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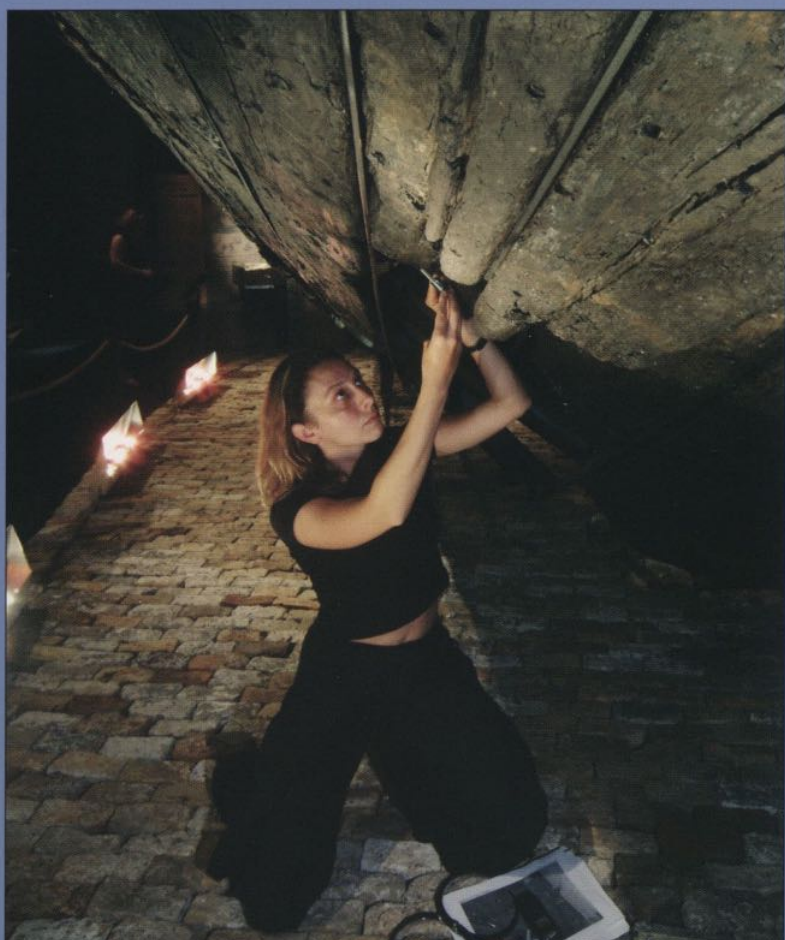

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On the cover: Wendy van Duivenvoorde taking manual measurements of the *Batavia* hull. Photo: Patrick Baker, courtesy Western Australian Maritime Museum, Fremantle

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Capturing Curves and Timber with a Laser Scanner: Digital Imaging of *Batavia*

Wendy van Duivenvoorde

Three-dimensional laser scans are no longer exclusively used with small archaeological artifacts; nowadays, they are also applied to entire ship hulls and architectural structures. The first shipwreck to be the subject of a high-tech, three-dimensional laser scan was the Confederate submarine *H.L. Hunley* in the year 2000. The famous Civil War submarine sank in 1864 near the harbor of Charleston, South Carolina, after becoming the first submarine in history to sink an enemy warship. It is currently undergoing conservation treatment. In 2002, researchers in Stockholm used a three-dimensional scanner to record both the exterior and interior of *Vasa*, the Swedish flagship built by King Gustavus Adolphus between 1626 and 1628. The excessively armed and unstable warship sank on its maiden voyage out of the harbor in 1628, and is now on display at the State Maritime Museum in Stockholm. Both *Vasa* and *H.L. Hunley* were raised from the seabed into arid environments that allowed for laser scanning. The three-dimensional model of *Vasa* consists of 1.3 billion data points, providing a data set of about 25 Gigabytes. Unfortunately, the current level of computer technology is unable to manage this amount of data and so it had to be broken down into smaller subsets for processing and viewing.

Ground-based laser scanners are revolutionizing the spatial data industry and, thus, also the field of archaeology. On January 29, 2005, the hull remains of the *Batavia* ship were scanned by Jochen Franke, a research associate from the Department of Spatial Sciences at Curtin University of Technology in Australia, with an IQ-Sun 880 laser scanner (figs. 1, 2). "Three-dimensional scanning is what eventually is going to play a prominent role in the field of archaeology," says Hanneke Jansen, an archaeologist and geodetic mapping expert participating in the *Batavia* Hull Reconstruction Project, "Imagine three-dimensional scanning of archaeological artifacts and structures in order to capture the data at greater precision. No more measuring tape, plumb bob, pencil, and paper!"

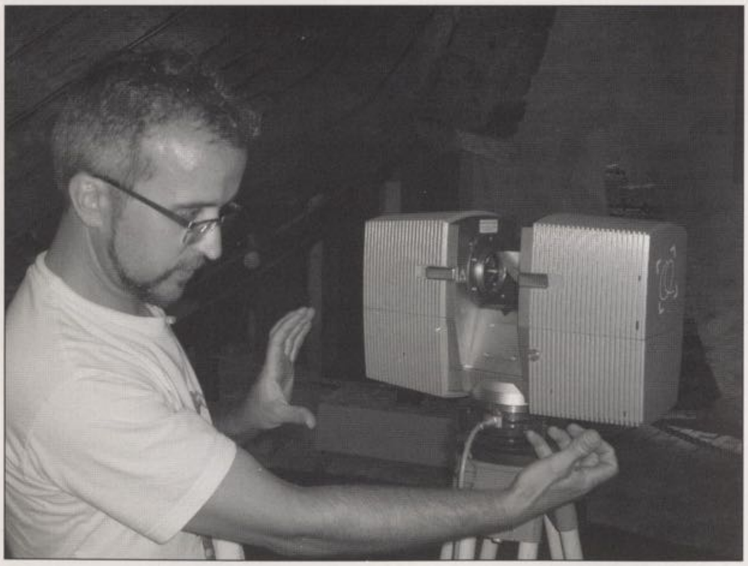

Fig. 1 (above). *Jochen Franke explaining how the IQ-SUN 880 scanner works. Photo: Courtesy Western Australian Maritime Museum*

Fig. 2 (right). *Jochen Franke and Wendy van Duivenvoorde reviewing the three-dimensional scan of the* Batavia *hull remains with the IQ-SUN 880 scanner. Photo: H. Jansen, courtesy Western Australian Maritime Museum*

Currently, there are at least six different models of scanners on the market offering a wide range of features and capabilities. These scanners rapidly acquire accurate, dense sets of three-dimensional point measurements of entire surfaces. Together with the return signal intensity attribute, scanners can provide complete three-dimensional images of topography, archaeological structures and artifacts.

Batavia's violent end

Batavia, a Dutch East Indiaman, sank in 1629 on its maiden voyage to the Indies on the Houtman Abrolhos reef off the coast of Western Australia. The new flagship of the Dutch East India Company (VOC), the world's first multinational corporation, had set sail from Texel in Holland to Batavia (modern-day Jakarta, Indonesia) eight months earlier, on October 28, 1628, with 341 people on board.

Batavia was not the first Dutch ship to sail Australian waters. The first recorded discovery of the Australian continent dates back to 1606, when skipper Willem Jansz and upper-merchant Jan Lodewijksz van Rosingeyn sailed the Dutch ship *Duyfken* (*Little Dove*) into the Gulf of Carpentaria in the Northern Territory. This Dutch expedition to discover the great land of Nova Guinea and other East- and Southlands pre-dates Cook's discovery of the continent, in 1770, by 164 years.

On the morning of June 4, 1629, the ship struck the Australian reef. Three hundred and three among *Batavia*'s crew and passengers survived the voyage and wrecking, and made it safely to the uninhabited and barren Houtman Albrolhos Islands. Commander-in-chief Fransisco Pelsaert left the floundering site in one of the ship's boats with 45 men, two women, and one child to seek help in Batavia. The tragedy that followed on the islands left only a few survivors, and makes the famous mutiny on the *Bounty* ship seem like a trivial incident in comparison.

Various Dutch authors from the 17th-century unfold the grisly events in which 116 men, women, and children were deliberately drowned, strangled, had their throats cut, or were brutally hacked to death by a group of men who had gathered around instigator and acting commander Jeronimus Cornelisz. A month after the wrecking, the organized killing began in secret at night. It did not take long before everyone on the island knew what was going on, but most had become too weak to fight off the killers. When help finally arrived from the Dutch colony, the remaining people on the island were brought safely to their final destination while the men who had formed the eager death squad were prosecuted and convicted by Dutch authorities.

The *Batavia* shipwreck was discovered in 1963 in shallow waters from three to seven meters deep. It was excavated between 1971 and 1980 by a team of archaeologists from the Western Australian Maritime Museum under the direction of longtime INA associate Jeremy Green.

In its day, *Batavia* was a substantial ship. An account of the Dutch East India Company (VOC), dated March 29, 1626, tells us that its length on deck was 160 Amsterdam feet, its depth of hold 12.5 Amsterdam feet, and its beam 36 Amsterdam feet (one Amsterdam foot is equivalent to 11.15 inches, or 28.32 cm). The surviving hull timbers, raised from the seabed by archaeologists, weigh 30 tons, and represent approximately eight percent of the original hull. They comprise part of the portside transom and stern quarter of the vessel, including the sternpost, a fashion piece, transom beams, 20 planking strakes, ceiling planking, and remnants of approximately 40 frames. A significant part of the hull

Fig. 3. *The* Batavia *Shipwreck Gallery in the museum. Photo: Courtesy Western Australian Maritime Museum*

