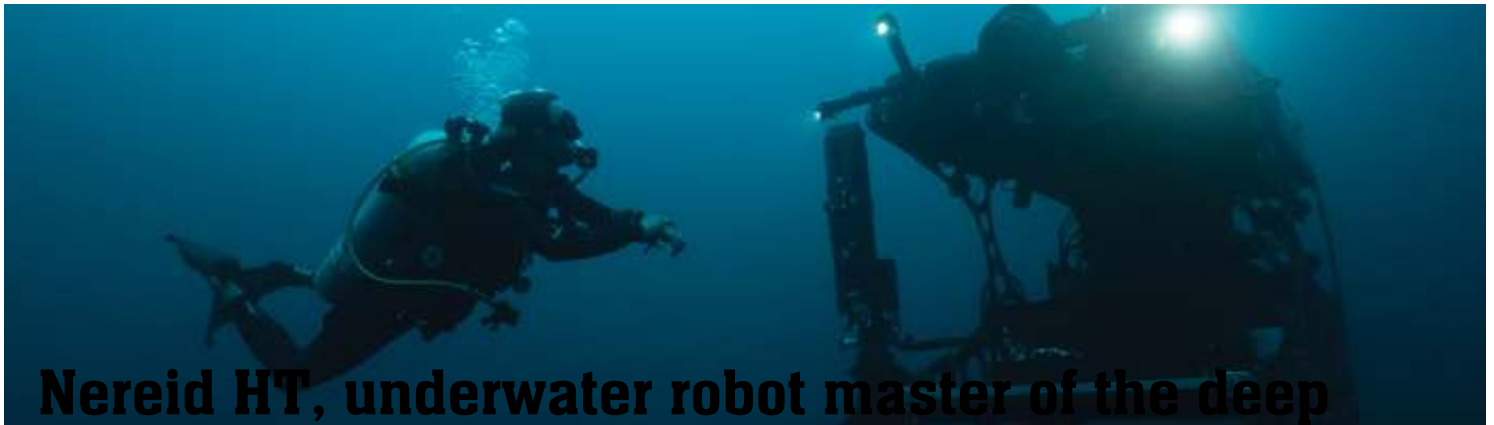




By Louise Murray

Published Friday, December 16, 2016

The design concepts tested in an exciting new underwater robot are set to make a great impact in fields as diverse as the oil and gas sector, marine archaeology and the military.

(https://oasc-eu1.247realmedia.com/RealMedia/ads/click_nx.ads/eandt.theiet.org/content/articles/2016/12/nereid-ht-underwater-robot-master-of-the-deep//1339190179@Top,Middle,x01,x02!Top?taxonomy=control_and_automation&taxonomy=vision_and_imaging&taxonomy=marine_transport&taxonomy=volume_11_issue_12&taxonomy=robots)

An underwater research vessel designed in the USA is set to be a testbed for a host of technical innovations. Nereid HT (Hybrid Tether), developed by the independent Woods Hole Oceanographic Institution (WHOI), is both a remotely operated vehicle (ROV) and an autonomous underwater vehicle (AUV) and can also operate on a spectrum between these control classifications.

Exploring the deep ocean is fraught with difficulties arising from the enormous pressures at depth and the difficulties of communication, particularly for untethered vessels. In-water transmissions have been restricted to relatively low-bandwidth acoustic communications.

Nereid HT can change between remote and autonomous control modes according to the communication systems available to it. These range from low-bandwidth acoustics to WHOI's new optical modem or gigabyte Ethernet connections provided by a physical connection through its tether. Nereid is said to be one of the most advanced and versatile unmanned submersibles in the world. In 2016 it was tested to a depth of 2500m during engineering sea trials in Panama.

Andy Bowen, inventor and lead engineer on the WHOI project, has 30 years' experience in developing cutting-edge submersibles, from the deep-sea manned submersible Alvin to the hybrid ROV Nereus, which could dive 11 kilometres.

