Robot Hands Could Revolutionize Deep Diving

Posted by Michael Lombardi of Ocean Opportunity Inc. in Explorers Journal on July 29, 2015

Throughout the history of human intervention beneath the sea, divers have struggled with making the best use of a human's most important tool: the hand.

In the shallows, thick neoprene gloves are used for warmth, and the diver must quickly learn how to adapt to perform fine motor tasks. Without this protection, the cold cripples the ability to perform at all. At depth, the hydrostatic pressure crushes the insulating rubber, leaving the gloves (and the cold hands) ineffective.

Bhargav Gajjar poses with an early 20th-century German ADS designed for Navy use and on display at the Man in the Sea Museum, United States Navy Experimental Diving Unit (NEDU) Panama City, Florida. Note the primitive jaw-like appurtances used for the "hands." (Photo Courtesy Vishwa Robotics)

Give 'em a Hand

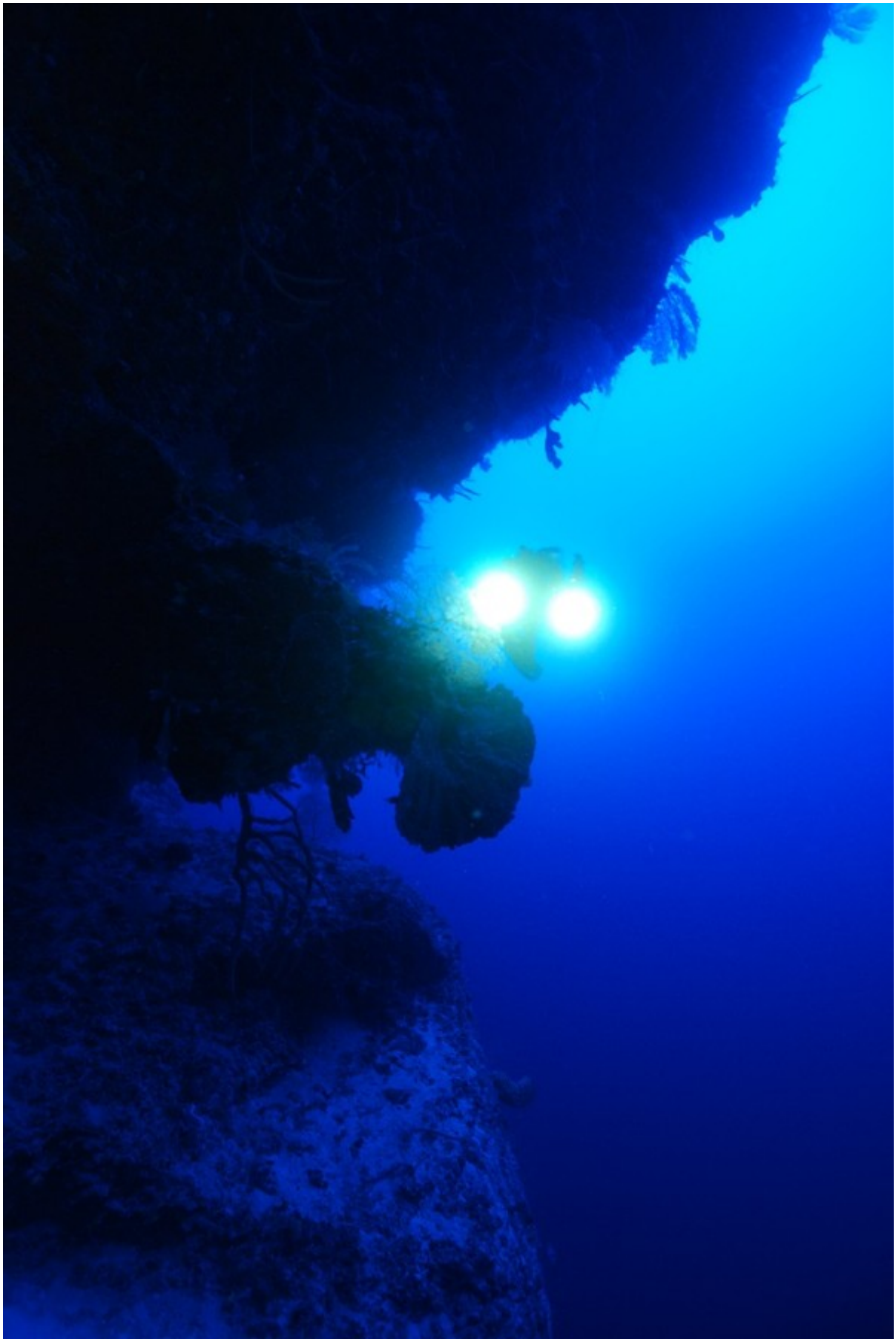
For centuries, when humans have ventured to depths beyond the norm for more conventional "wet diving," atmospheric diving suits (ADS) have provided a barrier of protection from pressure, and their "hand pods" have encapsulated and replaced divers' hands. However, these hand pods consist of just a set of crablike pincers, leaving many everyday tasks and the use of many tools outside the reach of even the most skilled ADS pilots.

