CAA 2009 Williamsburg

High Tech on a Budget: Recording Maritime Cultural Heritage Using a Total Station, RhinoPhoto, and Rhinoceros NURBS

Peter B. Campbell[1]

[1] Program in Maritime Studies, East Carolina University. USA.

Abstract

Small budget archaeological projects by cultural resource management firms, avocational groups, and universities can create three-dimension site plans from highly accurate methods now readily available. The recording of maritime cultural heritage using electronic distance measuring, photogrammetry, and computer-aided design creates a quick and cost effective methodology. Publications tend to focus on new technologies, however the majority of the field works on smaller budgets and contracts, making re-use of readily available technology in new methodologies beneficial. Using a total station as a primary recording device, rather than in a complimentary role, can create a high quality three-dimensional deliverable.

***Key words**: Total station, RhinoPhoto, Rhinoceros, photogrammetry, 3D modeling, maritime*

1 INTRODUCTION

Inevitably during high tech conferences, discussion is drawn toward cutting edge technology, innovative adaptations from other fields, and the latest computer programs. These developments are the future of archaeology, however, they often remain unaffordable to small cultural resources firms, avocational groups, and university programs for a number of years. While the goal of new technology is to increase the accuracy and speed of recording, the balance between cost and these two factors is a familiar battle in archaeology.

Richard A. Gould writes that, "nearly all archaeological recording techniques represent trade-offs between the desire for precision and the practical limitations imposed by funding, time, logistics, and personnel."[1] High tech methods often offer higher precision and speed, while, understandably, also raising costs. The adoption of new high tech methods are examined by Eppich and Chabbi, who identified three criteria needed for their acceptance. These are ease of use with limited experience, a decrease in the initial cost, and the ability to include further data at a later date.[2] This paper presents a high tech methodology that allows small crews with little training to record sites with technology that is readily available and adaptable. Most importantly, it balances precision and speed with cost.

Typically a secondary recording method, electronic distance measuring is the primary recording technique in this methodology, with photogrammetry as a supplemental method. Data from these sources are compiled in the Rhinoceros NURBS computer-aided design (CAD) program. These technologies are not new to archaeology, rather this paper presents a new and adaptable methodology that provides a cheap, but accurate, deliverable. Ease of use and versatility this methodology makes it applicable to a wide range

[1] Richard A. Gould, *Archaeology and the Social History of Ships* (London: Cambridge University Press, 2000), 21.

[2] R. Eppich and A. Chabbi, "Recording and documenting cultural heritage- 3D modeling for conservation in developing regions," in *Recording, Modeling and Visualization of Cultural Heritage*, ed. by Manos Baltsavias et al. (London: Taylor & Francis Group, 2006), 16.

of site types. Best suited for maritime sites on land or floating, this methodology can also aid in the recording of submerged sites.

Developed from an initial methodology created by Fredrick Hocker at Vasamuseet in Stockholm, Sweden, the addition of photogrammetry as well as streamlining the recording process creates a cost effective recording strategy. Over the course of a number of projects, this methodology proved efficient for small budget recording of maritime cultural heritage. The strength of the methodology is requiring only a few pieces of commonly available equipment and a small crew. A single person can operate the equipment to be discussed, however a crew of five is optimal. Aspects of maritime cultural heritage differ from traditional archaeology, though terrestrial archaeologists may find this methodology useful.

2 EQUIPMENT

Equipment for this methodology is chosen based on its availability to most individuals, either as standard office items or for rent from surveying companies. The basic equipment is a total station, digital camera, PC computer, and printer. A TDS Recon unit is recommended for easier interface with the total station. Rhinoceros NURBS is required software, while its photogrammetry plug-in RhinoPhoto is also recommended. Traditional recording equipment such as steel measuring tapes and carpenter's rules are helpful. Poster tack and printer paper are the only other items require to create an accurate three-dimensional site plan.

Total Station

The total station, traditionally a complimentary recording device, is the backbone of this methodology (see Figure 1). This device is a combination of a theodolite and an electronic distance measurer, capable of recording several hundred points per day. The total station measures distances and creates coordinates relative to one another, accurate to millimeters.[3] Prices begin at $3000 and increase based on accuracy. An affordable option is rental. Fortunately, most surveying or construction equipment rental companies carry total stations. Rental costs average between $50 to $100 per day.

Traditionally, total stations measure distance from the unit to a prism on a stadia rod. Archaeologists have used total stations in this manner for decades, typically for position fixing or recording stratigraphy. The surveying company Leica, however, has introduced small reflective targets that replace the prism. Rather than a complimentary role in recording, these targets allow the total station to become the primary recording device, useful for capturing small details. Ten-millimeter square targets are placed directly onto significant points, then recorded by the total station. Maritime cultural heritage, as well as architectural recording, has the difficult task of recording a site that is itself an artifact. Reflective targets are prefect for capturing construction details for documentation and reconstruction.

