Telepresence-Enabled Maritime Archaeological Exploration in the Deep

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Abstract

Telepresence-enabled exploration of deep sea environments has developed over the past 30 years, providing access to archaeologists, scientists, and the general public to sites otherwise inaccessible due to depth. Pioneered through the inception of the JASON Project in the late 1980s, telepresence missions have expanded to two dedicated ships of exploration, NOAA Ship *Okeanos Explorer* and Exploration Vessel *Nautilus*, and has been implemented on a series of opportunistic missions on other vessels. This paper chronicles the history of the use of telepresence for the exploration of shipwrecks in deep water as well as how this capability has allowed the public to engage with such missions. Broadening the scope of who can explore the deep sea, telepresence has also expanded what is observed and documented in the deep, which speaks to humanity's use of the maritime world and an archaeology of discard through our material disposed of into the deep sea.

Introduction

Investigations of shipwrecks in deep water are limited in scope by our ability to reach them. Rather than teams of divers poring over a site with tape measures and cameras and the ability to feel a site, we are limited to viewing a wreck through the single lens of a remotely operated vehicle (ROV), or in some cases the single porthole of a manned submersible. However, in addition to an ROV projecting the scientists and archaeologists onto the seafloor remotely in lieu of diving it themselves, the development of telepresence technology has allowed for expertise and participation in an expedition to join from locations on land. Telepresence vastly expands the ability to remotely participate in ocean science. For decades, scientists have operated exploration vehicles from the relative safety of the surface ship. There now exists the capability to bring experts from many disciplines to a site in real time and incorporate their knowledge into the assessment of a deep-water archaeological site, as the exploration is taking place (Figure 1). While expanding archaeological exploration into multidisciplinary capabilities, this mode of operation is also a paradigm shift. Archaeologists are no longer alone in conducting physical measurements and excavations, but instead now direct and oversee ROV pilots, navigators, and mapping technicians in the collection of measurements and photographs. Time on the seabed has to be used efficiently, balancing multidisciplinary needs and providing opportunity for a range of scientists and interests. This also enables an organic discussion of a shipwreck's site formation processes as an interdisciplinary team conducts exploration. Telepresence has become a more common, and substantial, tool for deep-water archaeological investigation.

The capacity to engage with an unlimited number of scientists, archaeologists, historians, and other specialists also broadens the scope of deep-water maritime archaeology. Where previous missions would target a single wreck and bring the "right" specialists on board, telepresence allows for shipboard personnel to respond to discoveries in real time and engage with whomever is needed, as dictated by each discovery. As ocean exploration expands, so too does the documentation of the modern seabed to include benthic ecology along with shipwreck sites, but also provides a means to assess humanity's broader impact on the ocean as artifacts of the recent past now imprinted on the maritime landscape. In this issue, we discuss an archaeology of

discard as it relates to ocean exploration and deep-water archaeology through the broadening scope of the manmade objects we encounter during deep sea missions. Most important, however, is the point that telepresence enables the public to not only watch but to also interact with archaeologists. Illustrating that archaeology is not some abstract science done by an elite group, missions are instead carried out transparently, open to all to experience and engage with in real time and provide feedback as we conduct our work. The following is an overview of the development of telepresence and use in maritime archaeology and the missions that have been conducted in this way.

The first telepresence-based investigation of a deep-water shipwreck site was in 1989 when Woods Hole Oceanographic Institute and the JASON Project investigated a Roman shipwreck at Skerki Bank between Carthage and Rome (Ballard, 1993). Subsequent expeditions located additional wrecks along this maritime corridor, which essentially became a testing laboratory for evolving deep sea technology, including mapping, high definition imaging, excavation, and telepresence. Since then, a slow but steady paradigm shift in how oceanographic research can be conducted has developed as more scientists and archaeologists have participated in what have for the most part been confined to deep-water projects, and due in a large part to support from agencies such as NOAA's Office of Ocean Exploration and Research (OER). Over the course of almost two decades, the capabilities of at-sea technology, satellite availability, and downlink site accessibility for the live feeds have organically expanded the reach of telepresence. The major infrastructural component is the downlink for the satellite feed to be distributed to command consoles and online media sites. A hub for this is the Inner Space Center (ISC), which was initially set up in a temporary capacity at the University of Rhode Island before a permanent physical center was constructed on the Graduate School of Oceanography campus and opened in 2009. The ISC can support telecommunications and interactivity from multiple ships of exploration at one time, which has included numerous expeditions by Exploration Vessel (E/V) *Nautilus* and NOAA Ship *Okeanos Explorer* (Coleman and Ballard, 2011). Video feeds are distributed from ISC to Exploration Command Centers (ECCs) set up at other universities and science centers where scientists can participate in expeditions, as well as internet portals for public viewership. Other research vessels have been outfitted with telepresence systems for particular missions including academic research vessels in the University-National Oceanographic Laboratory System (UNOLS) fleet such as the R/V *Atlantis*, R/V *Endeavor*, and R/V *Thompson*, and private vessels such as the M/V *Alucia* and R/V *Petrel*, who most recently broadcasted ROV dives during the investigation of the wreck of USS *Indianapolis*.

Through the combination of ships of exploration, ROVs, and telepresence technology, dozens of shipwrecks have been discovered and investigated while streaming the video and audio of this research live to audiences around the world, including shipwrecks in the Mediterranean and Black Sea (Brennan and Ballard, 2013), Gulf of Mexico (Irion et al., 2014; Brennan et al., 2015), and Pacific Ocean (Lickliter-Mundon et al., 2016). Most recently, *Nautilus* explored a number of shipwrecks along the western United States coast, including the WWII aircraft carrier USS *Independence* (Delgado et al., this vol.) and USS *Bugara* (Delgado et al., this vol). At the same time, *Okeanos Explorer* conducted a series of expeditions in the Pacific Ocean and Gulf of Mexico that included a number of shipwreck targets, including the wreck of a Japanese water tanker, *Amakasu Maru No. 1*, and a B-29 aircraft that crashed off Tinian, during the CAPSTONE project (Cantelas et al., 2017).

Ships of exploration paradigm

In 2000, then-President Bill Clinton convened a panel of the Nation's leading ocean explorers, scientists and educators to develop the first U.S. strategy for exploring the largely unknown world ocean. The resulting report, *Discovering Earth's Final Frontier: A US Strategy for Ocean Exploration* laid out their recommendations which included undertaking a national ocean exploration program and supporting dedicated ocean exploration "flagships" outfitted with state-of-the-art technologies. Such technologies would include outreach infrastructure to facilitate education and outreach from these ships through telepresence. These recommendations have come to fruition through NOAA's Office of Ocean Exploration and Research (NOAA-OER) and their support of two dedicated ships of exploration: E/V *Nautilus* and NOAA Ship *Okeanos Explorer*. *Nautilus* is owned and operated by Ocean Exploration Trust (OET).

Both ships use state-of-the art technologies to map and investigate unknown and poorly known areas of the ocean, and do this using a unique approach. Operations are multidisciplinary, and focused on high priority areas identified by the science and management community – primarily through community workshops. Operations are also telepresence-enabled and use satellite telecommunications and broadcasting technology to send live, high-definition video and data to shore. The live video, audio, data and other internet-based tools allow scientists onshore to provide input and help guide the seagoing operation in real-time while simultaneously engaging the general public and sharing the excitement of ocean exploration. Having a dedicated platform has also allowed NOAA-OER and OET to build an extensive Science, Technology, Engineering, Mathematics (STEM) education and outreach program around the E/V *Nautilus* operation that heavily utilizes telepresence.

Early Use of Telepresence for Archaeology

The initial concept of telepresence influenced the migration of deep-water submersible operations from manned to unmanned by allowing remote engineering control and remote scientific participation onboard the surface ship supporting ROV dives. For unmanned ROV operations, with scientists either aboard a ship or at a facility on shore, the idea is the same that participation is done remotely without sending humans below the surface. In his initial discussion of this new paradigm shift, Ballard (1993) saw scientists on shore as a second phase of using "teleoperated" technology after ROVs. Both were developed out of the idea of increasing the rate of exploration, which was restricted by human's limitations in getting to and staying at depth in manned submersibles. This led to the first academic ROV system of *Medea/Jason*, a camera sled eye-in-the-sky vehicle tethered to *Jason*, which was designed to work just above the seafloor with manipulator arms, sensors, and other tools. The development of this system was the first step in the larger objective of a system that could be controlled from shore with live participants anywhere in the world (Ballard, 1993).

