

# **Autonomous Underwater Vehicle**

**Final Report**

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## **Introduction**

The Autonomous Underwater Vehicle (AUV) project has been a work in progress for three years. The ultimate goal of the project is to participate in the Association for Unmanned Vehicle Systems International (AUVSI) competition. The competition, hosted in San Diego, invites universities from around the globe to participate. The first group worked on hull design while subsequent groups finished the hull design and came up with a simple electronics scheme. The 2004-2005 team devised a simple control system based on the PC/104 form factor that ran the motors and bilge pumps on the AUV.

## **Objective**

Our task was to develop a more robust electronics system that would ease the development process. In doing this our team wanted to streamline the development process such that a future team could come in and pick up where we left off. This meant eliminating the need for a traditional programming language, such as C++. Ultimately we hope that the work that we have done will not only lead future teams to competition but also help complete research for the Ocean Sciences groups on campus.

## **Design**

### **Controller**

Our first task was to choose a controller that would meet the requirements of small size, multiple forms of data acquisition and have the ability to be programmed on a number of different levels. All this had to be done at a reasonable financial cost. The group decided on the Hercules-EBX (see Figure 1.) from Diamond Systems.



Figure 1. Hercules-EBX

The Hercules has all the features that our team required. The Hercules is a complete computer on a small footprint of approximately 5" x 7". This includes both analog and digital data acquisition, 4 serial ports and Ethernet capability. The Hercules also contains a low power CPU so that our batteries will not take a serious hit when in use.

## Development Environment

The main idea behind choosing a new development environment was to allow Mechanical Engineers to get accustomed to it quickly. LabVIEW was chosen because is specifically designed for use in similar applications. The graphical programming environment will allow Mechanical Engineers to come in and learn LabVIEW in hours as opposed to weeks. Due to the nature of this project and the amount of time a team has, this is an invaluable asset.

## Sensors

Next, our team wanted to put together a working sensor array so that the future teams could come in and begin directly with programming a control scheme for the AUV. The most important sensors required for this array are an accelerometer and a compass/magnetometer. The accelerometer allows us to calculate the acceleration, velocity and position of the boat relative to some initial position and velocity. In order to choose the correct accelerometer an experiment had to be done to determine the range of accelerations that our AUV has (see “Experimentation”). The magnetometer will be used in directional control of the submarine. It detects the Earth's magnetic field and we will be able to control the roll, pitch and yaw based on these measurements. With that in mind we chose our two initial sensors from Spark Fun Electronics, the Serial Accelerometer Tri-Axis v5 (see Figure 2) and the MicroMag 3-Axis Magnetometer (see Figure 3).



Figure 2- Serial Accelerometer Tri-Axis v5      Figure 3- MicroMag 3-Axis Magnetometer

Our team has successfully programmed the accelerometer so our controller has the ability to track acceleration, velocity, displacement and this can be plotted in real time. We have also programmed our magnetometer such that we can get readings on all three axes. The magnetometer also came with a pre-built LabVIEW Virtual Instruments such that a heading can be read on two axes.

## Enclosure

The previous enclosure was not able to fully hold back water and this helped spark the design ideas for our new enclosure. Our goal was to create an enclosure with materials around Crosby lab that allows for future additions and a relatively small footprint. Using

the previous enclosure as a reference our team designed a new enclosure using SolidWorks (see Figure 4).

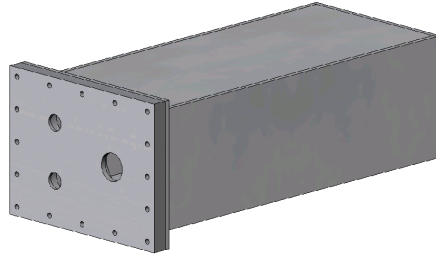


Figure 4 – SolidWorks enclosure design

This allowed us to tweak the design parameters before actually making the enclosure. With the design done, we chose the materials to make the enclosure. All but the lid is made out of Lexan, while the lid is made out of aluminum. Using Lexan allowed us to easily put the enclosure together using a technique known as Solvent Welding. The picture of the final enclosure can be seen below (See Figure 5.)



Figure 5 – Finished Enclosure

To finish off the controller three waterproof connectors manufactured by Bulgin were purchased. They are two 8-pole connectors and a waterproof Ethernet connector. The Ethernet connector was purchased so that next years team could run the computer without actually removing it from the enclosure.

