Assessing Plankton and Particles with an Autonomous Imaging LOPC

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LONG TERM GOALS

We wish to characterize and quantify particles and plankton in the pelagic ocean, to enable an understanding of their dynamics and their roles in ecosystems and biogeochemical cycles. Characterization and quantification are also necessary to describe the distribution and abundance of particles and plankton in the sea in relation to the environment, including its acoustic and optical properties.

OBJECTIVES

Our objective is to integrate the Laser Optical Plankton Counter (LOPC, Herman et al. 2004) with a video imaging system, REFLICS (REal-time Flow Imaging and Classification System, Iwamoto et al. 2001), and deploy this on a motored autonomous underwater vehicle (AUV). The result will be an instrument capable of autonomously assessing the distribution, abundance, size, and type of plankton and particles of 100 μm – 2.5 cm equivalent spherical diameter (esd). The novelty and strength of our work derives from combining video imaging, with its high resolution, the LOPC, with its high sampling rate, and the AUV, with its autonomous and quiet performance, to provide data useful for predictive models. Computer analysis of video images allows the classification of the plankters and particles that comprise dominant features of the size spectrum measured by the LOPC. Our intent is that this system will be commercialized for general use in measuring properties necessary to understand and predict optics and acoustics of coastal seas.

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APPROACH

We proposed three tasks: 1) fabrication of REFLICS to operate *in situ*; 2) integration of REFLICS and the LOPC for use on an AUV; and 3) development and proof-of-concept deployments. REFLICS was originally designed for use in a laboratory. We have preserved the simple yet effective operating principles of REFLICS while miniaturizing some components, reducing overall power consumption, and designing and fabricating an underwater housing. The LOPC has also been modified for use in the AUV, e.g., in regard to power consumption and weight. Bluefin payload and nosecone have been acquired and modified to accept REFLICS and the LOPC. Deployments will be on the Dorado AUV of the Monterey Bay Aquarium Research Institute (MBARI).

WORK COMPLETED

By fall of 2006, the following tasks were completed: 1) CAD design of the submersible camera REFLICS and commencement of machining and fabrication of mechanical components, 2) Re-design of LOPC power boards & ordering of the LOPC, and 3) ordering of the AUV payload section and design of the frame for mounting LOPC & REFLICS in the AUV payload section. Specific activities in 2007 consisted of: 1) assembly and testing of the underwater REFLICS, 2) LOPC power board development, testing and reprogramming of the LOPC firmware and, 3) assembly of internal components of the AUV payload section. Details of activities in 2007 follow.

Real-time FLow Imaging and Classification System (REFLICS)

During January – April 2007, the mechanical components of the REFLICS camera were assembled at BIO (Bedford Institute of Oceanography) and the optics assembled at SIO (Scripps Institution of Oceanography). The assembled internal components of the system are shown in Fig. 1 and consist of

