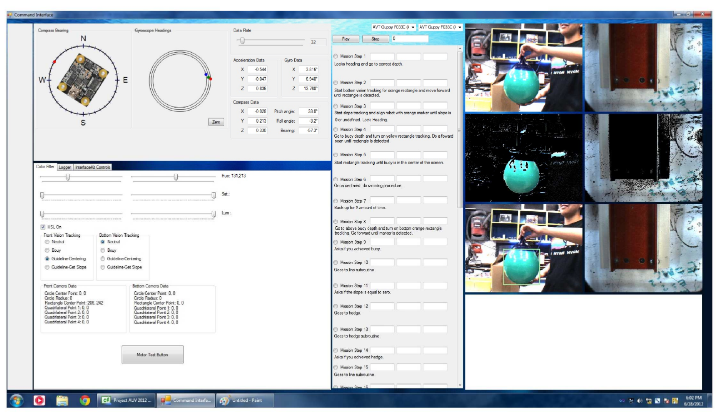
Overview

The basic overview of the code features a command interface where users can interact with the code to really get the most out of development of the autonomous code, and a mission planner that organizes when specific missions are carried out on the robot and decides what the robot will do if it does not complete a certain task in a specific amount of time. All of the code is written in C# using the Visual Studio 2010 ide, the aForge.NET Framework for vision processing, the Phidget code libraries to control the various motor speed controllers and sensors, and the SlimDX library for allowing the use of joysticks and game pads. The main programming goal this year is the implementation of highly effective organization, a feature that was clearly lacking last year, resulting in overall inconsistent code and frequent crashes.



Command Interface

The command interface is basically a giant “form” with a large variety of window controls. On it, a programmer can see six different video feeds and constantly updating visuals of the robot's compass and gyro readings, depth, and mission status. A programmer has a lot of control, including 1) the ability to change certain variables for the mission such as motor velocity, color filtering value, or depth on the fly; 2) change the video processing settings such as hsl values or object recognition for debugging; 3) control the motorized lenses for our cameras.

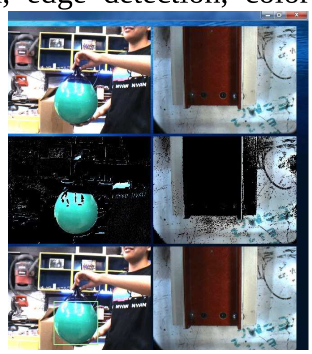


Mission Planner

The mission planner is a new addition to the code this year. While getting their “feet wet” in the competition last year it was evident that a reorganization of the code was clearly needed as well as a way to traverse between mission tasks more efficiently. The solution to alternating between tasks was a mission planner which cleanly switches between tasks based on the logic developed on a overall mission flowchart. The mission planner is also interfaced with the Command Interface so that, when developing the code, the user can pick which part of the mission he/she wants to start on and can also change certain variables of the mission, such as velocity, while running the code. This allows for the team to make impromptu changes and to test code repeatedly without having to restart the code each time.

Vision Processing

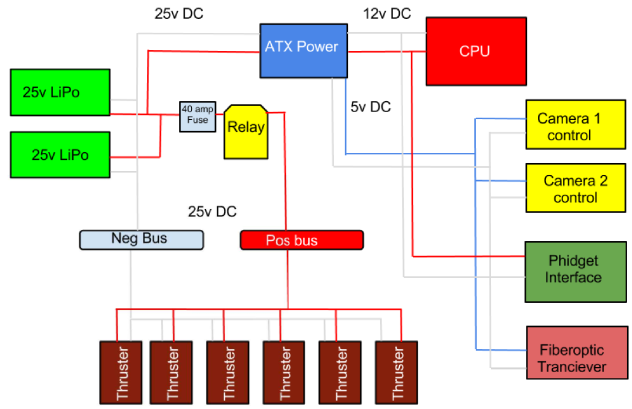
The vision code, which encorporates the careful use of the aForge.NET Framework, is one of the key aspects of the code. The aForge.NET Framework provides a lot of useful vision methods including, but not limited to, object recognition, edge detection, color filtration and



much more. Last year's efforts involved a lot of struggle to get the Framework's code to work as we wanted it to work. Disorganization led to a lot of failure in the vision processing. However, this year organization has been a key focus and the vision code is looking to be much more reliable in comparison to last year.

Electrical

The electrical system of the Sovereign Falcon is powered by two 25.9V 3.3 Amp/hr lithium polymer batteries hooked up in parallel, essentially providing a 25.9V 6.6 Amp/hr battery. The electrical system then splits the power two ways. One goes to a M4-ATX power supply which takes the power and converts it to 12V and lesser voltages for the computer and other devices that use 12 volts or less. The other path takes the power and runs it through a relay that can be switched from outside the hull using a magnet. This relay controls the voltage to the 25.9V buss that in turn supplies the thrusters' controls. There is a 40 Amp fuse on the 25.9V buss to protect the 25.9V circuits and there is a 52 Amp fuse in the M4-ATX power supply to protect the power supply itself.



The electrical system is also structurally arranged to allow surface voltage to run on the AUV via the use of an electrical tether. This is for the purpose of developing code for the AUV without taxing the capacity of the batteries which were designed to operate the length of the mission only, thus reducing the weight of the AUV as well as the cost by limiting the number of batteries required.

Future Plans

This past year alone, the Falcon Robotics team has accomplished many new firsts, further developing its potential, enabling it to reach its current capabilities, and cultivating greater ambitions for the future. The team hopes to use this AUV platform to continue developing primarily its coding abilities with less time spent rebuilding a new robot each year. The team will also strive to develop a sound triangulation system that can be incorporated into the current or any future AUV. Any subsequent AUV the team may build will be more physically capable and include a manipulator and an improved mass to capability ratio. These advancing efforts are guided by the intention of eventually winning this event.

Acknowledgments
Falcon Robotics would like to thank all its supporters and sponsors. Without you it would not be possible to complete projects such as this one. Thank you to Intel, Phidgets, Seabotix, Lights Camera Action, Science Foundation AZ, Steve Sanghi and Friends, Jaime Almanza, Marzee Water Jet, Chips inc., PNI, PADT, IMC Networks, Subconn, Seacon, SHPE, RMA Electronics, Solidworks, Arizona Sealing Devices, Aforge.Net, Open CV, Marcos Garcia Acosta, Ken Whitley, Faridodin "Fredi" Lajvardi, Steve Forbes, James Haugen, Srnka Johnson, and Jill Jones.

Contact us:
Carl Hayden High School
3333 W. Roosevelt
Phoenix, AZ 85009
602-764-3000
coachfredi@hotmail.com