Calibration of the USBL needed for successful homing and docking has been problematic, originally this calibration had been done by Benthos but we've since established the capability of calibrating the system here at MBARI to allow configuration alterations to be tested more quickly.

Testing of the transducer alone has shown the sensor to be accurate to within the manufacturer's specification (1 degree accuracy). When mounted in the vehicle the accuracy has been dramatically worse.

Transducer alone

The transducer alone has worked adequately and the concerns about using the system "end-on" have been alleviated as only a very minor sensitivity in the axis of the transducer has been seen. Figure 1 shows the measured accuracy of the system in this configuration. This graph shows the angular error between the actual sound vector and the measured sound vector as a function of sound source location in a vertical plane. The vehicle was 11 feet away from the plane the sound source was located on.

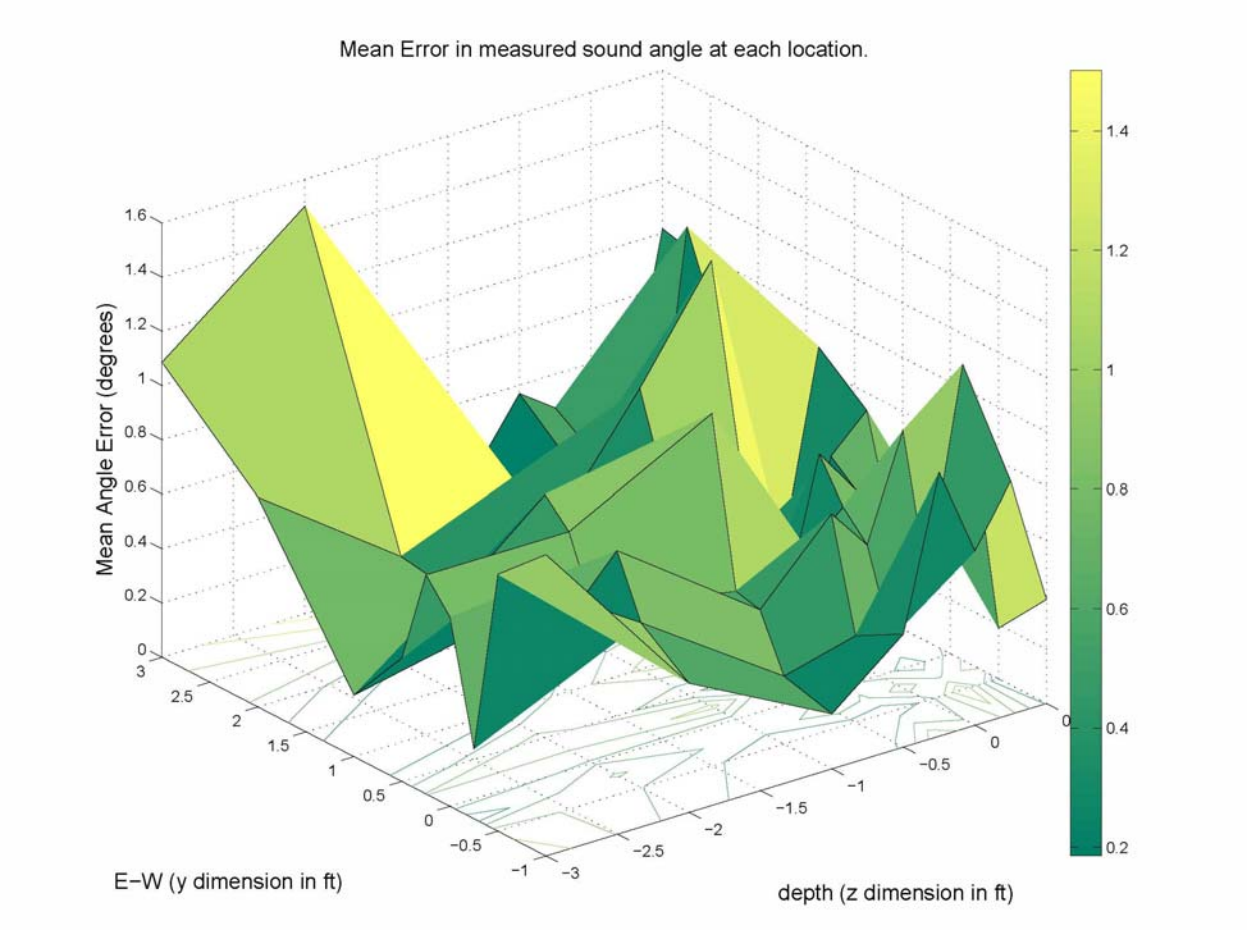

Figure 1: Accuracy of sensor in free space, no vehicle.