Figure 1. Placing reflective targets on the floating vessel *Wawona*, with a total station and a TDS Recon unit in the foreground. Photograph courtesy of Nat Howe and Northwest Seaport.

Leica's targets cost approximately $5 each, but there is a thrifty alternative. 3M manufactures reflective tape that can be cut into ten millimeter or one inch square targets. Fifty-foot reels are available for around $50 on the internet. 3M's

[3] Jeremy Green, *Maritime Archaeology: A Technical Handbook*, 2nd ed. (London: Elsevier Academic Press, 2004), 42.

Department of Transportation grade tape functions best with the total station. For a fraction of the cost, reflective tape provides the same result as the Leica targets.

A TDS Recon unit is suggested to provide user-friendly interface with the total station. This handheld device costs approximately $1000, however total station renters often include a TDS for an additional $5 to $20 per day. Worth the additional cost, a TDS allows easier set up, detailed labeling, manipulating of measurements, recalculations, a site map, and easier downloading after fieldwork.

Rhinoceros NURBS

Total station data is entered into the Rhinoceros CAD program, a versatile three dimensional design program. Rhinoceros uses the Non-Uniform Rational B-Splines, a mathematical model for creating geometric shapes. Several CAD programs, such as AutoCAD, have difficulty creating the curvature found on ships. Rhinoceros is well suited for maritime archaeology since B-Splines excel at these shapes.

The software can import or export a wide range of file types, making Rhinoceros compatible with a number of useful programs. File sizes are small, often less than ten megabytes, and can run on an average computer. In addition, there are a number of useful plug-in programs, including RhinoMarine for testing hull performance, Flamingo for rendering quality images, and RhinoPhoto for photogrammetry. Rhinoceros costs $995 for standard buyers and $195 for the fully functional education edition.

RhinoPhoto

RhinoPhoto software searches photographs for specialize targets and calculates their positions to create a three-dimensional point cloud. Photogrammetry, or the process of taking measurements from photographs, has been used for entire sites[4]; however within this methodology, RhinoPhoto is best suited for quickly recording associated artifacts and secondary features.

[4] Angela Fussell, "Terrestrial Photogrammetry in Archaeology," *World Archaeology* 14, no. 2 (1982): 157.

A digital camera, PC computer with Rhinoceros, and a printer are required. Program developers recommend a six megapixel SLR camera for the best accuracy, but any digital camera will create a model. During testing in ideal conditions, a 3.4 megapixel underwater camera had an error of less than 0.4 pixels.

RhinoPhoto's targets are created by the software and are fully scalable, limited only by printer size. The "Automatic Build" function searches hundreds of photographs for targets and builds a point cloud in less than twenty minutes. The point cloud can then be built into a three dimensional model.

Compared to other photogrammetry software, such as PhotoModeler, RhinoPhoto requires little time. PhotoModeler, by Eos Systems, is a popular photogrammetry software. PhotoModeler calculates coordinates based on the principle point in the camera and points in photographs, essentially the same theory behind RhinoPhoto.[5] The process between the two, however, is different. While RhinoPhoto creates a point cloud, PhotoModeler creates layers.[6] Layers can be time consuming and difficult to manipulate, but have a higher level of detail than a point cloud.

Therefore, the trade-off between RhinoPhoto and PhotoModeler is time and detail. Similarly sized objects that took 100 to 120 hours to create in PhotoModeler, took eight hours in RhinoPhoto. In another test, similar objects took thirty hours in PhotoModeler versus five hours in RhinoPhoto. The PhotoModeler models had higher detail quality, but RhinoPhoto took a sixth the time. PhotoModeler costing $995, while RhinoPhoto is $630 for standard users or $250 with the education discount. Preference between RhinoPhoto and PhotoModeler belongs to the individual researcher. As a part of the methodology, photogrammetry can quickly record associated artifacts.

[5] Jeremy Green, *Maritime Archaeology: A Technical Handbook*, 2nd ed. (London: Elsevier Academic Press, 2004), 182.

[6] Nathan Richards et al., *Virtual Modeling and 3D Photogrammetry for Maritime Heritage: Exercises in EOS* PhotoModeler *Pro 5.0*, East Carolina University Program in Maritime Studies Research Report Series, no. 18, (Greenville, North Carolina: East Carolina University, 2006), 44.

Reflectorless Total Stations and LiDAR Scanning

Two new technologies gaining popularity are reflectorless total stations and LiDAR scanning. Each would appear an upgrade over regular total station use, but experience has exposed several issues. Without care, both techniques can prove faulty.

The latest total stations are reflectorless, requiring no prism or reflective target. These units are typically more accurate than older reflecting total stations. Beyond the higher price tag, these units have a potential pitfall. Without targets to indicate point locations, it is not possible to correct for offset errors, discussed at length in the methodology section. This problem is corrected by placing targets, but this negates its chief advantage by replicating the cheaper reflecting total stations. An incorrectly sighted reflectorless total station will record anything it is facing, creating false points.

