

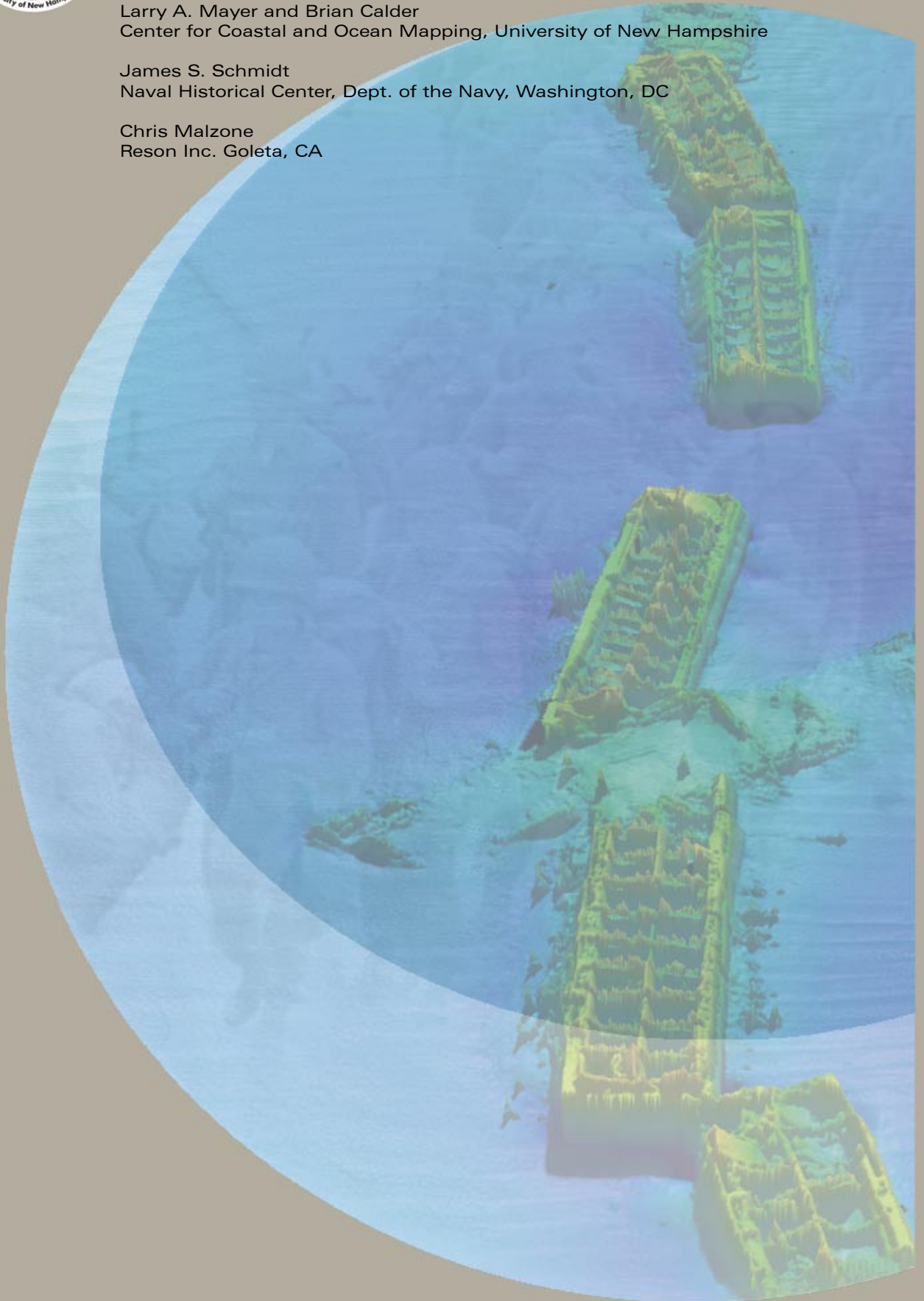


Providing the Third Dimension: High-resolution Multibeam Sonar as a Tool for Archaeological Investigations - An Example from the D-Day Beaches of Normandy

Larry A. Mayer and Brian Calder
Center for Coastal and Ocean Mapping, University of New Hampshire

James S. Schmidt
Naval Historical Center, Dept. of the Navy, Washington, DC

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Abstract:

In general, marine archaeological investigations begin in the archives, using historic maps, coast surveys, and other materials, to define submerged areas suspected to contain potentially significant historical sites. Following this research phase, a typical archaeological survey uses sidescan sonar and marine magnetometers as initial search tools. Targets are then examined through direct observation by divers, video, or photographs. Magnetometers can demonstrate the presence, absence, and relative susceptibility of ferrous objects but provide little indication of the nature of the target. Sidescan sonar can present a clear image of the overall nature of a target and its surrounding environment, but the sidescan image is often distorted and contains little information about the true 3-D shape of the object. Optical techniques allow precise identification of objects but suffer from very limited range, even in the best of situations.

Modern high-resolution multibeam sonar offers an opportunity to cover a relatively large area from a safe distance above the target, while resolving the true three-dimensional (3-D) shape of the object with centimeter-level resolution. A clear demonstration of the applicability of high-resolution multibeam sonar to wreck and artifact investigations occurred this summer when the Naval Historical Center (NHC), the Center for Coastal and Ocean Mapping (CCOM) at the University of New Hampshire, and Reson Inc., collaborated to explore the state of preservation and impact on the surrounding environment of a series of wrecks located off the coast of Normandy, France, adjacent to the American landing sectors

The survey augmented previously collected magnetometer and high-resolution sidescan sonar data using a Reson 8125 high-resolution focused multibeam sonar with 240, 0.5° (at nadir) beams distributed over a 120° swath. The team investigated 21 areas in water depths ranging from about three -to 30 meters (m); some areas contained individual targets such as landing craft, barges, a destroyer, troop carrier, etc., while others contained multiple smaller targets such as tanks and trucks. Of particular interest were the well-preserved caissons and blockships of the artificial Mulberry Harbor deployed off Omaha Beach. The near-field beam-forming capability of the Reson 8125 combined with 3-D visualization techniques provided an unprecedented level of detail including the ability to recognize individual components of the wrecks (ramps, gun turrets, hatches, etc.), the state of preservation of the wrecks, and the impact of the wrecks on the surrounding seafloor.

Introduction:

On 6 June 1944 the combined Allied forces began Operation Overlord, the invasion of Hitler's Fortress Europe, along the beaches of Normandy, France. This operation, described by Winston Churchill as "undoubtedly the most complicated and difficult that has ever taken place," was the decisive turning point of the Second World War (Bowden, 2002). The logistics of this effort were staggering. By the end of June more than one million men, 177,000 vehicles and 586,000 tons of supplies landed on the Normandy beachhead.

In support of the invasion, Allied naval forces mounted Operation Neptune involving nearly 5,000 vessels and an ingenious strategy to float concrete caissons across the English Channel, and create, in a matter of days, two fully functional ports (codenamed Mulberry). The creation of these ports was a key component of Operation Overlord, as the initial invasion avoided the strongly defended harbors of Cherbourg and Le Havre, but required the delivery of approximately 5,000 tons of material per day to the Allied troops. The capacity of these artificial ports, constructed in less than two weeks, would equal that of the Port of Dover that had taken seven years to construct (Ferrand, 1997).