The live outreach capability provided by the satellite connection, later termed 'telepresence', developed as The JASON Project, a non-profit organization that managed the educational curriculum based on yearly live expeditions enabled through telepresence technology. The first two years' expeditions were the only ones that focused on shipwrecks, whereas future projects expanded to include aspects of earth and biological sciences. The 1989 expedition brought *Jason* and *Medea* to Skerki Bank in the Mediterranean Sea for the vehicles' first major operation. The

expedition broadcast the exploration of the Marsili Seamount volcano and a 4th century AD Roman shipwreck that sank along the trade route between Carthage and Rome, which was found the year before with the towed camera sled, *Argo* (Ballard, 1993). The 1990 JASON Project investigated two War of 1812 schooners that sank in Lake Ontario in 1813 during a storm, USS *Hamilton* and USS *Scourge*. During this expedition, students at downlink sites were able to pilot the ROVs through a joystick and display connected to the controls on the ship by the satellite link and terrestrial network, illustrating the capability of remote operation from shore.

The integration of telepresence capabilities into expeditions continued over the next decade as technology improved. During this time, Ballard founded the Institute for Exploration at Mystic Aquarium in CT, and established the temporary facility for the Inner Space Center at the University of Rhode Island. Through these institutions, the first telepresence-enabled expedition returned to the Black Sea and Skerki Bank, where a variety of Roman and Byzantine shipwrecks had been discovered on expeditions in the late 1990s and early 2000s (Ballard, 2008; Ballard et al., 2000; Ward and Ballard, 2004). An expedition with the US Navy's research submarine *NR-1* in 1995 and a subsequent ROV expedition in 1997 had resulted in locating an additional seven shipwrecks at this trade route crossroads, including two 19th century wooden sailing ships, as well as two 'amphora alleys' where individual jars were hypothesized to have been thrown overboard during transits (Ballard at el., 2000). The following year, telepresence also enabled a live broadcast to the National Geographic Channel for the Return to *Titanic* expedition as well as a series of educational broadcasts from the ship to participating downlink sites where the JASON Foundation for Education had created learning modules based on the expedition (Ballard and Durbin, 2008; Ballard and Sweeney, 2004; Weirich, 2004).

The game changed in 2008 when two ships of exploration came online – NOAA Ship *Okeanos Explorer* by NOAA's Office of Ocean Exploration and Research and E/V *Nautilus* by Ballard's new Ocean Exploration Trust – which would both be outfitted with permanent telepresence technologies for conducting multiple yearly telepresence-enabled expeditions, working toward the goal of a continual, year-round streams from live expeditions. *Nautilus* conducted a 6-week expedition in 2009 ahead of major shipyard work to install dynamic positioning thrusters and controls, while its telepresence systems came online for the 2010 expedition in the Aegean and Mediterranean Seas. During that expedition, nine ancient shipwrecks were discovered, which were the first of dozens in areas in which *Nautilus* operated until 2012. Nautilus Live (www.nautiluslive.org), the web portal for the live stream from the ship, also launched in 2010. At the same time, *Okeanos Explorer* conducted its maiden voyage in Indonesia, where its live feeds were streamed to shore-side ECCs via Internet2. By 2012, the video feeds were publicly available to anyone with an internet connection via the Ocean Explorer web portal (http://oceanexplorer.noaa.gov). That same year, *Okeanos Explorer* expeditions conducted ROV dives on shipwrecks for the first time and explored five sites in the Gulf of Mexico. Both ships' live video feeds were routed through the Inner Space Center at the University of Rhode Island, which became the hub for all telepresence operations including a "mission control" space where teams of researchers could collaborate and interact with the ships' science teams. These expeditions proved that the use of hardened telepresence technology and the operational workflows associated with remote science participation could become the norm for the evolving ocean exploration program

Telepresence-enabled Exploration Workshops
In 2013, *Nautilus* changed operating areas from the Mediterranean Sea to the Gulf of Mexico and Caribbean Sea, and again when it moved to the eastern Pacific Ocean in 2015. Prior to these regional shifts, OET, in partnership with OER, held Workshops on Telepresence-enabled Exploration in the anticipated operating areas to convene experts in the regions to agree upon high-priority targets for exploration in these two areas (Bell et al., 2013; Bell et al., 2015). These workshops were two in a series of six hosted or co-hosted by OER from 2007 to 2014.

The Caribbean Sea and Eastern Pacific Ocean workshops began with talks about the history, theory, and practice of telepresence-enabled ocean exploration to introduce participants to the new paradigm since many had never used it before. Participants then broke out into groups according to scientific discipline - archaeology, biology, geology, and physics and chemistry - to (1) identify the most pressing regional questions that could be answered using telepresence-enabled exploration in each discipline, and (2) identify transects that could be executed to address and/or answer the key questions posed. Some of the key questions ranged from trade routes to the biogeography of deep reefs to regional tectonics. The transects identified by each disciplinary breakout group were then compiled and the overlaps between them were then discussed by a session of breakout groups according to geographic regions in the ocean (Figure 2). Those groups were tasked with refining the maps further to identify high priority target areas that could be explored with telepresence-enabled ships to address key questions in multiple disciplines.

The Caribbean Archaeology Breakout Group noted that "the region holds great potential for discovery of archaeological sites, as it has been a highly active area for maritime trade since the colonial period. Therefore, it is probable that shipwrecks will be encountered during exploration anywhere in the region, and exploration teams should be prepared for such events" (Bell et al 2013). The Pacific Archaeology Breakout Group focused on "hubs of historic maritime activity, known naval battle sites, and known or suspected deep-water wreck sites. The group also considered the development of Pacific maritime economies, intercultural exchange, and the movement of people within a marine landscape" (Bell et al 2015). These workshops were the first step in setting up the group of scientists and archaeologists who would later participate in the live expeditions from shore and provide input into identifying dive locations and planning the details of each dive. The reports from these workshops guided expeditions in these regions where the ships have been working, and continue to as new expeditions are planned.

Telepresence-Enabled Shipwreck Site Assessments
As telepresence capability developed on the two ships of exploration platforms, a slow acceptance of the new exploration paradigm began among the maritime archaeology community. Casual interest gave way to active participation as further infrastructure was developed to help enable connectivity, including conference calls, email lists, and chat rooms with the scientists on board the ships that allowed archaeologists and other interested scientists viewing from remote locations on shore to engage directly and offer comments, opinions, and even direction. During telepresence-enabled *Okeanos Explorer* expeditions, archaeology dives always engaged a large number of shore-side science participants with the archaeology team actively involved in dive planning. These dives also proved to be the most highly watched by public audiences on the internet, proving the incredible engagement opportunity afforded by maritime history and

underwater archaeology. Telepresence has become a tool in the arsenal of deep-water archaeologists that allows access to sites out of reach. Live feeds from an expedition are not only publicity, but in fact a mechanism for conducting real science efficiently in remote places. While direct control of the shipwreck surveys and investigations remains with the ROV pilots, the engagement of the shipboard personnel with the teams on shore has allowed for productive and successful exploration and documentation of numerous shipwrecks in deep water to archaeological standards. The diverse commentary by multiple remote historians and archaeologists during the live dives, as embedded audio tracks on the recorded video, proved to be a critically important data set valuable for the scientific assessment of the sites and useful for post-dive data processing and analysis.

Turkey

Due to the availability of shipyards for significant upgrades to the ship as well as access to both the Black and Mediterranean Seas, *Nautilus* spent the first four years of operations home ported in Turkey. During the first year of the Nautilus Live website in 2010, *Nautilus* revisited the World War I underwater battlefield of Gallipoli and conducted a live ROV dive to the wreck of the battleship HMS *Triumph* sunk in ANZAC Cove. During additional side-scan sonar survey in the area, a target was located that looked like an amphora-pile type shipwreck. The last dive of the cruise explored this target and determined it to be a Hellenistic shipwreck heavily encrusted with sponges and other growth. Named Gallipoli A, this is the first unknown sonar target to be identified as a shipwreck live via telepresence, something that would become much more commonplace as *Nautilus*' work continued. The ship sailed south through the Aegean Sea from there to continue earlier work off the Datça peninsula in southeastern Turkey where the ancient site of Knidos was located, and explored the waters south of the port of Marmaris in the Mediterranean. Five ancient shipwrecks were found off Knidos in addition to five found in 2009, and another four off Marmaris (Brennan et al., 2012). Each of these was found and documented with live viewers through Nautilus Live, which continued the process of identifying unknown sonar targets as shipwrecks live through telepresence.