Light Detection and Ranging, or LiDAR, systems are becoming popular in archaeology. A fast and efficient method of recording, this technology has yet to become an affordable option, to purchase or rent, for the small budget archaeologist.

LiDAR scanners rotate 360 degrees, recording points millions of points. Among the hundreds or thousands of useful points are millions of useless "noise". LiDAR files are typically several hundred gigabytes due to these points, requiring specialized computers. Once opened, finding significant points is time consuming. The millions of points become a three dimensional image rather than a useable model. Fortunately, the researchers are working on software to remove noise points from laser scans.[7]

LiDAR has proven to be a serious research liability on several sites. Despite being a high cost technology, it remains a "dumb" tool. A trained archaeologist is still required to determine which points are significant.

In maritime archaeology, LiDAR can capture both a ship's exterior and hold, however it cannot record internal components such as frames or futtocks, revealing little about construction. Objects between the scanner and the site block the electronic eye, resulting in an incomplete scan. Many dry-docked ships rest on bracings that cannot be moved, creating an obstacle for LiDAR scanning.

LiDAR scanning is an effective tool, however it must be recognized as one technique among an array required for recording a maritime site. In the cases of two historic vessels, *Vasa* and *Wawona*, it was determined that further recording was required beyond the LiDAR scanning, in the form of total station recording.

3 METHODOLOGY

This methodology is designed for speed and accuracy, thereby keeping costs low while delivering a high quality product. A single person can operate the equipment him or herself, but a five person crew is the most efficient. For this reason, the methodology is explained with five roles, though it can be adapted for any site.

Rather than position fixing, the total station records every facet of ships' features, from fastening patterns and carpenter's marks to curvature for lines drawings. Targets create hundreds of mini-prisms that capture nearly any detail. As the primary recording method, emphasis should be placed on the total station work, with measured sketches and photogrammetry acting as secondary methods.

Before entering the field, print point labels, catalog sheets, timber catalog pro-forma, and photogrammetry targets. Also, cut the reflective total station targets into squares, either one inch or ten millimeters (see Figure 2). Each of these tasks can be accomplished on site, however doing them before entering the field saves a great deal of time.

Point labels are placed below the total station targets to identify those points that have been recorded. These labels can be created using Microsoft Excel. Font size 72 is viewable in most

[7] D. Martin et al., "Feature Preserving Simplifcation of Point Clouds from Large-Range Laser Scanners," in CAA 2009 Computer Applications and Quantitative Methods in Archaeology: Program and Abstracts, ed. by Lisa Fischer et al., (Williamsburg, Virginia: The Colonial Williamsburg Foundation, 2009), 269.

photographs, saving time during the cataloging phase.

Figure 2. One inch square targets cut from reflective tape on the bow of the CSS *Neuse*.

The catalog documents significant information about each point, used while creating the digital model. Each point should be described by its place on a feature, its location using maritime terminology, and three offset measurements. Essentially small prisms, each reflective target has three potential offset measurements from the ideal point. These x, y, and z measurements can be listed as up/down, inboard/outboard, and fore/aft on the catalog for easier understanding.

Timber catalog pro-forma provide extra detail on significant timbers or sections, such as the keel, keelson, or garboard strake. These can be recorded using traditional methods on pro-forma and integrated into the digital model along with the total station and photogrammetry data. Some sections, such as a flat bottom or the chain locker, can be obscured from the total station. These areas are recorded using pro-forma. Recording the timber's name, location and description in maritime terms, wood, scarph, and fastener types, dimensions, photograph catalog number, and nearest reflective targets aids in modeling and interpretation.

Total Station

The first step is translating the research design to the site. Placing reflective targets on detail is time consuming, so choosing the gross anatomy and filling in details with measured sketches and photogrammetry is important. Total station points can be viewed a web of datums points, allowing information from other sources to be added, provided those sources record the distance to adjacent reflective targets. The entire total station process can be broken down into the following steps:

1. Identify the relevant data points.
2. Create a network around the data points of immobile datums for error checking and the movement of the total station.
3. Place reflective targets in a manner that will facilitate the recording of all relevant data points.
4. Record the reflective targets with the total station.
5. Catalog the location, description, and offset measurements for each point recorded.

Planning relevant data points is often easier than identifying them on site. Based on the research design, these points can be difficult to locate on maritime sites. Maritime cultural heritage includes three site types; vessels on land, floating, or submerged. The research questions for these sites can vary from construction features to spatial patterning. Specific data points need to be identified rather than attempting to record every facet of the site.

Vessels on land and those floating usually lack context, since they are mobile. Position fixing is not of great importance for these vessels, as they have likely been moved to a location irrelevant to the research. Submerged vessels, however, are *in situ* and require accurate position fixing. Due to this dichotomy, terrestrial and floating sites will be addressed first, followed by submerged sites.

Once the data points have been identified, delineate the site by creating a network of datums around it (see Figure 3). There are two types of datums, traverse points, also called occupying points, and datums for checking error. Each should be marked with a reflective target and an immovable marker.

