# Increased Underwater Optical Imaging Performance via Multiple Autonomous Underwater Vehicles

Jules S. Jaffe
Scripps Institution of Oceanography
University of California, San Diego
La Jolla, CA 92093-0238
phone: (858) 534-6101 fax: (858) 534-7641 email: jules@mpl.ucsd.edu

Award Number: N00014-08-1-1045
http://jaffeweb.ucsd.edu/

## LONG-TERM GOALS

The major long-term scientific goal of this program is to explore techniques for increasing the performance of underwater optical imaging systems using Autonomous Vehicles.

## OBJECTIVES

The major goal of this project is to explore the possibility of using Multiple Autonomous Underwater Vehicles for increasing the performance of underwater optical imaging systems. The main objective, in this context, is to simulate the potential benefits that multiple vehicles can have in increasing the range, imaging footprint, and potentially 3-dimensional applications that can be afforded using this new approach. This report details the Year 2 efforts that culminated in the execution of an experiment that was performed just a week ago (September, 2008) on a cruise in the Santa Barbara channel.

## APPROACH

Last year's efforts were focused primarily on a demonstration of the utility of the MAUVIO concept via underwater computer optical image simulations. Over the last decades, we have used an underwater optical imaging program entitle UNCLES in order to simulate the output from a proposed configuration of lights and cameras. The program has, as input, the 3-dimensional locations of lights and cameras and their pointing angles in a Eulerian frame of reference. The lights are considered to be monochromatic, however, wide band illumination can be determined via repeated simulations at different narrow bands with the concomitant environmental characteristics. The lighting pattern can also be varied to correspond to either a narrow sheet like beam or a wide beam with arbitrary theta and phi beam widths being specified by an arbitrary radial dependent intensity pattern. The camera description includes the f# of the camera lens in addition to the focal length and the number of resolution elements. A reflectance map is input with an arbitrary reflectance profile that can be used to simulate either interesting images or a range of contrast values that the user expects to encounter in real situations.

In previous work we demonstrated the advantages of the MAUVIO concept via the comparison of two configurations of lights and cameras. One configuration corresponds to a single AUV where the camera is mounted on one end and the lights are mounted on the other end. The other configuration

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| 1. REPORT DATE<br>**2008** | 2. REPORT TYPE | 3. DATES COVERED<br>**00-00-2008 to 00-00-2008** |
|---|---|---|

| | |
|---|---|
| 4. TITLE AND SUBTITLE<br>**Increased Underwater Optical Imaging Performance via Multiple Autonomous Underwater Vehicles** | 5a. CONTRACT NUMBER<br>5b. GRANT NUMBER<br>5c. PROGRAM ELEMENT NUMBER |
| 6. AUTHOR(S) | 5d. PROJECT NUMBER<br>5e. TASK NUMBER<br>5f. WORK UNIT NUMBER |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>**University of California San Diego,Scripps Institution of Oceanography,La Jolla,CA,92093** | 8. PERFORMING ORGANIZATION REPORT NUMBER |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | 10. SPONSOR/MONITOR'S ACRONYM(S)<br>11. SPONSOR/MONITOR'S REPORT NUMBER(S) |

12. DISTRIBUTION/AVAILABILITY STATEMENT
**Approved for public release; distribution unlimited**

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT<br>**unclassified** | b. ABSTRACT<br>**unclassified** | c. THIS PAGE<br>**unclassified** | **Same as Report (SAR)** | **5** | |

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Prescribed by ANSI Std Z39-18

corresponds to the same camera location, however this time the illumination is provided by an AUV that is located closer to the target with a broad illumination pattern. Figure 1a shows the geometric location of the devices including the beam widths of the light sources and the size of the reflectance map.

In order to test the concept in a more quantitative setting, an experiment was planned in concert with the RADYO program that is taking place. Shown in Figure 1b, the plan was to hang a target below a system of flood lights and suspend both lights and reflectance map below a high sensitivity CCD camera. The lights could be moved up and down via a series of pulleys and therefore, the distance between the target and the lights could be varied while the distance between the target and the camera was held constant. In order to prepare for this experiment, a frame was fabricated, single wavelength leds in the blue and green were purchased from Deep Sea Power and Light (San Diego, CA) and a test target was printed on a screen.

