# Schlumberger – SCOPE
# Final Report

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## Abstract

The Olin Autonomous Surface Craft (OASC) was developed during the 2007-08 academic year in a partnership between the Olin College of Engineering SCOPE program (Senior Consulting Project for Engineers) and Schlumberger. Five Olin students worked on the OASC over the course of two semesters towards the goal of presenting the sponsoring scientists at Schlumberger with a platform capable of doing underwater acoustic imaging. This paper will describe the OASC and its capabilities and present the results of some tests that have been performed.

## Goals of the Project

The OASC project was originally proposed by Dr. Douglas Miller and Dr. Jakob Haldorsen. The proposal called for a surface vessel capable of carrying acoustic imaging equipment and recording its position using a highly accurate GPS. Furthermore, work was to be carried out towards the secondary goal of making the platform partially or fully autonomous. Thus, scientists would be able to specify an area of water that they wished to have mapped by the OASC, and the platform would execute the test automatically.

Exploration of sunken ships without disturbing them is a field of particular interest to Drs. Miller and Haldorsen. They have extensive experience using acoustic imaging to explore shipwrecks in areas such as Madagascar and Norway. Images of objects buried beneath the sea floor are obtained by emitting acoustic waves from a source and recording the reflections using hydrophones. In order to construct a detailed image, however, information on the position of the hydrophones with accuracy of around 1/10 of the wavelength of the signal is necessary.

The best solutions that are currently available are either expensive or inaccurate. One method is to tow huge arrays of hydrophones behind a large ship. This, unfortunately, can cost many thousands of dollars per day. Another method Miller and Haldorsen have attempted in the past is to string rope between two stationary points in the water and have a diver pull an acoustic source along the rope. This, however, is time-consuming and rather unwieldy, and currents have a tendency to interfere with accurate positioning.

The OASC platform was designed to be relatively stable, carry the acoustic imaging equipment, and to know where its position is to a degree of accuracy that depends on the quality of GPS mounted to the boat. The platform supports control both via remote control and over an ad-hoc wireless network setup between the onboard computer and a laptop on shore. Scientists have the ability to run code on the OASC that will cause it to execute basic autonomous commands, such as waypoint and line following. Ultimately, the goal is for the OASC to be able to perform a "mow-the-lawn" behavior, whereby a scientist can specify a box he or she would like the platform to cover and have the OASC travel up and down rows until it has completely covered that area.

## Physical Platform

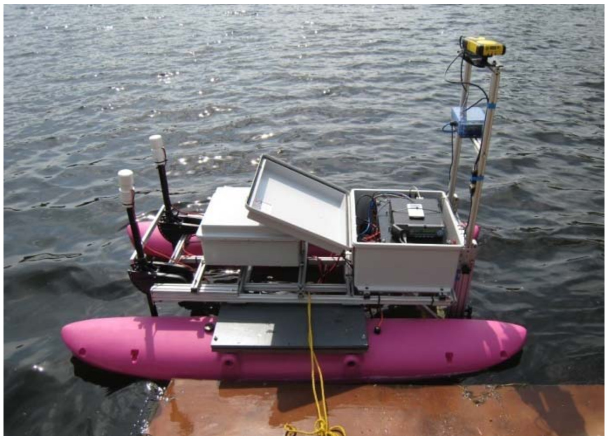

**Image 1:** entire craft

The platform base consists of two roto-molded (polyethylene) pontoons from a FloatCat 80 personal fishing craft. These rigid hulls provide a consistent and stable platform and minimal crate water disturbance in operation. The hulls are connected using 1.5 inch aluminum tube which is coupled to the primary frame. The frame is constructed from the 80/20 aluminum framing system which provides a light weight, easily modified frame that will not rust.