Traverse points are the locations that the total station will occupy and are located on the ground, deck, or ceiling planking. Each traverse point should be sighted from the previous and proceeding points. The most accurate traverse is a circle, however this is not always possible due to the site conditions. Having at least three traverse points, even for small sites, increases accuracy.

Datums for error checking should be viewable from multiple traverse points. Place them in highly visible locations, such as the stem, sternpost, or masts. Dividing datums on a ship into even numbers on port and odd numbers on starboard can make recording easier. Once in place, these datums create a grid around the site, allowing for the total station to record the relevant data points. Total stations have a small amount of inherent error within them. Recording a datum twice from a location, once with each vertical face of the total station, then comparing the difference can tabulate this error.

A backsight is required the first time the total station is set up. This is a point that is 180 degree from the point that the unit is occupying. Like the datums, it should be marked with a reflective target. When recording a vessel, it is best to set up on the bow and create a backsight that bisects the vessel along the keel.

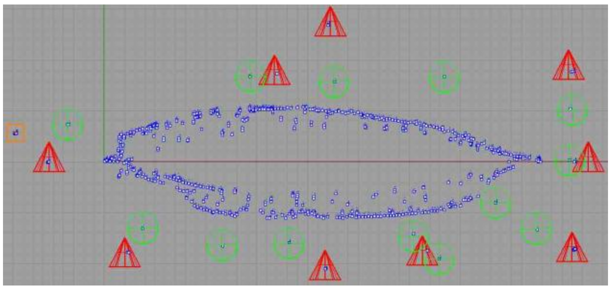

Figure 3. Rhinoceros display of the points network on the CSS *Neuse* site. Green circles indicate traverse locations, the orange box indicates the backsight, red triangles are datums, and blue points are reflective targets.

Total station set up is a simple process that can easily become time consuming and introduce error. Total stations use an arc and distance to find its relative location. Each set up requires the user to input this information into the unit in degrees for the angle, and record a reflective target for the distance measurement.

Once set up, record every datum visible to the unit. These will be recorded from multiple occupying points to determine the amount of error accrued over the project. Since each datum will be recorded multiple times, the distance between these points indicates the amount of error, determined during post-processing.

Once the datums have been recorded, the total station is ready to record the site. As one individual operates the total station, another places reflective targets on the vessel. Points should be chosen based on having multiple significance. A single point can hold many different meanings, all useful for building the digital model. For example, placing a target on a strake's hood end gives information on the timber's end, its connection to the bow, and its location to the strake above or below it. These multiple meanings are recorded in the cataloging step for the benefit of the computer modeler.

The total station operator can begin shooting points as soon as the first targets are placed. Another person keeps a list of points that have been shot and places labels under each target, indicating the target's number and that it has been recorded. These three individuals work in unison and with practice, a crew can quickly record a site.

The fourth crewmember catalogs each point, once the total station has moved to the next occupying point. Using the catalog sheet, this individual writes down each location, the point's multiple meanings, and offset measurements as a reference for building the Rhinoceros model. Extra crewmembers can be added to this job, as it is the most time consuming step.

Key to cataloging is recognizing the difference between the ideal and the actual recorded point. Due to degradation or objects obscuring the total station's line of sight, it is not always possible to place the targets directly on the ideal point. Therefore, the cataloger must measure offset measurements from the actual point to the ideal point. These measurements are used to correct point locations in Rhinoceros following fieldwork.

Photographs taken by the fifth crewmember document the location of the reflective targets and their labels. After photographing a section, the photograph is printed and each number is checked for legibility. The individual then records basic measurements of features on the photograph. This provides further reference for the digital model builder. On a historic ship, this can include timbers' sided, moulded, and length measurements.

An experienced crew can place, record, and catalog several hundred points per day. Only the total station operator requires previous training. This training is simple and use of a total station can be learned in a few hours. It is feasible to record a large vessel in a week with a crew of five.

RhinoPhoto Photogrammetry

RhinoPhoto's role in this methodology is capturing features or associated artifacts quickly, complimenting the total station data. One person can operate the RhinoPhoto recording.

Total station recording is best used for recording the gross anatomy, such as the structural components on ships. RhinoPhoto is used for capturing individual timbers or artifacts, such as hanging knees, capstans, and propellers. Since RhinoPhoto operates as a plug-in in Rhinoceros, the photogrammetry models are easily imported into the total station digital site plan.

Camera calibration and generating targets can be done in the field, though doing them before hand save time. The targets are scalable, making them suitable for any site or artifact. Camera calibration is the traditional complication for photogrammetry, however RhinoPhoto make calibration painless. After printing the calibration sheet from the program, take nine series of three photographs at different elevations. Download the photographs into the function named "Calibrate Camera" and RhinoPhoto stores the data. Once calibrated, a camera does not need to be calibrated again. By calibrating every camera and lens before entering the field, it is possible to begin photogrammetric recording immediately on site.