The following year, *Nautilus* made its first foray into the Black Sea. The goal of this expedition was to continue the work started by Ballard in 2000 and 2003 that explored the paleoshoreline and dynamics of the oxic/anoxic interface and also found well-preserved shipwrecks in the anoxic zone. *Nautilus* explored the shelf off Ereğli, Turkey (ancient Heraclea) and located five ancient and premodern shipwrecks, and then continued to the coast of Sinop where the previous wrecks had been found. During the ROV dives to the Byzantine shipwrecks found in 2000, the scientists on board were able to get input live through telepresence from the scientists and archaeologists who had led those earlier expeditions as those wrecks were revisited and remapped. In addition to returning to and documenting those already known, another four were located. Observations made at these sites paralleled those of wrecks found on the previous expeditions in the Aegean Sea, that many of the shipwrecks exhibited damage from bottom trawling. One of the wrecks found in 2000, Sinop A, was remapped and the new photomosaic showed changes due to trawl nets moving and removing amphoras and some timbers from the site. Some of the premodern wrecks that had much of the wooden timbers preserved were unidentifiable piles of jumbled wood due to trawl damage (Figure 3) (Brennan et al., 2013). The last shipwreck found on the expedition was Ereğli E, a Hellenistic shipwreck from the 3rd century BC, which showed evidence of having been extensively damaged by trawls to the point

that few artifacts remained intact. Trawls had also ripped up wooden timbers from the hull as well as what were later identified as human bones, a femur and teeth (Brennan et al., 2013; Davis et al., 2018). A return expedition by *Nautilus* in 2012, eleven months later, found this wreck to be even further damaged, the bones no longer there, and a remapping of the bathymetry of the site calculated that 15 m^3 of material was removed by trawls in the intervening time (Brennan et al., 2016).

Nautilus also returned to the Aegean Sea off Knidos in both 2011 and 2012 to continue sonar surveys and target identification in the deep coastal waters along the approaches to the ancient harbor. By the end of the 2012 expedition, a total of 26 ancient and premodern wrecks had been identified, named up through Knidos Z, ranging in date from the Archaic Greek period (6th-7th century BC) to the Ottoman period (15th-16th century AD). Two modern shipwrecks were also discovered during side-scan sonar surveys off the western end of the Datça Peninsula. These ships may have sunk in this region due to encountering strong winds and heavy seas as they rounded the peninsula heading north out of waters otherwise shielded by the land. The first was of M/S *Dodekanisos,* a Greek passenger ship that sank in a gale in 1958 and found during the 2011 expedition. Initially, the team thought the wreck was that of a destroyer or small warship but upon inspecting the site with the *Hercules* ROV, determined it was a passenger ship, however no name or hull numbers were visible on the bow or stern, making identification difficult. This is when the power of telepresence was illustrated. A viewer on the Nautilus Live website wrote in from Greece and said he recognized the ship as *Dodekanisos* and then forwarded a link to an article in a Greek newspaper from 1958. From there, it was easy to match the photos of the ship in the paper to the images on screen from the ROV. A month later, a message was received through the website from the grandson of the captain who died during the sinking and he sent further information about the ship and the sinking (Brennan, 2013).

The second modern shipwreck was located just a few hundred meters away from *Dodekanisos* during the side-scan sonar survey. While the sonar target initially suggested an ancient shipwreck, upon locating the site underwater, it was found to be a very recent shipwreck of a sailing yacht, its sail still raised and lines and buoys floating in the water column (Figure 4). The boat was a German-flagged yacht named *Miranda*. Despite reporting the find to the Turkish coast guard, no record of the sinking or the owners was found. *Miranda* likely sank due to higher-than-expected winds coming around the point of the Datça Peninsula.

Mediterranean Sea

During the time *Nautilus* was based in Turkey, expeditions were also conducted to other areas of the Mediterranean Sea. During one expedition in the Straits of Sicily off Italy, one of the most eerie moments in telepresence occurred. A Nautilus Live viewer - a veteran who flew planes in World War II - wrote into the website and asked if the team had ever found a WW2 plane under water. The ROV pilots had already been moving toward a target on the vehicle's scanning sonar and moments after the question was asked, they came upon the wreckage of an Italian Macchi C202 aircraft from WW2, which remains the only aircraft that a *Nautilus* team has found on the seabed, marking an exciting coincidence with the live audience.

Two expeditions - in 2010 and 2012 - explored the flat-topped Eratosthenes Seamount south of Cyprus to survey pockmarks on the surface of the seamount and the steep sides to examine

tectonic processes affecting the submarine feature. Three shipwrecks were also located during these ROV transects including two 19th century shipwrecks in 2010 (Wachsmann et al., 2011), and a 4th-5th century BC amphora shipwreck in 2012 (Cornwell et al., 2013). In addition to these wrecks, the team also came across more than 150 isolated amphora and other ceramic artifacts on the seafloor during the ROV's survey of the seamount crest. Lying at a crossroads between ancient trade routes from the Levant, Egypt, Cyprus, and the western Mediterranean, these artifacts are representative of sailors disposing of empty containers during transit, similar to the 'amphora alleys' identified during Skerki Bank surveys (Ballard et al., in press). Identified by artifact shape and type, the assemblage from Eratosthenes ranges in date as late as the 14th century AD and as far back as the second millennium BC (Cornwell et al., 2013; Ballard et al., in press). Such discoveries demonstrate the importance of live exploration of previous unexplored areas in deep water where unexpected finds may require the attention of experts who are not onboard.

Gulf of Mexico

While *Nautilus* spent its formative years exploring the Mediterranean Sea, *Okeanos Explorer* conducted expeditions in the Pacific Ocean, beginning with shakedown operations off the US west coast and around Hawaii starting in 2008. The first telepresence-enabled ROV expeditions with remote participants started in Indonesia in 2010 and the Galapagos in 2011 before transiting the Panama Canal into the Caribbean Sea. A three-leg expedition in the Gulf of Mexico brought *Okeanos* to the first shipwrecks it explored with an ROV, all of which were sonar targets located by the oil and gas industry during lease block surveys. The goal of the five dives was to ground-truth, image and conduct interdisciplinary site characterization of the anomalies to assist in the identification of the sites and possibly aid in determining their historical significance for eligibility to the National Register of Historic Places. The first site, in DeSoto Canyon at 2550 m depth, appeared to be a partially buried wooden vessel in the 2011 sonar data but had never been visually examined. The ROV dive yielded a surprise: a closer look at what first appeared to be a tangled pile of wire, on closer look revealed rigging elements and degrading wood. The site is thought to be the remnants of a mast either from a de-masting event or the mast of a shipwreck that has not yet been located (Faulk and Elliott, 2014).

Three more wrecks were investigated in the area of Viosca Knoll near the mouth of the Mississippi River. All were initially discovered during oil and gas industry surveys and then imaged with multibeam using the National Institute for Undersea Science and Technology's (NIUST) Eagle Ray AUV in 2009 (Diercks et al., 2010). A dive on site 15429 in 480 m depth revealed an ~80 m long iron hulled sailing vessel from the late 19th or early 20th centuries with steam-assisted machinery. The vessel's decking was gone, leading the team to conclude the deck had been wood and the bow was home to a large and thriving colony of *Lophelia pertusa*. Site 407 is a 45 m long wooden vessel resting at 280 m depth with the exposed frames on one side and at the bow covered so extensively by anemones and sponges it was difficult to obtain additional information. Site 359, which had been briefly investigated with a Deep Rover submersible in 2002, was found to be a large wooden-hulled sailing vessel 61 m-long in 400 m of water, stoutly built and remarkably intact (Warren et al. in prep). Initial observations date it to the late 19th or early 20th century and suggest it may be one of the best-preserved wooden shipwrecks yet discovered in the Gulf of Mexico. A later dive in the area of Keathley Canyon in the western Gulf of Mexico found the wreck of a copper-sheathed 19th century ship at 1330 m

depth that contained a large variety of artifacts and was thought to have the potential of being a privateer wreck (Austin, 2012). After a few hours of documenting the site, with numerous maritime archaeologists watching live from shore, the importance of this shipwreck was clear. Private funding was secured and an interagency, multidisciplinary team was assembled for both at sea and on shore participation, including archaeologists and scientists from NOAA, Bureau of Ocean Energy Management (BOEM), Bureau of Safety and Environmental Enforcement (BSEE), Texas Historical Commission, Meadows Center for Water and the Environment, Texas State University, Texas A&M University at Galveston, and OET. The following year, *Nautilus* was contracted to return to the site for high resolution mapping and targeted excavation of key artifacts.