During Operation Neptune, several hundred Allied vessels and tons of war material were lost off the Normandy coastline. Over the years, salvage operations removed many of the wrecks deemed hazardous to safe navigation and activities of the local fishing communities. While salvagers completely removed some ships, other vessels remain, some heavily impacted and others relatively intact - all an important but vulnerable testament to the courageous efforts of the Allied troops and to one of the most important operations in U.S. military history.

The Naval Historical Center's (NHC), Underwater Archaeology Branch, recognizing the potential historical significance of US Navy wreck sites off the D-Day beaches and seeking to fulfill its mandate to manage and preserve historic ship and aircraft wrecks, undertook a three-year remote-sensing study off the Normandy coast. The specific objectives of this study were to: 1- locate and confirm the existence of U.S. Navy wrecks associated with Operation Neptune; 2- provide identification and an indication of the state of preservation for each wreck site; 3- compare historical cartographic documents to remote-sensing analyses, and; 4- identify the authorities and agencies that have an interest in the preservation of these possibly significant historical resources and make the appropriate recommendations (Neyland and Schmidt, 2002).

In the first two years of its study, the NHC used the traditional tools of marine archaeology, sidescan sonar, magnetometer, and ROV video imagery, to locate and document potentially significant targets off Omaha Beach, Utah Beach and Point du Hoc. The study revealed nearly 3000 magnetic anomalies and more than 700 acoustic targets, including the submerged caissons that formed the Mulberry Harbor at St. Laurent sur Mer off Omaha Beach. After closer study, the NHC selected 30-40 targets as high-priority sites warranting further investigation (Neyland and Schmidt, 2002).

In the summer of 2002, the NHC, in collaboration with Reson Inc. and the Center for Coastal and Ocean Mapping/Joint Hydrographic Center at the University of New Hampshire (CCOM), returned to the waters off Normandy to conduct detailed surveys of these high-priority sites. This survey used innovative new, very high-resolution multibeam sonar operated to hydrographic standards. When combined with state-of-the-art visualization techniques, the data collected with this sonar provided an unprecedented view of the nature and state of the wrecks, addressing many of the key issues of concern to the marine archaeological community. This paper documents this operation and, in so doing, outlines the tremendous potential of multibeam sonar as a tool for underwater archaeology.

MARINE ARCHAEOLOGY -- TOOLS OF THE TRADE:

Archaeology is the study of the human past - the reconstruction of history, cultures and lifestyles through the collection and analysis of artifacts that survive the ravages of time and development. Marine archaeologists are faced with special challenges. The artifacts they seek are hidden from view, often by thousands of meters of water, and subject to decay and degradation from the harsh marine environment. Historical records describing clear landmarks and the continuity of human development often pinpoint the location for terrestrial archaeological investigations, but marine archaeologists are faced with searching vast expanses of featureless ocean with little initial indication of where their targets may be. Given the very poor light transmission properties of seawater, marine archaeology depends on acoustic and other remote sensing techniques, in particular sidescan sonar and marine magnetometers, to carry out the initial search for objects on the seafloor.

The sidescan sonar is the most commonly used tool for the physical search phase of marine archaeological projects. Sidescan sonar is typically deployed in a towed body and produces fan-shaped acoustic beams (broad [typically > 150°] in a swath orthogonal to the direction of travel and narrow [typically less than 1°] in the direction of travel). Pinging at a rapid rate (depending on the frequency and the range of the sonar), the energy returned from this insonification is displayed as a function of travel along track and range across track (converted from acoustic travel-time using a nominal speed of sound in the water column). The result is a plan view acoustic image of the seafloor that is sensitive to changes in topography (mostly through the generation of shadows) and to the composition or small-scale roughness of the seafloor through changes in the amount of energy backscattered to the sonar. Objects of archaeological interest (wrecks or other man-made objects) will sometimes sit proud above the seafloor and thus cast a recognizable shadow or be different enough in composition from their surroundings to present a change in acoustic backscatter.

As with all acoustic systems, the sidescan sonar experiences the typical trade-offs between range and resolution. Low-frequency sidescan sonar operates at frequencies of a few kHz to tens of kHz allowing for the insonification and search of swaths that are kilometers wide. While the ability to insonify many kilometers in a single pass is an efficient means of searching large areas of the seafloor, the resolution of these low

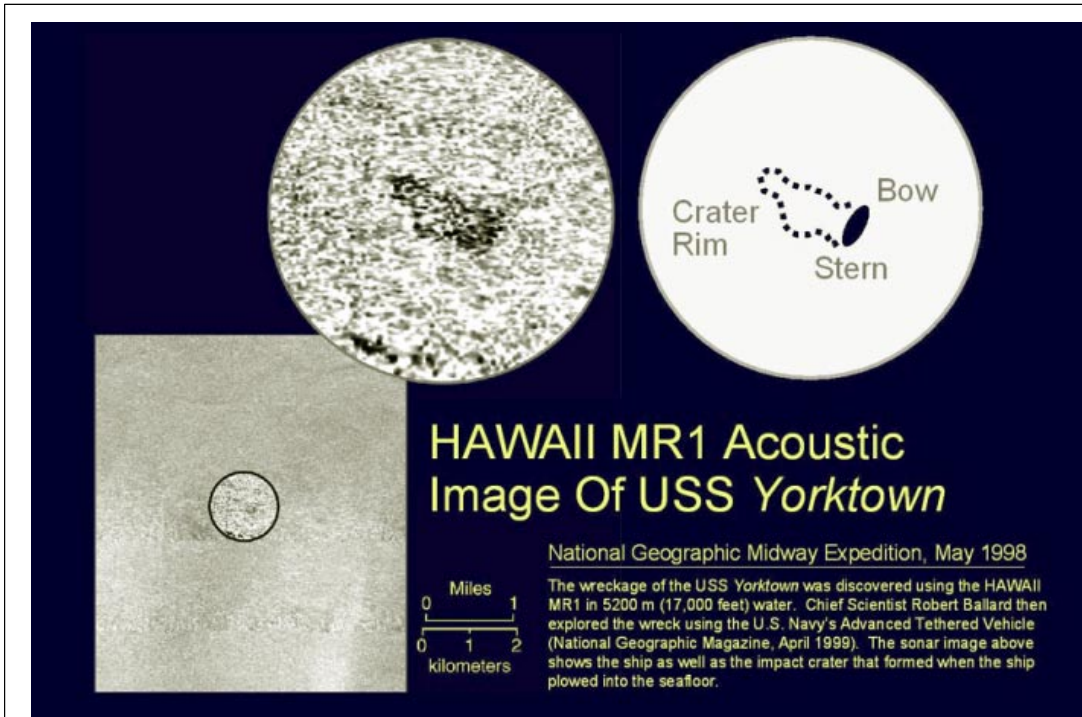


Figure 1. MR-1 long-range sonar image of the USS Yorktown. With permission of Bruce Applegate Hawaii Institute of Geophysics.
<http://www.soest.hawaii.edu/HMRG/MR1/mr1images>

frequency systems is such that only very large targets can be found. For example when the 11/12 kHz MR-1 long-range sidescan sonar from the University of Hawaii's Institute of Geophysics (<http://www.soest.hawaii.edu/HMRG/MR1/mr1images>) found the 245-m-long aircraft carrier USS *Yorktown* (CV-5) sunk in 5,200 m of water during the battle of Midway, the sonar target was nothing more than a few darkened pixels (Fig. 1).

