TONGS – AN EVOLUTION OF A HEAVY-LIFT SEARCH AND RECOVERY REMOTELY OPERATED VEHICLE

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ABSTRACT

The requirement for the location and recovery of objects lost or placed on the seafloor is often difficult and technically challenging. The Television Observed Nautical Grappling System (TONGS) remotely operated vehicle was placed in service in 1958 to support Navy subsea operations requiring a heavy-lift capability (10,000 lbs) in high-current waters up to 10,000 ft deep. The evolution of TONGS is presented from its origins to the present system. This latest third-generation vehicle offers substantially improved maneuverability, system portability, and operational capability.

INTRODUCTION

The Naval Surface Warfare Center, Carderock Division, South Florida Testing Facility (SFTF) owns and operates the Television Observed Nautical Grappling System (TONGS), a heavy-lift, high-current capable remotely operated vehicle (ROV) that can successfully operate in water currents exceeding 5 knots, and still recover items from the seafloor weighing in excess of 10,000 pounds. TONGS is an integral part of SFTF operations, and without such a capability, range maintenance and utilization would be significantly limited. While TONGS is a fairly simplistic vehicle in terms of ROVs, it is extremely capable. The TONGS system has evolved in both design and function along with the SFTF, which was initially established in the 1950s as an ordinance testing facility.

FACILITY BACKGROUND

The Naval Ordinance Laboratory (NOL) originally proposed the establishment of a test facility at Port Everglades, Florida, in 1951, and on 8 September 1952, the Secretary of the Navy officially established the NOL Test Facility (NOLTF) and the Fort Lauderdale site was born. Its mission was to conduct deep-water tests on ordinance systems and components.

The NOLTF Fort Lauderdale facility played an important role in evaluating Navy ordnance and underwater systems. The need for a test facility of this type arose after World War II as a result of the Navy's growing mine warfare program; this and other underwater programs required gathering information on system characteristics and behavior under real operational conditions. At Fort Lauderdale, field tests of air, surface, and underwater ordinance systems included mines, mine sweeping operations, torpedoes, swimmer weapons systems, environmental testing, and oceanographic research operations.

The Fort Lauderdale site was chosen for the unique characteristics of the geographical area and nearby waters – among them an open ocean environment and unrestricted waters, a hard sandy bottom and clear water for easy ordnance recovery, favorable climate suitable for year-round testing, and road, air, rail, and sea transportation services.

One of the additional environmental conditions associated with the location is the Florida Current, that portion of the Gulf Stream current that runs generally to the north through the Florida Straits between Florida and the Bahamas. This current can exceed 5 knots at times, particularly in the vicinity of the facility's 1800 ft deep cable range 20 miles offshore. Even as shallow as 60 ft, the currents can reach three knots, and typically approach four knots in the 600 ft region, just 3 miles offshore. Because of these high currents, it is often difficult or impractical for divers to reach test equipment, and in the case of the deeper ranges, the units are often well below diver depths.

TONGS DEVELOPMENT AND EVOLUTION

In order to work in this environment, NOLTF Fort Lauderdale personnel developed a unique underwater camera system, originally called the MONSTER due to its large size and bulky appearance. The MONSTER, officially designated the XN-3 underwater television device, was first placed into service in 1958 to assist in recovering test ordinance dropped offshore of Fort Lauderdale. The 900-pound device was used to rest on the bottom and observe diver recovery efforts, or was slowly pulled along just off the bottom while searching for test ordnance. In early 1960, the MONSTER was used during the search for a National Airlines aircraft that had crashed in the Gulf of Mexico. While the use of the

MONSTER dramatically reduced diver bottom time during the search, no major portions of the aircraft were found due to the extent of damage.

Later in 1960, NOLTF electronic technician Hugh E. Bowen took the lead on the MONSTER project, and incorporated a pan and tilt, support frame, and current vane to provide more search capability and improve its performance in high currents. Mr. Bowen (on the right) and the camera platform are shown in Figure 1.

Figure 1 - Original NOLTF Camera Platform, 1960

The vane served to stabilize the vehicle, and the pan and tilt allowed a broader search range for the camera. This system was used in concert with a surface-controlled clamshell bucket to retrieve ordnance from deep water. The camera and frame would be lowered to the bottom and would locate the object, then using the video from the camera as a guide, the clamshell would be lowered over the object, scoop it up, and the crane would lift it to the surface. While seemingly primitive and simplistic, it nevertheless proved very effective from 1960 to about 1969 as the primary recovery tool of the NOLTF Fort Lauderdale.