The 2013 mission to the site, which had been designated the "Monterrey Shipwreck" based on Shell Oil's leased "Monterrey Prospect," where the wreck is located, was a seven day project that mapped the site and conducted the first live telepresence-enabled deep-water archaeological excavation in U.S. waters. The excavation recovered sixty-four diagnostic artifacts for conservation and analysis, including ceramics, bottles, navigational instruments and firearms. Telepresence provided a live, real-time link to archaeologists and historians on shore, but also and importantly to a dedicated oceanographic and marine biology team at a specially-installed ECC at Texas A&M University, Galveston, as well as close to a hundred other scientists in the U.S. and abroad. Integrated, multidisciplinary research has been a hallmark of deep-water exploration on NOAA/OET expeditions, and in addition to the archaeology, the team made a series of biological observations, collected samples, including a previously undescribed anemone, and with push cores assessed sediment for biological/bacteriological colonization and the spread of metals from the corroding copper sheathing on the wreck's hull (Figure 5).

Telepresence also provided the international public with more than an "over the shoulder" look at archaeology. Similar to other missions, the scientists answered audience questions and shared what was happening through ongoing commentary throughout the mission. Because the project ran on a 24-hour rotation, that meant a global audience was reached and interacted with as the work spanned all time zones. The range and nature of the questions, particularly during artifact recovery, provided what was likely the largest interactive online experience in underwater and maritime archaeology for the public to date. The project attracted international media exposure and a feature article in Archaeology Magazine (Hilgers 2014). At the conclusion of the documentation and excavation, there was sufficient time for the team to examine two nearby sonar targets a few nautical miles away. They were two other early 19th century shipwrecks with similar artifact assemblages. The team believes the three wrecks, now known as Monterrey A, B and C, were sailing and lost together, likely in a storm.

Nautilus continued exploration cruises in the Gulf of Mexico in 2014 and conducted a series of dives on known shipwrecks from World War II. In 1942, Germany sent a fleet of U-boats to attack American shipping along the eastern seaboard where they targeted freighters and tankers with provisions to resupply the European Allies in the war effort. Operation Drumbeat saw U-boat attacks on American shipping in key maritime shipping corridors including off Block Island, New Jersey, North Carolina, and into the Gulf of Mexico along shipping routes between Houston, New Orleans, and Florida. Numerous oil tankers were sunk in the northern Gulf of Mexico, and *Nautilus* conducted ROV dives on two of these, *Gulfoil* (at 493 m depth) and

Gulfpenn (at 554 m depth) sunk by U-506 three days apart (Brennan et al., 2015). Both of these oil tanker wrecks lie within the depth where the deep-water coral *Lophelia pertusa* is able to grow, which is typically below the photic zone down to 630 m - although a recent *Okeanos* dive observed the coral at 799 m (Lunden, 2012) - so both tankers are encrusted with growths of the white reef-building coral. *Alcoa Puritan*, a freighter carrying a cargo of bauxite sunk by U-507, was explored later in this expedition at a depth of 1843 m, well below the depth at which *Lophelia* grow. During these dives, multiple biologists and coral experts joined the discussion while viewing the feeds from shore, helping to characterize the benthic communities using the wrecks as artificial reefs. These shore-based observations of biological communities thriving on shipwrecks that lie within an otherwise sparsely populated benthic environment has reinforced studies of the population dynamics and habitat characterization of marine ecosystems being influenced by shipwrecks, and thereby speak to the wrecks' site formation processes.

The main focus of the *Nautilus* expedition to document the wrecks of the U-boat assault on American shipping were U-166 and SS *Robert E. Lee*. In late July of 1942, U-166 entered the Gulf to lay mines off the Mississippi Delta, where it sank the passenger ship *Robert E. Lee*. Despite also rescuing the survivors of the sinking ship, anti-submarine escort, *PC-566* sailed over the last seen location of the U-boat and dropped depth charges. A few days later, an aircraft claimed the sinking of U-166. It was only once the wreck of the U-boat was found in 2001 only 2 km away from the wreck of *Robert E. Lee* that the kill was attributed correctly to *PC-566* (Church et al., 2007). The *Nautilus* expedition to these wrecks filmed the two halves of U-166, broken by the depth charge explosion, the fairly intact wreck of *Robert E. Lee*, as well as the passenger ship's lifeboats, which lay in a pile near the wreck. Photomosaic and bathymetry surveys were conducted of the sites with high definition imaging systems on the *Hercules* ROV (Brennan et al., 2015). Numerous archaeologists, including those who located the wrecks in 2001, viewed the live feed and gave input on the dives. This input became part of the record of observations associated with the dive and provided valuable additional information about the history and site formation processes.

A final shipwreck explored by *Nautilus* in the Gulf was an unknown sonar target provided by BOEM. Thought to be a large wooden wreck located during a lease block survey, upon locating the wreck with the ROV, it turned out to be the wreck of *Spruance*-class destroyer USS *Peterson*, which was sunk in 2004 as part of a training exercise (Figure 6). During the dive, veterans who had sailed on *Peterson* wrote into the Nautilus Live website, identifying *Spruance*-class features before the identity of the ship had even been confirmed by the name on the stern. This was an important telepresence-enabled dive because BOEM had previously not known details about this particular wreck's location and condition, so the telepresence connection assisted BOEM in managing cultural resources in the Gulf of Mexico.

Pacific National Marine Sanctuaries and Monuments

In 2015, both ships of exploration transited the Panama Canal and began work in the Pacific; this was a first for *Nautilus*, and a return for *Okeanos Explorer*, which had spent the last few field seasons mapping and exploring in Atlantic submarine canyons and throughout unexplored regions in the Gulf of Mexico. While *Okeanos Explorer* moved to the central Pacific to conduct exploration in the National Monuments, *Nautilus* worked its way up the west coast, conducting a series of expeditions in the National Marine Sanctuaries. Recently expanded, the Pacific

Sanctuaries, especially Cordell Bank and Greater Farallones (formerly Gulf of the Farallones) National Marine Sanctuaries, extend across a large swath of California's coastline and include numerous shipwreck and archaeological sites, including many potential sites that have not been found or documented. The first National Marine Sanctuary was in fact established for the protection of a shipwreck site in 1975 for the wreck of the Civil War ironclad, *Monitor*. Since then, the Sanctuaries have been established in large areas of US coastal waters to protect not only shipwrecks but entire marine environments and ecosystems. In 2015, *Nautilus* conducted its first work in the Sanctuaries, making a series of mapping dives to the wreck of the airship USS *Macon* at 460 m depth in the Monterey Bay National Marine Sanctuary.

Expeditions in 2016 saw the ships' greatest presence in the Sanctuaries as well as the National Marine Monuments and the largest number of shipwrecks explored via telepresence. Public interest in the expedition was bolstered by NOAA's own social media presence and outreach for both *Nautilus* and *Okeanos Explorer* missions. Early in the expedition season, *Nautilus* conducted a dive on a Canadian hydrographic survey sonar target suspected to be SS *Coast Trader*. The dive confirmed the identity of the wreck as the freighter sunk by the Japanese submarine I-26 just over the border in Canadian waters along the Olympic coast, the only ship sunk in Canadian Pacific waters during World War II. Listed on NOAA's Potentially Polluting Wrecks (PPW) list of shipwrecks suspected to be at risk of leaking oil, there was a concern that a spill from *Coast Trader* would impact the Olympic Coast National Marine Sanctuary. As this dive occurred during an expedition with no archaeologists aboard, multiple authors here participated in directing the dive on this wreck from the Inner Space Center in Rhode Island, communicating directions to the ROV pilots on board *Nautilus*. Because of this opportunity, we were able to evaluate the condition of the wreck and determine that its rivets showed little to no sign of weakening due to corrosion, thus there was little chance of oil leaking from the tanks that remained intact (Delgado et al., 2018).

Later in the 2016 field season, *Nautilus* conducted exploration in the Greater Farallones National Marine Sanctuary (GFNMS) with the objective of mapping and diving in undocumented areas of the newly expanded parts of the sanctuary in deep water. In addition to hard-bottom identification and subsequent coral and sponge sampling for expanding the species list for the Sanctuary, a series of shipwreck sites within the protected area were prioritized for exploration of the cultural resources for the sanctuary (Roletto et al., 2017; Delgado et al., 2017). Numerous shipwrecks speak to both the heavy use and hazards of San Francisco Bay, both within the Golden Gate and outside. The first shipwreck dive was on the wreck of SS *Dorothy Wintermote*, which ran aground south of Point Arena in 1938. This wreck is at a depth of 85 m and is so close to land that viewers on Nautilus Live commented that they could see the exploration vessel's lights from their home. The final dive of the expedition, on the way back to San Francisco, was on the wreck of the historic steam yacht, SS *Ituna*, which sank in a storm in 1920. Due to its shallow depth and exposure to warmer waters and biological activity, *Ituna* is corroding badly and heavily encrusted with invertebrates as the wreck structure acts as an artificial reef for anemones (Roletto et al., 2017).