To support the sensors and maintain consistent and ridged geometry a removable frame, again built from 80/20, was constructed and can be fixed to the front of the boat. The frame can be removed for transport and testing with individual sensors in the lab. When deployed the hydrophones and audio source array must be approximately four feet below the surface of the water. To ease launch and recovery this array is hinged and able to be held above the craft and manually lowered from a dock or chase boat when the craft is in adequately deep water. Figure 2 and 3 shows the array in its launch and deployed states. When the array is in its launch state care must be taken in operating the craft as it shifts the center of mass forward.

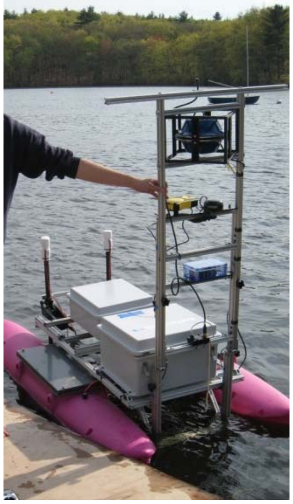

**Image 2:** Craft with hydrophone and source in launch/transport position.

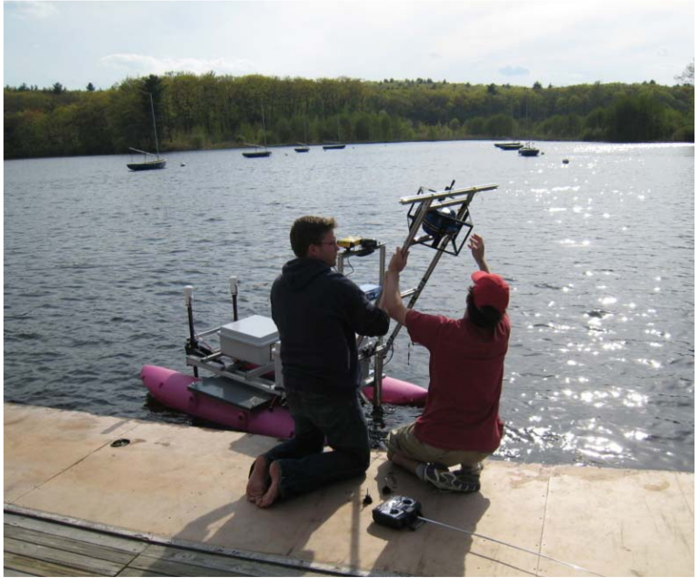

**Image 3:** The hydrophone and source array being deployed. On the main frame of the craft two IP67 water proof boxes house electronics and control systems. On each box IP67 pass-throughs are mounted through a plate which can be removed and altered without requiring additional modifications to the main housing. Additionally, the boxes are connected with a watertight tube allowing cables to be run between housings without additional pass-throughs.

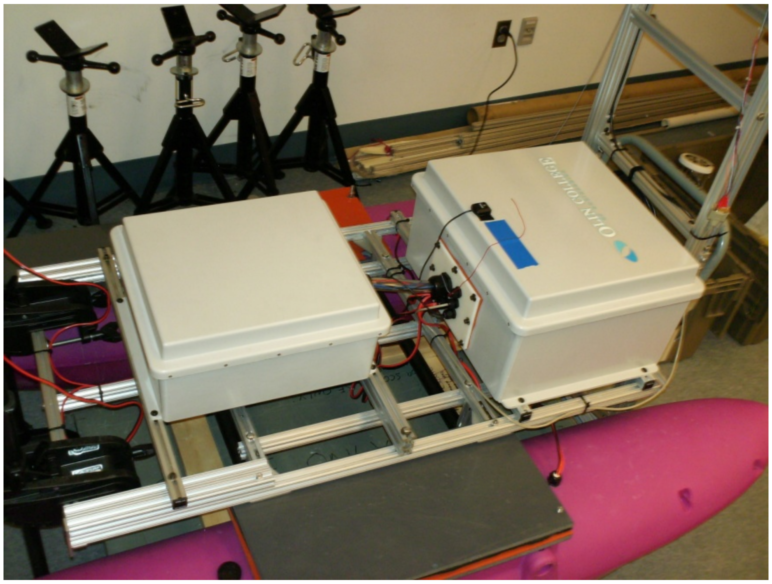

**Image 4:** Waterproof fiber-glass enclosures mounted on platform.

The craft is driven by two fixed electric trolling motors (model number here) mounted to the rear of the craft. Each motor provides 40 lbs of thrust (max) and is fixed to the craft using stock mounts. The motors are coupled using a horizontal beam that prevents their rotation and ensures a uniform depth (pictured in Figure XX). Differential steering simplifies the mechanical mounts (eliminates need for rotation) and has proven to be highly maneuverable. For deployment and transportation the motors can be raised above the base of the pontoons.