"Operating Nereus at 11,000 metres presented us with whole new set of challenges," he explains. "A lightweight tether cable between the submersible and its mothership was an operational necessity – traditional ROV design solutions would have resulted in a massive and very costly system. We have evolved

and refined this and other technologies, applying them to the Nereid. The compact, two-tonne, battery-operated Nereid can store large amounts of rechargeable energy on board.

“It has a refined manipulator design coupled with a very efficient hydraulic power unit and highly effective propulsion, lighting and control systems,” says Bowen. Taken separately, these are all incremental advances in design, but when combined with the powerful software embedded in the Nereid HT, it is transformative.

Nereid has three distinct operating modes. The first is similar to a conventional ROV, linked to the ship by a reusable reduced-diameter oceanographic cable. Mode two is also tethered, but uses expendable optical fibre that allows travel up to 20km from the host vessel. In the third operational mode, Nereid is controlled through an optical ‘wireless’ link with no physical attachment to the ship. In this mode Nereid can venture autonomously beyond the range of the optical link using acoustic communications.

All three modes use new technology to extend the abilities of the Nereid family (which already includes the ‘under ice’ Nereid UI), blurring the line between remotely operated and autonomous vehicles.

The Dalio Foundation supported the vehicle development and as part of its Dalio Ocean Initiative, also made the expeditionary vessel Alucia available. The Alucia is a 55-metre, 1396-tonne vessel, built in 1974 as a heavy lift ship and launch/recovery platform for diving and submersible operations. It was extensively refitted between 2008 and 2012 for its current science and filming role.

“What we are trying to do on-board Alucia is to give the ship and others like her the capability to access depths that would be impossible for a ship of this type using conventional technology,” says Bowen. “We are aiming for 5,000 metres using this novel, lightweight reusable umbilical system. It’s a much smaller diameter tether than would typically be used for ROVs of this size and capability.”

It’s important to note that most ships for deep-sea ROV operations require a dynamic positioning (DP) capability, allowing the vessel to hold a geostationary position above the ocean floor. This is needed to avoid putting undue stress on the umbilical cable running between the vessel and the robot. DP ship charters are costly and can be difficult to schedule.

The design of the umbilical in mode one combines optical and acoustic communication in a lightweight reusable tether and is in the final stages of a US patent application. The tether also contributes to making launch and retrieval operations simpler and faster, requiring less crew intervention.

The final 100 metres is specially designed to have varying density along its length, so the tether naturally forms an ‘S’ shape without the need to add weight or floats. This gives the vehicle enough freedom from the ship, decoupling the Nereid from the ship’s movements, allowing more streamlined operations, and may make missions possible in a higher sea state.

Bowen estimates that the size and weight of the winch and cable system are reduced by as much as 40 per cent compared to standard deep-sea ROVs. A large part of the weight reduction is in a smaller diameter cable because the Nereid is powered by its own battery, not via the tether. This in turn means that it can be deployed and retrieved from a relatively small electric winch, rather than a much larger bulky winch and tether management system.

Combined, these innovations mean that the ROV can be deployed from many more vessels, preparing the way for a sea change in ROV shipping and crewing requirements, which may one day radically alter the economics of deep-sea ROV operations.

Typically, ROV operations take place almost directly underneath the support vessel, but Nereid's long-distance tethered mode two, deployed with 20km of expendable fibre-optic cable, allows an extreme horizontal travel of the vehicle relative to the ship or ocean floor observatory.

This means that on science missions, Nereid can be sent safely into environments inaccessible to traditional ROVs, like the front of a glacier or under sea ice: ecosystems that are poorly understood and are very dangerous or impossible for humans to access. As oil and gas operations extend further into deep Arctic waters, this kind of capability will become more valuable.

The Nereid is powered by rechargeable lithium-ion batteries in a pressure-resistant custom casing designed by WHOI. The batteries can be trickle-charged as Nereid operates in mode one. In modes two and three, the batteries give a 12-hour mission life, but the pace of change in battery technology improvement is now very rapid, going hand-in-hand with developments in electric car design.