In 1969, with the establishment of deeper test ranges, approaching 1800 fsw, it was no longer practical to have the camera and the clamshell bucket suspended from two cables in close proximity, particularly in high current. Instead, a three-legged sling was fitted to the camera frame, along with two modified WWII truck generators as thrusters, a sonar transducer, a listening hydrophone, a thallium iodide lamp, and a new low-light tube camera. With these additions, the Television Observed Nautical Grappling System, or TONGS, was born. In this configuration, TONGS could search for, locate, grapple, and recover an object with no additional equipment. The system was rated to 10,000 fsw, and could recover items up to 10,000 pounds.

RECOVERY METHODOLOGY

The recovery procedure developed to use TONGS involved a surface vessel with multi-point mooring capability, a crane, a cable winch for the lifting wire rope, the electrical control cable, wire rope clips to marry the lifting and control cables, ships crew, control pod, and the TONGS vehicle. The support ship would establish a mooring over the target site, and TONGS would be lowered to the seafloor.

The recovery procedure involved a close collaboration between the TONGS operator, the crane operator, deck crew, winch operator, ship's captain, and ship's navigator, who controlled the movement of the support ship. TONGS would be lowered over the side attached to a wire rope strength member, and the electrical control cable would be attached with snap hooks to the wire about every 50 ft. TONGS would be lowered to within 30 ft of the bottom, and the sonar, hydrophone, and camera would be used to search for the target. Due to the limited thrusters, horizontal movement beyond about 30 ft was accomplished by moving the support ship on its moor to place TONGS in the proper location for recovery. The crane and winch operators, at the direction of the TONGS operator, controlled vertical movement.

Once a target was located and TONGS positioned above it, the operator would use the thrusters to place a large grappling hook into a lifting point. The hook would be attached to the TONGS frame by a small piece of manila line, which was intended to break away once the load exceeded approximately 200 pounds. Once free, two legs of the three-legged bridle would take up the load on the hook, and TONGS would hang to the side on the third leg. In this manner, the lifting wire itself would take a load of up to 10,000 pounds, not the TONGS frame. Once on the surface, the hook would be transferred to another wire and TONGS would be disconnected and placed out of the work area. This is shown in Figure 2, where the hook is holding the recovery bail, and TONGS is off to the side of the load. Also note the holdback line above TONGS, necessary in the high currents to reduce trailback at the surface.

Since the late 1960's, this method of deployment and recovery remains the primary procedure for recovering objects on the Fort Lauderdale range. By using the support vessel instead of the TONGS to maneuver, especially in high currents (often in excess of 5 knots), the vehicle itself does not require huge thrusters or the associated power systems that it would if free swimming. Also, since the vehicle is not required to swim, and therefore not required to be neutrally buoyant, the system may be weighted heavily so it essentially "drops" through the high currents and reaches the bottom with much less trail back, or catenary, in the support cable.

Figure 2 – TONGS and 3-Leg Lifting Sling, 1969

The ability to use the support cable also as the recovery cable provides a significant lift capability. In fact, in the event a recovery load greater than the standard 10,000 pound rating is required, a larger wire rope is married to the control cable and a higher capacity winch and crane are used to handle the larger load. No other system modifications are required.

JOHNSON-SEA-LINK RESCUE

One notable and important use of the TONGS occurred in June 1973, when the Harbor Branch Oceanographic Institute's (HBOI) submersible Johnson Sea Link (JSL) became entangled in the wreck of the former destroyer F.T. Berry. The ship, sunk as an artificial reef, is located about 20 miles east of Key West, Florida in approximately 360 fsw. The JSL had been recovering a fish trap placed earlier on the wreck as part of a fisheries evaluation project. The sub became tangled in fishing nets and other debris on the wreck, and was trapped on the bottom with four men aboard. The Navy submarine rescue ship USS Tringa arrived on site and established a four-point moor over the site, and attempted two surface-supplied MK5 dives to the trapped submersible. Due to the strong current and extreme cold temperature on the bottom (about 2 knots and 40 degrees F), the MK5 divers were unable to provide assistance. A roving diving bell was then lowered to the scene, but again strong currents and the risk of entanglement foiled the rescue attempt. A third attempt, made by a Perry Offshore, Inc. PS2 Cubmarine, ended without success after the sonar stopped working and the pilot became disoriented.