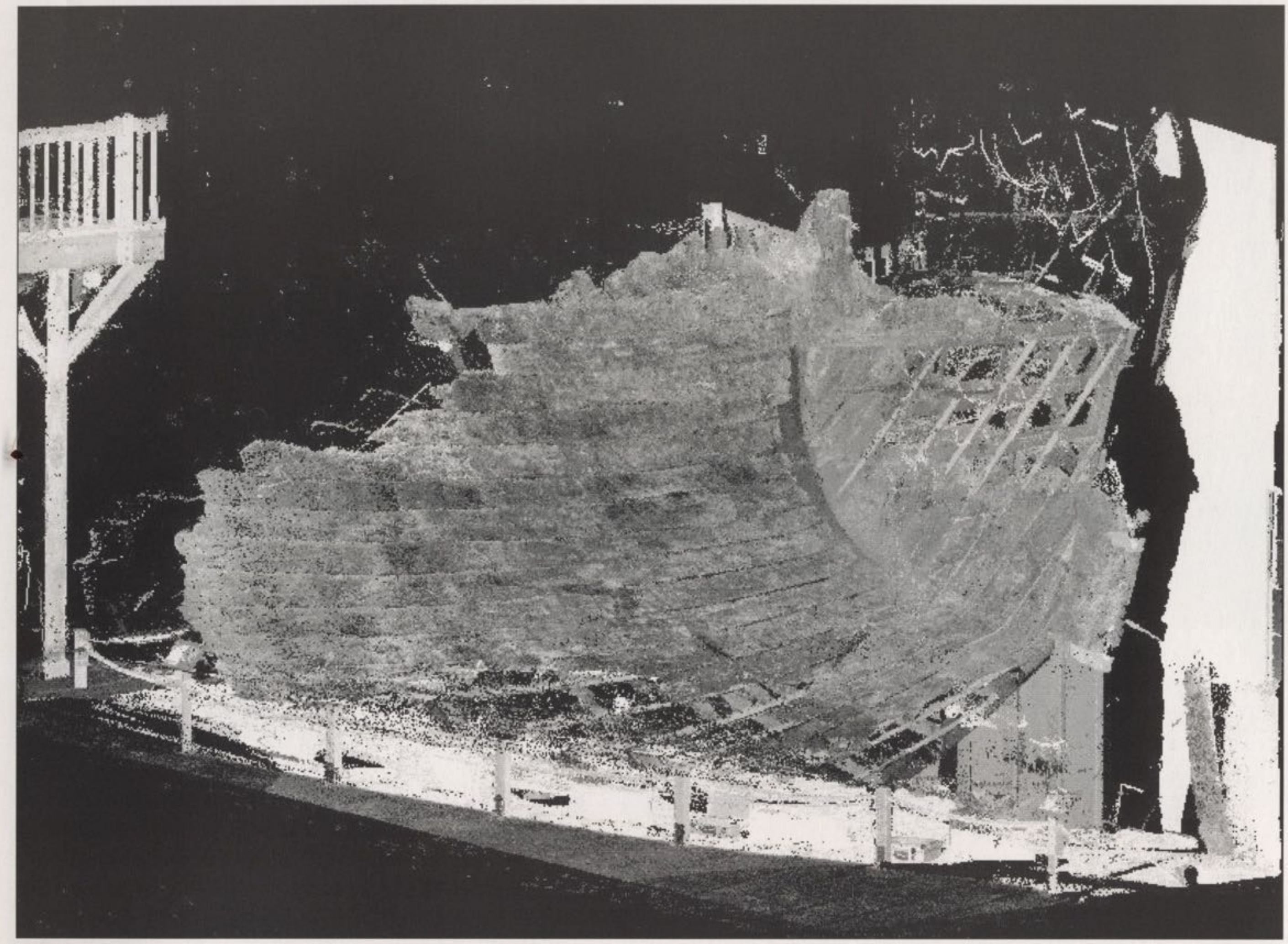

Fig. 4. *Three-dimensional scan of the* Batavia *hull. Image: J. Franke, courtesy Western Australian Maritime Museum*

remains has been reassembled and is on display in the Western Australian Maritime Museum (fig. 3).

To date, the *Batavia* ship represents the only excavated remains of an early 17th-century Dutch East Indiaman that has been raised and conserved in a way that permits detailed study. This is of great significance since there are no construction plans, lines drawings, or building records for any East Indiamen of this period.

In the field of ship reconstruction based on archaeological remains, the growing prevalence of computer technology has been a dramatic change; technology looms large! A three-dimensional laser scan as made by Jochen Franke (fig. 4) facilitates the reconstruction of *Batavia*'s original design and appearance. Timber drawings, perspective lines drawings showing *Batavia*'s shape, and construction plans detailing hull assembly can be extracted more easily from a three-dimensional model made by a laser scan than from measurements and observations collected with the eye, tape measures, pencil, and paper.

Though the technology still has limitations regarding file size and data management, it has certainly been helpful. It saved multiple hours taking curvatures of the hull with a bevel goniometer, and measurements with a conventional measuring tape. Within the two minutes for a typical individual scan, the instrument acquires over seven million three-dimensional points of data. Mr. Franke collected five laser scans of the hull from different angles so as to cover all otherwise obstructed portions of the timbers (fig. 5). This means that we collected over 35 million points in total with an accuracy of +/- three mm in range or +/- five mm in position for each individual point. Taking so many measurements by hand would require quite literally a lifetime using conventional methods.

As the *Batavia* hull remains are smaller than those of *Vasa*, the combined file size of all its scans is one Gigabyte in ASCII format, though native scan software compression typically significantly reduces this. A file of this size is still somewhat difficult to handle with a top-of-the-line comput-

Fig. 5. *Jochen Franke placing orientation spheres on* Batavia*'s hull before scanning. Photo: Courtesy Western Australian Maritime Museum*

er; the file can be opened and edited but processing takes considerable time.

Three-dimensional scanning also facilitates comparison. Although they are two different types of ships (*Vasa* a warship, and *Batavia* an East Indiamen), it would be interesting to compare the scans of their stern sections, as both ships were built in the same period according to the same Dutch shipbuilding tradition. The construction of *Vasa* was supervised by a Dutch shipwright and it is known from archival material that he applied "Dutch methods" in its construction. The technology of three-dimensional scanning may prove to be a useful research tool in setting both shipwrecks side by side, something that would otherwise be practically impossible (not to mention that the two hulls reside about 8,355 miles apart).

Three-dimensional scanning helps to provide detailed documentation of hull timbers and the original shape of *Batavia*'s stern. Such documentation has not been completed since its excavation and will, in the near future, be made available to the nautical and archaeological communities. The final study of the *Batavia* hull remains will be included in the author's Ph.D. dissertation on early 17th-century Dutch shipbuilding.

Acknowledgements: The research of *Batavia*'s hull is funded and supported by the following institutions: Prins Bernhard Cultuurfonds, Texas A&M University, Studiefonds Ketel I, Catharine van Tussenbroek Fonds, Jo Kolk Stichting, Stichting Fundatie Vrijvrouwe van Renswoude, and Dr. Hendrik Muller's Vaderlandsch Fonds. I thank Jeremy Green, curator at the Western Australian Maritime Museum, for inviting me to study the archaeological hull remains for final publication. I am especially grateful to Kevin Crisman and Cemal Pulak for accommodating and supporting my research, and sharing their experience and expertise. I must also thank my dear friends Hanneke Jansen and Corioli Souter for their assistance in sampling and recording the *Batavia* hull remains, and near endless scanning of archival records, and for their patience in spite of demanding and many overtime hours working in the Western Australian Maritime Museum. Thank you for your collegiality, support, and friendship. My sincere appreciation is offered to Lucas Brouwer, and Fik Meijer and Harald Kruithof (Stichting Trireme), for their financial assistance and caring encouragement. Without them, it would have been impossible to start or continue the *Batavia* Hull Reconstruction Project. Lastly, I would like to thank Fred Hocker, Robert Neyland, and Mike Scafuri for sharing their thoughts and data while writing this article. *wvd@tamu.edu*]

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New Tools for Archaeological Research: Digitally Imagining *La Belle*'s Figurehead

C. Wayne Smith

During the research and analysis stages of archaeological excavation, a variety of techniques and process are utilized to recover as much information as possible. The end result of archaeological study of course, should be to reconstruct the archaeological evidence and disseminate as much information about past cultural ways as possible.

Invariably, one result of extensive shipwrecks excavations is the need to construct one or more models of the vessel in order to rationalize aspects of a particular vessel's construction, since in many cases, only the lower portions of vessels are preserved when embedded in sediments. One such vessel, La Salle's *La Belle*, was lost off the coast of Texas in 1686. Excavated by the Texas Historical Commission, only the lower one-third of the hull was preserved in the sediments of Matagorda Bay. A detailed model of the vessel, constructed using archaeological data, information from ship treatises and other historical documents is the best way to create an overall picture of what it looked like. Glenn Grieco, our model builder in the Nautical Archaeology Program at Texas A&M University, constructed a detailed one-to-twelve scale model of *La Belle* (fig. 1).

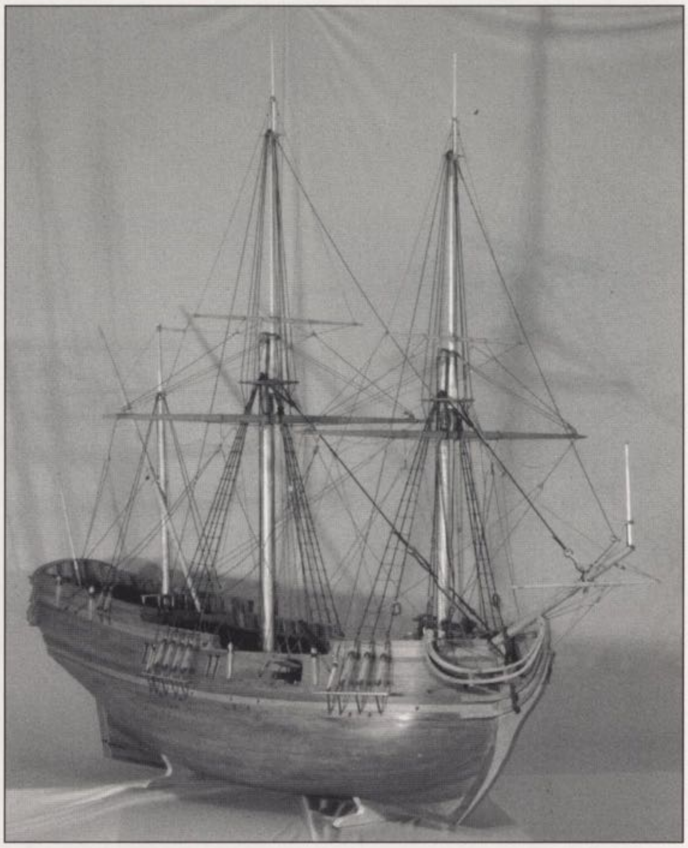


Fig. 1. *The completed model of* La Belle, *built by Glenn Greico. All Photos: C.W. Smith*

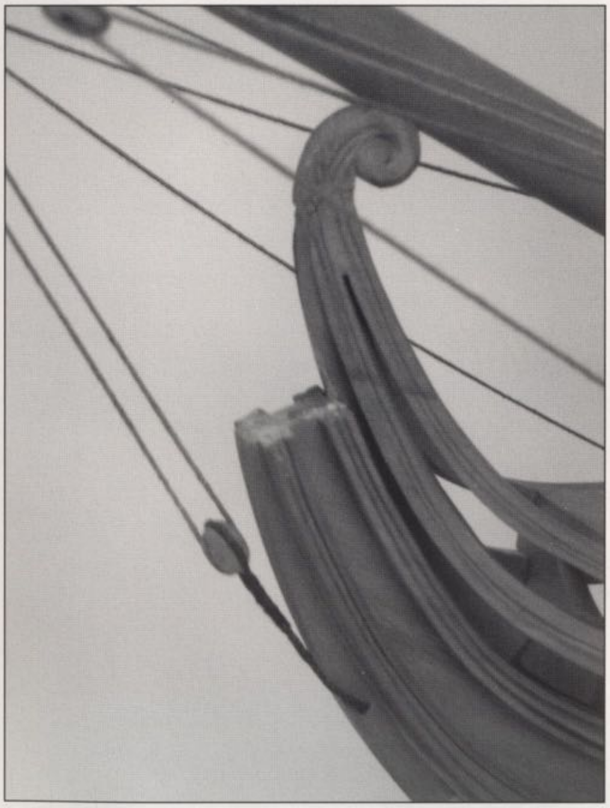


Fig. 2. *The stem of the* La Belle *model without a figurehead.*

Once Grieco finished the model, only one thing was lacking—a figurehead. While there is no account stating that *La Belle* actually had a figurehead, we felt that the addition of such an adornment would add to the completeness of the model. Figure 2 illustrates the bow section of the model minus a figurehead. The addition of a beautiful young girl, a belle, would be appropriate.