Affix the photogrammetry targets to the object using poster tack, similar to the reflective total station targets. The first five targets are the origin and the x- and y-axis. Place these in the center of the object or in the location that would best be suited for importation into Rhinoceros. Then proceed to cover the object in the remaining targets. Flat surfaces require few targets, while curves need several to capture their shape. There is an option to create uncoded targets, which are made especially for capturing curves. Once sufficiently covered in targets, photograph the object from multiple angles. Digital photographs are free, so feel free to take more photographs than are needed. These photographs are also useful as a trail of evidence.

Once full coverage of photographs has been taken, download the photographs onto the computer. Select the "Automatic Build" function in the RhinoPhoto menu, followed by selecting the correct file folder when the prompt asks. The program will then search the photographs for targets (see Figure 4). Hundreds of photographs can be scanned in less than twenty minutes. When finished, the program creates a point cloud from the targets. This point cloud is ready to be built into a model and added to the total station data.

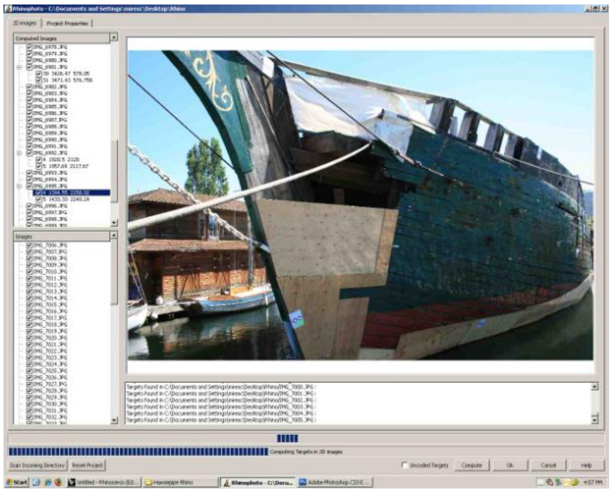

Figure 4. Screen capture of RhinoPhoto's "Automatic Build" function searching photographs of the *Wawona* for photogrammetry targets.

Another useful option is to use a wireless card in the camera. This enables simultaneous photographing and downloading into the

"Automatic Build," allowing user to see the photographs that do not work and the targets that have not been read, increasing speed and productivity.

Archaeological sites are often in difficult locations, with many obstructions between the recorder and the site. For this reason, programs such as PhotoModeler can be problematic. RhinoPhoto's target system works better with obscured objects than PhotoModeler. The ability to combine the photogrammetry with the total station data creates a streamlined recording process, culminating in the Rhinoceros digital site plan.

Rhinoceros NURBS

The Rhinoceros CAD program combines the total station and photogrammetry data, producing the primary deliverable, a three-dimensional site plan. For a CAD program, Rhinoceros has a short learning curve for those with basic computer skills. Approximately four hours working with the tutorial will allow an individual to construct a three-dimensional site plan.

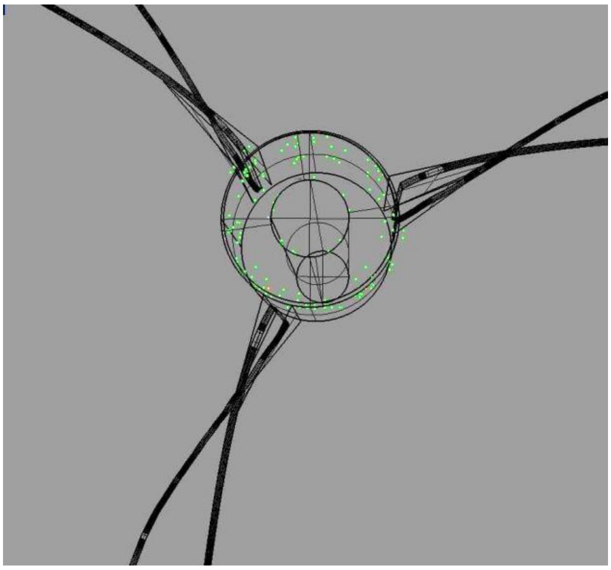

Figure 5. The second step in building a RhinoPhoto point cloud, shown as the green points, into a three-dimensional model, shown as the black lines.

Importing the total station data into Rhinoceros takes approximately half an hour. Connect either the total station or TDS Recon Unit to the computer. Both these units should be accessed similar to an external hard drive. The file, in a .RAW or .JOB format, is not readable by Rhinoceros and must be converted. Multiple programs can do this, such as Foresight DXM. After achieving a comfort level in the Rhinoceros tutorial, prepare to build the model by locating all field notes, photographs, and the point catalog. The sheer number of points is often confusing, so begin in an ordered manner, such as numerical order, by major construction features, or in order of construction.

The simplest method for a maritime archaeologist is to begin with the major construction features and build outwards, as the vessel would have been built. Timbers that are uniform over their length, such as the keel, keelson, and sister keelson are easily created using the box command. If these timber are not perfectly rectangular, such as the rabbet in the keel, create a two-dimensional cross section from the field measurements and use the "Slab" command to extend it to the desire length.