Following the unsuccessful attempt of the Cubmarine, the AB Wood II, support ship to TONGS at the time, was maneuvered alongside the Tringa to deploy TONGS. On the first dive TONGS reached the wreck and located the JSL, although the TONGS was on the opposite side of the ship. TONGS was recovered and rigged with a grappling hook, and the AB Wood II maneuvered about 50 ft off the side of the Trienga in order to lower TONGS to the correct side of the wreck. TONGS was again lowered to the site and the TONGS operator, coincidentally the original developer Hugh Bowen, guided the hook into position and grappled the sub in one of its propeller shrouds. The JSL was pulled free of the wreck and brought to the surface, concluding the 32-hour ordeal. Figure 3 shows the JSL after reaching the surface, with the TONGS hook in the shroud, and the TONGS trailing behind at the bottom of the photo.

Unfortunately, the two men in the aft compartment of the JSL, Clayton Link and Al Stover, did not survive, having succumbed to hypothermia and CO_2 poisoning. The other two men, however, Archibald Menzies and Robert Meek, did survive the accident.

Figure 3 – TONGS Rescue of JSL, 1973

This event was significant in that a ROV rescued humans trapped in a submersible, after every other available option was exhausted. In less than 90 minutes, TONGS was able to hook into the JSL and pull the submersible safely to the surface. The fact that TONGS was able to operate in the adverse conditions that had thwarted the other attempts, while also having the heavy lift capacity to pull the JSL free of the wreck, resulted in the successful Navy rescue mission. This success is one of many examples of the capability of a system that, while simple and lackluster, nevertheless provides an effective tool in the Navy's submarine and underwater rescue inventory.

1980 REDESIGN EFFORT

The first significant attempt to redesign the TONGS system occurred in the early 1980s, with the construction of "TONGS II". This new design increased the size and weight of the vehicle while providing the potential for an improved operational capability. The objective was to develop an improved, follow-on observation and recovery vehicle and provide significant performance improvements through better hydrodynamic design. Another goal was to utilize the frame as a garage for a smaller flyaway observation ROV. As a result, this new vehicle was physically a significant departure from its predecessor. The frame was constructed of stainless steel pipe, and the electronics housings were mounting within two streamlined pods located on both sides of the lift point. A large area within the frame was available for add-on sensors and equipment, such as the fly-away ROV and its tether management system, as shown in Figure 4.

Figure 4 – TONGS II, 1985

Tow tests of the new design were successful, and the vehicle was found to maintain stability at speeds up to 10 knots. The unit was successfully tested to a depth of 3000 fsw, and successfully lifted a 14,000 pound load (10,000 pound test weight, 4,000 pound vehicle weight). While the system was mechanically sound, the one-of-a-kind control, telemetry, tracking, and video system developed problems. Troubleshooting began in early 1987, with the assistance of Perry Offshore, Inc. of Riviera Beach, Florida. As the system was nearing serviceability, the new TONGS II was struck by lightning while located dockside for servicing and testing. Examination after the lightning strike determined the new vehicle was mechanically sound, but the control and communication system was severely damaged.

This setback proved fatal to the TONGS II project, since the funding required replacing and upgrading the unique control and communication electronics was prohibitive. While initial indications based on the few sea tests were promising, the large size and complexity of the TONGS II redesign was abandoned, and the next design returned to the basic deadweight frame configuration.

1991 CR TONGS

The latest operational version of the TONGS was developed and constructed in 1991 at the Fort Lauderdale facility, and was named the Corrosion Resistant TONGS, or CR TONGS. This version features the frame, pressure vessels, and associated equipment made of 316L stainless steel. This minimizes the corrosion and maintenance issues of the past, while also improving the vehicle's appearance. The new frame is shorter than the original, allowing easier access to equipment and pressure vessels.

Another major design change was to the thrusters that were previously modified truck generators fitted with oil-compensation bladders and small propellers. These thrusters were replaced on the CR TONGS by large electric trolling motors, each providing approximately 60 pounds of thrust at 24 VDC. These motors are readily available, sealed, and are provided with matched propellers. The motors are also fitted with oil bladders to compensate for depth, and they are controlled by solenoid-relay circuits similar to those used in the 1969 version. While still powered by batteries located in a housing on top of the frame, the motors improved the vehicles mobility and orientation ability. The major drawback to using trolling motors is the effect of the silicone oil on the carbon brushes. During use, the oil both softens the brushes, causing them to abrade rapidly, and cause the brushes to arc, generating deposits that abrade the motor windings and commutator. Fortunately, the motors are relatively inexpensive and readily rebuilt, so the oil effects do not significantly impact operations, although they do increase maintenance requirements.