Even a skilled model builder like Grieco however can find it difficult to dedicate the time needed to carve an appropriately sized figurehead. Grieco turned to the high-tech equipment of the Wilder 3-Dimensional Imaging Lab, part of the Nautical Archaeology Program facilities, to design and construct a figurehead for the model. Working with the latest in three-dimensional scanning and printing technologies, Wilder Lab staff were able to design, scale and produce a series of figureheads appropriate for the vessel.

First, Greico searched in a local hobby shop and found a Diana-like figurine that had the appropriate 17th-century hair and dress style, and was of a suitable size for scanning (fig. 3). The challenge of using this figurine for our model was the fact that the head was turned to the left and not facing forward as one associates with figureheads. Additionally, as the figurine was in fact the decorative addition to a bookend, it stood next to a plinth, which also would not be an appropriate addition to a figurehead. The architectural feature in the bookend was removed with the use of a band saw (fig. 4). The last great challenge was to rotate the head to a forward-facing position.

Using a Minolta 910 3-D digitizer, a high resolution, three-dimensional scan of the figurine was recorded. Using FreeForm® software, the head was placed into a forward-facing position. Small adjustments and cleanup were completed using Rhinoceros® software and the completed image was saved in stereo lithographic (stl) file format for reproduction purposes (fig. 5).

Fig. 3. *A single bookend served as a starting point for creating a front-facing figurehead.*

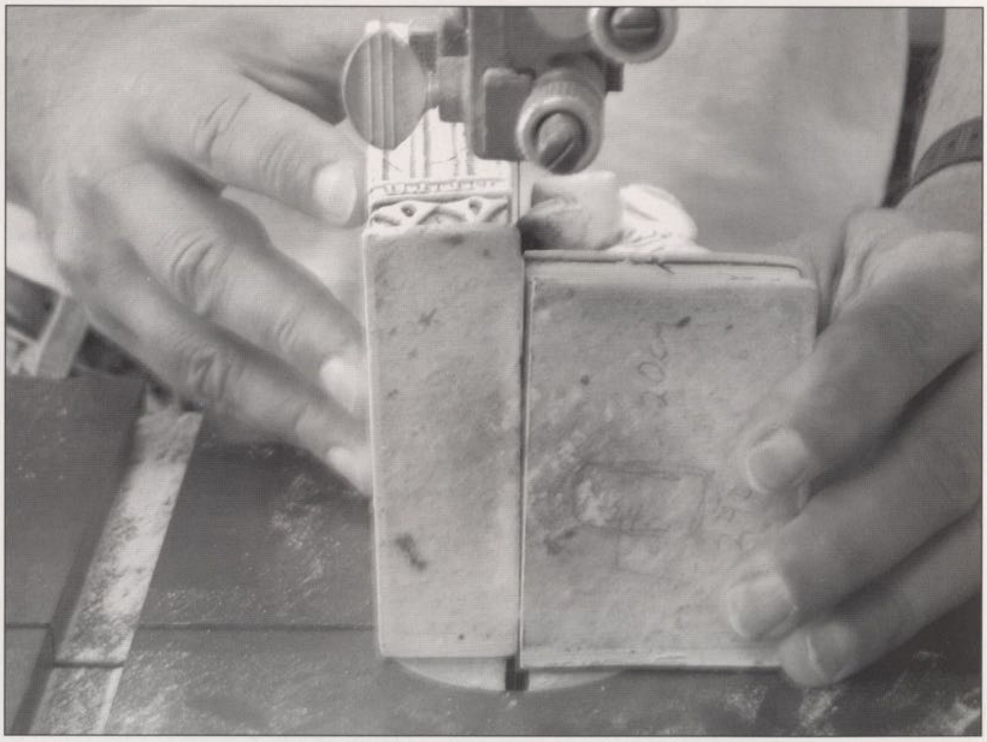


Fig. 4. *A bandsaw was used to separate the plinth.*

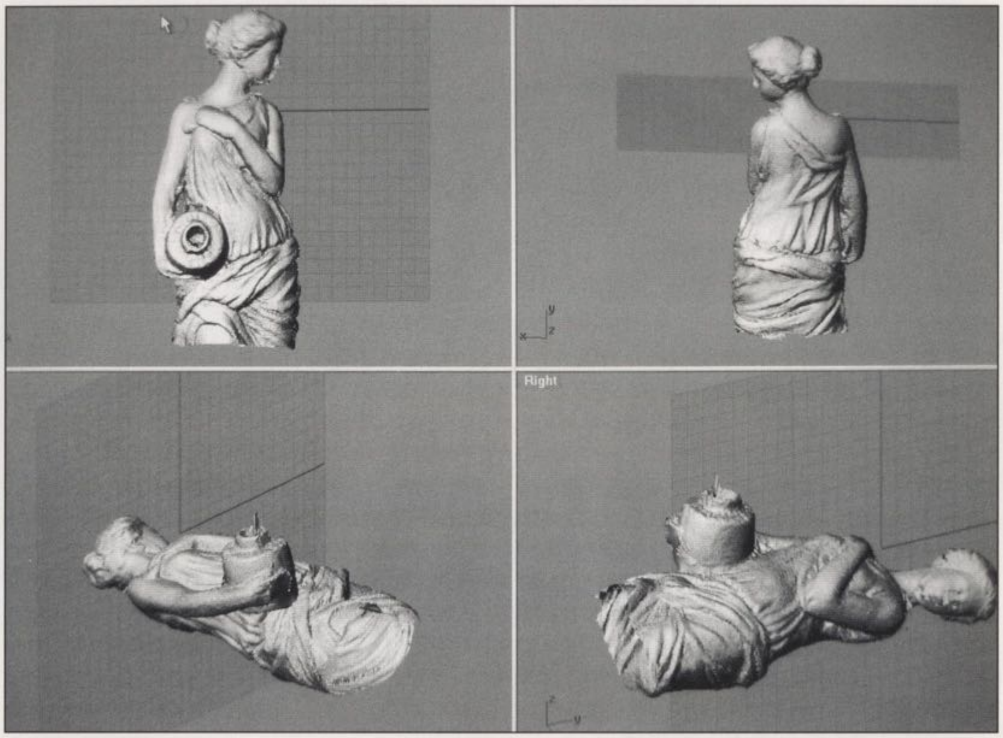
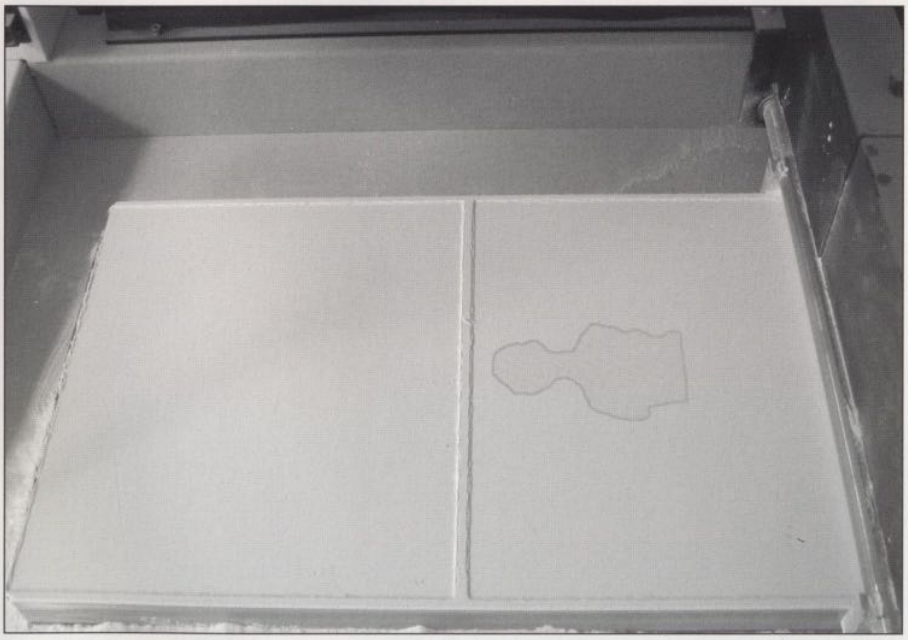


Fig. 5 (above). *Once the scanned image of the figurine was altered to a front facing position, the image was saved as a stereo lithographic (stl) format file. This file was then imported into Rhinoceros® software where additional refinements and texturing were used to give the figurine a weathered appearance. The file was once again saved in stereo lithographic format and then imported into Z-Corp® print software in preparation for scaling and three-dimensional printing.*

Fig. 6 (below). *The Z-Corp® three-dimensional printer showing the feed chamber on the left and the build or print chamber on the right. Visible in the build chamber is a printed cross section of the figurehead. Once completed, the compiled layers will result in an appropriately scaled figurehead.*



The Wilder Lab also possesses a Z-Corp® three-dimensional printer, a new-generation output device that allows us to replicate (print) scanned images or objects constructed in computer aided design (CAD) software. Fine-grained plaster in the feed chamber on the left side of the printer is laid down in the build chamber on the right side of the printer (fig. 6). The print head then moves across the build chamber, printing thin sections of the artifact, much like an ink jet printer prints on paper. Instead of ink however, the Z-Corp® printer prints with a bonding agent that solidifies the thin layer of plaster into a paper-thin slice of the artifact being reconstructed.

Technology however, must be combined with historical data and a liberal dose of artistry to accurately create a properly scaled figurehead. Appropriately replicating the weathered appearance of painted wood and clothing, size and coloration are all important features in the replication process. Once removed from the three-dimensional printer, models must first be consolidated with a bonding agent that makes them both durable and long lasting (fig. 7). A technician is pictured (fig. 8) cleaning residue plaster from the surface of the figure. Once stabilized, the figurehead model was painted by Nautical Archaeology Program student Rebecca Ingram using an artistic style and colors appropriate for the time period. The completed figurehead, mounted on the model of *La Belle* is pictured in figure 9.

