Overview

The Benthos USBL system used as the primary sensor for docking the LRAUV has exhibited a very sensitive calibration behavior that has resulted in large changes in the apparent dock location (in terms of heading and elevation) due to small changes in the vehicle configuration. In the worst case, the calibration table has become multi-valued, meaning that more than one physical orientation of the vehicle results in the same apparent location of the target. Obviously this sensitivity must be eliminated for successful docking. Figure 1 shows the current configuration of the sensor in the vehicle and the sensors coordinate system.

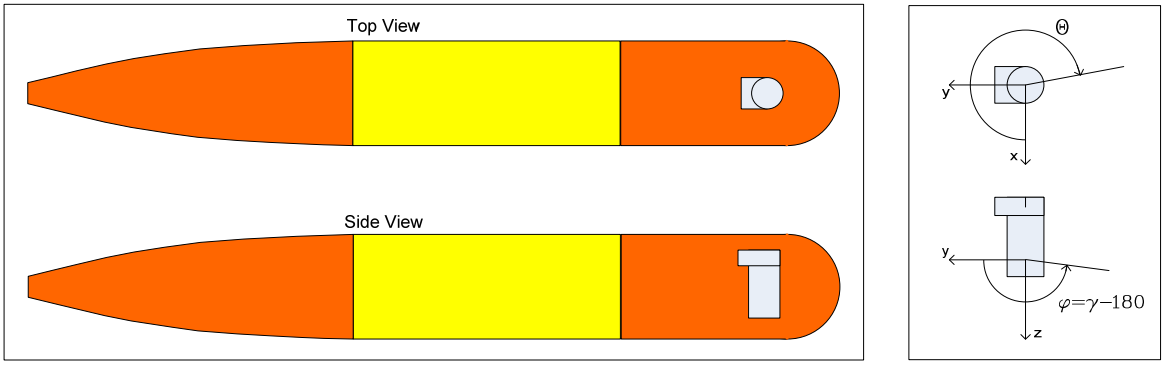

Figure 1: Current arrangement of USBL in vehicle and the sensors coordinate system.

The calibrations to date have been performed by Benthos as part of the initial purchase agreement. Because of shipping considerations and limitations of the Benthos test facility, only the nose of the vehicle has been shipped to them, with the sensor in free air or just in the nose fairing, acceptable calibration results have been achieved. When the sensor is mounted in the nose and the front end cap of the yellow section is included, the multi-valued problem has appeared.

In order to proceed with docking tests, this calibration issue needs to be resolved and confidence must be developed that the sensor is performing to a certain degree of accuracy and repeatability. Because more than one configuration change may be necessary to achieve this, and because it's possible that the entire vehicle may need to be present for accurate results to be achieved, further calibrations will be done at the MBARI test tank. A sub-set of such a calibration was performed here at MBARI previously when a Benthos engineer was here and subsequent discussions with the Benthos indicate that there are no fundamental reasons our tank will be inferior to the Benthos facility (it is in fact larger). The test plan involves aligning the pitch and yaw of the vehicle in the tank with the help of a laser rigidly mounted to the vehicle, roll alignment will be achieved using on-board AHRS instrumentation on the vehicle. With the vehicle fixed, an appropriate sound source will be positioned in the tank at a variety of locations by hanging it from the overhead gantry crane that allows x-y-z motions. Measurement of the cranes location to within 2 inches will result in angular accuracies of 1 degree, which is within the USBL's capabilities.

Possible Configurations to test for valid calibration

Benthos engineers have suggested that moving the face of the USBL transducer right up to the inside of the vehicle fairing could eliminate the multi-valued problem. If a valid calibration can not be achieved in this configuration the next step would be to have the transducer protrude through the nose, but this is undesirable for survivability and drag reasons so the inside-the-fairing configurations will be investigated first. There are two main mounting options illustrated by figures 2 and 3. Figure three shows an attractive arrangement but in this arrangement the

sensor coordinate system has a singularity straight ahead of the vehicle (at an sensor elevation of 90 degrees, all bearing angles refer to the same physical location, leading to numerical round-off errors near sensor elevations of 90 degrees.) For that reason the arrangement in figure 2 is attractive, although the internal mounting is more complicated.

By performing the calibrations of one or more of these mounting options here at MBARI, we should be able to establish the USBL's accuracy and repeatability performance in the exact vehicle that will be subsequently tested at sea. It should be remembered that in spite of a multi-valued sensor with resulting accuracy errors of tens of degrees, the vehicle hit the target on a few occasions and narrowly missed on many occasions. This seems to indicate that the homing algorithm is tolerant of bad data due to the filtering that occurs and that improved sensor data should improve homing and docking performance.