FACILITY MISSION CHANGE

In 1994, the NOLTF Fort Lauderdale Facility, which had been reorganized in the 1970's under the Naval Surface Warfare Center White Oak Division, was transferred to the Naval Surface Warfare Center, Carderock Division, and became the

South Florida Testing Facility (SFTF). This change in ownership also resulted in a mission change, and facility operations transitioned from mine research to signature measurement and trial support. While the facility mission had changed, the need for TONGS to operate and maintain the range did not, and as a result, funding was obtained for a modest system update. The improvements involved the sensors systems, namely the cameras, lights, sonar, and depth sensors. The installation of new lights and cameras, along with a new scanning sonar, improved visibility and target location at greater ranges.

Also during this period, the SFTF acquired and operated the OCP SEACON, a dynamically positioned (DP) vessel equipped with a 40-ton marine gantry crane and Voith-Schnider propulsors. These capabilities eliminated the need for anchoring and moving on the mooring to position TONGS over a target, and also provided a significantly larger deck area to work. By actively and more precisely controlling the position of the ship and TONGS relative to a target, the effectiveness of the system was dramatically increased. This was the first time a TONGS system had operated from a DP vessel, and the improvements were significant. An operation in 1000 fsw that previously took over 18 hours to complete due to anchoring and repositioning now took only three hours start to finish. Unfortunately, the SFTF disposed of the SEACON in 1998, due to reduced funding and ever-increasing maintenance costs. The CR TONGS, however, has continued to operate from other DP vessels such as HBOI's Seward Johnson and NUWC-AUTEC's Range Rover.

TONGS III – THE FUTURE

In 2002, funding was obtained for the upgrade of the TONGS system, as well as the incorporation of a fly-away observation ROV system to improve the survey capabilities of the system. A meeting was held between SFTF engineering and operational personnel to discuss the status of the TONGS system and to brainstorm about the possible improvements not only to the vehicle but also to the entire system and procedures. This discussion considered the following prospects:

- Opportunity to address historic limitations for improved capabilities, potential, and personnel safety.
- Opportunity to utilize advances in technologies using commercial off the shelf systems (COTS).
- Opportunity to incorporate a fly-away vehicle into the system.

There were several aspects of the present TONGS version that were desirable and would be beneficial to retain. These characteristics were:

- Simple design, robust, corrosion resistant, low maintenance.
- Large lift/recover capacity (10,000 lbs).
- Positioned by support ship, minimal vehicle propulsion required.
- Control cable easily repaired in event of damage.
- Simple attachment to recovered unit, no complicated grabs or claws.

There were also system drawbacks, which needed to be addressed, and they included:

- Separate lifting wire rope and control cable.
  - Requires strain relief clips to be installed manually every 50 ft.
  - Requires 3 to 4 deck crew to install clips and handle cable, both during deployment and recovery.
  - Deployment and recovery slow, especially in deep water (Number of clips/stops to install or remove = depth/50 ft)
- Existing control electronics antiquated and relatively undocumented, limited spares.
- Incapable of expansion or installation of new, updated components, such as a fly-away vehicle.
- Existing motors modified oil-filled, permanent-magnet trolling motors with limited brush life and frequent rebuild requirements.
- High current requirements from motors, powered by limited life (30 min – 1 hr) on-board batteries.
- Control van occupied 200 square ft of valuable deck space, especially on vessel of opportunity.
- Control electronics, computers, and software need upgrading.

The meeting provided a set of criteria for the "ideal" TONGS, and it became quite evident that several characteristics were incompatible. Since some features of the older version, including the ability to lift much heavier objects through a simple rigging change, are not as easily implemented with a single lifting/control cable configuration, it was decided to maintain the current version, the CR TONGS, "as is" and build a completely new vehicle with the proposed upgrades. The availability of a backup vehicle for redundancy would also be a valuable asset, and in the event of the loss of the newer TONGS, the previous version could be used as a recovery vehicle.

TONGS III DESIGN SPECIFICATIONS

Based upon the criteria identified regarding the ideal configuration, a new system was designed to meet those requirements. These improvements include a new control and telemetry system, new mechanical handling system, updated sensor systems (cameras, sonar, compass, altimeters), new propulsion and power, upgraded control van components, and even a newly designed structural frame. The flyaway vehicle also requires its own control and telemetry system, as well as a tether management system (TMS) and associated systems. The TONGS and flyaway vehicle, a modified DOE Phantom H4, are designed to operate either in tandem, with TONGS acting as a garage and main lift vehicle, or separately as stand-alone systems. This essentially provides three different ROV configurations in support of SFTF operations. These system improvements and components are provided in Figure 5.