The motors are controlled using a Victor motor controller that produces a PWM signal at 2 kHz. The input to this controller is provided by the control computer and can be manually over-ridden by the operator using the remote control.

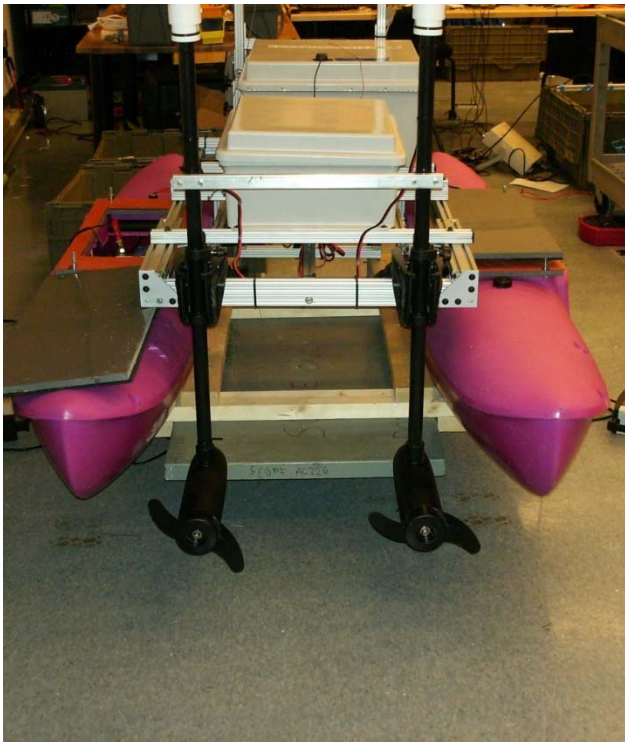

**Image 5:** Differential drive motors mounted on craft.

The power for the propulsion is supplied by two (model, voltage, amperage) batteries housed in the pontoons. A port was cut in the top of each pontoon and a gasket and bolt-on lid is used to provide a watertight seal. The battery position (fore and aft) can be adjusted to modify balance as additions continue to be made to the craft. Power for the electronics is provided by one (model, voltage, amperage) battery housed in the larger waterproof enclosure.

# Capabilities and Test Results

## Control

The OASC is capable of several different autonomous behaviors. There include

- Assuming a set velocity
- Assuming a given heading
- Basic waypoint following
- Basic line following.

The figures below show some of the results of autonomy tests.

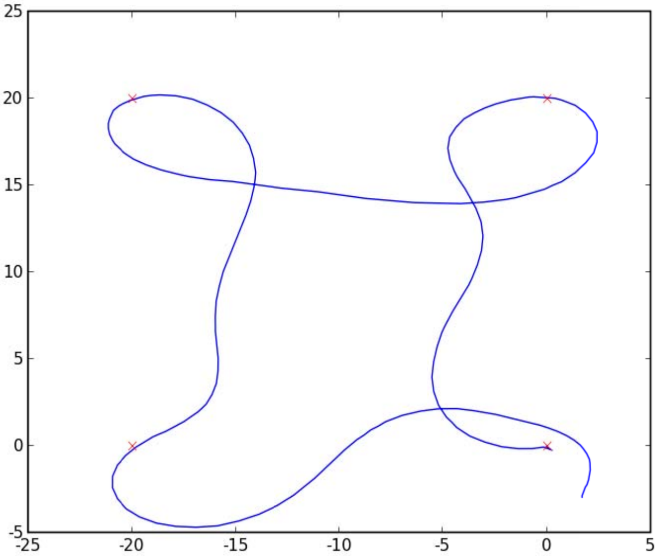

**Figure 1:** The platform is told to travel to four waypoints at the corners of a 20 x 20m square. As one can see, the boat hits each waypoint almost exactly.