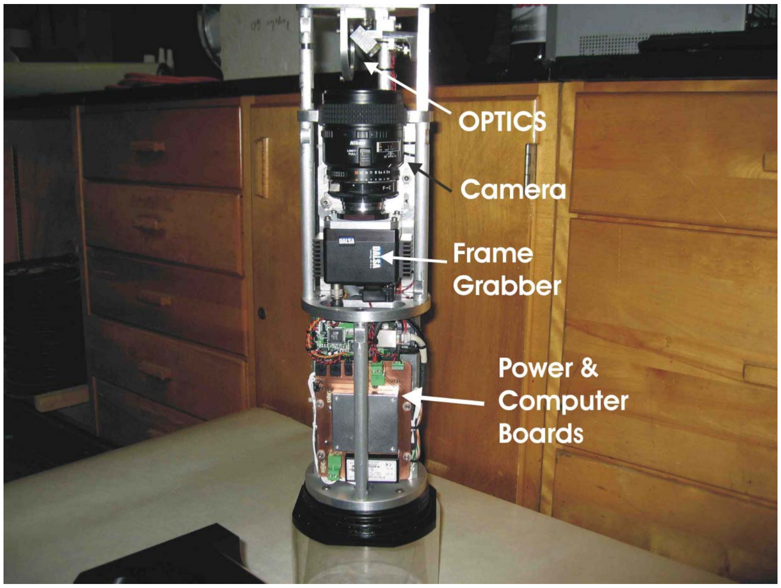

Figure 1. Photograph of Real-time FLow Imaging and Classification System (REFLICS) assembled for use in its underwater housing.[REFLICS is standing upright. From top to bottom are the optics, camera, frame grabber, and power and computer boards. The unit is approximately XX cm high and YY cm in diameter.]

power/computer boards, frame grabber, camera/lens and optics, where the latter includes a linear LED array, mirrors, and diffuser. The tested power requirements of the REFLICS were 30W at 12VDC. The completed assembly mounted inside its pressure case is shown in Fig. 2.

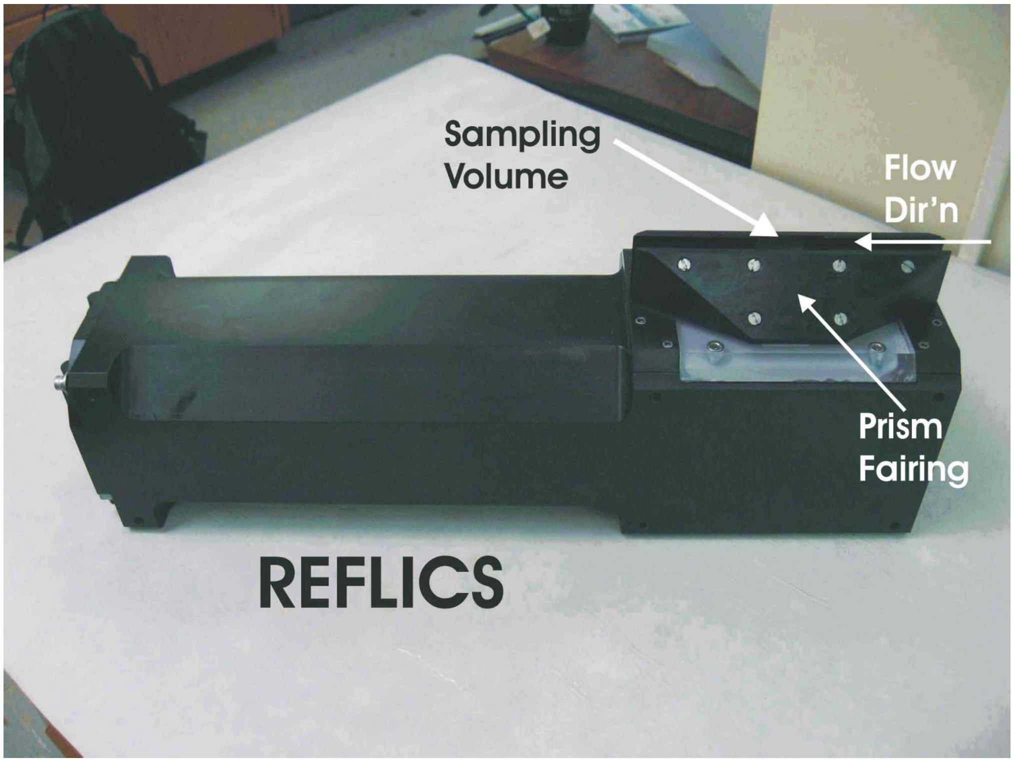

Figure 2. REFLICS in its pressure case. [REFLICS is black, lying flat, and is 11-cm in diameter and 71-cm long. On the right is the sampling volume, which is bounded on the bottom by an optical window and on the sides by the two prisms, which reflect light from the optical window through the sampling volume and back into through the optical window. The direction of flow is from right to left.]

