Legacies of an Old Design: Reconstructing Rapid’s Lines Using 3D Modelling Software

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Introduction

The early 19th century American China trader Rapid was excavated from 1978-1982 by the Western Australia Museum (WAM) and was a formative maritime archaeological project in the Australian development of the discipline (Henderson 1978, 1979, 1981a, 1981b, 1983a, 1983b, 2007). Since then, archaeologists have continued to develop and experiment with new technologies and their applications on this shipwreck. More recently, the Shipwrecks of the Roaring Forties Project was conceived to evaluate new ways of investigating the history of Europeans in the Indian Ocean off Western Australia by revisiting and applying new technologies to several of the foundational maritime archaeology projects conducted on Australia’s early shipwrecks. The wreck and legacy data of Rapid were chosen for the application of digital modeling software in an effort to re-evaluate the previous reconstruction efforts generated nearly 40 years ago. This paper outlines the use of Rhinoceros 3D modelling software to generate a 3-dimensional model (3D) of the China trader.

Rapid’s History

Shipwright and sailing captain Nathaniel Thomas constructed Rapid in 1807 at a shipyard in Braintree, MA (Henderson 1981:126). The ship was registered on 23 December 1807 and owned by Andrew Ritchie of Boston at the time of registration. However, Rapid did not sail until August 1809 due to US President Thomas Jefferson’s signing the Embargo Act only one day after Rapid was registered. Rapid was owned by Paschal Pope, William Boardman, Jonathan Amory, Ebenezer Dorr, Jonathon Dorr, and Joseph Bray when it made its first voyage to China in 1809. The success of the voyage allowed for the planning of a second voyage in 1810. Henry Dorr captained Rapid on both of its China voyages. American trade with China necessitated the outbound transportation of large amounts of valuable Spanish dollars, since Chinese merchants accepted little else in return for their goods. As a result, Rapid carried 280,000 Spanish silver dollars as its cargo. The Boston Marine Insurance Company insured the vessel and its cargo (Henderson 1981:130).

Rapid departed Boston for Canton, China on 28 September 1810 (Henderson 2007:101). It rounded the Cape of Good Hope and crossed the Indian Ocean in good time. Dorr plotted Rapid’s course to intersect with the North West Cape in Australia. Once there, Dorr planned to check his longitude and sail to Canton. On 7 January 1811, the 98th day of the voyage, Rapid struck a reef near Point Cloates. A storm struck the next day and threatened to break the ship apart. Dorr ordered the crew to abandon the ship, but before leaving, the crew burned the vessel to avoid detection and possible looting by passing ships (Henderson 1981:127).

After abandoning ship, the crew sailed for Batavia in three small boats (Henderson 2007:101). Dorr sailed in a leaky jolly boat and reached Batavia 37 days later (Henderson 2007:103). He captained General Greene to Philadelphia on a return voyage and arrived on 27 July 1811. Once there, Dorr arranged for the salvage vessel Meridian to recover the 260,000 coins left on board. It arrived in April 1812 after picking up divers in an Asian port, most probably Batavia. By this point, it is likely that illegal salvage had already occurred, as word of the silver laden shipwreck spread through Batavia. Dorr salvaged just over $90,000 of Rapid’s remains. Around $20,000 of silver remained in the shipwreck as deteriorating relations between the United Kingdom and the United States forced the discontinuation of the salvage mission. Dutch Java was under British control since August 1811, and war was declared by the United States on the United Kingdom in June 1812. Meridian risked capture by British naval vessels or privateers if it remained any longer.

Previous Work

Rapid was located again in 1978 by spearfishers Glynn Dromey, Larry Paterson, Frank Paxman, and Barry Paxman (Nash 2007:64). The shipwreck is located on a reef near Point Cloates on the central coast of Western Australia (Henderson 2007:100). Discovery and recovery of copper bolts, glass fragments, ceramic sherds, and 600 silver coins confirmed the existence of a potentially valuable shipwreck (Nash 2007:64). In
accordance with the 1976 Historic Shipwrecks Act, the collection was turned over to WAM for treatment and conservation. Due to the monetary value of the artifacts, the finders received $30,000 as a reward (Nash 2007:65).