On the other end of the spectrum, a high-frequency sidescan sonar can have extraordinary resolution, but very limited range. The Klein 5000 dynamically focused high-speed sidescan sonar operates at 455 kHz and can detect objects less than a meter in size, but only over ranges of tens to a few hundred meters. Systems are available at many frequencies and resolutions between these end-members; the appropriate system must be selected based on the particular circumstances of the search.

Even when the highest resolution sidescan sonar is used, however, the data collected cannot necessarily provide an easily interpretable and unambiguous result. It is the unusual case when a sidescan sonar image can be unambiguously identified as a man-made artifact and even rarer when specific details of the artifact can be gleaned from the sidescan imagery. The standard sidescan sonar does not provide information on the depth of the target being insonified (interferometric sonar can provide depth information but this technique is inappropriate for most surveys over wrecks) and thus the images provided by

sidescan are created by assuming a linear, monotonic increase in travel-time away from the sonar transducer. This “flat seafloor assumption” leads to a range of distortions when a target that has much local relief (like a wreck) is insonified. Additionally, poor control on the precise position and motion of the sonar tow vehicle leads to other distortions along with the inherent danger of towing a vehicle near a wreck. The result is a distorted, plan-view image of the seafloor, which contains backscattered reflections off targets on the seafloor and, most importantly, shadows cast by objects on the seafloor. In areas where a man-made object sits proud above a relatively flat seafloor, the backscattered reflection from the object and particularly the shadows cast by the object leave little doubt of the presence of a target (e.g., Fig. 2a). Even in the very high-resolution example shown in Figure 2, however, neither the nature or details of the object are clear.

In environments where the seafloor is rocky and rough, it is often impossible to separate man-made objects from natural features using the sidescan sonar record alone. To aid in the detection of man-made artifacts in these rough environments as well as in those areas where objects may be buried (and thus not detectable by sonar), marine magnetometers are used as an additional search tool in support of marine archaeological studies. A marine magnetometer measures anomalies in the earth’s magnetic field caused by ferrous objects. The size of the anomaly will be a function of the size and composition of the object as well as the distance of the object from the magnetometer (typically towed behind a vessel, much like a sidescan sonar). As the magnetometer is towed through a search area, the anomalies can be contoured (assuming that the position of the tow-body is being tracked) providing a coarse picture of the general distribution of ferrous objects on or below the seafloor (Fig. 2b).

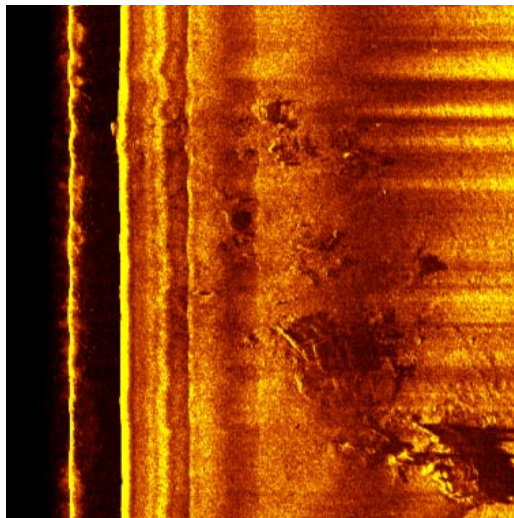


Figure 2a. Sidescan sonar image of the wreck of the tug USS Partridge sunk by torpedo off Omaha Beach on 11 June. Marine Sonic Technology 300 kHz Sea Scan sidescan operating at 75m range.

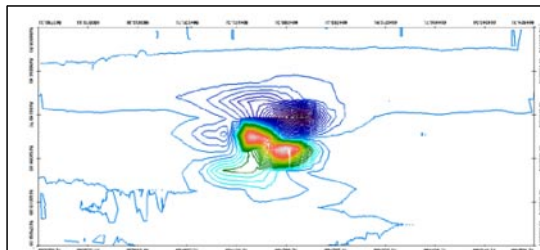


Figure 2b. Magnetic anomaly contours over the wreckage of the USS Partridge.



Figure 2c. Photograph of USS Partridge from <http://www.navy.mil/photos/infocenter/partridge.htm>

While sidescan sonar and magnetometers provide a means to locate potential archaeological targets, neither of these approaches resolves the detail needed for a complete archaeological study. In order to be able to identify marine artifacts, ascertain their state of preservation, make historical inferences, and plan recovery, the marine archaeologist must call upon optical techniques (underwater photographs, video, and when possible, direct observation by a diver or submersible). Optical techniques provide the ultimate level of resolution (Fig. 3a) but are severely limited by the attenuation of light in most marine environments. Cameras must be deployed, or direct observations made, within a few meters of the object. As a consequence, the field of view of most optical images is rather limited, often making it difficult to extract the context of the image (Fig. 3b) and thus get an overall feel for the nature of a large target. Mosaicing techniques applied to wreck imagery allow larger areal coverage (e.g., Singh, et al., 2000), but these techniques are complex and often very time-consuming.

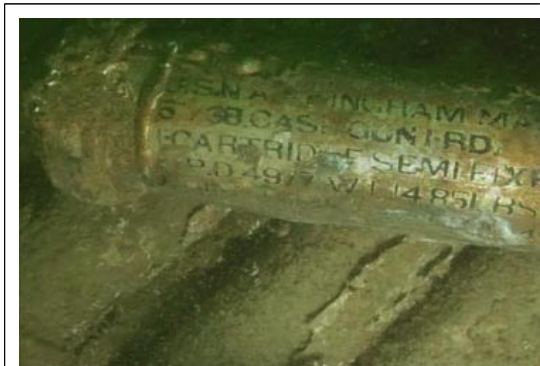


Figure 3a. Video image of cartridge shell demonstrating the ability of optical imagery to provide critical information in support of archaeological studies.



Figure 3b. More typical situation of poor visibility and limited field of view in photographic or video imagery, making context difficult to discern.

In this paper we explore another approach to marine archaeological studies, the use of a new generation high-resolution multibeam sonar. This new type of sonar uses dynamically focused beams to collect extremely detailed bathymetric data over relatively long ranges (as compared to optical systems); when operated to hydrographic standards and combined with state-of-the-art visualization tools, a quantitative 3-D image of the targets and the surrounding seafloor can be generated at a resolution that addresses many of the key questions posed in an archaeological study. The feasibility of this approach was first demonstrated in a recent study of the scuttled WWI German High Seas Fleet off Scapa Flow, Scotland (<http://www.com.unh.edu/scapa>). Here we use examples from the ongoing NHC survey of the D-Day beaches off Normandy, France to demonstrate the tremendous potential of this approach for marine archaeological investigations.