The uniqueness of the optical design lies in the use of two, right-angled prisms which apply 2 x 90^0 reflections to the emerging light beam thus return it back to the case via an acrylic window. As a result of this optical design, only a single pressure case is required. The sampling volume shown in Fig.2 is surrounded by the two prisms, which face one another and are separated by a distance of 1.2 cm. The prisms are housed inside aluminum fairings (Fig. 2), which provide optimal, undisturbed flow and also mechanical protection for the prisms. The 'effective' volume sampled by each 512 x 512 frame is 3.8 milliliters.

In addition to lab tests, REFLICS was also tested off San Diego on the R/V Sproul in April 2007. The case was mounted within a protective frame shown in Fig. 3 and was 'yo-yoed' by winch from 3-8m depth at a nominal speed of 1 m sec^{-1}. The field trials also provided us an insight into data volumes that can be expected under normal operational conditions. In 1/2 hr. of deployment, approx. 300,000 images were acquired, consisting primarily of marine snow particles.

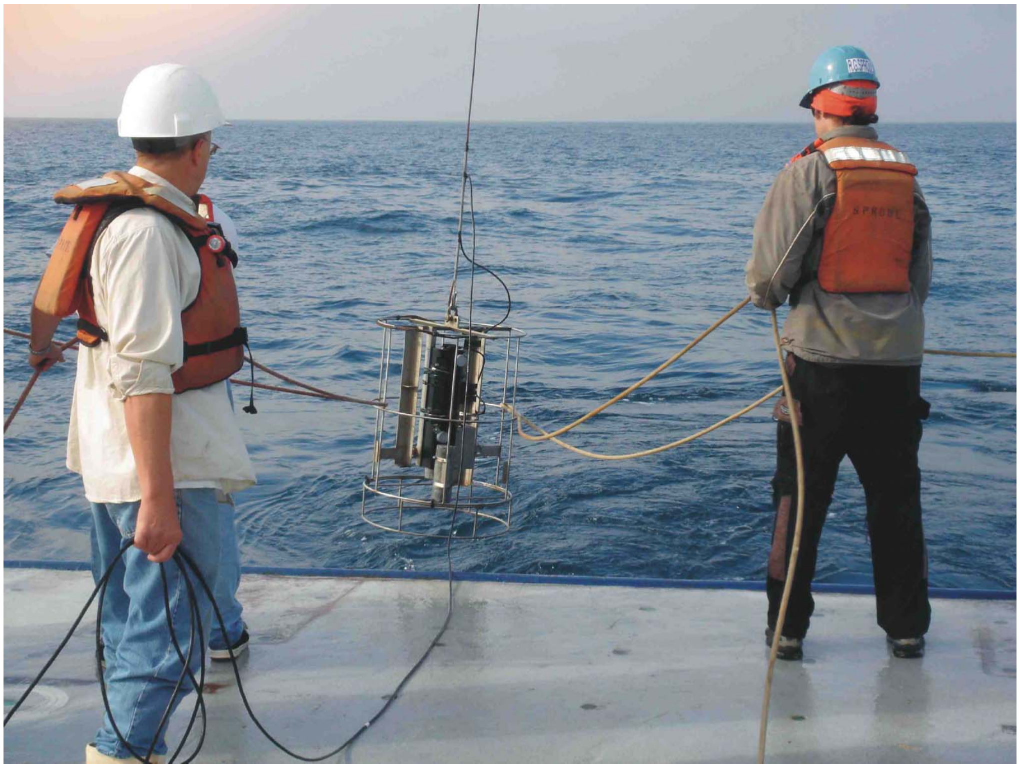

Figure 3. REFLICS being deployed off San Diego from the R/V Robert Gordon Sproul in April 2007. [Two men are handling ropes attached to a frame containing REFLICS as it is lowered by an electromechanical cable over the stern of the ship into the ocean. REFLICS is visible as the long, black pressure case in the middle of the stainless-steel frame.]