Fig. 7 (above). *A close-up of the consolidated figure shows the rough surface texture that was created using a course-haired brush. Once painted, this helps give the desired effect of weathered wood.*

Fig. 8 (above). *Siarita Kouka, a visiting conservator to the Institute, brushes the surface of the model with a course-haired brush to remove powdered plaster and create a wood-grain surface texture. The model is then consolidated with a thin, hardening solution of PVA in acetone.*

Fig. 9 (right). *Finishing touches on the figurehead include sculpting and adjusting it to fit the model of* La Belle, *and painting it with a style and colors appropriate for the period.*

New Tools for the Trade

The use of 3-D digitization and printing technologies may seem to be disparate tools to be used in the fine art of ship model making. Discussions with Grieco however have brought to light many considerations that helped validate the use of these tools in the model-making process. Grieco's work is unique because he integrates archaeological data with historical documents including ship treatises, chandlers' lists, paintings and other sources of information into his designs. The inclusion of archaeological data, along with extensive training in the development of ship design technology and a large database of archaeological data on construction features of other vessels ensures that Grieco does not have to rely solely on the cryptic writings of an ancient shipwright to develop his vessel designs. Indeed, very few shipwrights committed their design ideas and secret building techniques in written form. This is why the archaeological data is so important.

In the case of *La Belle* and many other shipwrecks that have been archaeologically excavated, figureheads are either seldom present or are not sufficiently preserved to supply accurate data for the purpose of reconstruction. At best, one has to rely on generalizations regarding styles and decoration that would have been used for these adornments. In the absence of archaeological data, the investment of the time and resources required to hand carve a figurehead is costly. Three-dimensional digitization and printing makes the process of fabricating a figurehead affordable and adaptable, since digital data is scalable and easily augmented. Unlike the science of ship reconstruction and analysis, which requires extensive study and knowledge of the mechanical properties of materials and their interactions, decorative elements such as figureheads and other statuary that are periodically found on historic vessels are highly variable. Accordingly, there is often little to be learned from them. In fact, it is common for many model makers to remain highly focused on details of construction and merely use store-bought fittings. This can be problematic since these adornments are sometimes poor quality compared to the craftsmanship that has gone into the construction of the model.

In the event sufficient archaeological data is available to warrant hand sculpting a figurehead, digital technologies are useful tools for developing a range of prototypes to aide in the production of the formal carving. Although master craftsmen like Glenn Grieco use the resources of the Wilder 3-Dimensional Imaging Lab to help create museum-quality ship models, three-dimensional scanning and printing technologies are also useful tools for teaching aspects of lines drawings and modeling. Students are incorporating these technologies in their Computer Graphics in Archaeology classes for use in many aspects of their research.

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Recording the Newport Ship: Using Three-Dimensional Digital Recording Techniques with a Late Medieval Clinker-Built Merchantman

Toby Jones

In late June 2002, the extensive remains of a massive clinker-built ship were discovered during the construction of the new Riverfront Theatre and Arts Centre situated alongside the River Usk, in Newport, Wales, United Kingdom. Prompted by public pressure, the Newport City Council and the Welsh Assembly Government recognized the significance of the vessel and identified funding to excavate and conserve the ship. The vessel was dismantled and raised piece by piece over a period of twelve weeks between August and November 2002. The Newport ship is the most complete example of a 15th-century clinker-built merchant vessel ever found in the United Kingdom (fig. 1). The ship was likely constructed in the Northern European "keel first" or shell-based tradition.

The ship was uncovered during the excavation of the new theatre's orchestra pit. It was an accident of fate that the only part of the construction site that required deep excavation would yield a Medieval ship. A sheet pile cofferdam had been installed in order to facilitate the safe removal of the soil, prior to the pouring of the foundation. A large portion of the vessel was eventually found to lie within the confines of the sheet piling. However, the extreme bow and stern sections of the vessel, as well as a fraction of the starboard side, were thought to lie immediately outside or underneath the walls of the cofferdam. The stern was probably destroyed by the installation of the sheet piling. In addition to the damage caused by the installation of the sheet pile cofferdam, numerous concrete pilings were unknowingly driven through the hull to stabilize the alluvial sediment prior to the pouring of the orchestra pit's concrete foundation slab.

After the overburden was excavated, the visible pieces of timber were labelled and systematically removed, beginning with the ceiling planking, stringers, and bow and stern framing timbers. The keelson and integrated mast step were removed, exposing the remainder of the framing elements. The massive floors of the vessel were removed by carefully inserting wedges between the hull planking and the frames, and then sawing through the exposed treenails (fig. 2). These timbers were lifted using an overhead crane utilizing padded straps and special lifting slings. The iron clench nails

Fig. 1. *View from inside of the cofferdam, looking from the port bow quarter aft. The ceiling planking has been removed, but the other structural timbers remain, including all of the stringers and frames. Note the piling driven through the mast step and the frames chopped off on the port side. All Photos: Courtesy Newport Museum and Heritage Service*

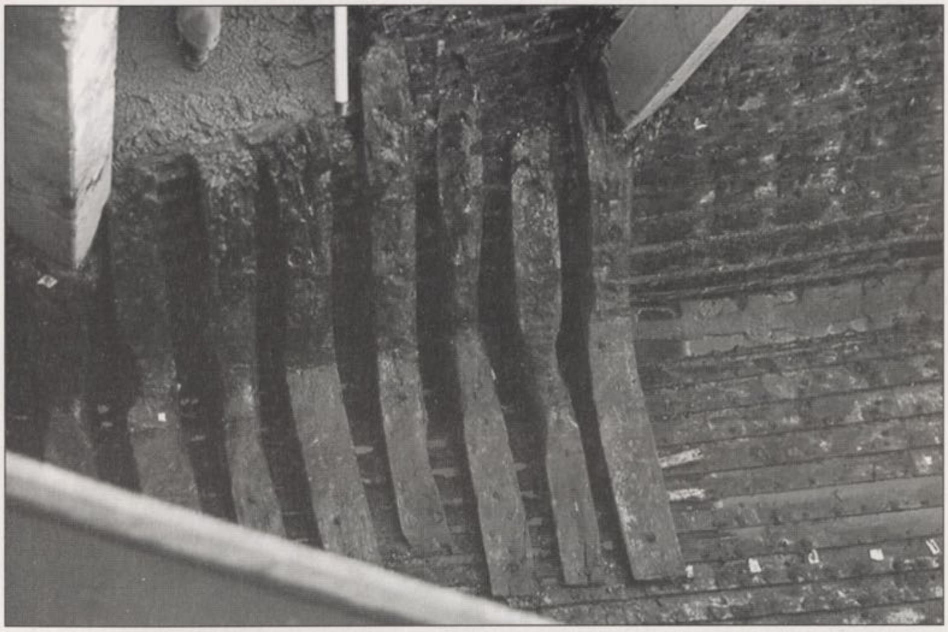

Fig. 2. *Plan view of the stern quarter of the vessel. The frames are being removed with the help of wedges seen in the lower right. Note the compression marks visible on the keel where the frames have already been removed.*

that held the planking together were highly corroded and structurally weak, making the planking easy to remove by simply peeling them away from the soil.

The *in situ* position and shape of the ship were recorded with photogrammetry and direct survey measurement. There were two phases of photogrammetry, one with frames and stringers *in situ*, and one with the clinker hull and keel (fig. 3). Over 22 meters of the beech keel is extant, and had to be cut into six pieces for removal. All of the remains within the cofferdam were removed in this fashion and stored offsite in large tanks filled with fresh water. The portion of the bow outside of the cofferdam, including remains of the stem, was also subsequently raised. A total of 1,700 ship timbers (weighing approximately 25 tons) and over 600 associated timbers and small finds were retrieved and catalogued.

It appears that the ship was brought into Newport for repairs or dismantling. The vessel had been brought into a narrow channel and was supported with a series of struts, which eventually collapsed under the starboard side, causing the vessel to heel over, leaving the starboard side nearly horizontal and the port side upright. There is also evidence that,

Fig. 3. *Archaeologists working to remove the last frames from the Newport Ship. Looking aft, the clinker hull planking and the keel are visible among the numerous concrete pilings.*

after the ship collapsed, much of the structural timber that was still visible was removed, as indicated by the consistent chopped off ends of the framing elements along the upper port side.

A dendrochronological sample taken from one of the strut timbers has yielded a date of 1468 or 1469. A repair on the vessel, using timber identified as being grown in South Wales, has been dated to 1465 or 1466. There are a number of small repairs on the ship, primarily the use of many small iron nails to close cracks along the outboard edges of the hull planking. The mast step had extensive cracking. Three separate pump holes were found, one each in the bow and stern, and one cut into the keelson near the mast step.

A total of 63 frames were recovered during the initial excavation, with one additional frame being uncovered during the subsequent bow excavation. It is likely that several frames were destroyed during the cofferdam installation. Elements of 34 strakes (runs of planking) survive on the starboard side of the vessel, while 17 strakes are extant on the port side. The overall dimensions of the vessel are a subject of debate. The surviving length of the remains is 26 meters, and an estimate of the ship's total length on deck is approximately 35 meters. The precise length cannot be determined until the timber recording has been completed and the amount of *in situ* distortion (and loss due to the cofferdam installation) has been taken into account.

The entire hull, with the notable exception of the beech keel, is made of oak. The state of preservation is remarkable, with clearly visible tool marks, intentionally inscribed lines (marking the joggle locations, lands, and scarves), and even complete preserved barnacles. The planks appear to be radially split, not sawn, with carefully hewn scarves and lands. The clench nails are driven in from outboard and peened over roves on the inboard face. The most interesting feature of the frames are the concave rebates cut into each joggled face, which accommodate the peened rivet and rove, allowing the frame to seat tightly against the clinker planking. During the recording process, planks with tight grain and sapwood will be selected for dendrochronological sampling.