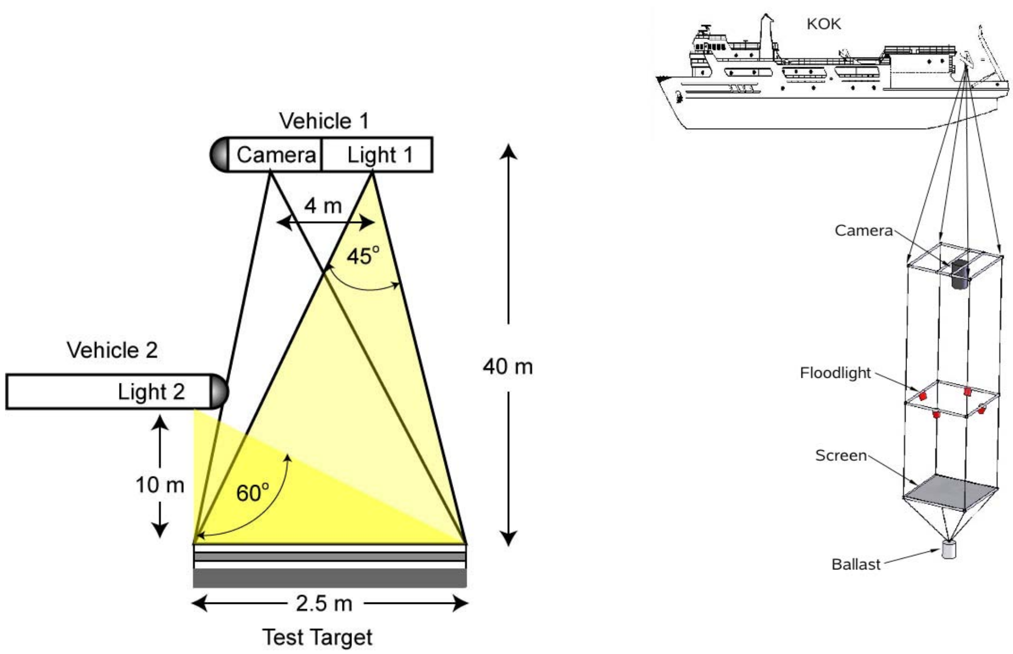


***Figure 1. (a) The geometry used to compare the potential performance increase possible with multiple vehicles. Shown are a single camera and 2 light configurations to be illuminated separately. (b) The experiment performed this past September on the Kilo Moana. Shown are a camera, several floodlights, and a screen upon which a test target is painted.***

Figure 2 shows the experimental apparatus as it was tested in one of the tanks at the Scripps Instution of Oceanography. Mr Kevin Liu, an electrical engineering undergraduate in our lab helped in all tests. The apparatus consisted of a set of floats that were anchored to an underwater camera frame that floated up to a set of stainless collars that were placed on the suspension rope. The camera used was a sensitive CCD camera (Cooke Sensi-Q) enclosed in an underwater housing. The lights are shown below the floats. In the water, the lights were negatively bouyant so they sunk to a set of collars that were attached to the ropes at a strategic location. A pulley system was then used to raise or lower the lights. The test target was screen printed onto a 1 m x 1 m white surface. It hung at a fixed distance from the lights that was established by another set of collars that stoppered the camera  A variable resolution reflectance map was used to test the resolution of the target as a function of the settings of the apparatus.

**RESULTS**

The system was deployed on the Kilo Moana during the RADYO cruise with our nightime deployments taking place on Sept 17, 18, 20, 21, and 22.  In all deployments the cameras and lights functioned well.  The initial deployments used a 30 m separation between the camera and the test target.  However, due to strong shear currents in the water column, the test target “kited” away from the viewing area of the camera, preventing the camera from seeing the target.  Since we were only allocated a four to five hour block of time each evening, we were unable to readjust the distance and refocus the camera until the next night.  By the last several nights, we had shortened the distance to 10 meters and this worked well.  Over the course of several hours, the lights were raised and lowered and a series of experiments were performed.

***Figure 2.  A photograph of the apparatus show in Figure 1b.  A camera with floats is on the top of the fixture.  Below is a set of four lights and below that is a test target that is printed onto a screen.***

The results are shown in Figure 3 for one of the series where the target-light distance was varied from six feet (upper left) to almost twenty feet (lower right).  As expected, the amount of backscatter increased for each picture.  Since these results were only obtained relatively recently, we have not had time to analyze them thoroughly.  Synergistic activities by the RADYO Principal Investigators were being carried out and Inherent Optical Properties were measured such as absorption, scatter, and even some indication of the Volume Scatter Function (VSF). Future work will use computer modeling in conjunction with the IOPs to quantify our trade-offs in image contrast and resolution with target light separation.