Laser Optical Plankton Counter (LOPC)

The LOPC power boards were redesigned to decrease power consumption for deployment on an AUV. The new power boards were essentially an adaptation of those used on the LOPC mounted on the SOLOPC, an autonomous Lagrangian drifter/profiler developed by Checkley, Herman, R. Davis, and G. Jackson with NSF funds. The final design of the LOPC used on the AUV will require only 8W at 12VDC. The LOPC firmware has also been modified to operate autonomously by auto-starting its programs on power-up and storing its data to an onboard flashcard. Since data transfer to flashcard is a slow process, storage will occur when the AUV surfaces for a position fix. Data acquisition will commence as the AUV descends >5m depth and will be stopped as the AUV as the AUV ascends <5m depth.

AUV Payload Section

The LOPC/REFLICS will be mounted inside a payload section of dimensions 101-cm (40-inches) length and 53-cm (21-inches) diameter and interfaced to the Monterey Bay Aquarium Research Institute (MBARI) Dorado AUV. A frame designed for mounting the LOPC and REFLICS was fabricated in 2007. The frame assembly is then mounted and attached to the inside of the payload section as shown Fig. 4, where the section has been split for purposes of access.

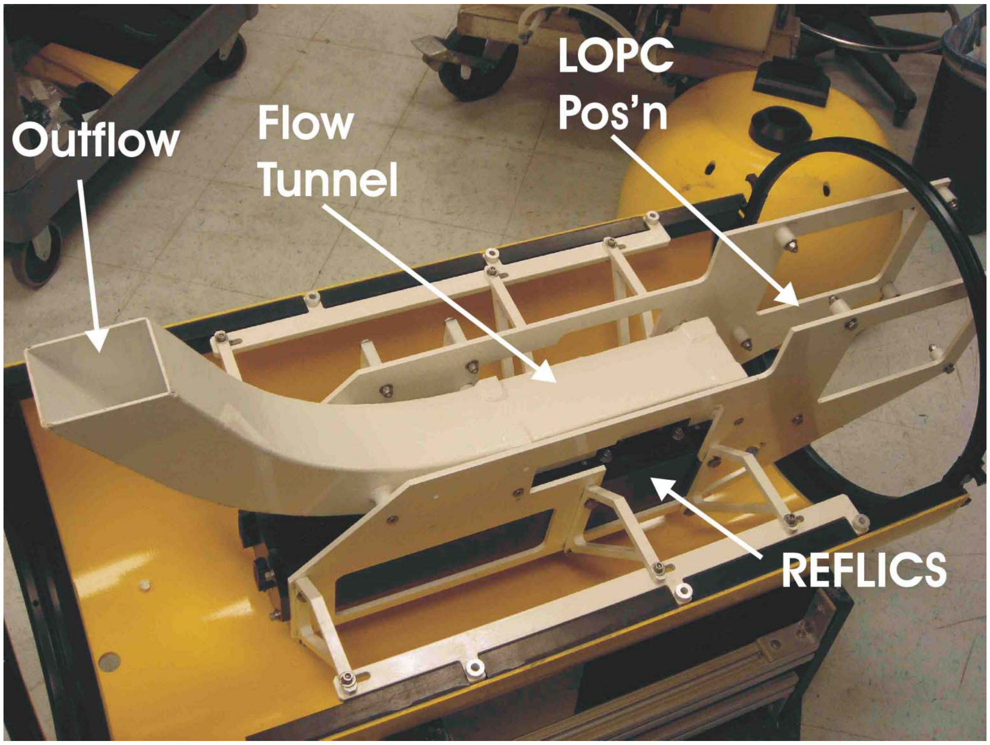

Figure 4. Photograph of flow assembly to hold LOPC and REFLICS in MBARI's Dorado AUV. [The upper half of the cylindrical, 53-cm-diameter outer casing of the AUV payload section is shown with the flow channel exposed. Flow enters the front of the AUV on the right, passes in its entirely through the LOPC sample tunnel, and in part through the REFLICS sample volume, before exiting the sample tunnel through the outflow port. The nose cone is shown in the background, with rectangular port.]