Methodology:

The Reson 8125 multibeam sonar was the primary survey tool for investigating the high-priority targets selected by the NHC. The Reson 8125 is the first of a new generation of dynamically focused multibeam sonars. Operating at 455 kHz, the system forms 240, $0.5^\circ \times 1.0^\circ$ beams over a 120° swath. The very narrow beams are achieved by the use of a relatively long array (0.5 m), which, in a standard multibeam sonar, would preclude working at short ranges from the transducer face (in the near field). The 8125, however, uses dynamically focused beam-forming that allows for operation of the sonar in the near field. Thus very high frequencies and short pulse lengths can be used (providing excellent vertical resolution) while maintaining very narrow beam widths (providing excellent lateral resolution). In addition, the focused beam-forming process reduces the energy levels associated with side lobes, making for an inherently cleaner return and, particularly important for archaeological surveys, the ability to coherently track features in the complex environment of wreckage.

The 8125 was deployed on a custom-built pole mounted to the starboard side of the M/V *Genesis*, an 11.3-meter catamaran chartered by the NHC from Tech Marine Service, out of Great Yarmouth, UK (Figs. 4a and b). The *Genesis* is very stable and has the ability to transit at speeds of 20 - 30 knots (surveys were conducted at 3 - 6 knots), making it an extremely efficient platform for operations. A TSS DMS2-05 dynamic motion sensor monitored vessel motion, and a TSS Meridian gyrocompass measured heading. A Trimble AG132 differential GPS receiver using Fugro SeaSTAR corrections and local RTCM, determined vessel position with sub-meter accuracy. The Reson SVP-C sensor continuously monitored sound speed at the transducer head and a Reson SVP-14 sound speed profiler established velocity profiles. Offsets between all of the sensors were carefully measured and standard hydrographic patch test and calibration procedures followed to minimize any integration or alignment errors.



Figure 4a. Motor vessel GENESIS used for deployment of Reson 8125 multibeam sonar.



Figure 4b. Reson 8125 and sound speed sensor mounted on pole (in non-deployed position).

Sound speed profiles were taken before the start of every new survey, at intervals of no longer than three hours, and whenever real-time quality control (QC) indicated a potential problem. For the most part, the water-column structure remained remarkably constant through the seven days of survey work. The tidal range off Normandy is large (on the order of 6 m) and tidal corrections are critical. The Service Hydrographique et Oceanographique de la Marine (SHOM) of France, kindly provided predicted tide models for each of our work areas.

Since tides controlled entry into port, accurate weather data provided a critical link between sea state, personnel safety and the ability to collect quality data. The U.S. Naval European Meteorology and Oceanography Center (NEMOC) in Rota, Spain, provided 48-hour regional weather forecasts and emergency fax broadcasts. The harbor master at the port authority of Grandcamp-Maisy posted a local 24-hour forecast and alerted the *Genesis* crew of any hazardous conditions reported by the fishing fleet.

A Reson 6042 data acquisition system was used to digitally acquire data, integrate data from the ancillary sensors, and to store raw data files. Data from the 6042 were exported into a Triton Extended Format (XTF) for further processing and cleaning with CARIS HIPS, which produced cleaned and gridded data. Interactive Visualization Systems' Fledermaus software was used to produce interactive 3-D visualizations of the targets and their surrounding environment. Depending on the complexity of the data set collected, the turn-around time from data acquisition to interactive 3-D viewing ranged from minutes to several hours.

Results and Discussion:

Despite the challenges provided by weather, tides, currents, and fine French food and wine, the use of a dynamically focused multibeam system in support of the D-Day archaeological studies proved to be a tremendous success. Over approximately seven days of operation, 35 hours of surveying were carried out, imaging much of the remains of the Mulberry harbor off Omaha Beach as well as approximately 40 other distinct targets. We will focus here on only a few examples, but a more detailed discussion of the results of this work can be found in Malzone, et al. (2002).

Omaha Beach Mulberry Harbor:

As mentioned earlier, one of the greatest challenges facing the Allies was to ensure a steady stream of supplies and troops into France before the capture of a major harbor facility. The plan called for the establishment of two artificial harbors, one off the Omaha Beach and the other off the British sector at Gold Beach (Fig. 5). Ocean tugs towed the harbors, constructed of massive (the largest were 60 m long, 17 m wide, and 18 m high, displacing 6,044 tons) concrete caissons (code-named Phoenixes), across the Channel and sunk them about 3/4 of a mile offshore in about 9 m of water (Fig. 6). Inside the line of caissons, floating loading docks, pier heads and metal roadways, created a sheltered anchorage leading to the beach. For added protection the Allies sunk a string of obsolete warships and merchant ships (known as blockships) along with the caissons.

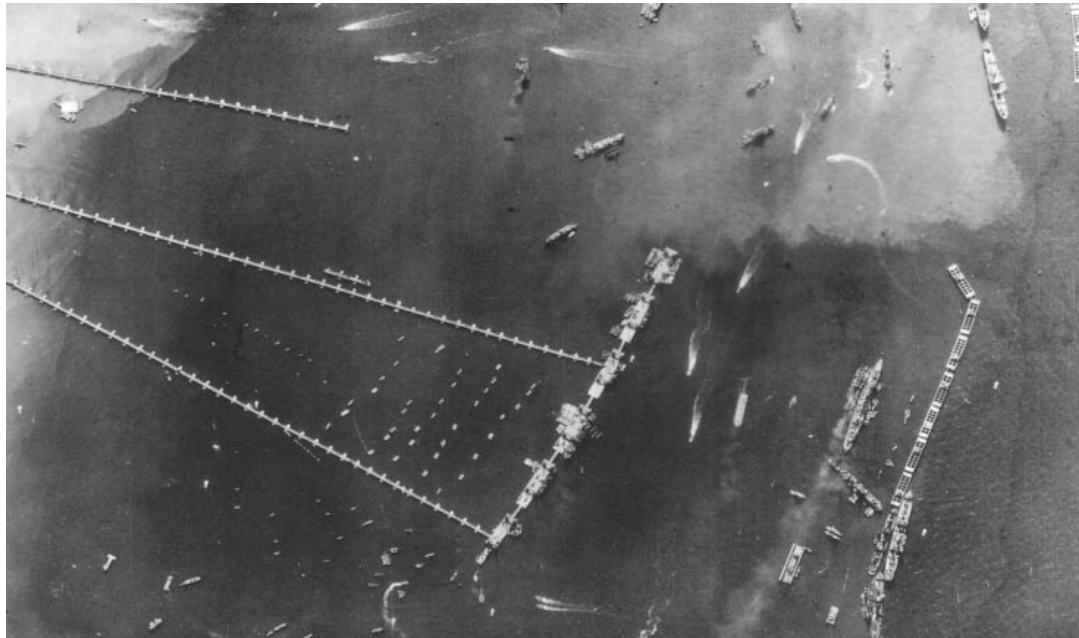


Figure 5. Aerial view of Mulberry Harbor at Gold Beach (Arromanches). Photo from Desquesnes, 1993.