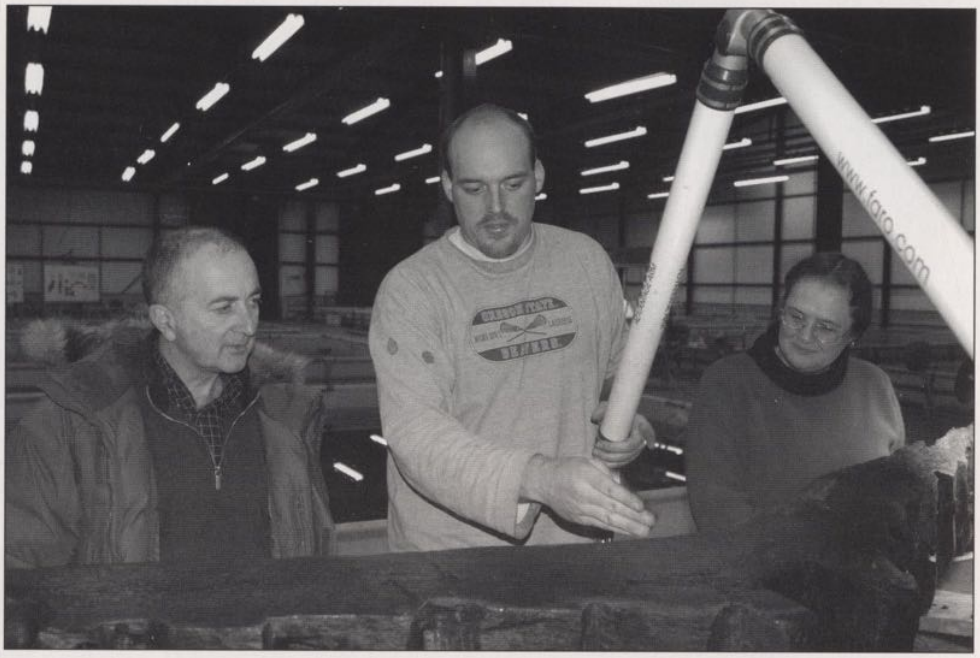

Fig. 4. *The author, flanked by British comedian and keen archaeologist Tony Robinson and project leader Kate Hunter, explaining how the FaroArm® is used to record a floor timber.*

Digitally recording the Newport Ship

In November 2004, an international team, under the guidance of project leader Kate Hunter, began the detailed examination, cleaning, and recording of the Newport ship timbers. The planks were covered with copious amounts of tar, plant and animal fiber (in the form of caulking and luting) along with localized corrosion and concretion of the iron clench nails and roves. This was overlain with a considerable layer of alluvial clay. A variety of cleaning methods are being employed, including brushing, probing with dental tools, and flushing with water. There are iron concretions packed into each of the rebates cut into the joggled surfaces of the frames. There is a negligible amount of salinity present in the ship timbers, and no evidence of damage caused by marine borers.

The project management team investigated numerous methods of recording the timbers, and decided to use a FaroArm® three-dimensional digital measuring device, the output of which was captured using Rhinoceros® software. A layering system developed by the Viking Ship Museum in Roskilde, Denmark, was incorporated into the digital recording process.

The use of the FaroArm® allows for the rapid and accurate three-dimensional digital recording of a variety of complex timber details and shapes that comprise the Newport Ship. The 12-foot arm has six axes of rotation and is fitted with a non-marking probe tip (fig. 4). It is fairly easy to grasp and maneuver, as the weight of the probe is offset with a spring balance. The FaroArm® uses internal sensors to keep

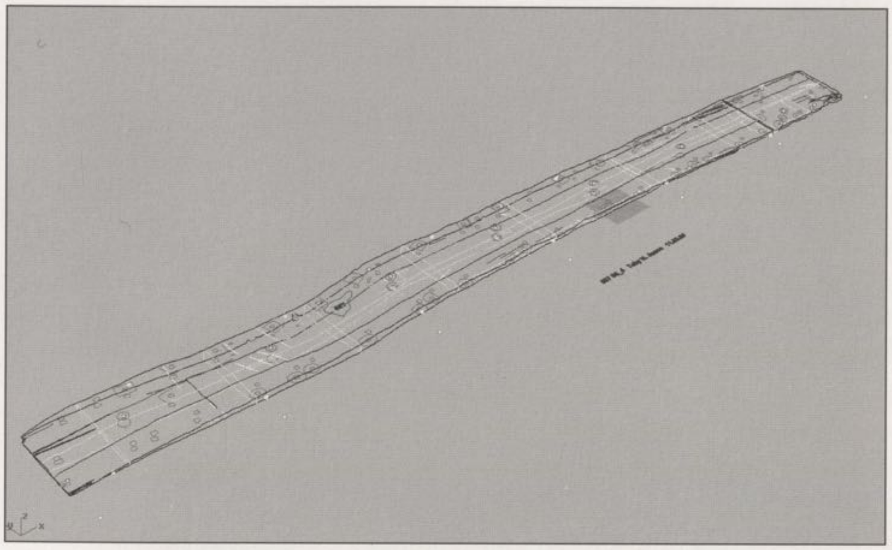

Fig. 5. *Digital record of starboard hull plank from amidships, created using a FaroArm® and Rhinoceros® software. Note the post-depositional distortion, which must be taken into account prior to reconstruction efforts.*

constant track of its probe tip in three dimensions. The point data generated by the arm is recorded and displayed as three-dimensional (x,y,z) coordinates in the Rhinoceros® program. The drawings that are produced using the Rhinoceros® software can be rotated in three dimensions and oriented to one another, allowing for the virtual reconstruction of the vessel as it was found *in situ*.

The three-dimensional renderings can also be easily converted to traditional two-dimensional drawings that can be utilized in the same manner as hand drawn records. Using the layering system, specific features (represented as distinct coloured layers) within the drawing can be selected and highlighted or removed so that, for example, only metal fasteners or wood grain is visible. Accurate direct measurements can be taken quickly and easily from the digital Rhinoceros® renderings.

To date, eight complete frames (floor and futtocks) have been recorded, along with six strakes of planking (fig. 5). It should again be noted that these records represent the shape of the ship timbers as found. As with two-dimensional reconstruction drawings, these three-dimensional renderings will have to be manipulated in order to recreate the original shape of the hull.

After cleaning, recording, and conservation (probably utilizing a combination of polyethylene glycol and freeze drying) , the team plans to use the three-dimensional virtual blueprint to construct a set of ship lines for use during the reassembly of the vessel. The size of the vessel necessitates the manufacture of a cradle arrangement with both external and internal supports. Ideally, the reconstructed remains of the vessel will be publicly displayed in a purpose-built museum in Newport, alongside the other ships found in South Wales, including the Bronze Age Goldcliff boat planks (ca. 1170 BC), the Romano-Celtic Barland's Farm boat (ca. AD 300) , and the Magor Pill Vessel (ca. AD 1240).

The public will be able to view the ship timbers as well as the cleaning and recording process during several annual open days. It is necessary to maintain a high level of public interest and support in this project, given that it will likely take at least 15 years from the initial discovery to final display. Short-term targets include expanding the recording capabilities and team size, as well as publishing annual research updates, prior to the final archaeological report. The Newport Ship project offers an array of thesis and dissertation opportunities, and is seeking outside partnerships and additional funding for these research initiatives.

Aknowledgements: The author would like to thank Kate Hunter, Nigel Nayling, and the rest of the ship team. For further information, see *http://www.thenewportship.com. Toby.Jones@Newport.gov.uk*]

Suggested Readings

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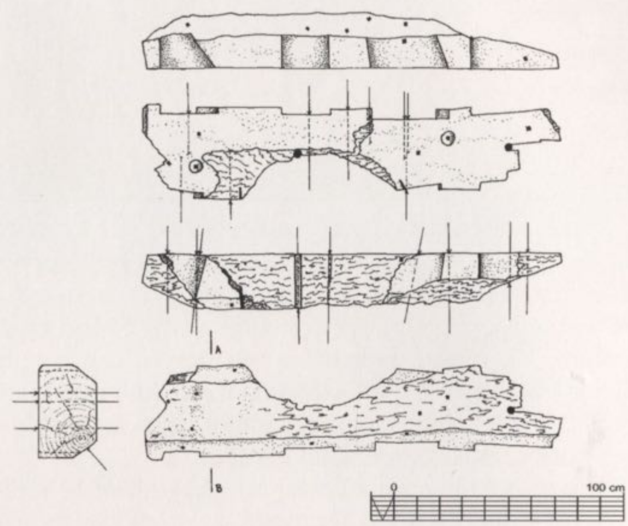
Methods for Recording Timbers in Three Dimensions

Randall Sasaki

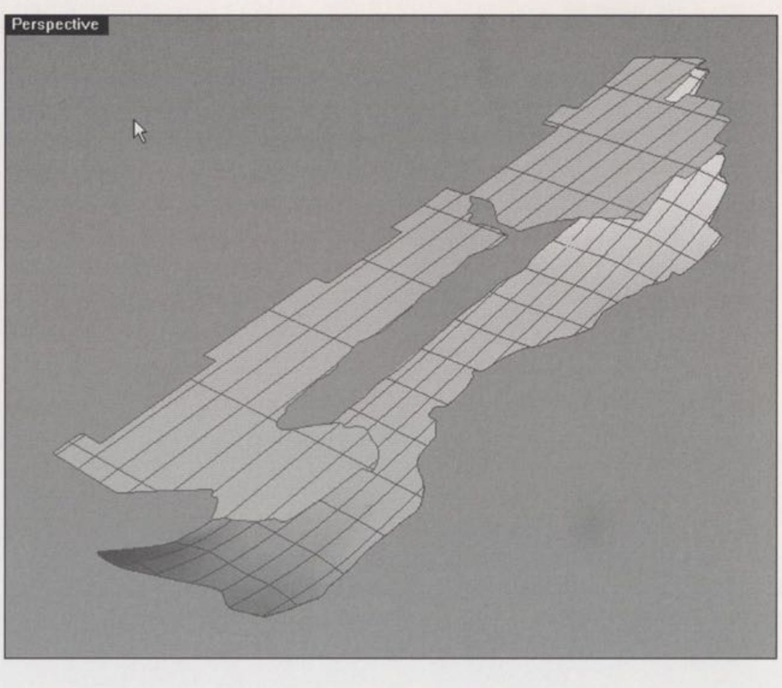
Imagine trying to reconstruct a ceramic pot using only sketches of the broken sherds. It would not be enough to simply cut out the pictures and assemble them like flat puzzle pieces, because there is no way to know exactly how the pieces curve to fit one another in three-dimensional space. But with "virtual archaeology," the same technology that is now allowing the public to remotely tour famous archaeological sites such as Stonehenge and Petra is also revolutionizing the way archaeologists collect and manage data on individual artifacts.

Traditional two-dimensional drawings, made by archaeologists in recording the size and features of an artifact, can leave something to be desired when they must be used to reconstruct the object in 3D. This can present a problem for nautical archaeologists, who are interested in reconstructing exacting hull shapes from timber remains.

I conducted a study to see if an accurate 3D model could be created from the 2D drawings of individual timbers from the Pepper Wreck (presumed to be the *Nossa Senhora dos Mártires*, 1606) using the Rhinoceros® 3D modeling program. For most of the timbers, this was an easy task, and it took a relatively short period of time. However, for several timbers, there was missing information that limited the accuracy of my 3D models of the timbers (figs. 1a, 1b). It is not possible to create a 3D model based only on traditional 2D drawings, unless archaeologists include in their 2D drawings all the information that will be necessary for a reconstruction, and that are generally stored in other supports, such as pictures and field notes (fig. 2).



Figs. 1a (above), 1b (below). *It is difficult to create an exact 3D model from an artifact drawing because the curvature of the rough, broken face can only be estimated. Drawing: F. Castro; Digital image: R. Sasaki*



From this study, I realized there is a need to create a bridge between hand drawings and digital modeling. We need to tailor our 2D drawings, in order to facilitate an easier translation from traditional 2D artifact records to 3D models. Accurate 3D artifact or timber models can in turn make for an easier reconstruction process, and ultimately lead to faster and clearer public access to the information these artifacts convey.