The "Slab" command turns two-dimensional features into three-dimensional figures. If connecting points in the point cloud, select all the points on one edge of the timber and create a line through them. Next, use the "Slab" command to extend the line into a plane, using the opposite edge as a guide for its size. Repeat this process three additional times so the timber has four sides.

It is possible to indicate breaks, fastener holes, or other such irregular features. First, build a model of the object that created the feature, such as a fastener. Place the object model into the location where the hole is desired. Select the "Trim" function, choosing the object as the "Cutting Object(s)" and the timber as the "Object to Trim." When choosing the timber, only click on the area inside the fastener. Remove the fastener model and the fastener hole will remain.

The "Trim" function is also useful for fitting timbers, such as hanging knees, chocks, or deadwood that need to fit the contours of the timbers they are abutted against. To do this, build the timber, and then place it in the correct location. The edges will overlap into the surrounding timbers, such as ceiling planking. Select the "Trim" command and choose the surrounding timbers, such as ceiling planking, as the "Cutting Object(s)." Then select the overlapping sections of the timber as the "Object to Trim," which will disappear and create a form fitting timber. Use this technique carefully, as the timber must match the measurements from the field.

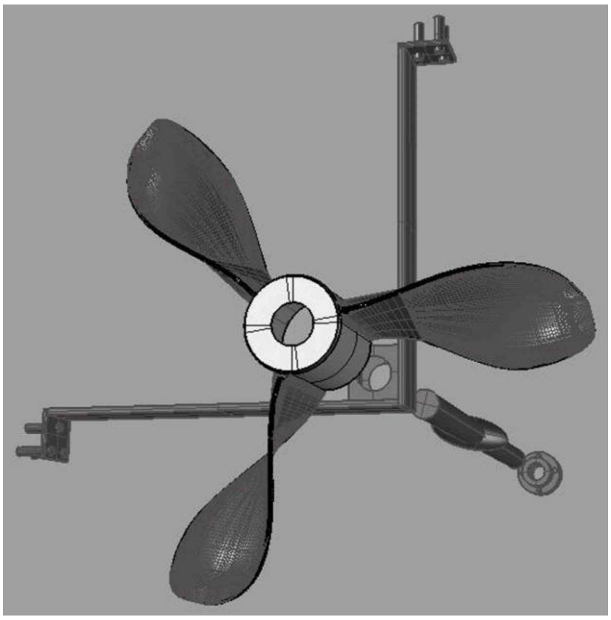

Figure 6. A RhinoPhoto point cloud built into a Rhinoceros model incorporating traditionally recorded parts.

Between creating a line, the "Slab" and "Trim" commands, most timbers can be modeled. Further commands, such as "Twist", useful for making a rockered keel, are learned through practice with the program. For beginners, nearly the entire model can be created from the commands described. Rhinoceros' help menu is thorough and easy to use, facilitating utilization of other commands.

Once the total station data has been built into a model, open the RhinoPhoto data in its own window. Be sure that the model is in the same units of measurement and scale as the total station data. Use the same techniques as above to build the photogrammetry point cloud into a model (see Fig. 6). When completed, copy and paste the RhinoPhoto model in the digital site plan (see Fig. 7). Drag it into the correct location, fitting it into place using the "Trim" command if necessary. Translating a point cloud into a three dimensional model is time consuming, though it only requires an individual with average computers skills.

4 SUBMERGED SITES

Sites that are partially or fully submerged present another set of considerations. This methodology does not translate completely underwater, though it can augment other recording techniques. Archaeologists have attempted to use each of the technologies discussed in this paper underwater; electronic position fixing, photogrammetry, and three-dimensional site plans.[8] Each has met with varying results.

Total Station

Archaeologists' attempts to transfer the ease of total station use to submerged sites usually culminate in extremely large stadia rods or individuals floating with expensive prisms.[9][10] Both of these methods introduce error and place costly equipment in harm's way. Total stations remain an excellent tool for position fixing and a water-resistant reflective target can be built for less than $50. This technique remains as limited as earlier methods, only preserving the expensive prism from damage. The total station must remain on land and within line of sight with the reflective target, so this method is not suited for sites far from land.

Buoyancy's natural properties can be harnessed to create what is essentially a reverse plumb-bob.

[8] Jeremy Green, *Maritime Archaeology: A Technical Handbook*, 2nd ed. (London: Elsevier Academic Press, 2004), 42, 202.

[9] Kenneth J. Vrana, Preliminary Archaeological Site Report Historic Shipwreck *New Orleans* Site Number 2OUH209, (Alpena, Michigan: Thunder Bay Marine Sanctuary and Underwater Preserve, 2004), 8.

[10] Clair P. Dappert, *Oaken Whale with a Cast Iron Tail: The Single-Decked Wooden Bulk Carrier Monohansett*, East Carolina University Program in Maritime Studies Research Report Series, no. 13, (Greenville, North Carolina: East Carolina University, 2006), 41.