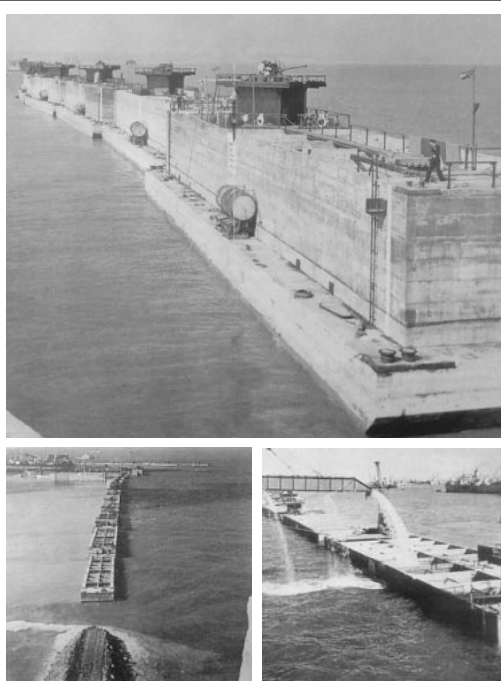


Figure 6. Phoenix caissons before being installed (top), being submerged (bottom right) and in place (bottom left). Photo from Ferrand (1997)

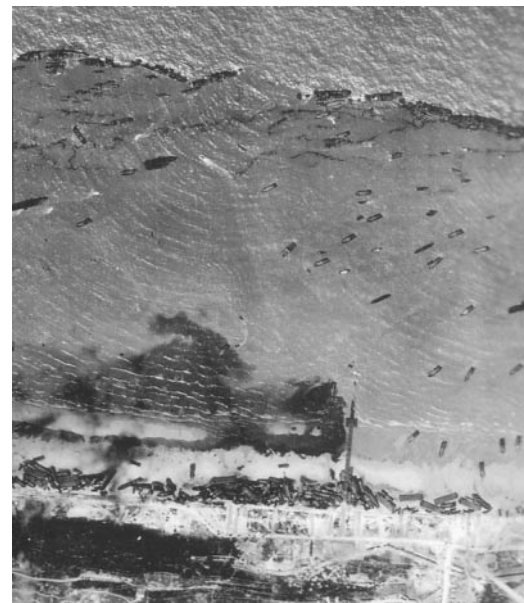


Figure 7. Omaha Beach after the 19-22 June storm. Note the many vessels washed on the beach. The remnants of the Mulberry Harbor can be seen at the top of the photo – despite the destruction of much of the artificial harbor, its effectiveness as a breakwater can still be seen. Photo from Desquesnes, (1993)

On the 19th - 22nd of June a rare, Force 6 -7 storm struck Normandy, washing more than 800 vessels onto the beaches (Fig. 7). This storm wreaked havoc on the American Mulberry harbor (which was less complete and generally more exposed and vulnerable than the British Mulberry which survived the storm). The storm surge destroyed 20 of the 30 caissons at Omaha Beach forcing the Allies to abandon the American harbor.

Our survey of the remains of the Mulberry harbor focused on an approximately 1.7 km x 200 m wide area parallel to the beach and an approximately 300 x 200 m area perpendicular to the beach (Fig. 8). Surveying was difficult as pieces of some of the caissons come within several meters of the surface, even at high tide. Nonetheless, the multibeam sonar data presents a clear and unparalleled view of the state of destruction of the caissons (ranging from near complete destruction to excellent preservation) as well as the effect of the caissons on local sediment transport. The wreckage of one blockship can be seen lying almost orthogonal to, and on top of, the line of caissons. Most impressive is the ability of the sonar to track the near-vertical walls and remaining steelwork of the better-preserved caissons (Fig. 9).

The images presented here are based on multiple, overlapping passes of the targets allowing insonification from all sides. The data from these multiple passes have been gridded at 25 cm intervals and rendered in 3-D. Given the fact that each grid node represents input from multiple passes, any positional uncertainty will be propagated into the grid resulting in a defocusing of the image. It is thus surprising that the rendered

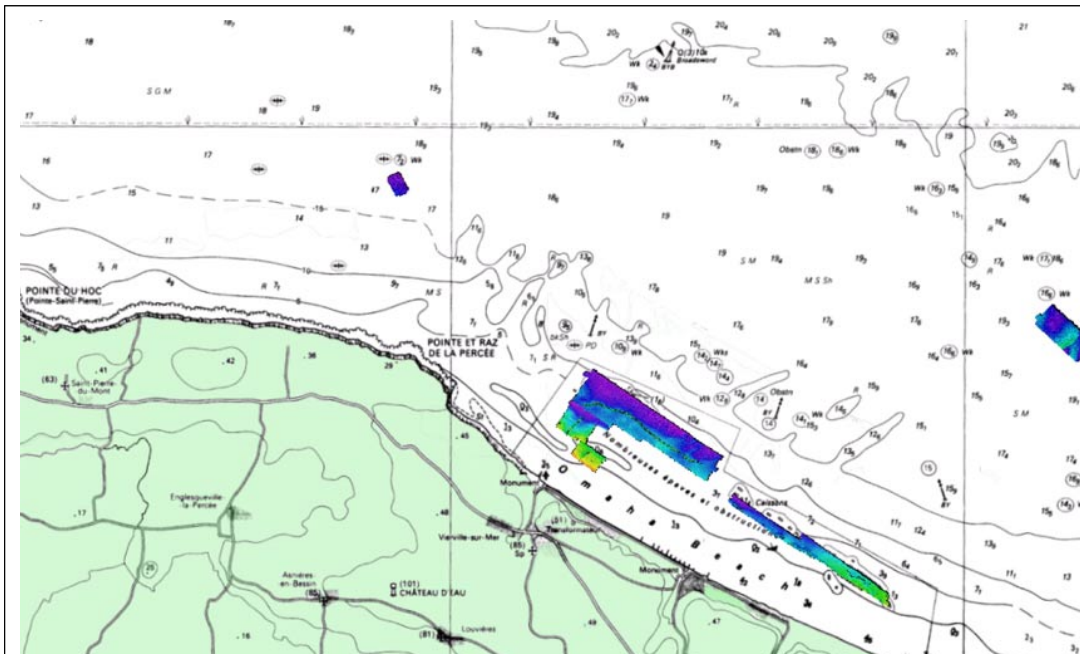


Figure 8. Surveys conducted off Omaha Beach, Normandy. The survey of the Mulberry Harbor off Omaha Beach is seen in two sections parallel to and about 1 km from the beach; the survey of the DD tanks is seen on the eastern edge of the chart approximately 4 km from the beach.