Tasks and Schedule

There are four main tasks to accomplish the testing described above

1) Return the vehicle to seaworthiness after the damage that was done when it was lost. The vehicle as significantly disassembled after that event and it will be operational in the test tank by the end of next week.
2) Set up test tank to accommodate these tests. This includes aligning the vehicle in the tank and establishing a system to accurately position the sound source. To increase the speed at which the tests can be performed, one axis of the crane will be instrumented to report position and the other two axes will be measured by hand. This will allow "sweeps" of measurements to be made across bearing at a fixed elevation angle.
3) Establish the necessary USBL data acquisition software. This is facilitated by existing software on the vehicle and is a relatively straightforward task that can be accomplished in a day or two.
4) Mechanical USBL mounting in vehicle for each configuration to be tested.

It is expected that the calibration work can be completed by the end of May, 2012.

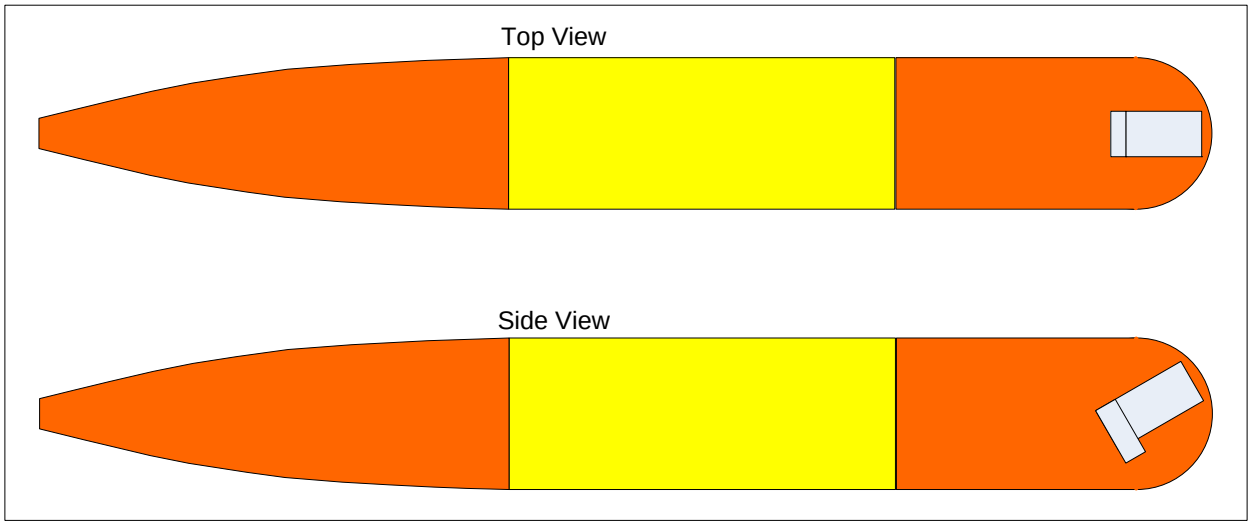

Figure 2a: USBL mounted inside fairing at an angle to avoid coordinate system singularity.

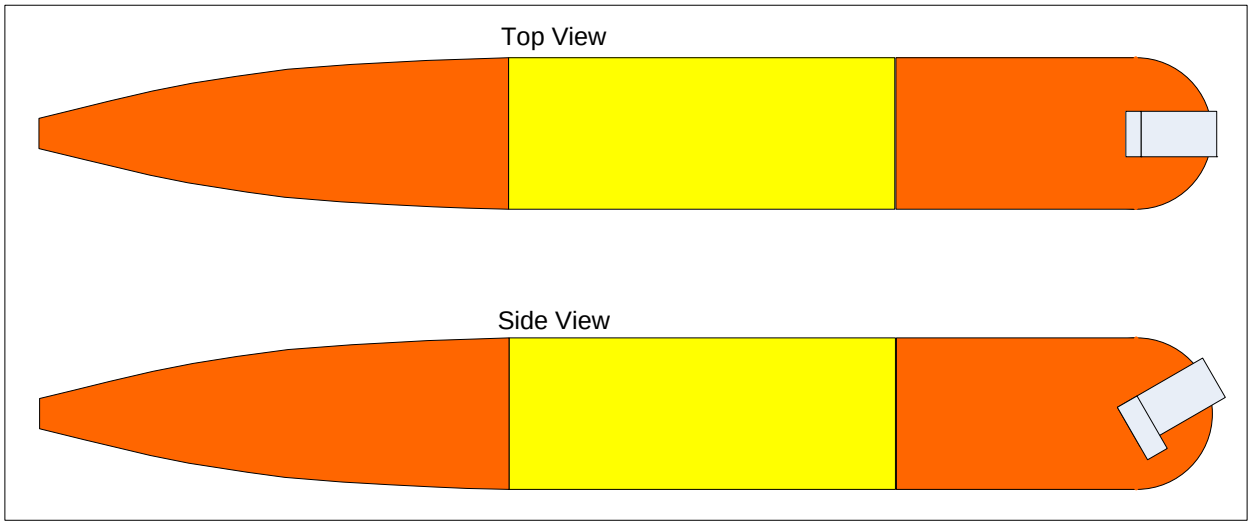

Figure 2b: USBL mounted outside fairing at an angle to avoid coordinate system singularity.