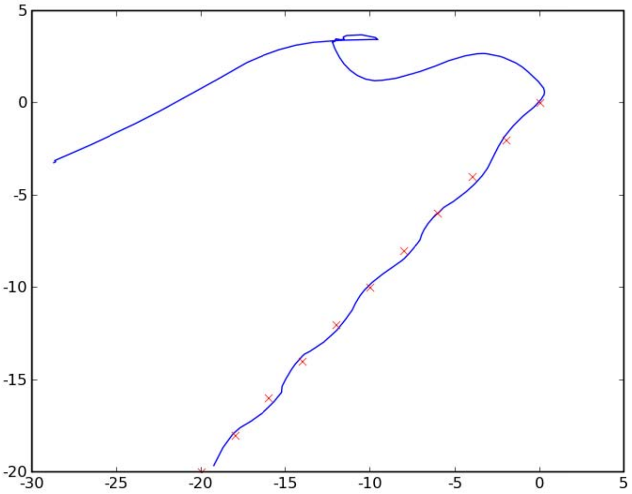

**Figure 2:** The platform is told to follow a series of points in a line. Note that the boat slaloms through the line, keeping fairly close to its goal.

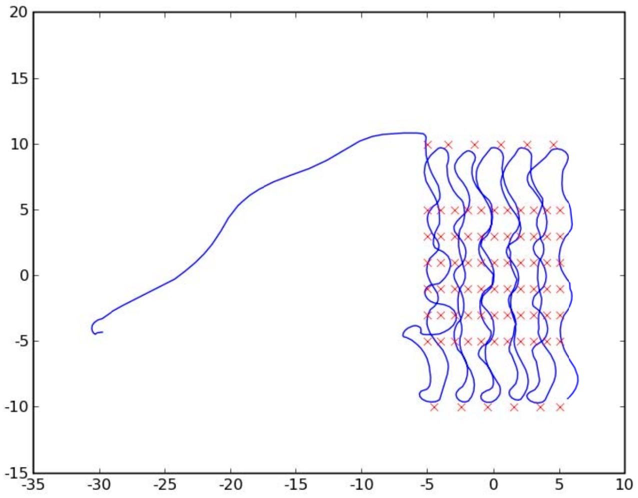

**Figure 3:** The platform is told to exhibit "mow-the-lawn" behavior. Note that the boat is consistently to the left of its goal. The control code for this portion of the test uses simple proportional control.

## Imaging and Acoustics

In order to perform acoustic imaging, the OASC carries on board a source and a collection of receivers. The source is an omni-directional underwater speaker purchased from Lubell Labs which is connected to the on-board computer. The computer drives the speaker with a series of sound files, usually either square wave impulse trains or sine wave sweeps. The speaker is mounted to the aforementioned frame at the bow of the OASC and drops down to about 3 ft. below the bottom of the pontoons.

For acoustic receivers, the OASC supports up to 8 hydrophones, also attached to the frame just below the speaker. When all 8 hydrophones are attached to the frame, they cover a length of about 0.5 m parallel to the beam of the boat, running port to starboard. Thus, when the OASC is executing a mow-the-lawn maneuver, it can "cut" a path of about 0.5 m on each pass. This reduces the time it takes to cover a given area.

As yet, no tests have been carried out using all 8 hydrophone; the team has instead concentrated on performing tests that involve just one of the on-board hydrophones, as the OASC is largely designed to be a proof-of-concept platform.