Tests with transducer behind fairing

Two main configurations with some variants have been tested. The first is shown in Figure 2 and has the USBL inside the fairing of the vehicle. This configuration performed poorly, we believe that reflections off the pressure hull and other elements in the vehicle corrupt the sound that the USBL sees (see Figure 4). Improvement was achieved by installing sound deadening material in the form of open cell foam behind the transducer. With this foam installed accuracies of about 10 degrees across were achieved.

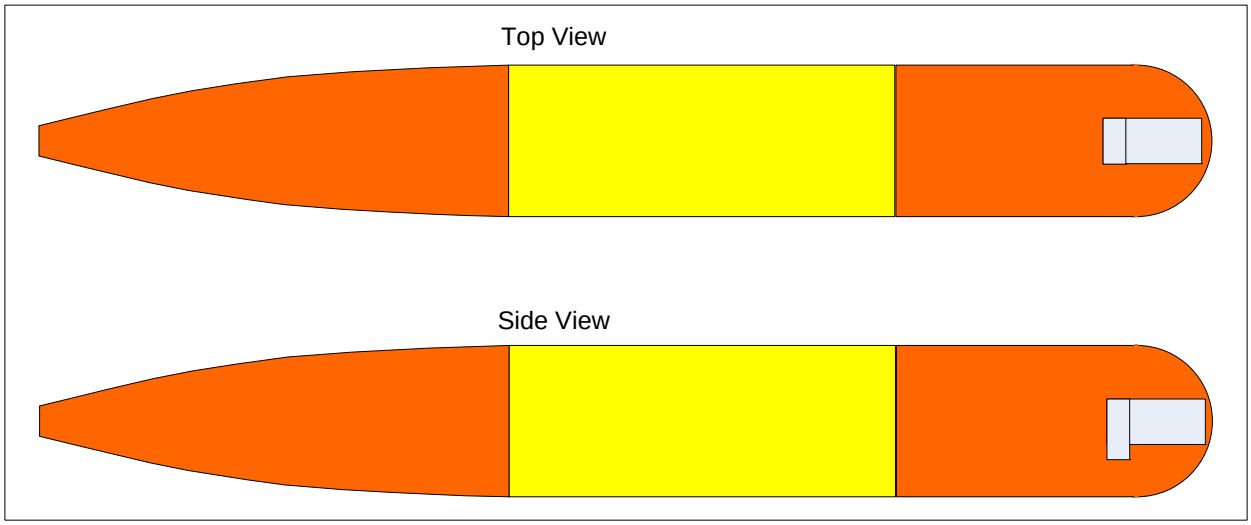

Figure 2: USBL mounted inside fairing.

Test with transducer outside fairing

A second configuration with the transducer protruding through the fairing was also tested, see figure 3. Not shown in the figure is the steel bail that is needed for vehicle operations, but this was included in the testing. This arrangement worked better and brought the accuracy that could be achieved down to 3-5 degrees after calibrating. The results were more consistent and included dramatically less “bad hits”.