Rather than a string attached to a lead weight, a steel cable is attached to a float with a reflective target on it. Air seeks the path of least resistance, causing the float to pull the steel cable directly upwards and taunt, provided there is no overhead environment. Buoyant force is equal to the weight of water displaced, minus gravity. For example, a one cubic foot lift bag in seawater will have the upward force of nearly sixty-three pounds.

Provided the float continues to displace its full potential, it should continue to seek the path of least resistance and supply a force equal to its buoyancy. Should the float break the surface, displacement will decrease, causing the line to become loose, similar to a plumb-bob when it touches the ground. Any individual who has used a lift bag understands the force that buoyancy can exert while rising through the water column, as well as how that force is lost once the lift bag breaks the surface. Therefore, the diver on the bottom must be sure that the float does not lose its full buoyant force. For the total station to record the point, atop the float is attached a rod with reflective tape on top of it. A counter weight can be added at the bottom to help the diver control the float.

The steel cable is graduated every meter. As one diver holds the line, a second diver measures from the nearest meter line to point of interest, recording the entire depth on a slate. Two deliberate tugs on the line indicates to the total station operator that the cable is in place. By recording each point with a rod height of zero, the depth values can be added and recalculated later. The diver can be given the go ahead by striking a metal object underwater.

Heavy current sites can use a goniometer to find the angle that the cable is displaced. The use of goniometers underwater has been a success.[11] A diver can place the goniometer at the base of the cable and record the angle. The point placement can then be rectified in Rhinoceros following the fieldwork by using the Pythagorean theorem.

This method is not as accurate as the total station recording discussed in the previous section. For the purposes of position fixing, however, it is effective. If used beyond position fixing the bow and stern in adverse conditions or grid corners in ideal conditions, the archaeologist risks introducing error into the project. The two other pieces of technology, RhinoPhoto and Rhinoceros, offer much better results for underwater archaeology.

RhinoPhoto

Archaeologists have successfully used photogrammetry underwater, but have been limited by camera calibration issues, equipment, and visibility. RhinoPhoto offers answers to each of these problems. The previous section discussed RhinoPhoto's simple calibration, while any underwater digital camera can be used.

Most underwater photogrammetry has been used on high visibility sites, but the target system works well in low visibility conditions. Only three targets need to be present in a given photograph, making it possible to record a site that a diver cannot see in entirety.

Printing targets on yellow paper reduces halation and laminate makes them waterproof. Due to the author's testing, RhinoPhoto now offers an underwater option in its menu. Unless a target's center is fully obscured, suspended sediment in the water does not affect the accuracy of photogrammetry. Each underwater test performed had an accuracy of less than 0.6 pixels, the highest level for the software.

Rhinoceros NURBS

Rhinoceros use on submerged sites is well documented. Jeremy Green reports the success of a three-dimensional site plan using Rhinoceros on the underwater Tektas Burnu site.[12] Artifacts locations were recorded and then each artifact was built as a Rhinoceros model. Each model was then placed in its position on an underlay of the seafloor. This created an accurate and useable three-dimensional model.

5 DELIVERABLES

[11] J. Cozzi, "The Goniometer: An Improved Device for Recording Submerged Shipwreck Timbers," *The International Journal of Nautical Archaeology* 27, no. 1 (1998).

[12] Jeremy Green, *Maritime Archaeology: A Technical Handbook*, 2nd ed. (London: Elsevier Academic Press, 2004), 202-203.

Cultural resource management is often measured by deliverables. The main deliverable for this methodology is a three-dimensional site plan that allows additional data to be added at a later date. The methodology allows for more accurate measurement than traditional recording methods, at a faster rate, and in three dimensions. The digital model is excellent for presentations and public outreach, but also as a scientific tool from which measurements can be taken.

Most important to many researchers, the methodology uses a small crew and budget. Five individuals were used for the recording of the *Vasa* beakhead and CSS *Neuse*, and six for the *Wawona*, while nine were used for the simultaneous recording of the CSS *Jackson* and CSS *Chattahoochee*. The recording of the CSS *Jackson*, CSS *Neuse*, and CSS *Chattahoochee* were all paid for by a single mini grant.

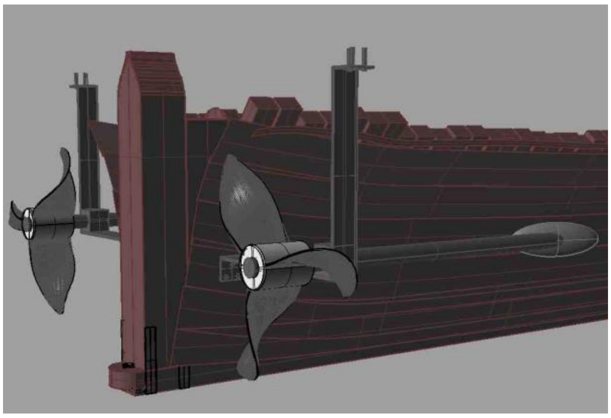

Figure 7. Screen capture of the stern of the CSS *Jackson* in Rhinoceros, combining total station data, photogrammetry, and traditional methods.