### Testing

Most of the testing for the acoustic imaging package has been carried out at Lake Waban on the campus of Wellesley College in Wellesley, MA. The tests have been performed in 10-12 ft. of water. An air-filled sphere (in this case, a basketball and later a hard plastic trawl float) was tied to a cinder block with a corner reflector between the ball and the block. When lowered into the water, the ball floated about 6 ft. above the lakebed. Another hydrophone was attached to the cinderblock and was connected to a separate computer on shore. This hydrophone was tapped against one of the hydrophones on the

OSPRE at the beginning and end of each test so that the two sound files could be lined up. The OSPRE would then maneuver in the area around the float. The speaker would be used to produce acoustic waves, while the hydrophones recorded.

It was ultimately decided that the best sound files for the speaker to be playing were those that made it easiest to determine when exactly a hydrophone began recording that sound and when that sound ended. Originally, sine sweeps from 100-4000 Hz were used, but the lower frequencies had much lower power and thus were lost in the background noise in the hydrophone attached to the cinderblock. The sound file used for testing is shown here.

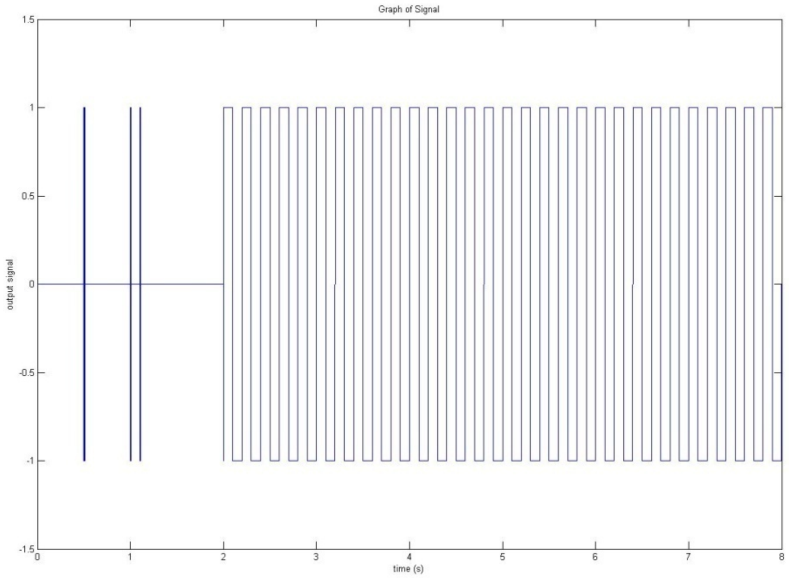

**Figure 4:** The transmit signal has a 10 ms 9000 Hz signal at the beginning, followed by two 10 ms 10000 Hz signals in quick succession. The signal then turns into a train of square wave pulses with frequency 5 Hz. The square wave signal lasts for about 1 minute before the synchronization pulses are repeated.

The pulses at the beginning and end of the signal are designed to help line up the recordings made by hydrophones on the boat with a stationary hydrophone attached to the target and connected to a computer on shore. The hydrophones are all held next to one another at the start of the test, and the sound file is started. The figure below shows the two files synchronized.