As articles later in this volume detail, *Nautilus* conducted two ROV dives on the wreck of USS *Independence* during this expedition. The World War II aircraft carrier was a floating target at Bikini Atoll during the first two atomic test blasts in 1946, towed to San Francisco for

decontamination testing the following year, and then scuttled off the Farallon Islands in 1951. At a depth of 900 m, the wreck is located at the very northern edge of the Monterey Bay National Marine Sanctuary, but due to proximity, is managed by GFNMS, which is fitting as the wreck is certainly part of the San Francisco Bay Area's maritime cultural landscape. The discovery of *Independence* wreck in 2015 by an AUV sonar survey was well publicized, including a special issue of this journal (see Delgado et al., 2016), so by the time of the Nautilus expedition, the buzz about the shipwreck had built, including anticipation regarding the formerly "radioactive" ship from Bikini. As such, and given the opportunity provided by the Nautilus Live platform, the messaging of the shipwreck investigation was steered toward responsible stewardship of the site within the sanctuary and openly and transparently assessing whether the wreck posed any radiological risk. The consulting nuclear scientists who participated in the mission had briefed the team that there was no risk, even if the ROV landed or collected samples, but it was imperative that this be demonstrated, something that telepresence uniquely provided the opportunity to do. Based on the insulating properties of water and the half-lives of the isotopes involved, no radiation levels above those ambient in seawater were expected. Divers have been working in and around the shipwrecks still at Bikini Atoll at the site of the nuclear detonations for decades with no problems. Scientists from UC Berkeley's RadWatch team participated in the expedition, and took readings for radioactive materials and isotopes on the ROVs throughout the mission. The telepresence capability of *Nautilus* allowed the scientists and archaeologists on board to engage in real time with the public, with complete transparency about what was being seen and done at and around the *Independence* wreck, and with the capability of maintaining a message of site conservation and management through the Sanctuaries. This was a rare opportunity in archaeology for such direct involvement with the audience. The website and social media statistics for these two dives are discussed in the next section.

While *Nautilus* explored the west coast Sanctuaries, *Okeanos Explorer* worked in the central and western Pacific and had the opportunity to explore several shipwrecks and an aircraft during their three-year CAPSTONE expeditions. The multi-year effort focused on collecting baseline information on deep-water regions of U.S. marine protected areas. *Okeanos Explorer*'s track to remote areas of the Pacific touched on vessels and aircraft lost in major campaigns and actions of WWII and others important to U.S. history. In 2015, *Okeanos Explorer* conducted a dive on the WWI era S-Class submarine, S-19, near Oahu, scuttled by the navy in 1938. With a known date of sinking, coral scientists participating from shore were interested in the site as hard bottom habitat for deep coral colonization. The following year, while working just offshore of Wake Atoll in the Wake Atoll Unit of the Pacific Remote Islands Marine National Monument, *Okeanos Explorer* searched for the Japanese destroyer, *Hayate*, sunk in December 1941. *Hayate* was the first major Japanese surface vessel sunk by American forces at the outset of the war. Several promising sonar targets were selected to dive on with the ROVs *Deep Discoverer* and *Seirios*. One target, suspected to be *Hayate*, turned out to instead be the Japanese water carrier, *Amakasu Maru No. 1*, which was sunk by a US submarine in December 1942 and is one example of the numerous merchant ships targeted during World War II to slow the war effort by both sides. With Japanese characters visible on the stern, telepresence once again demonstrated its value when a Japanese scientist translated the name of the ship and within minutes participating historians and archaeologists were able to piece together the vessels history and demise while on site (Cantelas et al., 2017).

Late in WWII, Tinian Island, now part of the Commonwealth of the Northern Mariana Islands, became a major airbase for the B-29 Superfortress. Historical records document numerous B-29's crashing in the deep water of Saipan Channel, a narrow three mile wide gap separating Tinian and Saipan. Following an intense effort to map and analyze data from part of the channel to find one of these sites, *Deep Discoverer* identified a target as a crashed B-29 aircraft and associated debris trail. During this dive, a family member of a missing airman from a crashed B-29 watched the live feed, although this specific aircraft was not identified (Cantelas et al., 2017; Lickliter-Mundon et al., this vol.). Rounding out the year while conducting ROV engineering dives off Pearl Harbor, south of Oahu, numerous items of unexploded ordinance were found including 500 pound bombs. The area was used for disposal by the armed forces during and after WWII. A brief revisit was made to S-19 and to a sonar target identified as the *Royal Taipan* by the name on its stern. Archaeologists participating from multiple locations on shore soon discovered the wooden vessel was a WWII auxiliary motor minesweeper, *YMS 470*, built in 1944 and after a long and varied career, was intentionally sunk in 1996. The final dive of the year explored the wreck of a Japanese midget submarine on December 7, the 75th anniversary of the Pearl Harbor attack. This submarine was sunk by USS *Ward* just outside the entrance to the harbor and marked the first shot fired by the United States in World War II (Delgado et al., 2016). This dive occurred in the morning of December 7 and the timeline of the attack, including the moment of the *Ward's* opening shot, were marked by the on board science team in commemoration along a live audience of over 1.5 million people.

The following year, *Nautilus* dove on the wreck of the submarine USS *Bugara*, which sank while under tow off Cape Flattery, WA in 1971 on its way to be sunk as a target, and *Okeanos Explorer* dove on USS *Baltimore*, the wreck of a late 19th-century cruiser that had served in the Spanish-American War and World War I, and was scuttled off Pearl Harbor in 1944. Numerous archaeologists tuned into the *Baltimore* dive from across the country, lending guidance and expertise to the documentation of the cruiser's wreck (Van Tilburg et al., 2018). For the *Bugara* dive, a team assembled at the Inner Space Center at URI to lead the dive. Joining the team was the former captain, LCRD Ed Ettner, brought back to his ship 59 years later, connected live through the satellite connection from *Nautilus* (Guerrero, 2018). This dive is chronicled later in this volume.

Okeanos Explorer then transited the Panama Canal and carried out a 2017 mission in the Gulf of Mexico where it conducted dives on two sonar targets identified by BOEM archaeologists as possible shipwrecks. The first target was found to be a nineteenth century shipwreck, immediately identifiable by the copper sheathing preserved in the outline of the ship's hull similar to that found on two of the Monterrey wrecks that both *Okeanos* and *Nautilus* made dives to between 2012 and 2014 (Irion, 2017). Notable features of the wreck include a large sheet anchor amidships and lead draft marks - numbers 12 and 13 - hammered into the stem post at the bow. Preliminary analysis of the hull and artifacts on the site by the variety of archaeologists tuning into the live feed that this wreck is that of an early-to-mid nineteenth century, three-masted, square-rigged merchant ship. The second sonar target was a large reflection with a scatter of what appeared to be debris extending out from one end. Upon visual inspection, this target turned out to be a sunken container that had fallen off a cargo ship at some point in the recent past. Spilling out of the broken container was a shipment of washing machines (Figure 7). While not the historic shipwreck the large number of archaeologists who were watching from

various locations ashore were hoping the target would be, the documentation of sunken material in the deep Gulf and hard ground for habitat in the future remain objectives of exploratory deep water missions.

Lastly, following the discovery of the battleship USS *Indianapolis* in September 2017 by Paul Allen's R/V *Petrel*, a live event from the ship was televised to PBS. During this live broadcast, a dive to the shipwreck was shown. While not a true telepresence-enabled expedition in the sense that scientists were not participating remotely, nor was there an interactive component by audiences during the live event, the capability of the live presentation from *Petrel* suggests a capability that could be utilized for future telepresence-enabled missions.

Shipwrecks and the public landscape of the National Marine Sanctuaries

The coasts of the United States are the most populated areas and the coastal waters the most heavily used and trafficked. These coastal waterways can be viewed as the exit ramps from maritime shipping lanes heading into ports. Additionally, Americans use and experience the waters along the shoreline constantly and in numerous varied ways. Many of the country's National Marine Sanctuaries, especially those off California, encompass such areas of heavy use such as off San Francisco and Los Angeles. Therefore, these Sanctuaries are not only protecting marine ecosystems, but also preserving a public landscape and history of our use of these waters. While this may be the case, most Americans know little about what lies offshore. One of the greatest capabilities that telepresence provides is the ability to bring the deep ocean to the public, which has been done to great extents by both ships of exploration, through the websites of Ocean Explorer and Nautilus Live. These sites are the internet platforms where the live video from the ROVs plays live during expeditions. These sites, plus extensive social media presences and other outreach activities, are live portals to the deep ocean for everyone.