The mounting position for REFLICS and the LOPC are also shown in Fig. 4. Water flow begins at the tip of the nose cone, enters the LOPC, passes, in part, through the sampling volume of REFLICS (Fig. 4), and subsequently by CTD sensors (not shown). The flow then exits at the side and back of the payload section. The assembly shown in Fig. 4 was shipped to MBARI in April 2007 for initial lab configuration tests conducted jointly with MBARI staff.

Planned Activities 2008

The REFLICS is currently being tested in the Bedford Basin at BIO mainly for purposes of software development. The large data volumes encountered require improved software protection from 'acquisition crashes' and improved data downloading. Tests and development will continue throughout Nov.-Dec 2007 and the REFLICS will be shipped to SIO in Jan. 2008. Software development for the LOPC has been completed and the LOPC will be tested and shipped simultaneously with the REFLICS. The first field deployment of the LOPC/REFLICS mounted on the MBARI DORADO AUV are planned between Feb-April 2008.

RESULTS

We have only briefly tested REFLICS in seawater to date. Images, of zooplankton, acquired in April 2007 from the R/V Sproul are shown in Fig. 5.

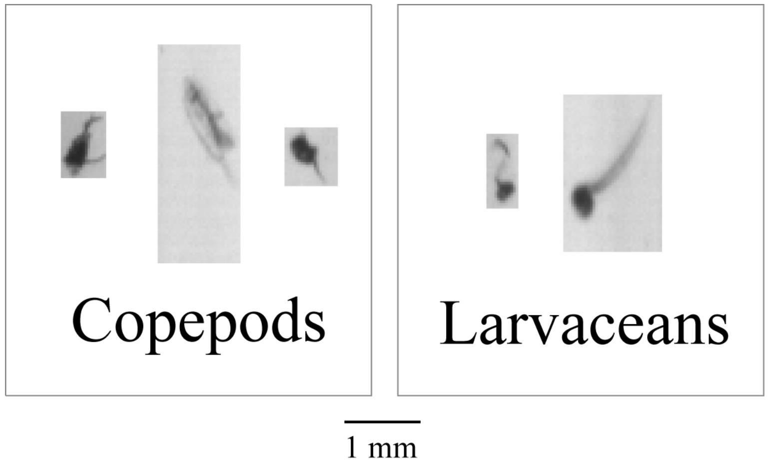

Figure 5. Images of zooplankton obtained during first use of REFLICS. [Each image has been segemented, in real time and in situ, from a 512 x 512 pixel image and written to file. The three images on the left are of copepods and the two images on the right are of larvaceans. The scale bar is 1mm. The zooplankters shown here range in size from about 0.7 mm to about 5 mm in length.]

IMPACT/APPLICATIONS

Our objective is to create an autonomous instrument capable of assessing particles and plankton in situ. Further, we are attempting to create the underwater version of REFLICS, for use independently or with the LOPC on an AUV, for general use, commercial production, and with a reasonable cost. We anticipate that our system (AUV, LOPC, and REFLICS) and REFLICS alone will be of significant value to marine scientist assessing and investigating particles and plankton in situ.

TRANSITIONS

Our project is not far enough along for transitions to have occurred.

RELATED PROJECTS

Checkley and Herman, with Russ Davis (SIO) and George Jackson (TAMU), have a Major Research Instrumentation grant from NSF is to create the SOLOPC, a profiling, Lagrangian, autonomous float consisting of a SOLO float, LOPC, fluorometer, and Iridium communication. Two SOLOPCs have been constructed and tested. Two excellent datasets (3 days and 63 dives in 2005 and 5 days and 88 dives in 2006) have been obtained and are currently being analyzed. Modifications to the LOPC made for the NSF MRI project are transferable to the present project with REFLICS and the AUV. In addition, important characteristics of the float (SOLOPC) and envisioned AUV are similar in important ways, particularly being autonomous and free from ship motion, thus giving us confidence that the present project with REFLICS, LOPC, and the AUV will succeed.

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PUBLICATIONS

None.

PATENTS

None.

HONORS/AWARDS/PRIZES

None.