A 3D reconstruction is often believed to be expensive and to require extensive training, but this is not always the case, especially at the level of individual artifacts. In this brief article, I will discuss the limitations of 2D drawings and how to improve the recording process with the eventual creation of a 3D model in mind. Some characteristics of this method, which combines both new and traditional practices, are described. Three-dimensional artifact recording is one step towards more interactive virtual archaeology, and its use should be encouraged in all student and professional research.

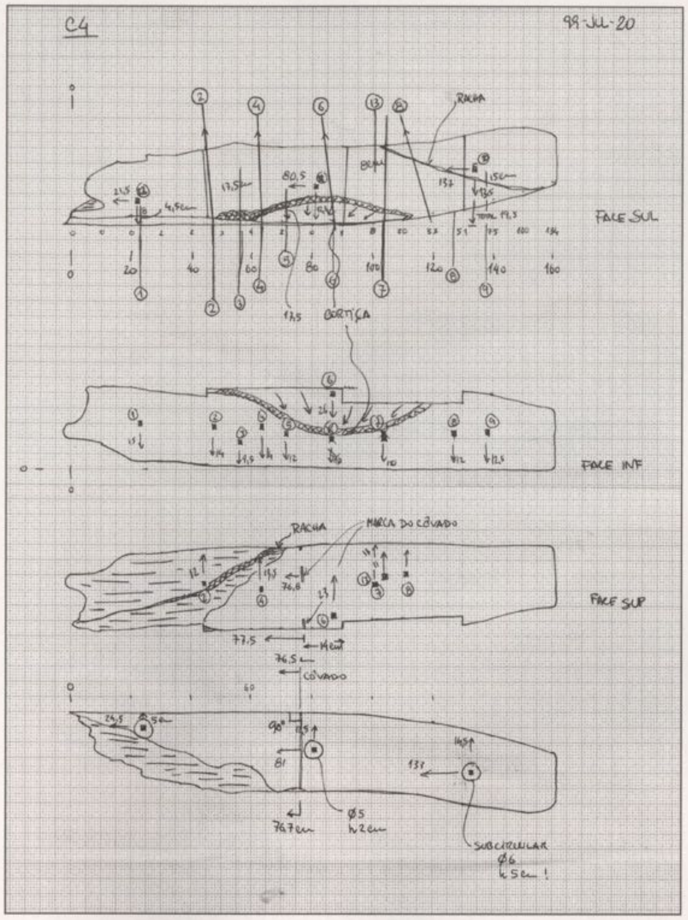


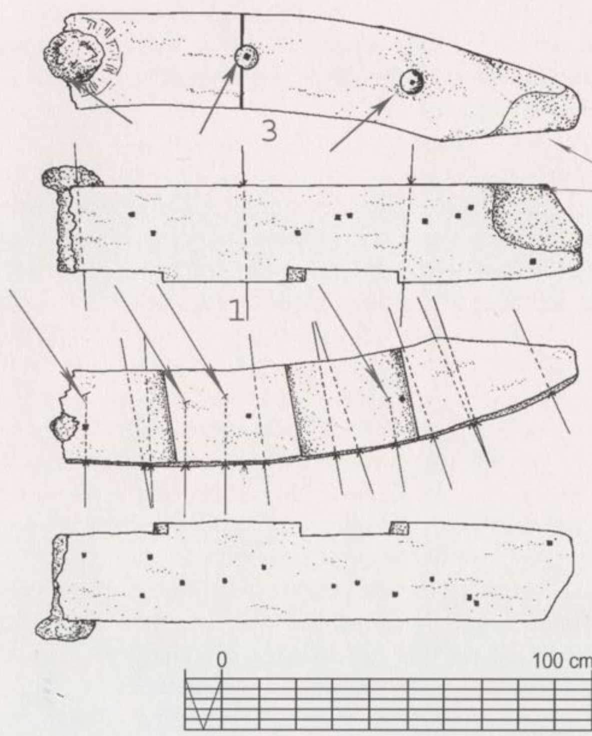
Fig. 2 (above). *A "complete" 2D drawing contains so much information as to become obscured and even unreadable to anyone besides the artist. Because of this, final drawings tend to omit many of the detailed notes associated with it. Drawing: F. Castro*

Fig. 3 (right). *Some of the limitations that can be seen in a final, published drawing of a timber from the Pepper Wreck. 1) No information on the angle of the nail is indicated. 2) The diagonal surface cannot be accurately described; it is difficult to say if the surface is concave or not. 3) There is no given depth for the nail recesses. Drawing: F. Castro*

Limits of traditional recording methods

As I attempted to reconstruct 3D models of the Pepper Wreck timbers, the most common error in the 2D drawings was missing nail angles. The true shape and size of a timber can also be distorted depending on the concavity of the surface and the resting angle of the timber when the initial recording took place. A 2D drawing is a projection of a volume on a plane and the angle at which a curved timber is recorded must be factored into the reconstruction to avoid errors. These and other similar errors can be noted in the drawings of multiple published authors. These are not necessarily "mistakes" made by the researchers, but rather illustrate the limitations of 2D drawings. Several examples will be described that were found from the Pepper Wreck timber drawings (fig. 3).

When recording a ship timber such as a floor or a futtock, the most detailed surface can sometimes be the top face—the one that faces up or inwards when mounted on the structure where it belongs—because of the fastening pattern. This is not to say that the fore and aft faces of floor timbers and futtocks are not important, namely for the information that they yield on such features as curvature and carpenter marks, but these are typically flat surfaces, easier to draw than the curved faces of a timber.



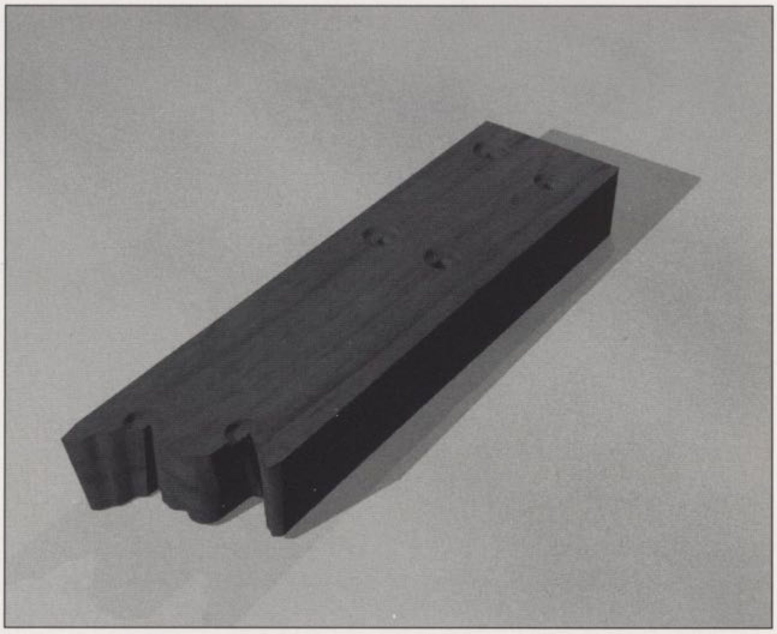


Fig. 4. *A simple model such as this one can be rendered in less than an hour. Images: R. Sasaki*

The angle of the nails cannot be reconstructed just by looking at the nail holes from the top. To accurately reconstruct the angle of a nail, several data points are required. First, the location of a nail hole, in one side, or in two sides if the nail goes through, is required. It is a good idea to note which hole corresponds with another on the opposite side. The angle of the nail, in a side view, is needed as well; this seems obvious, but is oftentimes neglected. More problems were discovered when the nail did not go through the thickness of the timber. In this case, the angle of the nail must be drawn not only in the side, but also in the section view. Without this information, an accurate reconstruction is not possible.

Another subtle error that is created in 2D drawings is the distortion in relative angles. The 2D drawing is flat, and rarely does a timber exhibit right angles. The angles of intersection for each face of the timber can only be estimated when projected to the surface in any of the side views. If shared surfaces are visible in more than one view, it is a good idea to note that in the drawing. A final related problem for 2D artists is concave surfaces or indentations in the artifact. For example, a hole that houses the head of a nail in a Pepper Wreck timber can be seen in the 2D drawings, but the depth of the hole is not illustrated in the drawing. The depth can be described in words or more pictures elsewhere, but a 3D model can visually show all these details in one image. Other small indentations such as tool marks and detailed surface shapes cannot be described accurately with a 2D drawing, and therefore cannot be reconstructed unless the person who makes the drawing is actually creating the 3D model in mind while taking measurements.

To create an accurate model, better 2D drawings need to be prepared, and all the information required to create the model in virtual reality needs to be recorded. This process of studying the actual artifact enhances one's understanding of the artifact. Without a full understanding of each timber, making a model is difficult, time consuming, and may not be accurate. If an artifact is well understood however, creating the model is easy, fast, and accurate. When all necessary information is present it can take as little as 30-45 minutes to create a simple curved plank (fig. 4). It is just a matter of entering in the data. Difficulties arise when the shape has to be "made up." The most time consuming aspect of this process is when there are diagonal surfaces where the relationship between angles is missing. The 3D program then has to approximate how the edge of one surface corresponds with another surface. If the artifact is present or if the timber was recorded for the purpose of making it a 3D model, this problem is eliminated, and the model building process itself takes less time.

Methodology

The first step in creating the model is to draw, or trace the original 2D drawings into "Rhino," as the program is commonly called, using scanned, scaled and properly oriented images (fig. 5). A typical archaeological drawing of a ship timber includes a separate drawing depicting each face of the timber. Once this is done, the outline of the artifact has to be properly oriented in all three dimensions, by comparing the drawings of different views, and finding the common or shared lines and surfaces (fig. 6). Gradually, several surfaces are built. Once all the surfaces are made, these are connected together to create a solid model (fig. 7). Nail holes and other details are added or subtracted from this basic, solid model (fig. 8). If all the necessary information is present, the process itself is simple.