We will use the Greater Farallones *Nautilus* expedition as an example of the reach of these outreach platforms here. This expedition in particular was important because it came following the expansion of the Sanctuary from a 1,282 square mile area outside San Francisco Bay to encompass 3,295 square miles by adding a large swath of northern California coast to the north of Cordell Bank National Marine Sanctuary in 2015. The following summer's expedition was the first exploration in these newly added areas, including the multibeam sonar mapping of the deeper areas. These protected waters comprise a public landscape extending offshore, making systematic and accessible exploration of them important.

As mentioned previously, some of the work during this expedition focused on some of the shipwrecks in the Sanctuary: SS *Dorothy Wintermote*, USS *Independence*, and SS *Ituna*. The first two of these had never been seen before. This work followed other work on shipwrecks outside the Golden Gate and around the Farallones, including the wrecks of SS *City of Rio de Janeiro* and *Conestoga* (ONMS, 2014; Delgado and Schwemmer, 2016). All of this work, and the media attention and outreach efforts it generated, adds to the public awareness and understanding of the cultural resources offshore. For the 2016 expedition, the telepresence capability of *Nautilus* and the outreach platform of Nautilus Live allowed for further live dissemination of the research, which included live interactions with schools, museums and aquariums, and giving thousands of the worldwide public a front row seat through the live video feeds while providing science interpretation and answering questions submitted online. Table 1

shows the Nautilus Live and social media data for the two days of USS *Independence* dives along with the dives on SS *Coast Trader* and USS *Bugara*. The excitement that built for the *Independence* dives is apparent in these numbers, which was bolstered by the Sanctuaries' own outreach activities, which included joint events with OET at the Exploratorium in San Francisco. The viewership for Nautilus Live grew organically year to year since the site's inception in 2010 and the growth of the social media impressions between the wreck dives in 2016 and 2017 also indicates this.

As later papers in this issue detail, the live exploration of *Independence* and *Bugara* presented an opportunity to refine the messaging of maritime archaeology to a public audience tied to the National Marine Sanctuaries, as *Bugara* lies within the Olympic Coast NMS. Maritime archaeology in the public eye is often blurred by the allure of treasure hunting. Tailoring the messaging of exploration live to the audience, and giving them access to the onboard scientists through the ability to ask questions through the Nautilus Live website, allowed for an interactive discussion about what we were doing and why. We were able to recount the archaeology of the Cold War from both the Bikini Atoll tests and the service history of Bugara through these two wrecks and what can be learned from studying the modern wreck sites, tied to the biology and marine environments today, all of which is part of the public landscape of the National Marine Sanctuaries.

Table 1. Nautilus Live website viewership statistics from the time frame during dives on three shipwrecks

	Date of dive	Total Nautilus Live pageviews	Total NL unique users	Facebook impressions	Twitter impressions
SS *Coast Trader*	June 2, 2016	31,705	6,354	52,500	22,965
USS *Independence*	Aug 22, 2016	91,095	23,885	1,071,213	318,396
USS *Independence*	Aug 26, 2016	38,692	9,438		
USS *Bugara*	Sep 25, 2017	19,821	4,473	165,828	65,534

Telepresence and the Archaeology of Discard

Telepresence-enabled exploration provides a new avenue for archaeology as it allows us to investigate the recent past on a broader scale, as opposed to expeditions that target a specific wreck. What has come to light from recent work is an ability to find and document – sometimes accidentally – some of the more mundane features of human activity in a maritime world. For centuries, mankind has used the ocean as an 'out of sight, out of mind' place to dispose of unwanted or old material. As archaeology expands into a new paradigm of exploratory projects, such 'junk' becomes part of the archaeological record, a component of human use of the oceans, and which contributes to anthropogenic impacts on the marine environment. As such, it is an

archaeology of discard. This term has been previously applied to terrestrial sites and studies of refuse, middens, or deposits of lithic debitage from stone tool manufacture (e.g. Holdaway et al., 2004). Arnshav (2014) recently applied the study of garbology to marine debris and the maritime cultural landscape, which had previously not been included in the study of trash, again likely due to the fact that people do not live in the sea and the material remains out of our way.

Nevertheless, we have an impact on the seabed and marine environment with our actions and our disposed material. Arnshav applies the term 'Seafloorscape' to avoid the implication of a visitable area, as the seafloor is uninhabitable to humans (214: 3). The footprint of past and contemporary civilization is represented here by shipwrecks but also by such things as trawl scars, constructed works such as oil rigs, and of course garbage and debris from human activities. Archaeologically, human actions are represented on the seafloorscape differently than in the layered deposits typically encountered in archaeology. The seabed acts as a two-dimensional palimpsest upon which the human actions in a three-dimensional world are imprinted and can also be erased through sedimentation, bottom trawl fishing, or other such actions. Trawl impacts to shipwreck sites has been well documented through numerous telepresence-enabled missions as substantial (Brennan et al., 2012; 2013; 2016) as well as physical debris of nets, rollers, and floats hung up on wrecks like *Coast Trader* (Delgado et al., in press) and *Independence* (Delgado et al., this vol.). Three mediums of human action can be represented on a single seabed surface - submarine, surface, and aerial - and such an approach may be taken to World War II and later naval battlefields where action took place underwater, on the sea surface, and in the skies. The physical remains of all such actions upon a single parcel of sea would be imprinted on the respective single area of seabed below.

The idea of garbology as archaeology, especially in a maritime context as Arnshav discusses, becomes more realistic with time. In approaching the archaeology of discard, the majority of the material was disposed of accidentally, for example, the container with washing machines located by *Okeanos Explorer* in the Gulf of Mexico. Another example is a dive with ROVs *Hercules* and *Argus* from *Nautilus* off southern California that came across a group of soda cans in a small pile wedged into a crevasse in a rock outcrop that date to the early 1970s (Figure 8). Due to their grouping, it appeared the cans fell overboard in some sort of degradable package that sank them together. Even these examples of modern trash are nearing the 50 year mark. Traditionally, plastic has not been considered 'archaeological', but as Arnshav (2014) points out, marine debris reflects humanity's use of the sea. This is apparent in the Great Pacific Garbage Patch that has recently been drawing attention and concern. While microplastics are a large component (94% of the pieces) and a concern for wildlife, the majority of the material by tonnage in this floating patch of plastic is actually discarded fishing gear (Parker, 2018) - like that which we see hung up on shipwrecks - including nets, floats and rollers. Many shipwrecks also fall into the category of accidental losses, like those that sink in storms or run aground; the foundering of USS *Bugara* is one example.

With increasing areas and depths of exploration, the idea of marine 'disposal' is revealed to have been nothing more than a convenient illusion (Arnshav, 2014). Unlike accidents, disposal and abandonment are acts of intent (Richards, 2013; Lenihan, 2013). The archaeology of discard becomes further apparent with extended forays into the marine environment that deep-water exploration provides, and we get a glimpse into the mindset that led to disposing of dangerous,

unwanted, or unsavory materials into the deep. Nowhere is this mindset more apparent than with the irradiated shipwrecks of the Bikini Atoll nuclear tests. The 78 ships moored at Bikini Atoll during the Able test blast in July 1946 (and 75 during the Baker test later that month, sans the three that sank from Able) were not a collection of only derelict, outdated ships ready for retirement or scrap; they included newer ships and the intent following the blasts was to reuse those that did not sink (Lenihan, 2013). A total of 16 ships sank during the two blasts, but another 61 were determined to be unfit for further use and disposed of in a number of locations either by scuttling or sunk as test ships (Delgado et al., 1991). These included USS *New York* and USS *Nevada* off Pearl Harbor; USS *Crittenden*, USS *Gasconade* and USS *Skate* off southern California; and finally USS *Independence* off San Francisco in 1951. Few of these have been located since their sinking.