Speed is another benefit. Three weeks were needed to record the *Vasa* beakhead, a structure 15 meters long and spanning three decks. In two weeks, the hold and deck of the *Wawona*, a 165-foot vessel, were recorded. The interior and exterior of the 140 foot CSS *Neuse* was recorded in two and half weeks. Finally, it took five days to record the 180-foot interior and exterior of the CSS *Jackson* and the 20-foot interior and exterior of the CSS *Chattahoochee*.

6 CONCLUSION

For every substantially funded archeological project, there are dozens on shoestring budgets. As a field, archaeology strives for precise and accurate recording, whether funded by grants or working with volunteers. The majority of this field works by contract[13]; though few discussions of cost-effective reuse of common equipment are found within printed material.

Within the maritime cultural heritage community, there are few sources dealing with cheap, though accurate, methodologies. Many publications deal with new technologies focused on capturing accuracy less than a millimeter, though it is unlikely that shipbuilders with handsaws were concerned with dimensions that precise, therefore not affecting interpretation.

For questions other than conservation, this methodology presents a cost effective option for accurate recording between one to three millimeters. This method has proven successful in the recording a number of significant maritime cultural sites using small crews with limited experience. The use of the total station, photogrammetry, and the Rhinoceros CAD program meet Eppich and Chabbi's requirements for the acceptance of high tech methods in a low budget project. The deliverable is an accurate three-dimensional site plan, allowing small CRM firms, avocational groups, and universities to produce professional high tech archaeological reports.

---

[13] Randall H. McGuire, *Archaeology as Political Action*. (Berkely, Califorinia: University of California Press, 2008), 110.

Acknowledgements

Dr. Frederick Hocker (Vasamuseet) and Dr. David Stewart (East Carolina University) taught the initial total station methodology to students of the Program in Maritime Studies at East Carolina University in December of 2007. The North Carolina Sea Grant funded the research and recording of three historic vessels. Thank you to the institutions, Vasamuseet, Northwest Seaport, the CSS *Neuse* North Carolina State Historic Site, and Port Columbus (Georgia) Civil War Naval Museum.

Bibliography

Cozzi, J. “The Goniometer: An Improved Device for Recording Submerged Shipwreck Timbers.” *The International Journal of Nautical Archaeology* 27, No. 1 (1998): 64-80.

Dappert, Claire P. *Oaken Whale with a Cast Iron Tail: The Single-Decked Wooden Bulk Carrier Monohansett*. East Carolina University Program in Maritime Studies Research Report Series, No. 13. Greenville, North Carolina: East Carolina University, 2006.

Eppich, R. and A. Chabbi. “Recording and documenting cultural heritage- 3D modeling for conservation in developing regions.” In *Recording, Modeling and Visualization of Cultural Heritage*, edited by Manos Baltsavias, Armin Gruen, Luc Van Gool, and Maria Pateraki. London: Taylor & Francis Group, 2006, 11-20.

Fussell, Angela. “Terrestrial Photogrammetry in Archaeology.” *World Archaeology* 14, No. 2 (1982): 157-172.

Gould, Richard A. *Archaeology and the Social History of Ships*. London: Cambridge University Press, 2000.

Green, Jeremy. *Maritime Archaeology: A Technical Handbook*, 2nd ed. London: Elsevier Academic Press, 2004.

Martin, D. and Fco. Javier Melero, P. Cano, and J.C. Torres. Feature Preserving Simplification of Point Clouds from Large-Range Laser Scanners. In CAA 2009 Computer Applications and Quantitative Methods in Archaeology: Program and Abstracts, edited by Lisa Fischer, Bernard Frischer, and Sarah Wells. Williamsburg, Virginia: The Colonial Williamsburg Foundation, 2009, 268-269.

McGuire, Randall H. *Archaeology as Political Action*. Berkley, California: University of California Press, 2008.

Richards, Nathan, and Sami Seeb, Brian Diveley, and Michelle Liss. *Virtual Modeling and 3D Photogrammetry for Maritime Heritage: Exercises in EOS* PhotoModeler *Pro 5.0*. East Carolina University Program in Maritime Studies Research Report Series, No. 18. Greenville, North Carolina: East Carolina University, 2006.

---. “Virtual Modelling and 3D Photogrammetry for Maritime Heritage: Exercises in EOS PhotoModeler.” *Bulletin of the Australasian Institute for Maritime Archaeology* 32 (2008): 27-41.

Vrana, Kenneth J. Preliminary Archaeological Site Report Historic Shipwreck *New Orleans* Site Number 2OUH209. Alpena, Michigan: Thunder Bay Marine Sanctuary and Underwater Preserve, 2004.