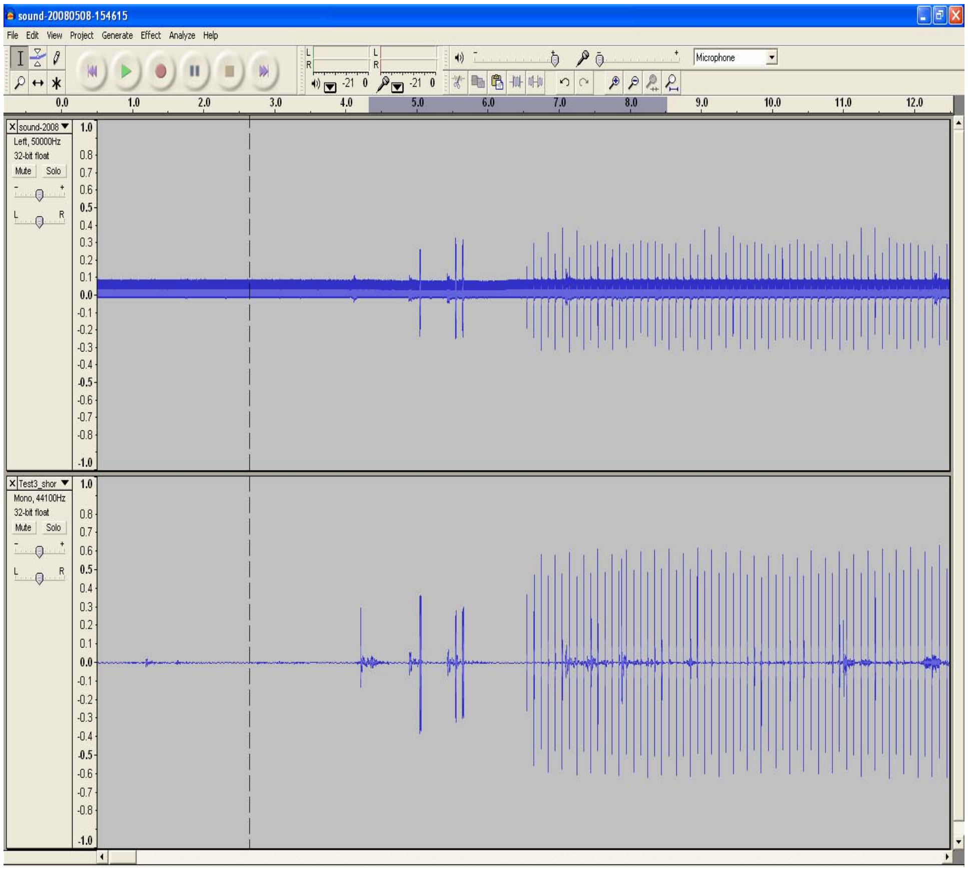

**Figure 5**: The top and bottom signals are the recordings made on the on-board and shore hydrophones, respectively. The sound files are moved until the pulses at the start of the recording line up.

There are several different preliminary acoustics tests that the Olin team carried out. One of the first was to make sure that neither signal was being clipped, as this would result in the loss of important information. The analog-digital converter on the OASC does not have a gain that is easily tunable. However, the shore hydrophone was running through a simple pre-amplifier and was recorded using a sound program called Audacity, which does have an easily tunable gain. Thus, the Olin team first tuned the volume on the speaker to such that the on-board hydrophone would be recording at about 50-80% of maximum, and then set the gain in Audacity to such that the same would be true of the shore hydrophone when the two were next to each other.

After this, several tests were carried out in which the platform was maneuvered around the target. The figure below shows one of the results.