As we mentioned earlier, and as is further discussed later in this volume by Delgado and colleagues, *Independence* was also filled with 55-gallon drums of low-level radioactive waste in concrete before its sinking, therefore not only being discarded itself, but used as a vehicle for such. The 2016 *Nautilus* mission to *Independence* observed a few of these barrels, including latex gloves and concrete (Figure 9), as well as the remains of two aircraft still on board, knocked into the hangers from the deck where they had been positioned during the test blasts (Delgado et al., this vol. aircraft), suggesting behavior in the disposal of these ships that was intended to remove the ships from public sight as quickly as possible. The telepresence-enabled mission to *Independence* in 2016 not only allowed for shore-side participation from scientists, but like the Monterrey wreck excavation, the ROV investigation of the formerly radioactive ship was done transparently in real time so viewers could understand the work being done and what lie just offshore in the public landscape off San Francisco. While not radioactive, other derelict warships were sunk as targets at other times, as would have been the fate of USS *Bugara* had it not sank while under tow. USS *Baltimore* was sunk off Pearl Harbor in 1944 after decades of service and USS *Peterson*, more recently, was sunk in the Gulf of Mexico in 2004 as a test for the new *Zumwalt*-class DD(X) destroyer. Expeditions of ships of exploration, like *Nautilus* and *Okeanos Explorer*, have had the opportunities to locate and document such relics of our maritime history through the ability to conduct exploratory missions with the expertise available to appropriately respond to unplanned discoveries.

The paradigm of telepresence-enabled ocean exploration is broader than the scientific missions of the past have traditionally been. Instead of targeting a specific research question with hand-picked scientists of certain specialties, the ships of exploration focus on targeted areas selected by the community based on workshops where any number of discoveries and observations are possible. This only functions because of the telepresence capability that allows scientists of any specialty access to the live expedition, and gives the at-sea team access to their input and knowledge. In regard to shipwreck exploration, a new phase of maritime archaeology is organically growing as research questions can expand beyond a targeted mission to "map *Titanic*" to one such as documenting the cultural landscape of the Gulf of Mexico. Exploration, driven by the capacity to connect people through telepresence, provides the opportunity for systematic, regional work, and expands the potential of research beyond the hypotheses of a single scientist or group. We are seeing a paradigm shift among the archaeological community from an attitude of "why are we wasting time zooming in on biology on a wreck site?" to interdisciplinary coordination to include biological research as an integral part of site formation

processes at shipwreck sites, as an example. Due to the cost of deep sea exploration, the objective is to use time on the seabed efficiently, thereby approaching shipwrecks as both archaeological sites and time-stamped deposits as hard bottom for colonization. Telepresence provides the opportunity to bring an unlimited number of scientists, specialists, and researchers to the sites, maximizing the information that can be obtained from every minute of bottom time. Through such missions, the telepresence-enabled exploration of the deep sea, maritime archaeology is also beginning to document a broader view of the impact on the planet by mankind's use and disposal of materials. There are trawl nets hung up on USS *Independence* and SS *Coast Trader* (Figure 10), modern trash on *Titanic*, soda and beer cans on ancient shipwrecks in the Mediterranean, and entire shipping containers in the deep sea. A larger picture of humanity's material impacts on the ocean is part of archaeology's place in ocean exploration. This is where the deep frontier of maritime archaeology is headed, and telepresence is bringing everyone there.

Figures

Figure 1. Archaeologists in the control van on *Nautilus* directing the exploration of USS *Independence*. *Image courtesy of Ocean Exploration Trust.*

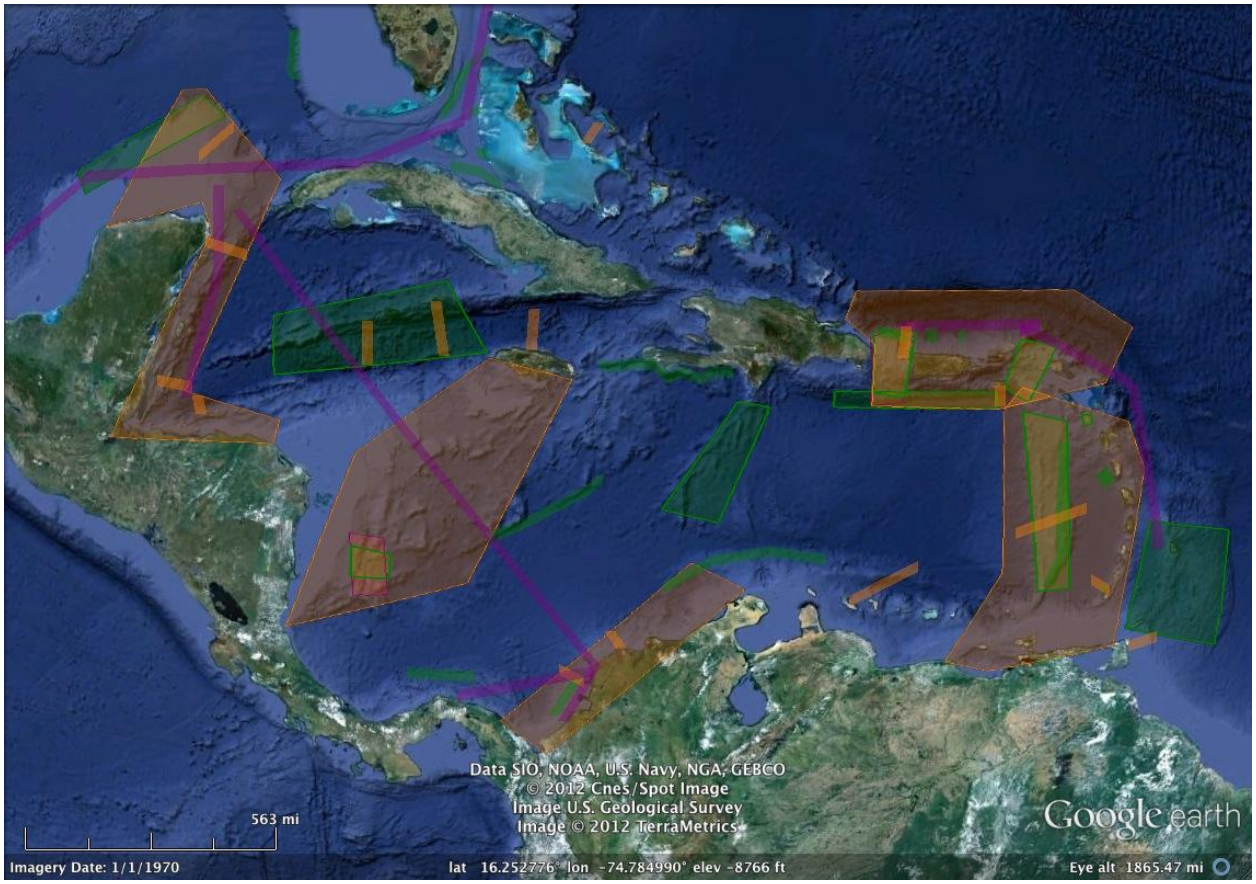

Figure 2. Results map from the Caribbean workshop identifying areas of interest. Archaeological target areas are shown in purple (from Bell et al., 2013).


Figure 3. ROV image of Eregli C shipwreck from the Black Sea (from Brennan et al., 2013). *Image courtesy of Ocean Exploration Trust.*

Figure 4. ROV image of a recent shipwreck of a sailboat, *Miranda*, located off southwestern Turkey. *Image courtesy of Ocean Exploration Trust.*