In writing this piece, I came to the realization that it has been more than two years since my first National Geographic blog post on the subject of ADS for science, with a piece entitled "Hand in Hand." It is this very subject—enabling the human hand to routinely work freely at extreme depths—that is the key to furthering the exploration of the deep ocean for and by humans.

Just last year, during preparations for two deep-water scientific missions utilizing ADS, participants arrived at an overwhelming consensus. First was that bringing the "human element" into these novel environments is the principle value that ADS affords. Placing humans on site, at depth, and while unencumbered by the stress of time typically associated with scuba diving, allows the pilots to settle in and make good use of our natural tools: our senses, our situational and spatial awareness, and our ability to respond to change. The information that is learned through immersive experience, rather than simply remote observing, is second to none.

In my own work, I can recount several deep mixed-gas dives where a few extra minutes at depth would come at the expense of additional hours of slowly ascending to avoid decompression sickness ("the bends"). ADS solves

this problem of time pressure while still allowing humans to act and react within the environment using a familiar anthropomorphic form (instead of sitting within a torpedo-shaped sub).



The mesophotic environment from 200 to 500 feet, particularly its lower limits, is infrequently explored by scientists due to time limitations associated with decompression. ADS provides the ideal vehicle for this type of intricate work. (Photo by Michael Lombardi)

Back to the Claw

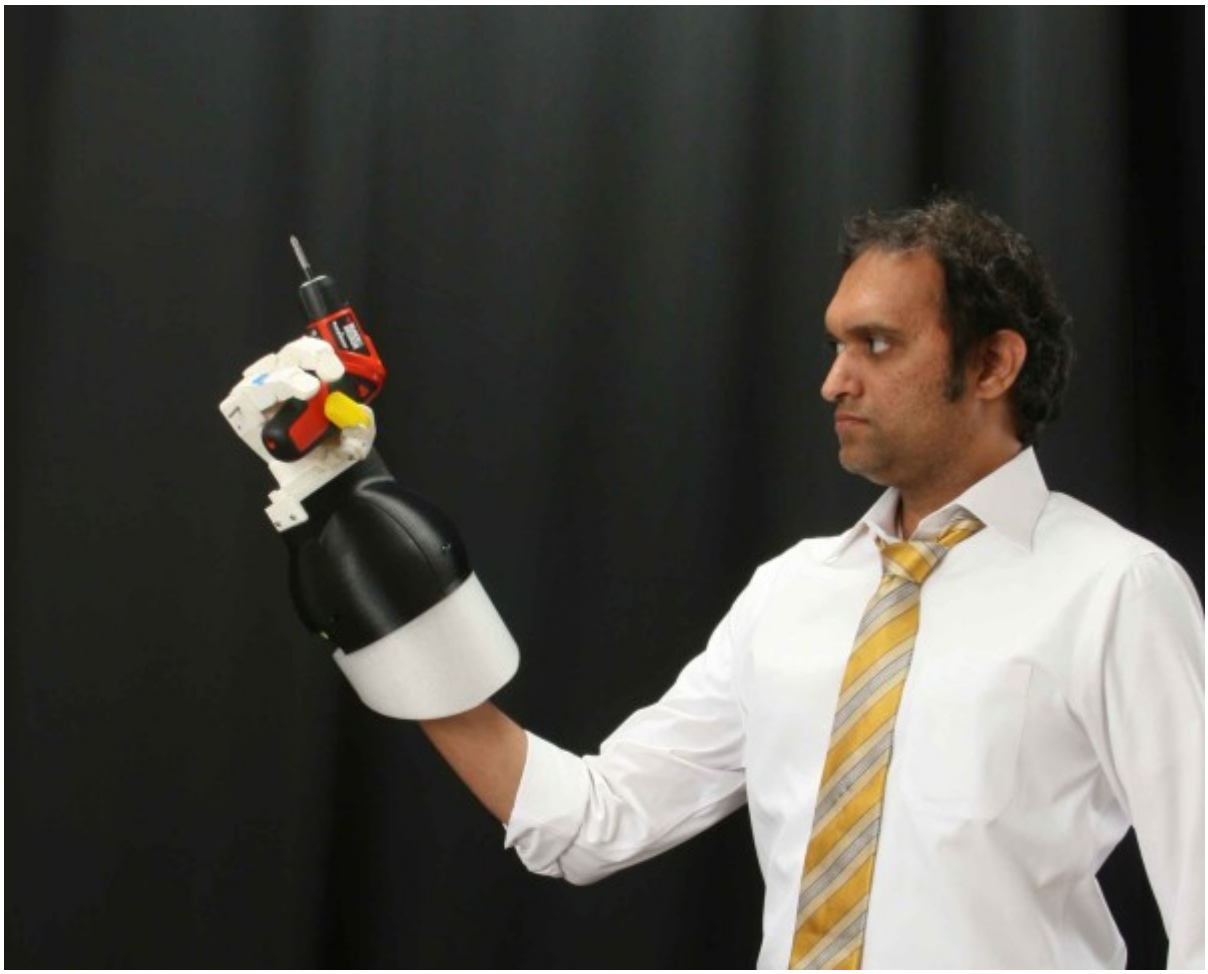
With ADS, the lack of fingers and thumb means that significant time must be spent learning how to accomplish tasks without the dexterity we are used to. This often also requires fabrication of custom tooling or modifications of existing tools.