Bowen is confident that this will be less of a factor in future, as greater amounts of energy can be stored on board the vehicle. "More on-board power could enable extension of the vehicle's capabilities, eventually allowing it to take over some of the tasks normally reserved for heavy-work-class ROVs, like cable laying or pipeline work," he says. Battery power also does away with the requirement for specialised high-voltage power supplies on board the mother ship.

([https://oasc-](https://oasc-eu1.247realmedia.com/RealMedia/ads/click_nx.ads/eandt.theiet.org/content/articles/2016/12/nereid-ht-underwater-robot-master-of-the-deep/1339190179@Top,Middle,x01,x02%21Middle?taxonomy=control_and_automation&taxonomy=vision_and_imaging&taxonomy=marine_transport&taxonomy=)

[eu1.247realmedia.com/RealMedia/ads/click_nx.ads/eandt.theiet.org/content/articles/2016/12/nereid-ht-underwater-robot-master-of-the-deep/1339190179@Top,Middle,x01,x02%21Middle?](https://oasc-eu1.247realmedia.com/RealMedia/ads/click_nx.ads/eandt.theiet.org/content/articles/2016/12/nereid-ht-underwater-robot-master-of-the-deep/1339190179@Top,Middle,x01,x02%21Middle?taxonomy=control_and_automation&taxonomy=vision_and_imaging&taxonomy=marine_transport&taxonomy=)

[taxonomy=control_and_automation&taxonomy=vision_and_imaging&taxonomy=marine_transport&taxonomy=](https://oasc-eu1.247realmedia.com/RealMedia/ads/click_nx.ads/eandt.theiet.org/content/articles/2016/12/nereid-ht-underwater-robot-master-of-the-deep/1339190179@Top,Middle,x01,x02%21Middle?taxonomy=control_and_automation&taxonomy=vision_and_imaging&taxonomy=marine_transport&taxonomy=)

Research engineer Chris Taylor was the pilot for this year's sea trials in Panama. "The pilot interface has been built to make Nereid as accessible as possible to a wide range of potential pilots," he says. The software was written by WHOI's own engineers. Ex-gamer Taylor says it is very easy to use. An Xbox joystick is the pilot's direct interaction to manoeuvre the vehicle and scale thruster outputs and is also used to control pan and tilt of the cameras.

On-screen, the graphical user interface or GUI provides the usual information for tethered operations, and also allows access to engineering data such as motor controller status for the thrusters, battery statistics and status, hydraulic power systems and valves and in a battery-powered vehicle, power management systems to monitor overall power and active consumption. A subset of this information is available to the pilot/supervisor even when the vehicle is operating as an untethered system.

"The thrusters are our number one power consumer on the vehicle," says Taylor, "with lights and hydraulics the next largest. We have optimised our hydraulic power unit to minimise power consumption when operating the manipulator arm, grippers and related systems." The arm is custom-built by Kraft TeleRobotics to a WHOI design that has been refined from the Nereus project.

WHOI is well known for its stunning visual imaging capability, having partnered its submersibles and camera systems with film productions from the BBC, NHK, National Geographic and Discovery Channel. The camera systems on Nereid were designed in the Advanced Imaging and Visualisation laboratory (AIVL) at WHOI.

Evan Kovacs, director of photography at AIVL, explains the thinking behind the Nereid HT imaging systems: "We wanted to use imaging to completely overhaul the ROV control room interface by better connecting the pilot to the vehicle's entire field of view."

There are three main camera systems on the vehicle in its peak imaging configuration: a triscopic 3D setup made up of three cameras in a single custom housing, three separately housed HD cameras that record a panoramic view, plus various simpler situational awareness cameras that view the ROV's basket and manipulator arm actions. There are also hook-ups for high-resolution cinematographic and speciality cameras.

The triscopic system produces three baseline streams of calibrated RAW video with a viewing angle of 50-60 degrees; the pilot can switch between them for an appropriate viewpoint. The setting means that this feed can be used to map archaeological sites or historical objects in situ, or aircraft, oilfield artefacts or shipwrecks before salvage is attempted.