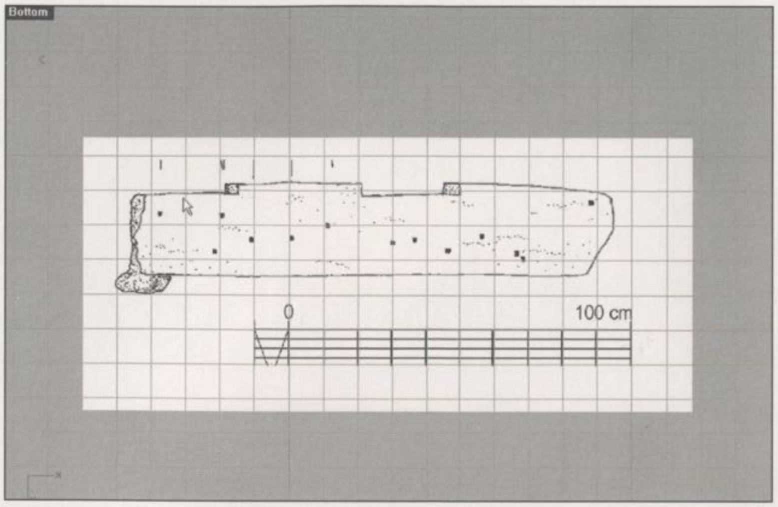
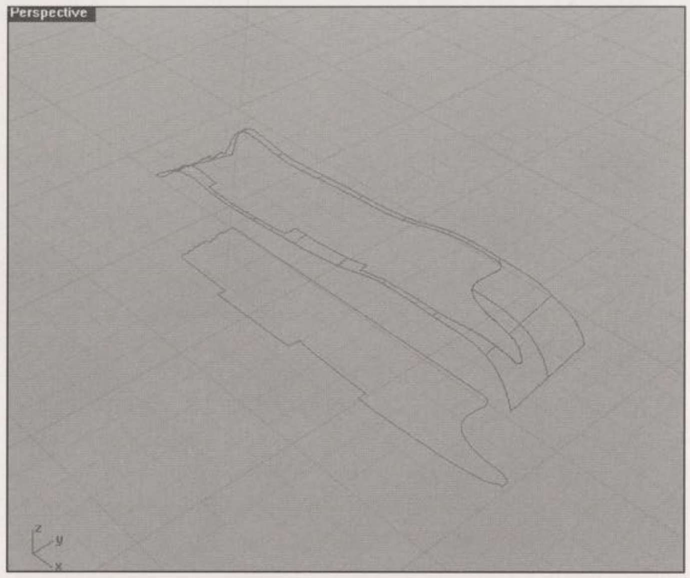


Fig. 5 (left). *Tracing an outline of a scaled 2D drawing using Rhinoceros® software.*

Fig. 6 (below). *Projecting the outline on a curved (lofted) surface.*



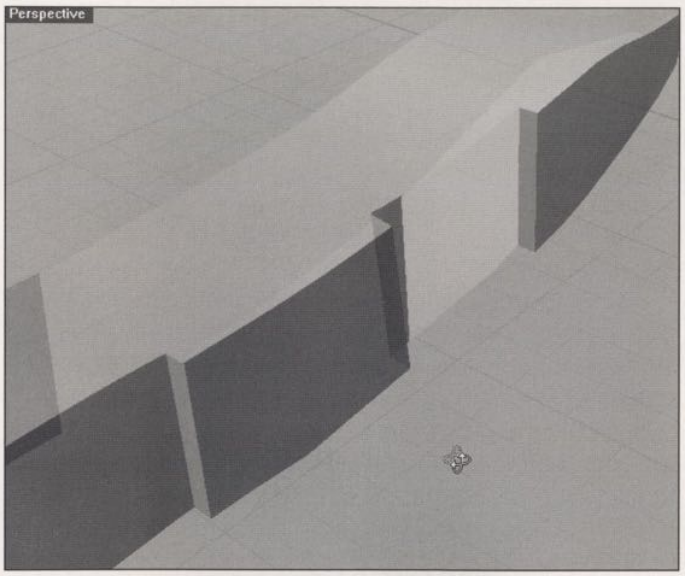
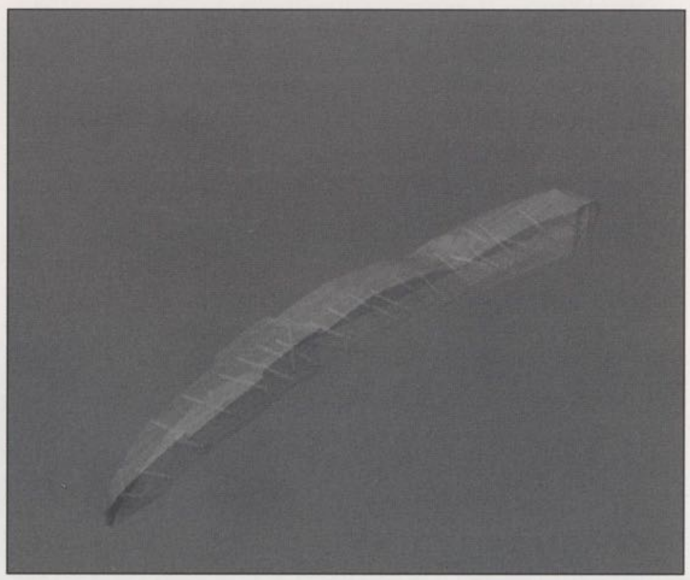


Fig. 7 (above). *Adding surfaces to create a solid model.*

Fig. 8 (right). *A finished model that shows the angles of the nails by making the surface transparent.*



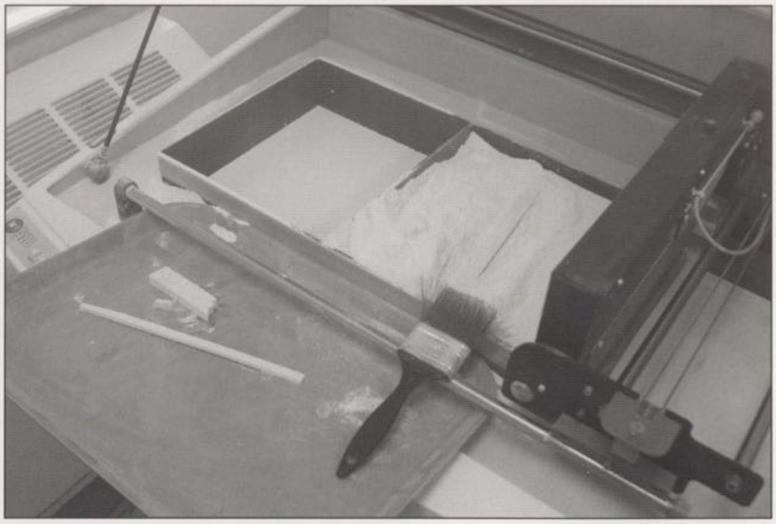


Fig. 9. *Physical models of the timbers created by stereo lithography, or 3D printing. Photo: R. Sasaki*

Weighing benefits and limitations

Compared to costly technical products such as the FaroArm® 3D coordinate measuring machine (see Toby Jones' article in this issue for more discussion of the FaroArm®) and digital 3D scanners, one can easily make a 3D model with computer aided design (CAD) programs such as Rhinoceros® and 3ds max®. These programs cost between $200 and $1000. A new user can master Rhino by committing about 4-5 hours per week for about three months (the typical duration of a university semester) to learn the basic commands that are required to create a model, and to understand how the program works. If one is only interested in learning how to produce a 3D timber model, it will take less time. These programs can be used at home, or in the field. Many people can work on one project at the same time, if given the program and data, regardless of their proximity to one another. This is not possible with the digital arm or the scanner, which can only handle one artifact at a time, thus limiting efficiency in recording individual objects.

Some skill is required to perceive three dimensions from a flat, 2D drawing. Although archaeologists are trained to glean certain information from 2D drawings, this same information is often invisible to the layperson. The goal of archaeologists is to transmit the knowledge that we gather from excavation. Because conveying every detail about an artifact in 2D drawings is so difficult, this traditional method, in one sense, limits the spread of information to trained scholars. Three-dimensional models are better able to represent, in one easily digestible image, the correct orientation of each timber face, and accurate depths and angles of fastenings. Furthermore, with the use of stereo lithography, or three-dimensional printing of a digitally reproduced artifact (see C. Wayne Smith's article in this issue), one can create a replica of the timber (fig. 9). By literally printing out several timber models, a scaled replica of a wreck site, as well as a reconstructed model of a hull can be made.

Although there are numerous advantages to this method, it is not without its problems. Because it is based on 2D drawings and an approximation of the surface curvature, it is less accurate than directly measuring such parameters. Despite this fact, it does not seem the error is too great, unless the researcher is concerned about each timber's volume, or details such as tool marks and the direction of the grain. In any case, we must always keep in mind that different artifact representations (photos, drawings, 3D images, field notes etc.) have different functions and must therefore highlight different features. The model created with the method I have described is perfect for measuring distance and angles between nails, measuring timber dimensions, and creating a physical model on a smaller scale. It is tailored to 3D hull reconstructions.

As mentioned above, all 2D and 3D drawings must be made with a function in mind, which depends on the research question and on what information a researcher wants to be transmitted to his peers or the public. Digital 3D drawings can be as complete and accurate as any 2D drawings, when considered face by face, and can represent all the features that normally are stored in other supports, such as the wood grain, carpenter's marks, tool marks, and fastening details. It is just a matter of how much time or, in other words, money, we want to put in each drawing.

Conclusions

Digital recording by way of an arm or scanner can be considered "passive" because the researcher needs only operate the equipment as one might a digital camera. Researchers tend to ask more specific questions about an artifact only after the data is gathered, and that is the advantage of using a method more mindful of three dimensions. Compared to "passive" digital recording, the method described in this article is time-consuming; it is more "active," requiring each person to think further about an eventual 3D reconstruction during the 2D recording process. The goal of this method, therefore, is not to try to ease the process of recording, but to try to make a more accurate record of the artifact, thus providing a deeper understanding of the artifact, and at the same time, to provide the public with more accurate and visual images of artifacts.

For some researchers and students, the virtual archaeology technology that is available seems to be out of reach because of a limited number of trained personnel and the cost of using such technology. Others might think that the traditional method works well enough, and may not see a great potential in using new technology. I still see the need for 2D drawings because it is useful in illustrating certain features that the archaeologist may want to portray, and because many times timbers can only be recorded *in situ* under water. However, the limitations of the traditional method are outweighed by many good reasons to start using the new technology.

The method described here does not require elaborate training or large and expensive equipment, and it still relies on old technology. A working knowledge of 3D modeling is a very useful tool, and by learning how to use this technology, other similar technology becomes easier and quick to use. Depending on budget and what information researchers wish to acquire, the use of a digital arm or scanner may also be warranted. Once a step is taken forward, the door to the reality of virtual archaeology will open.

Future study from the field

After trying to reconstruct a timber in 3D using 2D drawings, I realized that the next step is to test my proposed methodology by taking measurements of a timber myself with the intention of creating a 3D model. This will allow me to study the accuracy and efficiency of this method in practice. I am currently conducting a timber recording project in Japan from the wrecks of the lost fleet of Kublai Khan. (See my previous article in *INA Quaterly* 32.1 for a detailed historical background of the site.) This particular site has numerous timber fragments that need to be recorded and it will be a perfect candidate for developing this method. The recording project was started in early June and will finish in mid August. The results of this study I plan to publish in a future issue of *INA Quaterly* along with detailed discussion of methodology and analysis.