### **Experimentation**

In order to purchase an accelerometer that met our needs we needed to conduct an experiment to determine the acceleration of our AUV. The AUV team determined an estimate of the acceleration of the AUV with use of the University of Maine's swimming facility. This information was essential in the selection of an accelerometer which we will use to determine acceleration, velocity and displacement of the vehicle. With an estimate of acceleration we can determine the range and sensitivity needs of our accelerometer. The following specific results were determined, and compared:

- Method 1: Acceleration based on velocity change and distance change
- Method 2: Acceleration based on distance change and time change

A visual diagram of how the experiment was setup and run was as follows (see Figure 6.):

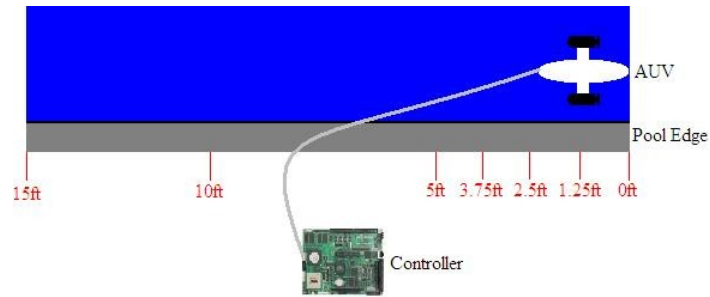


Figure 6 – Experiment Configuration

The following charts (see Figures 7 & 8) represent the accelerations calculated based on Method 1 and Method 2 as described above.

### Average Velocity and Acceleration

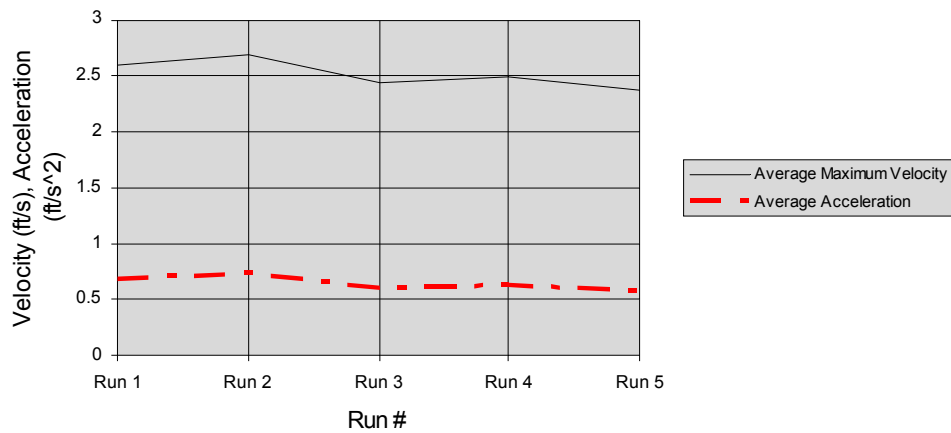


Figure 7 – Acceleration Based On Method 1

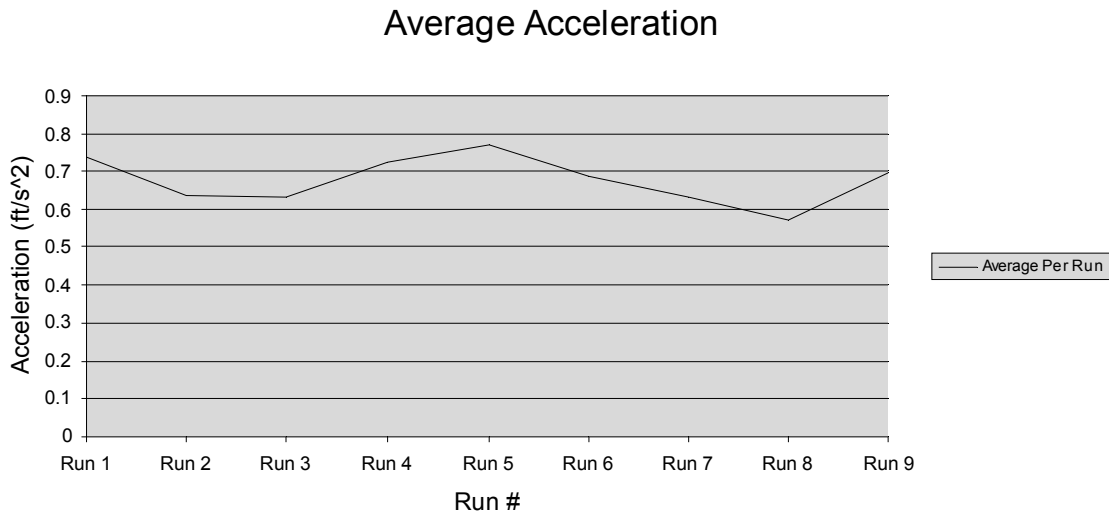


Figure 8 – Acceleration Based on Method 2

As shown in both of the charts it is a reasonable assumption that the acceleration in this experiment was relatively constant. With the values of the acceleration known the specific accelerometer for our needs was chosen. Based on all the data above the following final average accelerations were (see Table 1):

| <u>Method</u> | <u>Average acceleration (ft/s<sup>2</sup>)</u> |
|---------------|--|
| 1             | 0.635  |
| 2             | 0.676  |

Table 1 – Average Acceleration Results

### **Future Work**

In order to ensure that the project stays on track there are a number of tasks that our group has come up with that need to be worked on next year. All these tasks are essential in getting the AUV in the water and possibly to competition. These should be made the highest priority when continuing the project. These tasks are in no specific order.