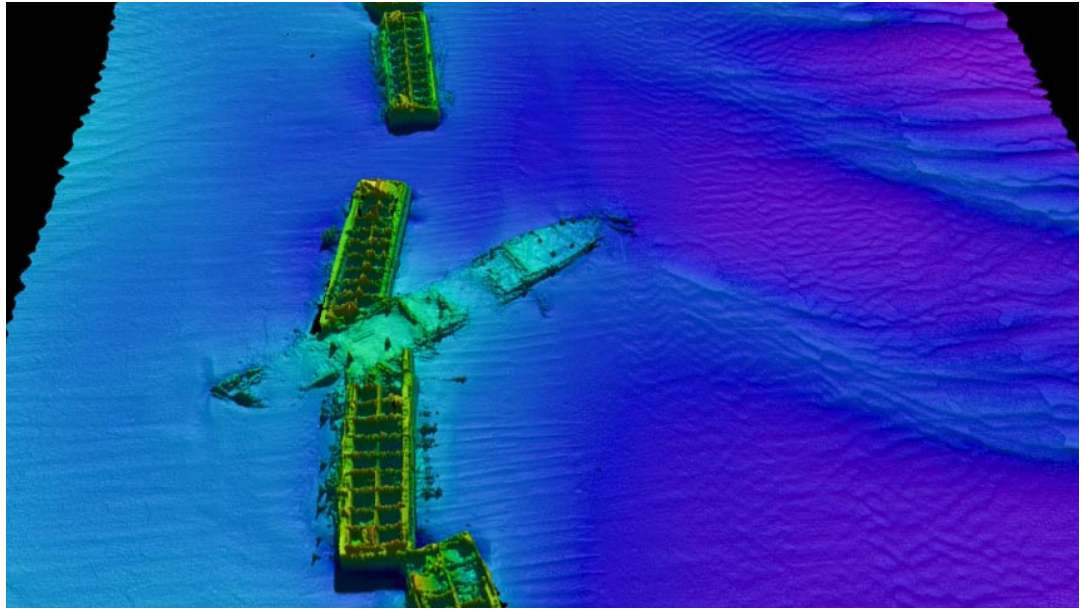


Figure 9. Reson 8125 survey of wreckage of Mulberry harbor off Omaha Beach, gridded at 25 cm resolution and rendered in 3-D. Several caissons can be seen (the two in the middle in very good state of preservation) as well as the wreckage of one of the blockships that had been deployed to add substance to the wave barrier. The distribution of bedforms around the caissons clearly indicates the nature of flow in the region as well as the effect of the wreckage on the flow. Image represents about a 300m x 400m area. Location of these targets can be found on Figure 8.

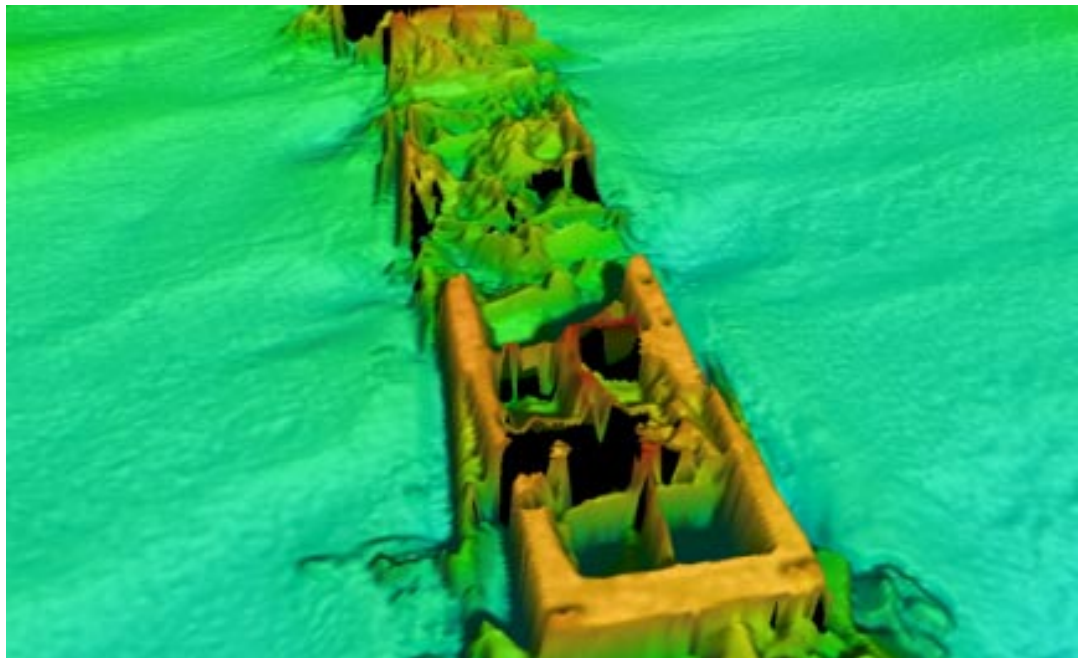


Figure 10a. Image of Phoenix caisson constructed from multiple passes over target, gridded at 25 cm and rendered in 3-D.

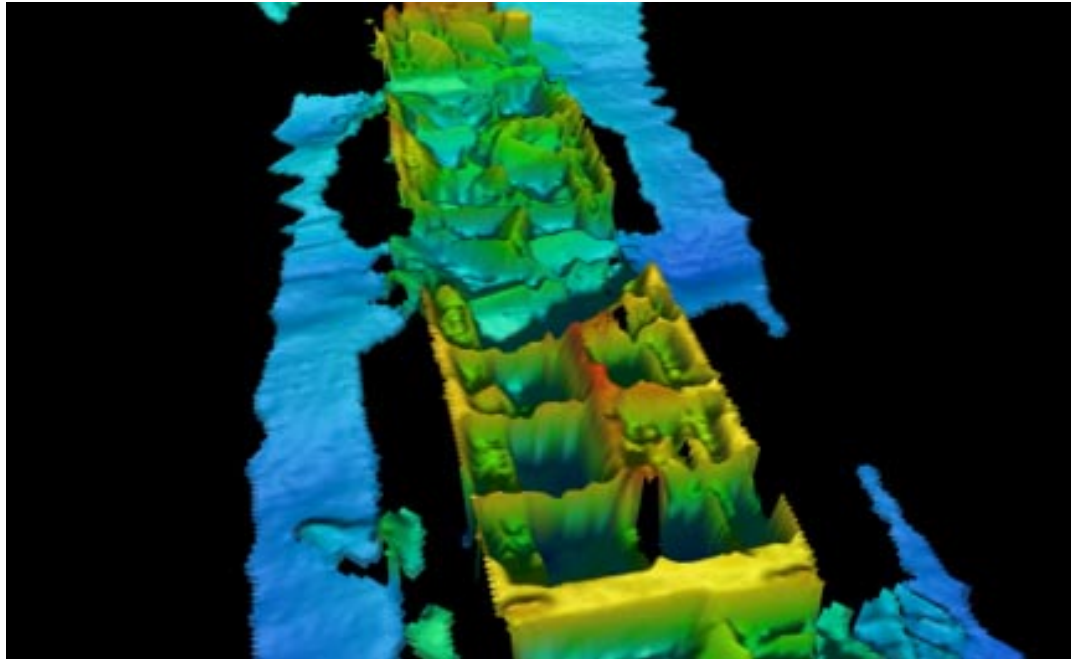


Figure 10b. Image of Phoenix caisson constructed from a single pass over target, gridded at 25 cm and rendered in 3-D.

images are so remarkably crisp, particularly in the coherent depiction of vertical structures. The implication is that the horizontal positioning is highly accurate and consistent during the course of multiple passes over the target. When, however, a single swath is examined (i.e., no positional uncertainty), a clear improvement in horizontal resolution can be seen (Fig. 10a and b).