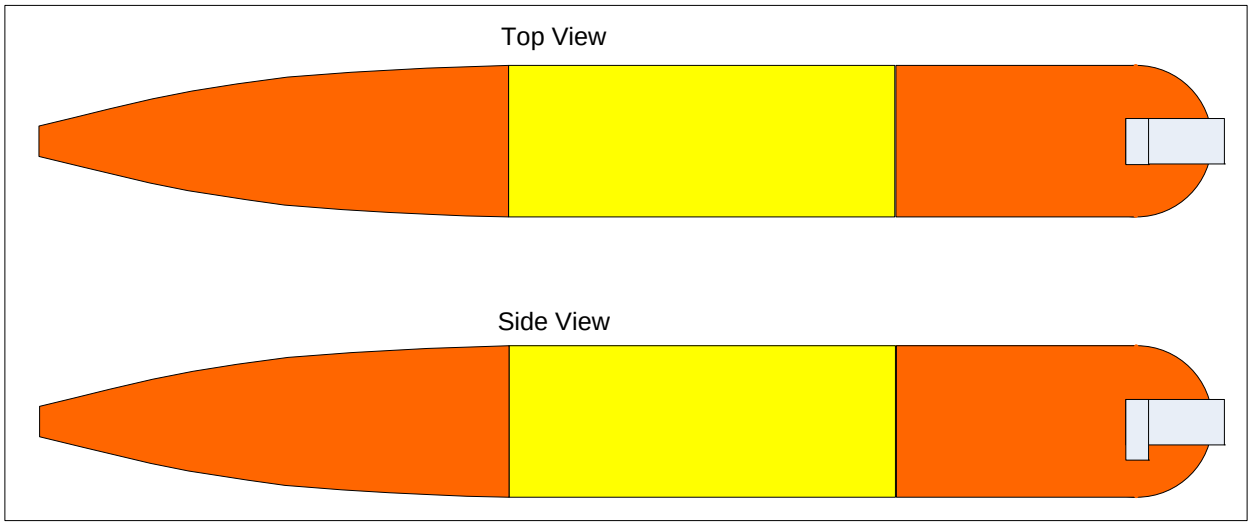

Figure 3: USBL mounted outside fairing.

Discussion

It is believed that reflections from the internal elements of the vehicle are contaminating the results of the USBL sound direction measurement as illustrated in Figure 4. Testing has shown that the presence of the fairing in front of the sensor does not have a strong effect on the accuracy. The results have been improved by adding sound deadening material behind the USBL and the internal pressure hull and other structures behind the transducer. These tests have utilized bits of open-cell foam and similar, not materials that are engineered for sound absorption. There are materials for this purpose and that can stand the pressure of being deep under water. The next step would be to repeat the tests of one or both of the above configurations with a more carefully designed and installed sound deadening block of such material. At the frequency range of this system (16kHz-21kHz), the attenuation of this type of material is 15-20dB, which is significant. See attached.

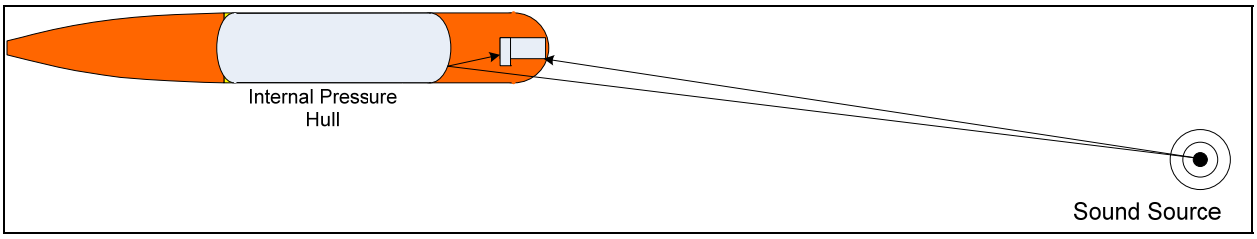

Figure 4: Illustration of possible reflections that corrupt USBL readings. Sound absorbing material between the pressure hull and the transducer improves performance.