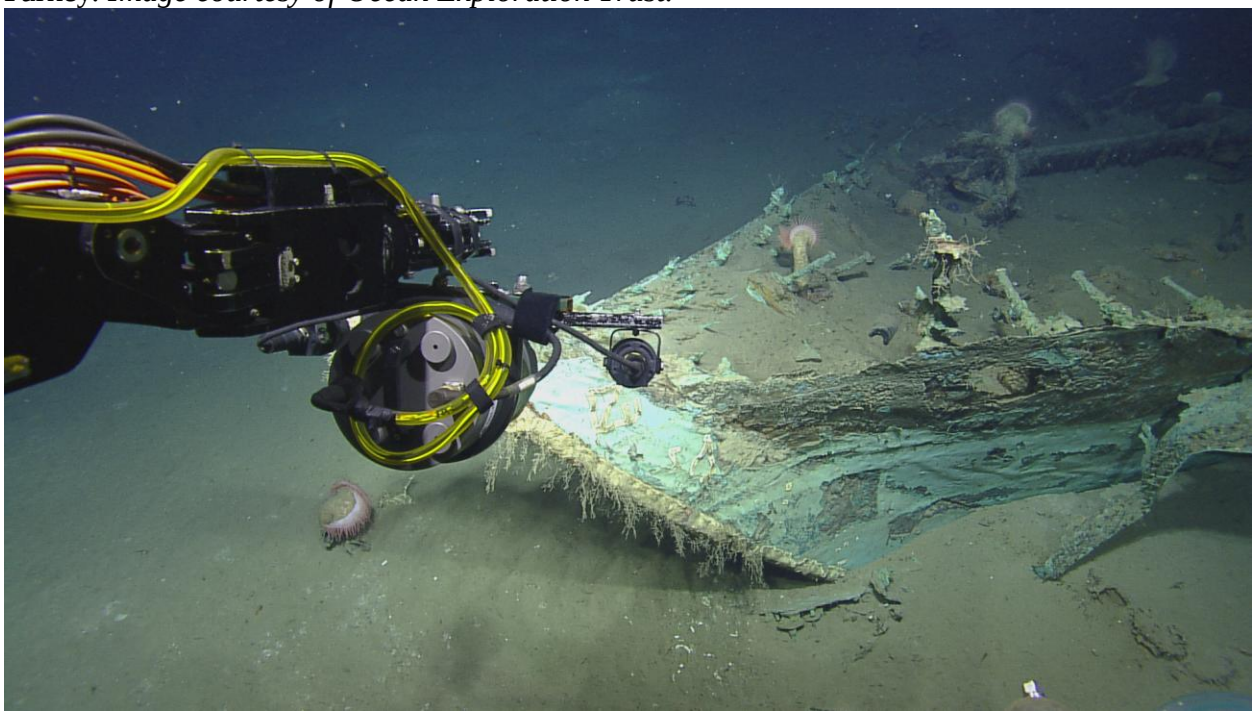

Figure 5. ROV image of the copper-hulled Monterrey A shipwreck in the Gulf of Mexico. *Image courtesy of Meadows Center for Water and the Environment and Ocean Exploration Trust*

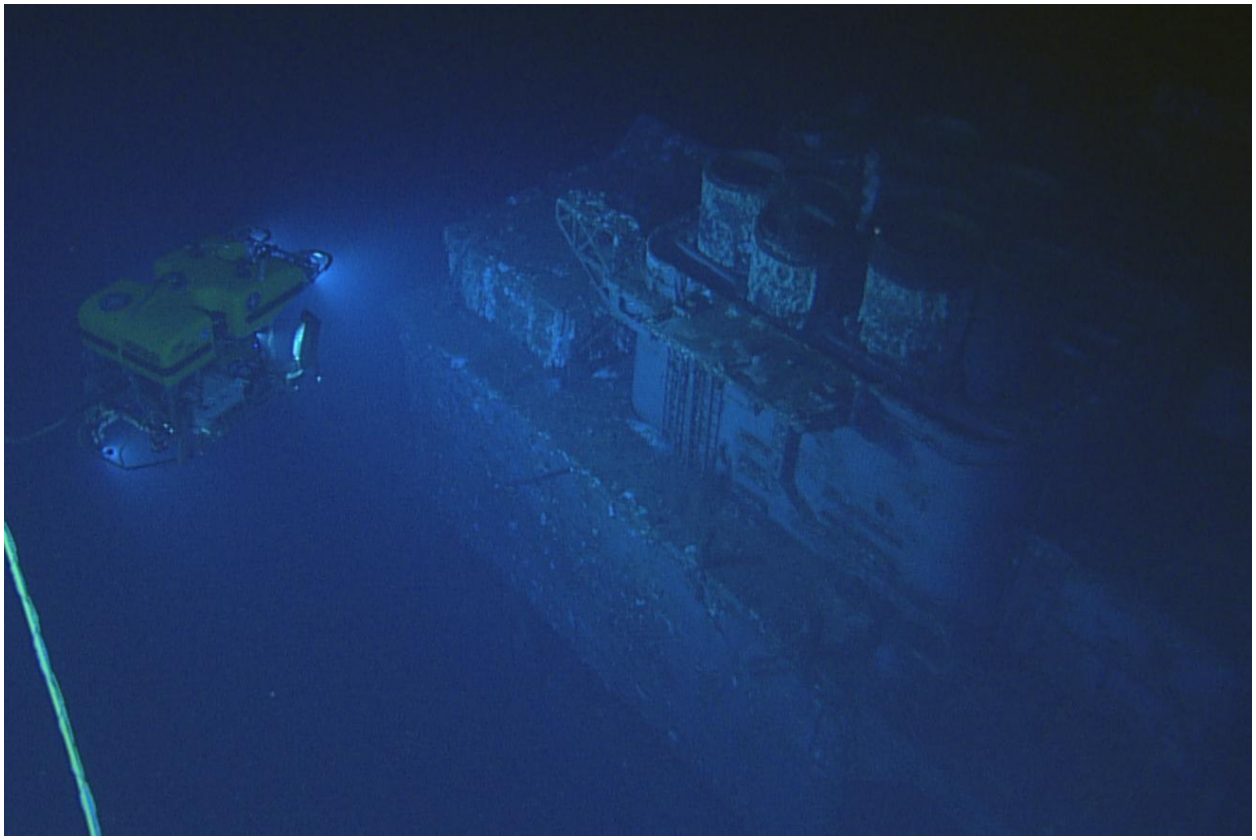

Figure 6. Image of ROV *Hercules* inspecting shipwreck site of ex-USS *Peterson*. *Image courtesy of Ocean Exploration Trust.*

Figure 7. ROV image of a sunken container carrying washing machines, located in the Gulf of Mexico. *Image courtesy of the NOAA Office of Ocean Exploration and Research, Gulf of Mexico 2017.*

Figure 8. ROV image of a group of 1970s soda cans observed off southern California. *Image courtesy of Ocean Exploration Trust.*

Figure 9. ROV image of 55-gallon drums inside USS *Independence* showing latex gloves, among the low-level radioactive waste inside, visible after the barrels corroded. *Image courtesy of Ocean Exploration Trust.*

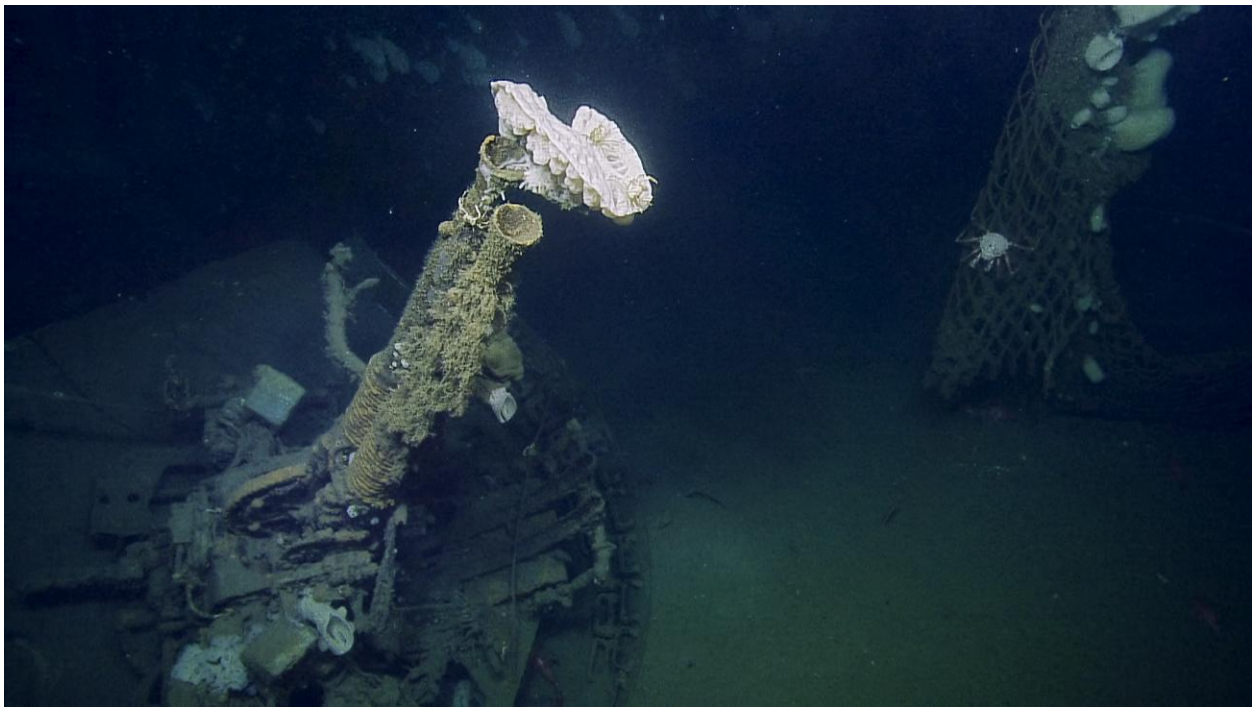

Figure 10. ROV image of anti-aircraft gun on USS *Independence* showing a snagged trawl net in the background. *Image courtesy of Ocean Exploration Trust.*

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