New Techniques in Applying Additive Manufacturing to Deep-sea Ocean Exploration

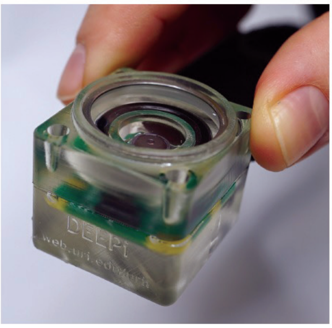
by Brennan Phillips

A global community of deep ocean scientists relies on technology to enable exploration, sampling, and observation of this extreme environment. An impressive array of remotely operated vehicles, unmanned underwater vehicles, and manned submersibles are employed in these efforts; these systems can be physically large and often cost millions of dollars to build and operate. The technology development behind most deep-sea platforms is driven by the offshore oil and gas industry and naval applications, whose needs are often focused on heavy-duty operations. The net result is a limited array of options for deep-sea scientists, who are always limited in funding and often require more nuanced and delicate tools to conduct their research.

Recent advances in additive manufacturing can be employed to reduce the cost of deep-sea technology, and also offer an unprecedented ability to produce custom and purpose-built sampling devices. For example, the DEEPi camera system (Figure 1) is a Raspberry Pi-based camera tested to depths >5 km and has been used to record and broadcast live imagery on multiple expeditions. Using a 3D-printed "shell" as a mould, the camera is partially potted without filling the optics assembly with epoxy, and no other manufacturing process is required to produce the required o-ring seal. The same stereolithography (SLA) 3D-printing process can be used to fabricate small pressure housings and endcaps, which I have personally tested to depths >1 km. This capability is critical for rapidly transitioning technology development from the laboratory into the field, and also empowers students in ocean science and engineering to directly design and produce their own deep-sea devices.

The idea of using additive manufacturing to enable "do-it-yourself" and "deep and cheap" technology is a trend that many researchers and laboratories are pursuing – and it is really fun. But beyond the simple utility of being functional and cost-effective, additive manufacturing techniques also enable us to create underwater designs and devices that were previously unattainable. As an example, the RAD Sampler (Figure 2) was created to provide a new way to encapsulate delicate midwater animals using origami-inspired geometry. This project took approximately seven months to transition from its original centimetre-scale conceptual model to a field-tested prototype, and involved design features that were impossible to create without additive manufacturing. The RAD2 is currently under development with support from the Schmidt Ocean Institute, and will include imaging and tissue sampling capabilities to allow for rapid in-situ characterization of deep-sea specimens. Using similar prototyping techniques, recent advances in applying soft robotics to deep-sea manipulation and grasping are allowing marine biologists to investigate questions that were previously impossible to address.

Reducing the time and effort involved in transitioning technology from the laboratory



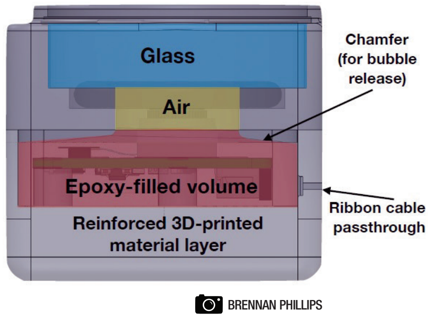


Figure 1: The DEEPi camera shown fully assembled with fingers for scale (left) along with the internal layout inside the 3D-printed "shell."

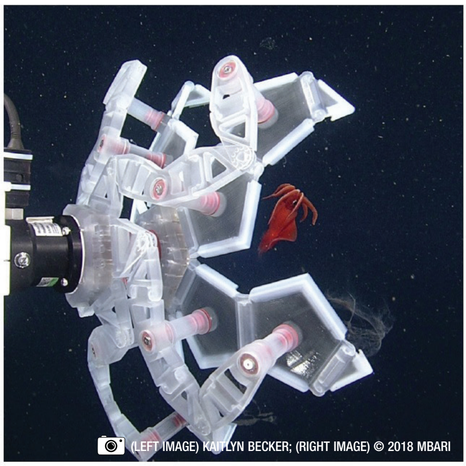


Figure 2: The RAD sampler mounted on MBARI's Ventana ROV manipulator arm (left) and deployed at 563 m in Monterey Bay, C.A., to encapsulate a deep-sea squid.

to the field has obvious benefits for today's oceanographers and engineers. But research vessels themselves are floating laboratories, and there are countless examples of ingenious designs and heroic hacks that have saved the day in a far-flung offshore location. 3D printers are now making appearances on research vessels, allowing for on-the-fly solutions and adaptations. Not all 3D printers are created equal; the standard fused filament fabrication printer can be used on a moving ship without any modifications, while the aforementioned SLA printer has been demonstrated to work with a passive stabilization gimbal. These desktop-sized solutions are making rapid prototyping a reality on board the research vessel, opening up all kinds of new solutions and applications for the modern ocean scientist.

Research and development in additive manufacturing is advancing at such a rapid pace that it is difficult to keep up with every latest trend and technique. It is a very exciting time, and it seems as though new potential applications for ocean science appear on almost a daily basis. Metal 3D printers are becoming (somewhat) affordable, along with ceramic materials and stronger and more durable polymers. These developments will continue to open new possibilities and capabilities for the ocean science community – both in the lab and in the field.

Dr. Brennan Phillips is an Assistant Professor in the Department of Ocean Engineering and the Graduate School of Oceanography at the University of Rhode Island.