No other component of the ADS matters more for usefully mimicking the human form than the hands and arms. Without movement at the neck, torso, or even legs, a marine scientist or working diver can still have a meaningful underwater experience; however, without his arms and hands he would lose the ability to sample from the environment or perform the manual work that is required of divers.

Chief Navy Diver Daniel Jackson completes a successful dive using a modern ADS. This system still uses the rudimentary pincers developed for the Navy over a century ago. (Photo by Mass Communication Specialist Seaman Chelsea Kennedy)

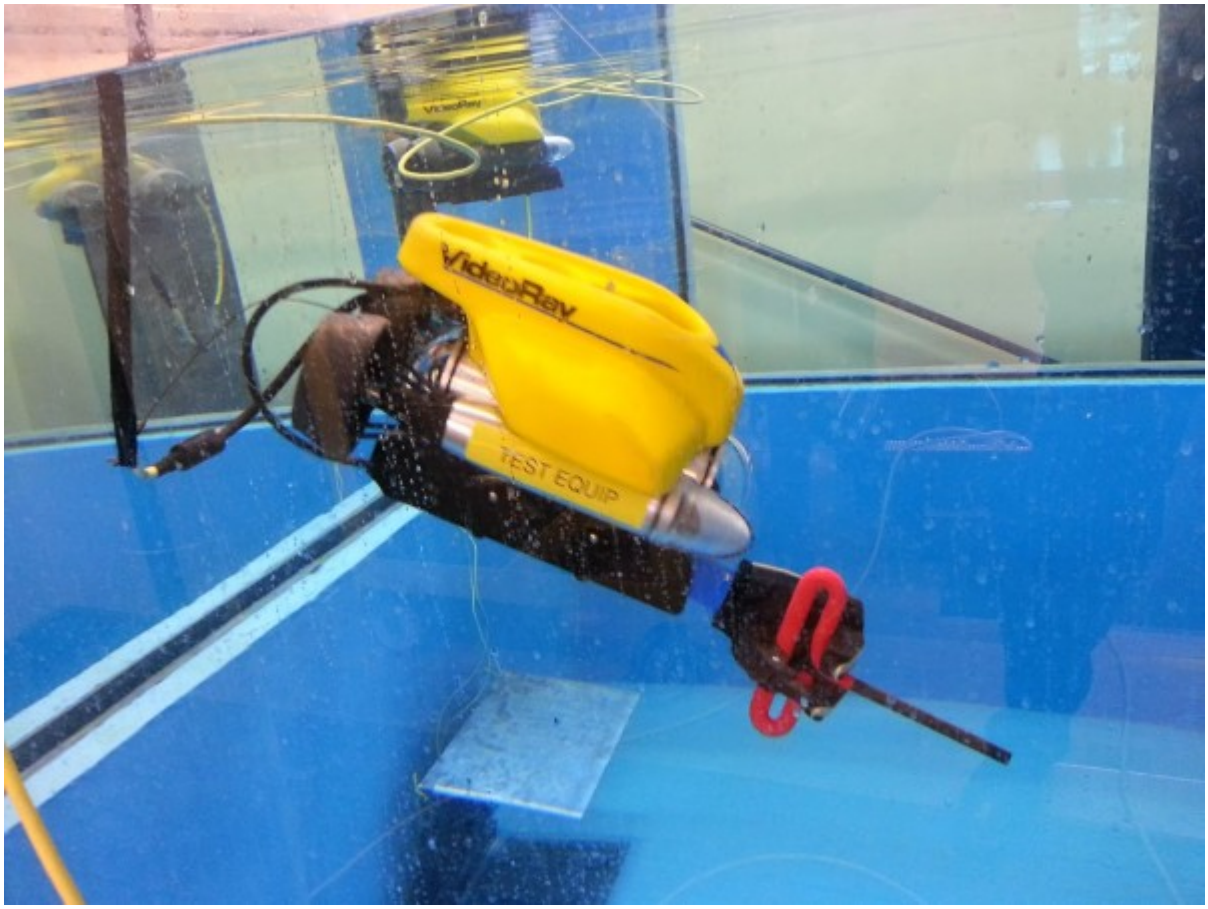
The technological limitation that is missing from ADS hand pods currently is the fine motor control needed to collect or manipulate delicate, slippery, or wet specimens or instruments. The major challenge in correcting this fine motor control is at the confluence of two different fields (bio-inspired robotics and manned submersible development), and compounded by another (understanding the musculoskeletal mysteries of the human hand).

In the terrestrial world, we are also more acutely aware of advances in prosthetics and/or robotic grasping devices that may augment human needs or actions. In comparison to robotic hands for ADS or remotely operated vehicles (ROVs), these are relatively easy to build since they do not have to work underwater, or in space, while subject to extremes of pressure, corrosion, temperature, or other forces that the human operator is being protected from with the submersible exoskeleton. A mistake in air is easily rectified, while a small error in water could subject the diver to great risk.



Bhargav Gajjar demonstrates a prototype Extensor, a manually actuated three-finger “hand” that can be used for modern ADS. (Photo Courtesy Vishwa Robotics)