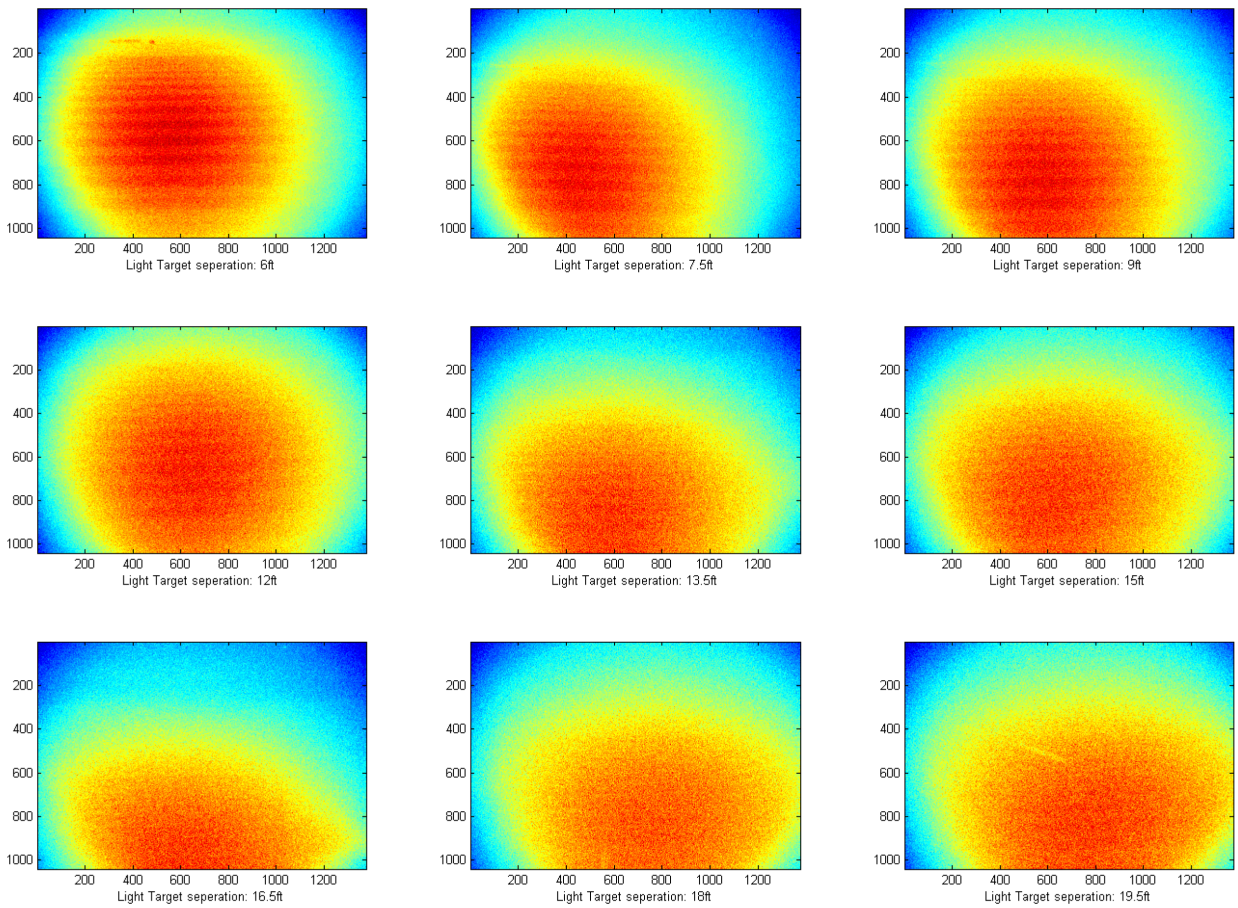


***Figure 3.  A pseudo colored set of images from the experiment where light target distances were varied with the camera target distance fixed.  The images show that as the lights are moved from being close to the target (upper left) to farther away the image contrast decreases.***

## RELATED PROJECTS

This experiment took advantage of the underwater sensitive CCD cameras that are in Dr. Jaffe's lab. NSF funded these for a project that used stereo cameras to perform underwater Particle Imaging Velocimetry.  In addition, our experiments were carried on board the Kilo Moana that was being used primarily for the RADYO "calm waters" deployment in the Santa Barbara Channel.  Numerous researchers were on board making extensive measurements of the water column that will be used for our computer modeling of the experiments.  Since these researchers were interested in day measurements of the water column radiance, the ship was available in the first part of the evening for our use exclusively.  We anticipate that these IOP measurements will be a valuable adjunct to our next phase that will be a modeling study to quantify the relative trade-offs in a realistic environment.