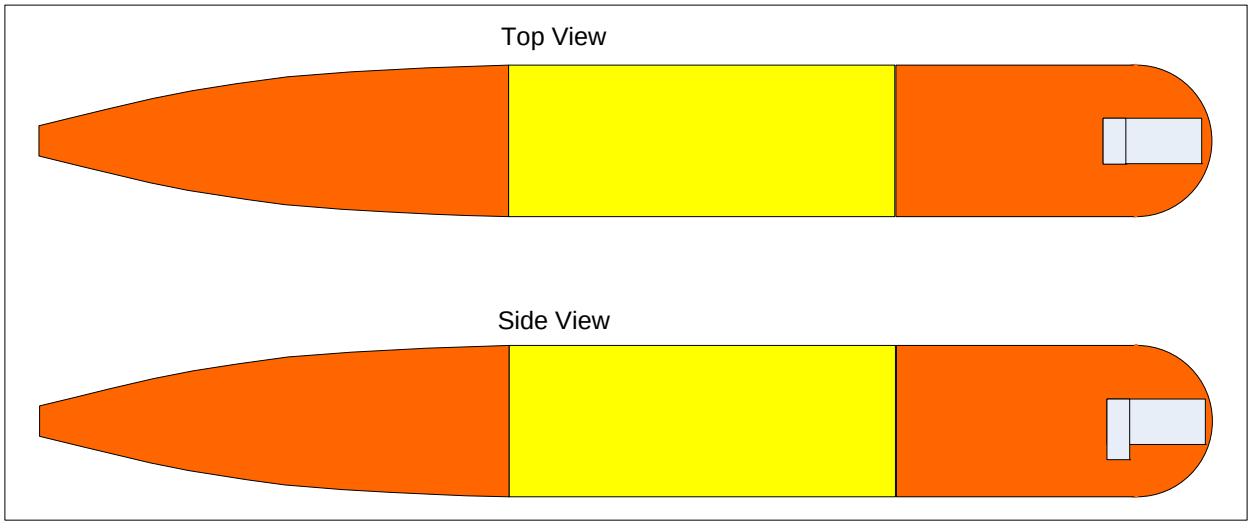

Figure 3a: USBL mounted inside fairing, coordinate system is ill-conditioned straight ahead.

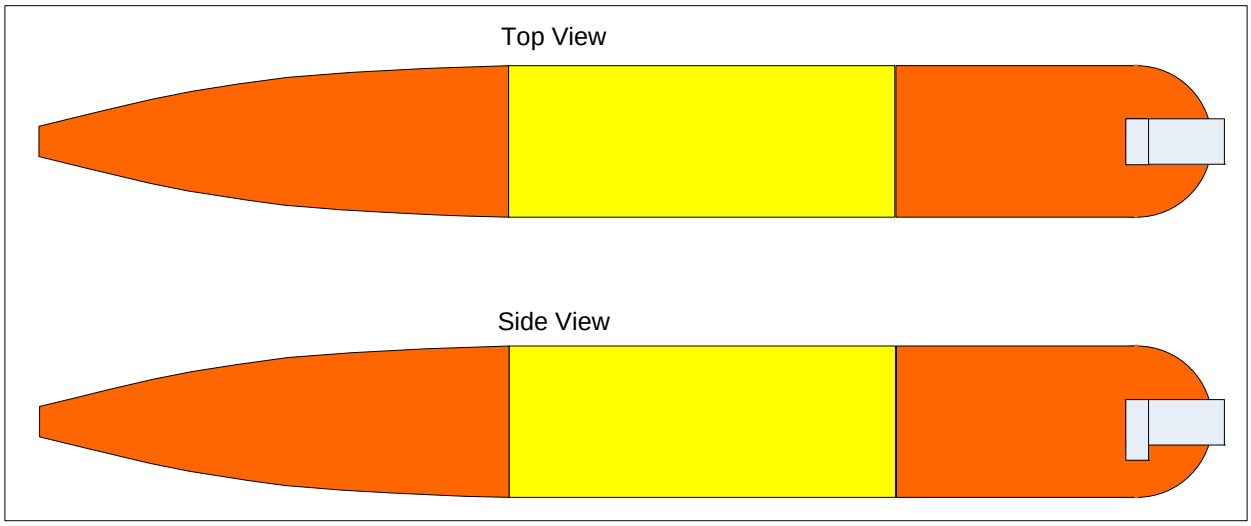

Figure 3b: USBL mounted outside fairing, coordinate system is ill-conditioned straight ahead.