The panoramic camera set of three HD AIVL-built cameras gives the operator a live feed with a 180-degree angle of view. The three feeds are stitched together using software jointly developed by AIVL and Sony to produce a seamless real-time live output to the control room. Both 3D and panoramic imaging capabilities have been around for some time, but where this system really takes imaging to another level is this on-the-fly panoramic processing.

One major advantage is to provide the pilot with a much better sense of immersion in the environment. Taylor says the panoramic mimics the way human eyes work, making it much easier to spot things. "It was like night and day, compared to a single high-definition camera system, just spectacular."

He envisages that pilots would use the panoramic camera systems continuously, then deploy the 3D system on a complex site where depth perception was critical, for example to gather up precise geological or biological specimens. The vehicle is tooled according to its mission, so simpler tasks would only have a utility HD video camera and lights.

When operating as a tetherless ROV in mode three, WHOI's new optical modem technology provides operators with real-time control, including full motion video uplinks and direct downlink control of thrusters, manipulators etc. The system allows total control over the vehicle off-tether, and Panama was the first test of the modem for bi-directional communications.

Norman Farr, an optical engineer at WHOI who designed the system, says: "We can wirelessly control the untethered vehicle while transmitting live video back to the pilot. The modem is limited to a range of approximately 100 metres but it's very exciting to now have a link that is just rock-solid, one that you don't really have to worry about."

It took the team over five years to reduce the form factor of the modem to a workable size. "We've never had high bandwidth under the ocean. It was slow communications or none at all," adds Farr. "Acoustics can of course go a long way through water, but you have low bandwidth and low data rate. Transmitting live video to and from untethered vehicles has never been possible until now,"

The optical modem operates using LEDs. The wavelength used is determined by the operating depth and levels of ambient light. Most of the time a 50-metre range was achievable in the biologically productive coastal waters of Panama, but earlier tests confirm that in clearer water a range of up to 100 metres is to be expected. In Panama, bi-directional communications worked effectively at over 10Mbit/s, and 20Mbit/s is technically possible.

Virtual tethering opens up the possibility of entirely new mission types where global experts or remote engineers can tap into live visual feeds and contribute remotely to expeditions or inspections without the need of a berth on a ship above site.

As their abilities grow, smaller ROVs like the Nereid class are increasingly deployed by navies, coastguards and ports around the world, including the US Coast Guard, the US Navy, and the Royal Navy. Hybrid ROV/AUV vehicles can be used for a huge variety of underwater tasks such as explosive ordnance disposal, meteorology, port security, mine countermeasures, oil and gas support, marine science and archaeology, and maritime intelligence, surveillance and reconnaissance.

As the vehicles become more capable and ever more versatile, Bowen envisages a future where shipless systems could prevail: “I can see a Nereid covering hundreds of kilometres under simple acoustic communications control, then at a work site linking to an optical modem, receiving instructions wirelessly, while working under the control of a human pilot. Or further ahead, actually residing on the seafloor, available to respond when needed, such as to harvest data from an undersea observatory or provide timely intervention.

“The robot can respond no matter the sea conditions. Indeed, in locations like the high Arctic, shipless intervention might be an imperative,” he says. Many airborne drones already operate like this, flying to their operations site under little or no human control. WHOI advances in underwater robotics, autonomy and communications technology make it extremely likely that we will see these kinds of missions under the surface of the ocean before too long.

Small, highly capable hybrid vehicles like Nereid could eventually become vessel staples, ready to deploy at a moment’s notice.

[CONTROL AND AUTOMATION \(/TAGS/CONTROL-AND-AUTOMATION\)](/tags/control-and-automation)[VISION AND IMAGING \(/TAGS/VISION-AND-IMAGING\)](/tags/vision-and-imaging)[MARINE TRANSPORT \(/TAGS/MARINE-TRANSPORT\)](/tags/marine-transport)[VOLUME 11 ISSUE 12 \(/TAGS/VOLUME-11-ISSUE-12\)](/tags/volume-11-issue-12)[ROBOTS \(/TAGS/ROBOTS\)](/tags/robots)

Image credits: Woods Hole Oceanographic Institution (WHOI).

Related stories