#### *Kill Switch Redesign*

Approximately mid-year the mechanics of the kill switch started to fail. The temporary fix is to set a piece of lead on top of the kill switch so it remains in the depressed position. It is our belief that the kill switch mechanism has been worn out due to use. A

similar system should be implemented as it's required to go to competition. In addition to an physical kill, a LabVIEW kill switch should be created as well. Its function will be to set all servomotors to 0 in times of emergency acting much like the mechanical kill switch for use in times of automated motion. There is a sample VI called "kill example.vi" provided from our group.

### *Power Relay Investigation*

There have been two separate occurrences where motor controllers have failed due to unknown causes. Both times the power relay has gotten excessively hot. It is our belief that there is something wrong with the circuit design such that the power relay is causing some sort of overload that is causing the motor controllers to fail. Consulting with the Electrical Engineering department with this portion of the project may be necessary. There may be a need to either replace the power relay altogether or come up with another circuit design which accomplishes that same task in a different manner.

### *Waterproof Testing*

Due to unforeseen circumstances our team was unable to test the newly designed enclosure for water tightness. Before doing any water related runs with the AUV the enclosure needs to be tested. It is not worth jeopardizing the equipment. There are two ideas for a water tightness test. First, one could close enclosure with nothing inside according to the User Manual and submerge it in water and then check some time later to see if any water has gotten inside. Secondly, the enclosure could be filled with water and sealed and placed upside down on a lab surface. After a certain amount of time the enclosure should be checked for leakage. The first method is most likely more viable because the water pressure at competition depths should aid in keeping the watertight seal on the enclosure.

### *Standalone Power*

In order for the boat to perform its tasks the Hercules EBX needs to be powered via the onboard battery supply. After doing preliminary research the Hercules EBX will have to be powered via the ATX connector. There are many commercially available DC-ATX power supplies for vary little cost. This would allow the Hercules EBX to take the 12v signal from the batteries and run it directly too the motherboard. The only catch is the Hercules EBX does not have a standard ATX connector. Therefore the purchased power supply will have to be modified in order to be connected to the Hercules EBX. This task should be fairly straight forward due to the readily available information on the internet about ATX supplies.

After this the Hercules EBX needs to be configured to either 1.) Power on when a power source is connected 2.) Power on via a switch attached to the enclosure 3.) Be powered on via Wake on LAN support. Method 1, was previously working and it is unknown why it has stopped working. This may either be a BIOS setting or a jumper setting on the motherboard. Method 2, would need a momentary switch that runs directly to the power

switch pins on the motherboard. Method 3, was tried by our group but we could not get it to work successfully, more research is needed.

### *Magnetometer Calibration*

In order to get accurate readings from the magnetometer a calibration program has to be written. The need for this arises from the close proximity to electronic components, specifically the hard drive. This magnetic interference causes a skew in the actual data that needs to be collected. The raw data needs to be adjusted such that a correct heading with respect to the Earth's magnetic field can be used.

### *Accelerometer Calibration*

At its current state the accelerometer is configured to read acceleration, velocity and displacement in real time. One problem needs to be resolved and it arises when the accelerometer is under acceleration and then stopped. The accelerometer will report a constant acceleration value, which in a way is correct because motion has ceased, but it is not "smart" enough to know that it's actually under zero acceleration instead of constant acceleration. The hardware is measuring the correct data but a filter needs to be inserted to correct for these times of zero velocity and a non-zero acceleration.

Also, if the accelerometer is mounted at any orientation that is not parallel to the Earth's gravitational field inaccurate acceleration values will be reported due to the Earth's vector of the gravitational field having an affect on all three axes. Once the orientation is known, using dynamics will allow for the subtraction of the gravity vector on all three axes to get the true acceleration.

### *Control Scheme*

Once the issues of the accelerometer and magnetometer are ironed out a control scheme needs to be created. This control scheme can be created in two parts. Initially program a path that the AUV should take in the test pool. If this proves successful then other sensors should be implemented into the control scheme such as hydrophones and cameras. They should be implemented in such a way that if the hydrophone picks up an audio signal the AUV should be able to lock onto the target and reach it. As a rudimentary control scheme it will probably be possible to use proportional or feedback control schemes from the Control Systems class taught by Professor Senthil Vel.

### **Acknowledgements**

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