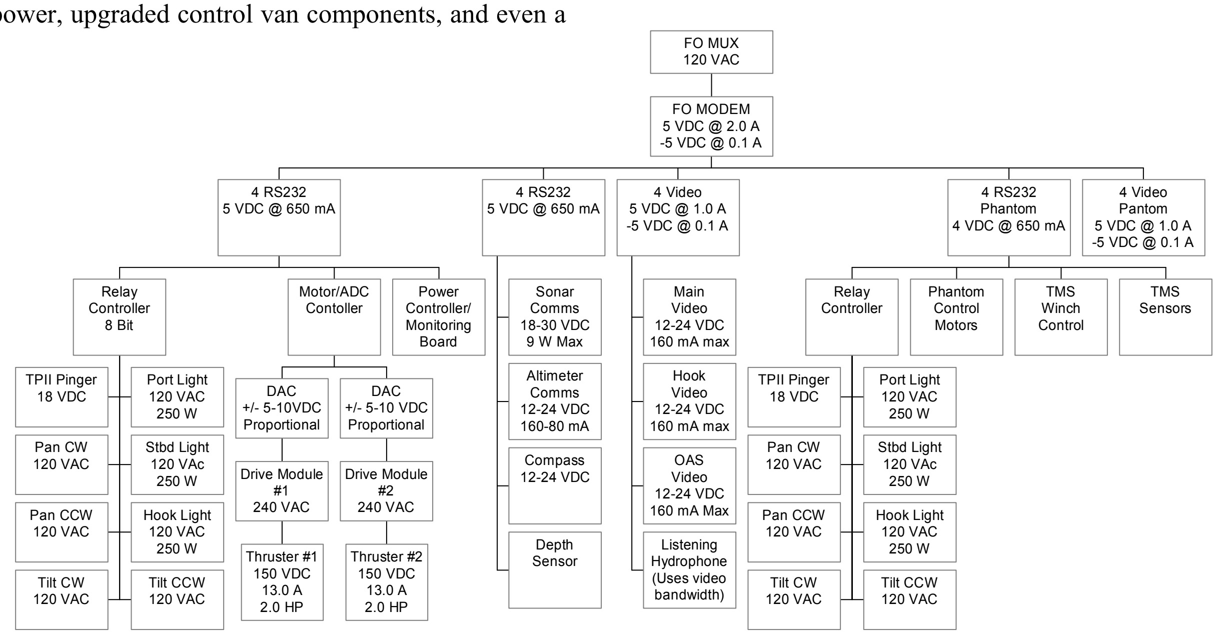

Figure 5
TONGS III Subsea System Flowchart

SUBSYSTEM OVERVIEW

The primary TONGS subsystem, upon which the entire operation is dependent, is the control and telemetry system. A fiber optic-based telemetry system replaces the current copper multi-conductor system, while at the same time significantly increasing capability and expansion potential. The fiber optic system provides 8 video channels, 8 serial communication channels, sonar communication channels, and significant expansion capability with simple card additions. This increased control/information pipeline is also suitable to support a highly sophisticated fly-away vehicle and its submersible tether management system.

The incorporation of a fiber optic system necessitates the use of a fiber optic control cable and associated connectors and interfaces. A single EOM tether is used for both control and deployment/recovery functions. The support system includes a handling winch with an electro-optical slip ring assembly, a fiber optic rotary joint (FORJ) load swivel, and associated underwater, pressure-balanced connectors.

These connectors eliminate the need to move the cable with TONGS or the pod as an attached unit, reducing storage, shipping, and handling requirements substantially.

The submersible FORJ load swivel allows the TONGS to orient itself with the current, without the hazard of twisting the cable or payload around itself.

The sensor upgrade includes new low-light color search cameras, obstacle avoidance and hook cameras, improved lights, upgraded sonar, sonar altimeter, pressure sensor, hydrophone, and tracking transponder interface. The new pan and tilt unit has a sufficient load ratings to support the new sensors, with additional capability for later add-on systems. These upgrades will significantly improve the search, location, and navigation of TONGS, and reduce actual bottom time for recovery operations. They will also allow operation in close quarters with other items on the seafloor, such as units surrounded by cables and other debris.