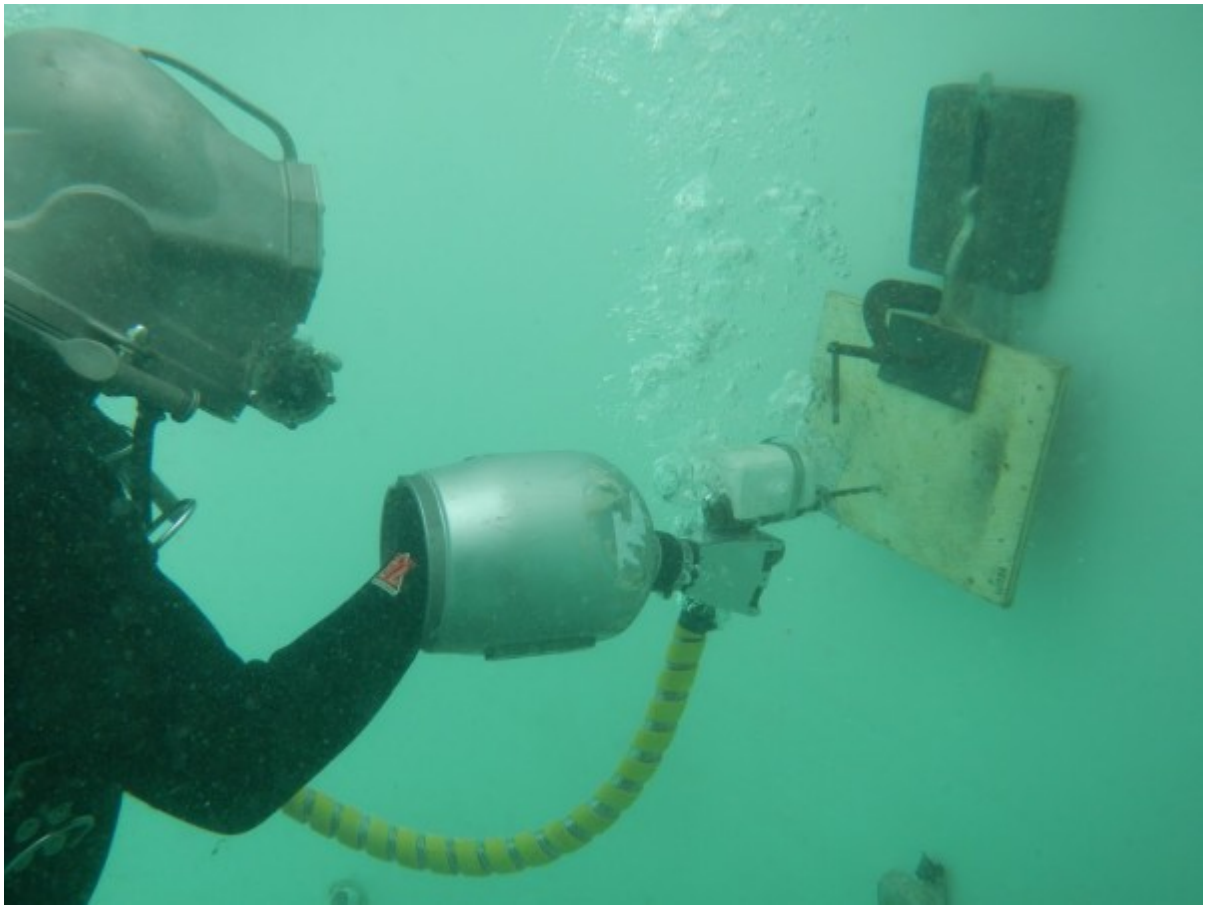
To solve these problems Bhargav Gajjar of Vishwa Robotics and the Massachusetts Institute of Technology (MIT), with funding from the Office of Naval Research (ONR), is conducting research into deep-sea anthropomorphic manipulators in an effort to “lend a hand” to deep underwater work. Currently, he works with a three-fingered hand called the Vishwa Extensor. Given the extreme pressure and mobility requirements, as Bhargav has explained to me, tele-operated hands developed for the marine environment have to be “better than biology.”



Vishwa's robotic Extensor fit to a remotely operated vehicle. The ROV is demonstrating use of a simple t-handle allen wrench. Teleoperation of these deveices places the function of the human hand in remote or hostile environments. (Photo Courtesy Vishwa Robotics)

In the most recent experiments conducted by Bhargav at the US Navy's MDSU 2 test facility, Vishwa's robotic fingers were able to grasp cylindrical and spherical objects. Additional demonstrations were carried out with the Vishwa Extensor while fitted to an ADS hand pod to demonstrate use of a conventional off-the-shelf pneumatic drill.

A diver emulates an ADS underwater drilling test using the Vishwa Extensor. Typically drills or other manual tools would need to be modified to be compatible with the ADS, and often require tool activation from topside personnel. (Photo Courtesy Vishwa Robotics)



Using the Vishwa Extensor, the ADS diver can now pick up a tool and immediately start using it through his “hand.” The reduction in complexity of the mission will be immensely valuable to ADS pilots of the future for both scientific and commercial diving. (Photo Courtesy Vishwa Robotics)

While they represent just a small step on a long road of innovation in underwater hands, these recent demonstrations are a giant leap for us all in considering that this next level of human adaptation to the marine environment may well be within reach. As with all paradigm-changing efforts, their success often lies within the “hands” of those with the ability to catalyze future science markets—perhaps the research investments of both government and private corporations. Without question, it is the scientific relentlessness of the inventors that will ultimately prevail in the exploration of the final frontier.

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