LCT524:

The remarkable consistency of positional information is clearly evident in the survey of a Landing Craft Tank (LCT-524) in about 18 m of water off Utah Beach. The vessel is well preserved with a number of recognizable features including the bow ramp, 20-mm gun mounts, and debris in the hold. A large scour pit can also be seen on the port side indicating strong local current regime (Fig. 11). If we look at the individual soundings associated with two crossings of the vertical gunnels of the vessel, color coded by line number (Fig. 12), we see that sonar hits on the vertical wall are typically within a few cm of each other and never more than 50 cm apart, indicating a high degree of precision in the horizontal positioning. We assume that we were able to achieve this degree of precision due to the fact that the overlapping lines were collected within a few minutes of each other (typically less than 20 minutes) and within this time period the GPS satellite geometry remained stable. We did notice occasions where there were sudden (small) offsets in the position of vertical targets (resulting in an apparent double hull) and these cases appeared to be related to a change in the satellite constellation.

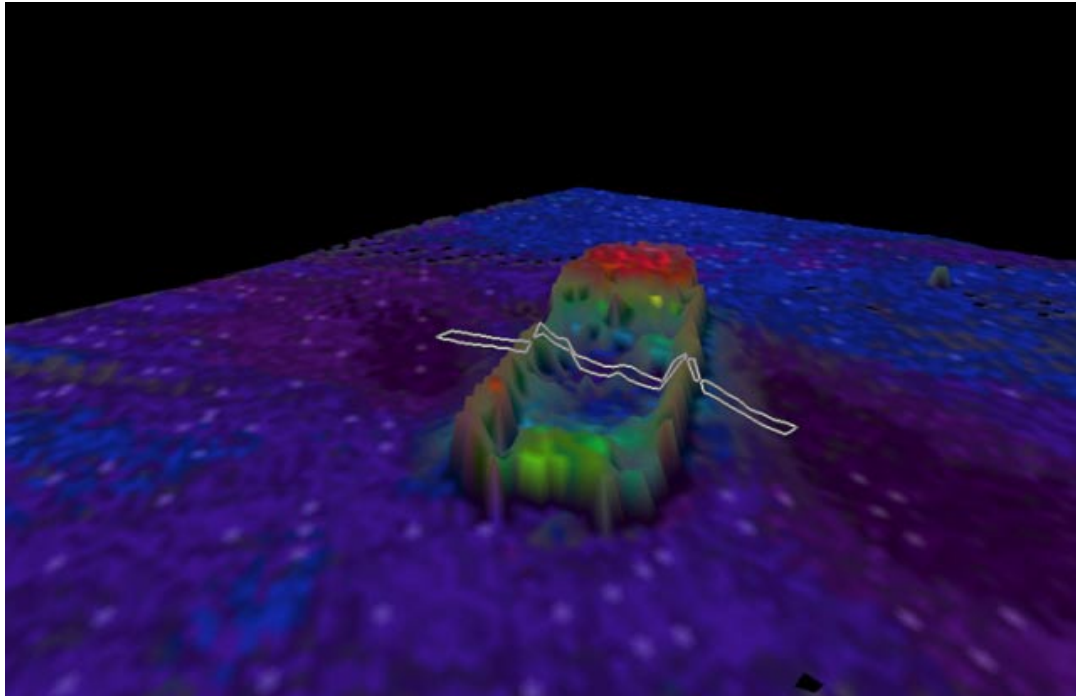


Figure 11. Reson 8125 survey of LCT 524, gridded at 25 cm and rendered in 3-D. Cross-section represents the region from which soundings were extracted and displayed below.



Figure 12. Soundings from two separate lines crossing LCT 524. Color represents the individual lines. Note the consistency of position of the soundings on the gunnels from line to line. Grid cells represent 50 cm distance.

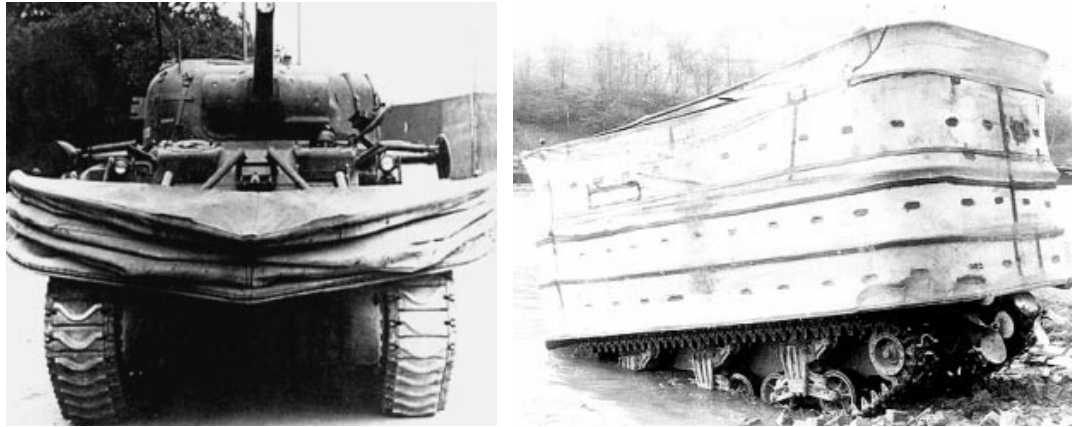


Figure 13. Duplex Drive “DD” tanks used in the Normandy invasion. These were Sherman tanks with propellers and a canvas flotation skirt added. Image on left is with skirt lowered, on right with skirt raised. Note propellers on image on right. Images from the Lewis Vince, website: <http://www.vlewis.net/omaha.html>

DD Tank:

The final example we present is from a survey of several Sherman duplex drive (DD) tanks sunk approximately 4 km off of Omaha Beach. The Sherman DD tanks were modified into amphibious tanks with the addition of twin propellers and a canvas skirt fitted around the hull to provide flotation (Fig. 13). The DD tanks were designed to be part of the first wave of the invasion, maintaining a low profile while “swimming” to shore and then providing covering fire for the first waves of infantry. The seas on 6 June were too rough for the fragile flotation mechanism of the DD tanks and of the first wave of 32 tanks launched approximately 5 km off Omaha Beach, all but 3 sank (Ambrose, 1994). Witnessing this disaster, the skippers of the LCT’s carrying other DD tanks brought their tanks directly to the beach.