The fly-away vehicle, a modified Phantom H4, is equipped with new search and survey equipment, compatible with the TONGS equipment. The structure of the Phantom, as well as the thrusters, has been modified to operate to 6,000 fsw. By using both vehicles in concert in the fly-away configuration, the maneuverability and inspection capabilities will be dramatically improved, enabling a wide range of new operational scenarios for the TONGS system to perform.

In addition to improved controls and sensors, new thrusters were also acquired for the vehicle. These motors are more efficient, are designed for underwater operation, feature variable-speed controls, and are not dependant on a limited battery life. They are commercially available with full technical support and service.

The TONGS power system has also been redesigned. With the elimination of the batteries, only AC power is required to operate all TONGS components. The present configuration uses 208 VAC, single phase. A commercially available voltage converter provides all required DC power. This power system is also compatible with the previous version of TONGS when required.

Since SFTF no longer has a dedicated support ship, it is necessary to use various vessels of opportunity, each with different deck layouts and available space. In order to readily utilize these vessels, and to take advantage of the upgrade process, a portable control system has been designed. The control systems are mounted in three ruggedized shipping containers.

The surface control components include two large monitors for the search camera and sonar, one large monitor divided into four smaller sections for the obstacle avoidance, hook, and deck cameras, and another split-screen monitor for the computer control, plotting, and system monitoring displays. Three rack mount computers are required for control, sonar, and plotting interface (Trackpoint / GPS / Nobeltec). The fly-away vehicle's camera and sensors are also integrated into the TONGS control console, to improve operator efficiency as well as to conserve space. The winch control is incorporated into the portable system as well, providing the operator and assistant with complete system control. A separate case includes repair and diagnostic equipment and spares.

The unique TONGS shape, a strong, basic frame of stainless steel, is as much an asset as it is a recognizable characteristic. The new TONGS frame is much smaller than its predecessor, yet it retains the weight required to handle the high water currents on range. Since the large battery housing and other control electronics housings are no longer needed, the two required pressure vessels are mounted below the top plate and protected from damage. The pan and tilt, sonar, lights, cameras, and motors will remain mounted to the bottom of the top plate.

The new, smaller frame allows for TONGS operations off many more vessels of opportunity. For example, the new design permits operation from HBOI's Seward Johnson without removing the sub handling gear, at a large cost and time savings compared to removal and reinstallation costs. The smaller size also facilitates shipping, allowing the entire system to be loaded on a flatbed or box trailer truck without special height permits, or be placed into a standard cargo shipping container for use at other sites.

The frame will also have mounting plates for installing the fly-away vehicle and its TMS. The short, stout frame will be able to handle the fly-away vehicle without the need for additional supports or attachments. All equipment (fly-away vehicle, TMS) will be modular, to facilitate installation as well as shipping and storage.

NEW OPPORTNITIES FOR TONGS III

The redesign and significant improvements to the TONGS ROV system provides an extremely capable and versatile system for a wide range of new and exciting opportunities. The increased detection and location capabilities from the sonar and camera upgrades, the improved mobility due to the new thrusters, the efficiency of the EOM cable system, and the flyaway vehicle capability, makes TONGS the ideal system for use throughout the world, not just at the SFTF facility. Several projects are already on the schedule that will benefit from the new TONGS. These include the Ocean Acoustic Observatory installation on the SFTF range, sensor array recovery and replacement activities at the Southeast Alaska Acoustic Testing Facility (SEAFAC), deepwater mooring inspections to 6,000 fsw in the Tongue of the Ocean (TOTO), Bahamas, and many other engineering projects.

The scientific community, led by the South Florida Ocean Measurement Center (SFOMC), also has installation and recovery tasks scheduled across the Florida Straits. These include deep-water ADCP installations, seafloor classification and sampling projects, and deep-water, high current biological studies in environments too extreme for typical ROV or submersible systems.

These are but a few of the projects that TONGS, a vehicle capable of operations in high currents (exceeding 5 knots), along with a lift capacity of 10,000 pounds, is uniquely and ideally suited.

CONCLUSION

The TONGS system has performed very well at the Fort Lauderdale facility, and it remains a vital tool for the range. Due to changes in support and mission after transitioning into the South Florida Testing Facility (SFTF), however, the system was in dire need of a significant upgrade. Through detailed and insightful discussions with SFTF personnel, as well as lessons learned during past TONGS experience, the new upgraded TONGS III provides the essential capabilities, reliability, and flexibility required perform at the SFTF, as well as many other extreme work sites throughout the world.