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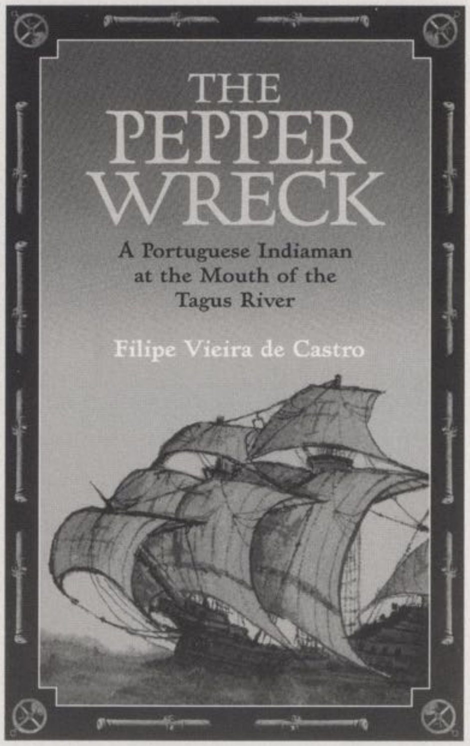
Filipe Castro and Kirsten Jerch contributed to this article.

Just Released

The Pepper Wreck:
A Portuguese Indiaman at the Mouth of the Tagus River
by Filipe Vieria de Castro

This is a story of a maritime disaster and its meticulous reconstruction some four centuries later, assembled in a handsomely presented volume that will interest popular and academic readers alike. In 1606, the Portuguese East Indiaman *Nossa Senhora dos Mártires* returned to Lisbon from Cochin, India, her hold filled with pepper, porcelain, and other exotic cargoes. Attempting to enter a small channel at the mouth of the river Tagus, the 1,200-ton freighter struck a submerged rock and sank in front of Fort São Julião da Barra. As she broke up, a black tide of peppercorns washed ashore for miles along the coast and river banks.

Like many shipwrecks that occurred during the period of Portuguese maritime expansion, the remains of *Mártires* were forgotten as European commercial and political competition for trade and power in Asia continued into the 17th century. And, like many colonial shipwrecks in shallow water, her remains were rediscovered by fishermen and divers in the late 20th century. In 1993, a portion of wooden hull with sherds of Chinese ceramics was identified by the



College Station: Texas A&M University Press 2005
ISBN: 1-58544-390-5, 287 + xi pp, 30 black and white photos, 50 illustrations, 10 maps, 46 tables, bibliography, index. Cloth: $60.00

National Museum of Archaeology as most likely the remains of the merchant nau *Mártires*. Excavations in 1996 and 1997 produced many artifacts that were displayed at EXPO '98 in Lisbon, prompting new historical research that revealed many details about the ship and people who sailed on its last voyage. Two additional campaigns of excavation in 1999 and 2000, sponsored by the Portuguese Institute of Archaeology and the Institute of Nautical Archaeology, focused on the hull of *Mártires* to learn about its shape and dimensions.

The Pepper Wreck is the result of seven years of historical and archaeological research, combining analyses of artifacts and hull data to identify the ship and to study its characteristics. Author Filipe Castro sets the stage by describing how Portugal, a small nation of some 1.2 million people, managed to build an extensive sphere of influence during the 16th century, with fortresses, factories, and settlements on four continents. Principal seaborne commerce was conducted along the India route (*carreira da Índia*), between Lisbon and the Indian ports of Goa and Cochin via the Cape of Good Hope. Under royal monopoly, distribution of cargos was controlled by the Casa da Índia, which divided merchandise into four major categories: *drogas* (spices, dyes, lacquers, resins, incense, exotic woods, and ivory), *fazenda* (cotton and silk cloth and thread, as well as slaves), *miudezas* (miscellaneous products from furniture to musk oil), and *pedraria* (semiprecious and precious stones, such as diamonds, pearls, and rubies). Peppercorn (*pimenta*), used to season and conserve food, was a primary and most lucrative commodity carried by ships on the India route, taking up most of the space below decks and causing overloading with other cargoes on deck. The homeward route to Lisbon was perilous; many Portuguese merchantmen were lost to violent storms or to Dutch and English corsairs. The whereabouts of several identified shipwrecks are briefly described by the author.

Portuguese freighters that sailed the India route evolved from the Mediterranean round ship that originally was developed in Italy, where simple proportional and predetermined measurements were used by shipwrights to construct seaworthy vessels of desired cargo capacity. Arab influences, as well as the adaptation of traditional Iberian coastal craft for exploration of the African coast, also contributed to the evolution of the Portuguese *nau*, as ships grew larger and voyages grew longer. New hull shapes were conceived, constructed, and tested at sea. This evolution in ship design is reflected in several contemporary shipbuilding manuscripts from Italy, France, England, Spain, and Portugal, each of which is described by Castro to illustrate a growing standardization of design and dimension that produced the India *nau*. Castro then takes the reader through a typical *nau*'s construction sequence, from the laying of keel, insertion of stem and sternposts, erection of frames, and planking and rigging of the hull.

To reconstruct the last voyage of *Nossa Senhora dos Mártires*, personal narratives of similar voyages, sailing itineraries, and contemporary letters and chronicles help to paint a picture of a floating microcosm full of people crammed together for six months with livestock and cargo, enduring seasickness, fevers, and scurvy only to succumb to shipwreck at its final destination. When the microcosm came apart, more than two hundred bodies washed ashore together with boxes, barrels, bales, and a black tide of pepper. Castro continues the story of *Mártires* and its transformation from ship to archaeological site on the bottom of the Tagus River. Contemporary salvage after the wrecking continued again in the 1970s and 1980s before the National Museum of Archaeology began its survey of the waters around Fort São Julião da Barra in 1993.

The second half of *The Pepper Wreck* addresses the archaeology of *Mártires*, which is the heart of the book and contains abundant diagrams, photographs, and tables. Artifacts that support the shipwreck's identity include Chinese porcelains and stonewares, three astrolabes (one dated 1605), and pottery and a portion of a sword from Japan. An exhaustive study of the hull components provides, for the first time, a detailed record of the scantlings of a large Portuguese *nau* built specifically for the India route. Each structural component of the *Mártires*'s hull is analyzed and compared with contemporary treatises on shipbuilding dating between 1580 and 1640. Author Castro concludes that the types of timbers used in the ship's construction and their size and shape mirrored descriptions in the theories, guidelines, and rules of the principal Portuguese texts, reflecting a time when the scarcity of large trees and compass timbers forced shipwrights to build large vessels as a patchwork of small logs. As a final note, Castro explores recent theoretical research on the tradition of Iberian Atlantic shipbuilding, based on other 16th- and early 17th-century shipwrecks found in the New World and recently in the Azores. Although not enough of *Mártires*'s hull remained to conclusively match its construction with the common traits, or "architectural signatures" of the vessels in that study, it is likely that the India *nau* was part of the Iberian Atlantic family.

-Roger Smith

From the President

July 18, 2005, somewhere near Çeşme—WOW, What a week! The Institute of Nautical Archaeology 2005 summer meeting and tour (July 11 to 17) has concluded, and all the INA directors and their guests have departed. For the first time since July 11, I have time to sit and reflect on the past week's events. Of course, I have little option, for I am sitting on a bus for the two-day ordeal of getting back to the Kızılburun Project camp site.

Everyone started arriving in Izmir on Monday, July 11 and were transported to the Süzer Hotel in Alaçati, known as "the wind surfing capital of the world." That evening I presented a brief introduction to all the work that had gone on at the Kızılburun site from the first of June to the present – like building a livable camp on a barren rocky shore.

INA Director Bob Walker takes his turn aboard the submersible Carolyn, *piolted by Feyyaz Subay. Photo: D. Hamilton*

On Tuesday, July 12, about half of the group took a day trip to the site to observe the daily operations, talk to the divers, walk through the camp, go on the research vessel, *Virazon*, and look at the recovered artifacts. The highlight of the day was a short ride on *Carolyn*, the INA submersible, down to a nearby shipwreck site we call the Millstone Wreck because it was carrying a cargo of millstones. In one day we made 14 separate dives, breaking a past record of 11 dives in one day.

Wednesday, July 13, differed only in that the other half of the group made 20 separate sub dives, establishing a record that will not be soon broken! Feyyaz Subay, *Carolyn*'s pilot, is to be commended for piloting every trip, one passenger at a time. That experience was the highlight of the trip for most, if not all. I was even able to take my first ride on *Carolyn*, and I was surprised to see that the team had conspired to treat me with a special view. Thanks team!

That evening, we took a bus to the home of Oğuz and Ella Aydemir's stunning hillside home for dinner. Words cannot describe the elegance and planning that went into the event. There were an interesting blend of Turkish and American guests with excellent food, drinks, and atmosphere. The Aydemir's even designed and passed out a special gift commemorating the social event that was even covered by the newspapers!

On Thursday, July 14, we took a tour of the ancient Roman city of Ephesus, perhaps one of the best-preserved classical cities in the Mediterranean. Our tour guide was a specially selected archaeologist who took us to areas of the town not opened to most visitors. The terrace houses constructed by the elite of the city with their elaborate architecture, painted murals and mosaic floors were stupendous!

The highlight of Friday, July 15, was a guided tour by Dr. George Bass through the Bodrum Underwater Archaeology Museum. At the Uluburun, Serçe Limanı, and Amphoras exhibits, Drs. Cemal Pulak, Frederick van Doorninck, and Don Frey delivered the tour. We had to literally drag people out of the museum! After lunch we toured *Hercules*, the research vessel of the RPM Nautical Foundation founded by INA Director, George Robb. Everyone was impressed with the sophisticated instrumentation, and the computerization required for modern, scientific surveys.

Friday was topped off by an evening garden dinner in the courtyard of Ercan Açikel, an associate director of INA. In addition to excellent Turkish cuisine, he had Turkish folk dancers to entertain us. Boy, it takes stamina to do all that fancy footwork! The folk dancers were followed by a belly dancer and even I left with a lipstick smudge on my left cheek, which I only reluctantly washed off the next day!

The official INA Board Meeting was held on Saturday morning. All the required business was handled efficiently without a hitch and plans were finalized for the next board meeting on October 21 and 22, 2005 in New York City.

The grand finale of the tour was a banquet at the INA-Bodrum Research Center headquarters that included all the tour participants, all the INA-BRC staff and researchers. The crew of the RPM Nautical Foundation's research vessel, *Hercules*, and the new Director of the Bodrum Underwater Archaeology Museum, Yaşar Yıldız, were also present.

All came away from the tour with a better appreciation of what INA does and how well it does it. In addition, everyone met new friends and supporters and solidified relationship with current supporters. Everyone proclaimed this tour to be the most successful that INA has conducted. I hope that is the case, as we put in a lot of effort to see that everyone's time was well spent. From the beginning, I wanted it to be entertaining, enlightening, and educational. I particularly want to single out the INA Bodrum Administrator, Tufan Turanlı for all the time and effort he put into detailed planning of the events.

-Donny L. Hamilton