Figure 14 shows a remarkable image of what is unquestionably a Sherman tank, located in approximately 19 m of water and pointed directly toward the beach. Again, the

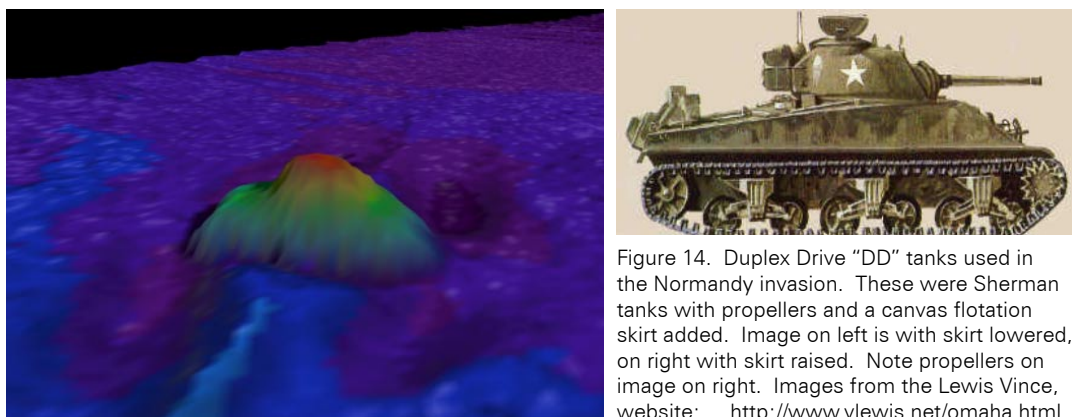
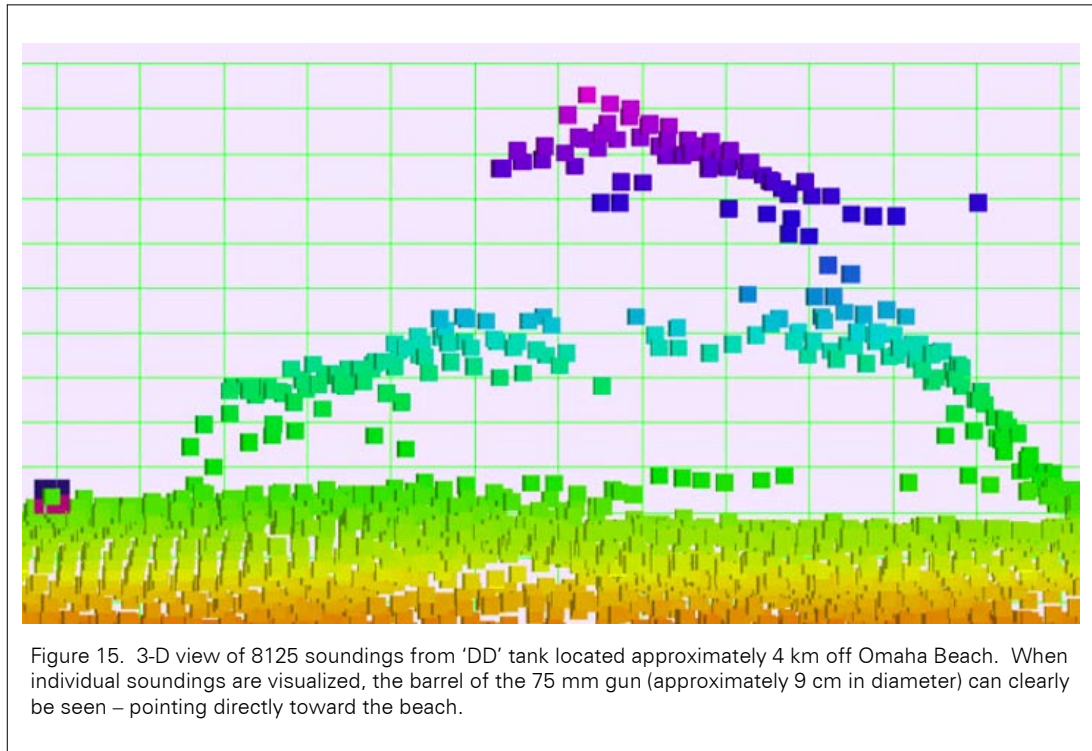


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evidence of scour around the tank is quite clear. While the rendered image (based on data gridded at 25 cm) clearly has the characteristic shape of a Sherman tank, it appears that the gun barrel is missing. Closer examination, however, reveals that this is not the case and points out that in some circumstances, the gridding and rendering (formulation of the 3-D image) process can remove potentially important detail. If instead of looking at the rendered gridded surface, we look at the individual soundings rendered in 3-D, we can clearly see four hits of the sounder on the approx. 90mm-wide barrel of the 75mm gun.



Conclusions:

As part of an ongoing investigation of the wrecks and artifacts remaining off the American sector D-Day beaches of Normandy, a team from the U.S. Naval Historical Center's Underwater Archaeology Branch, Reson Inc. and the University of New Hampshire's Center for Coastal and Ocean Mapping/Joint Hydrographic Center, carried out a series of surveys aimed at exploring the applicability of using a hydrographic-quality, high-resolution multibeam sonar for marine archaeological studies. The system used for these surveys (the Reson 8125) operates at 455 kHz with dynamically focused near field beam-forming that allows 240, 0.5° (at nadir) beams to be formed over a 120° sector. The short pulse length and very narrow beam widths of this sonar provide extremely high-resolution and very reduced sidelobes that allow for the robust tracking of complex targets. We surveyed 21 areas in water depths ranging from about 3 - 30 m.

Some sites contained individual targets such as landing craft, barges, a destroyer, a troop carrier, etc., while others contained multiple smaller targets such as tanks and trucks. Of particular interest were the well-preserved caissons and blockships of the artificial Mulberry Harbor deployed off Omaha Beach and destroyed by a Force 6 – 7 storm that started on 19 June 1944.

Unlike traditional marine archaeological search tools (sidescan sonar and magnetometers), the multibeam sonar can provide detailed, undistorted, and quantitative information on the 3-D geometry of the target being surveyed from a platform that is safely above target. Unlike traditional visual or photographic inspection, the multibeam sonar insonifies a relatively large area (tens to hundreds of meters) allowing the full context of targets to be established quickly. When combined with state-of-the-art 3-D visualization techniques that allow the viewing of both rendered surfaces and individual points, the data returned provides an unprecedented level of detail including the ability to recognize individual components of the wrecks (ramps, gun turrets, hatches, etc.), the state of preservation of the wrecks, and the impact of the wrecks on the surrounding seafloor. Given these capabilities we suspect that the multibeam sonar will play an increasingly important role in future marine archaeological studies.

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References:

Ambrose, S., 1994, D-Day, The Climactic Battle of World War II, Simon and Schuster, N.Y., 655 pp.

Bowden, M., 2002, Our Finest Day, Chronicle Books, San Francisco, 31 pp.

Desquesnes, R., 1993, Normandy, 1944, Edilarge, S.A., Editions Quest-France, Rennes, France, 236 pp.

Ferrand, Alain, 1997, Arromanches, History of a Harbour, OREP Publications, Cully, France, 28 pp.

Lewis, Vince, website <http://www.vlewis.net/omaha.html>

Malzone, C., Schmidt, J., Mayer, L.A., and Calder, B., 2002, High-resolution Multibeam Survey of Operation Neptune: The D-Day Landings, Internal Reson Report 69 pp.

<http://www.navsource.org/archives/>

Neyland, R. S., and Schmidt, J.S., 2002, Archaeological Remote-Sensing Survey of Operation Neptune, The D-Day Landings at Omaha and Utah Beaches, Normandy, France, Letter Report, Dept. of Navy, Underwater Archaeology Branch, Naval Historical Center, Washington, D.C., 29 pp.

Singh, H., Adams, J., Mindell, D., and Foley, B., 2000, Imaging Underwater for Archaeology, Jour. of Field Archaeology, Vol. 27, no. 3, pp. 319-328.