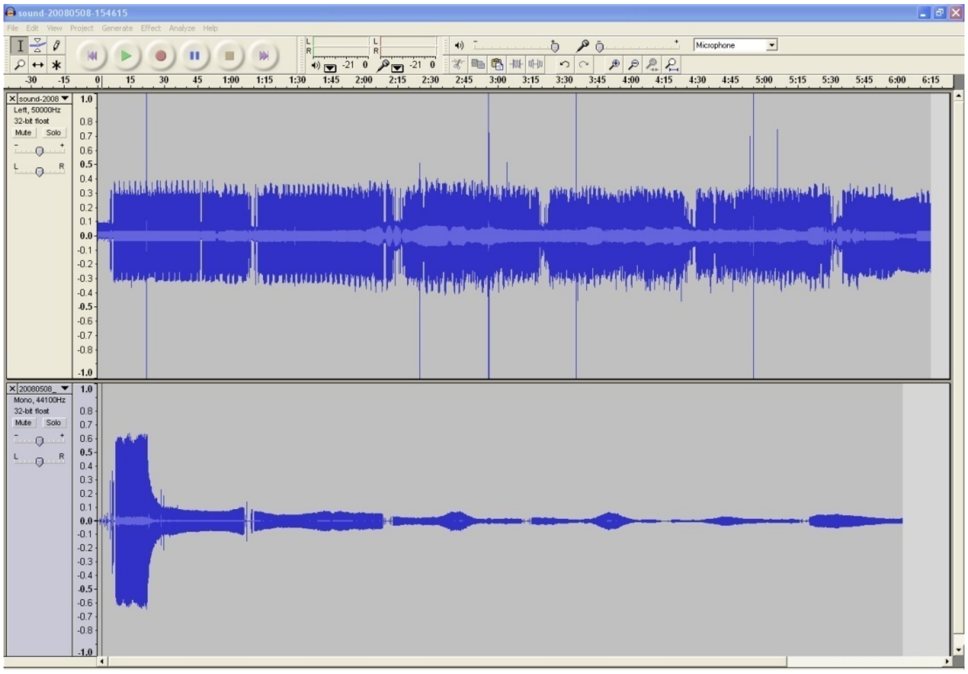

**Figure 6**: The top and bottom signals represent the signals recorded by the on-board and shore hydrophones, respectively. The boat was driven in a rough spiral via remote control in the area around the target. Note that while the magnitude of the on-board hydrophone signal remains consistent throughout, the magnitude of the signal recorded by the shore hydrophone decreases as the boat moves farther away from the target.

Also of particular interest is what the waveform looks like. Shown below is a sample of one of the pulses recorded by the shore-based hydrophone.

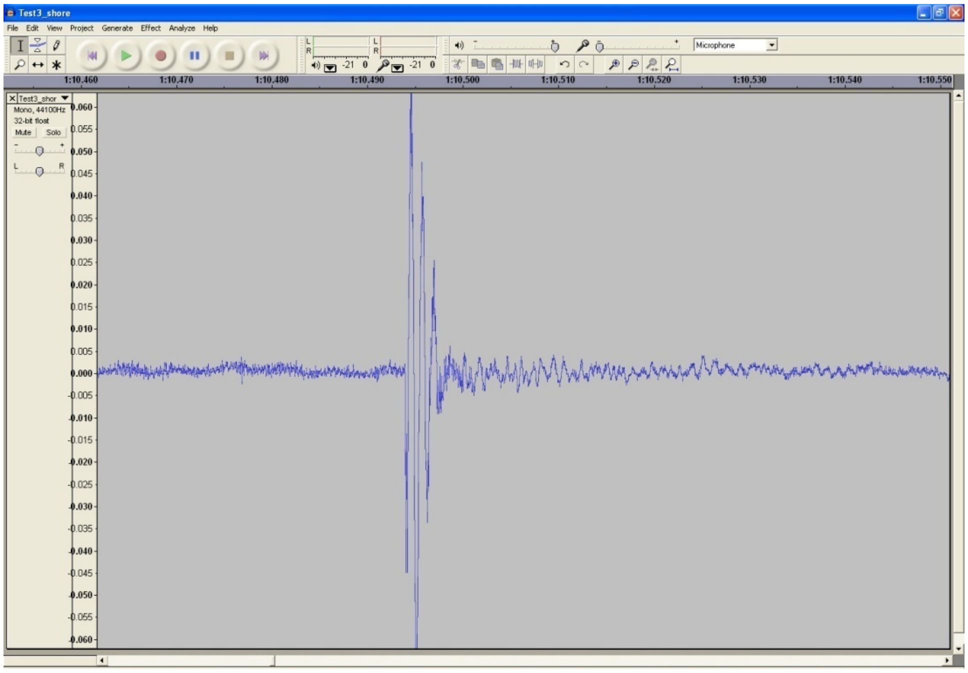

**Figure 7:** Note that, while the signal given to the speaker was a square wave, the speaker response is somewhat different.

The next step in testing is to begin analyzing the position data along with the acoustic data. Given that the speed of sound in water is known, one would expect to see a predictable difference between the time pulses were recorded on the boat and shore hydrophones. The time difference should be proportional to the distance the boat is away from the target, with the speed of sound being the constant of proportionality. This test has yet to be conducted, but it is the next step towards developing a platform capable of acoustic imaging.