An initial inspection of the shipwreck site by WAM occurred in November 1978 (Nash 2007:65). It revealed a shipwreck in 6 m of water buried in sand in a channel on the edge of the reef. Extending over 36 m was a large central ballast mound. Also on site were three anchors, small cannons, and several copper artifacts amongst the ballast. Most of the silver coins and copper bolt remains were deposited in an area of the stern measuring 4 m by 6 m. The quality and quantity of valuable artifacts resulted in Rapid's registration as a protected historic shipwreck on 14 December 1978.

The WAM team completed three excavation seasons on Rapid between 1978 and 1982 (Nash 2007:65). A reference grid of 16 m by 48 m was created and 2 m sections were uncovered using an airlift. A total of over 50 tons of ballast stones was removed from the site. The third season (Jan – Feb 1982) focused on the ship's structure. Trenches uncovered the remaining hull and keel timbers and a cross section of the hull was completed (Nash 2007:72). While the stern structure was disintegrated beyond recognition, the keel and port hull structure survived in good condition (Henderson [1980s]:18). Over 70 timbers survived in situ attached to the keel. A total of 32 ship timbers were recovered, and profile drawings were made of them (Western Australian Museum 2015). Later, these data were used to create a lines plan based on the archaeological and historical data available (Figure 1).

Historical data focused on archival work in Boston. After archaeological data pointed to Boston as Rapid's homeport, registration papers revealed the official dimensions of Rapid upon construction and subsequent voyages to China. On 14 September 1810, Rapid was listed as a ship of two decks and three masts. Its length was 104 ft., beam was 28 ft. 4 in., and its depth was 14 ft. 2 in. Total displacement was stated as 366 84/95 tons (U.S. National Archives 1810:1). It was thought that the use of a fraction of 95 indicated the following equation was used historically to calculate depth at 14.1666 (Hutchins 1941:217):

\[
\text{Tonnage} = \frac{(\text{length} - 3/5 \text{ beam}) \times \text{beam} \times \text{depth of hold}}{95}
\]

However further research revealed it was conventional to simply set the depth at half the beam. As a result, it is impossible to establish an accurate depth for Rapid.

Using the historical information above, a reconstructed lines plan was developed by WAM researchers; however, the steep angle of the stem; lack of tumblehome; and the sharp bow established on the lines plan resemble a Baltimore Clipper design more than an American China trader.

Hull design was the most important element of a Baltimore Clipper. A long and narrow hull yielded a greater length:beam ratio than other ships of similar length. Waterlines narrowed towards the bow to create a sharp bow, which cut through water easily. Draft along the keel line was twice that of the bow (Davis 1984:40). While other ships rode over waves, or pushed them aside, these design factors allowed Baltimore Clippers to cut through waves, giving them a decided advantage in speed.

Shipwrights designed Baltimore Clippers to provide stability along with increased speed. A wide deck quickly narrowed to the keel, giving the hull a bell-like, or heart shape. The center of buoyancy was thus kept high, while the center of gravity remained along a vertical center line. These two forces worked to naturally right the vessel when it heeled (Chapelle 1967:212). While this narrow hull provided clear advantages, it did not allow for large cargo capacity, limiting the Baltimore Clipper’s role as a merchant vessel.

American China traders, while smaller than their British counterparts, were similar in design (Richards 2003:15). Although Rapid displaced under 400 tons, it likely shared several characteristics with its British cousins. While the American shipbuilding industry did keep a clear record of the lines of merchant ships, artwork and a look at British construction styles provides some insight into Rapid’s design. China traders had full hulls and bluff bows, and while these features did not yield great speed, they did increase cargo capacity. As the round trip often consumed more than a year, it was critical that as much cargo as possible was transported back to the ship’s port of origin. Such designs also served an economic purpose, as they yielded increased profits for merchants and ship owners, who often had a stake in the cargo.

The 3D Design Process

With discrepancies in design and measurements, it was thought that a new approach to the legacy data was needed to reevaluate Rapid’s hull lines. The full process included building the initial 3D model recreation after the 2D lines plan which was drawn after the excavations. From here the model will be analyzed for hydrodynamic statistics and the computed values of those from the drawn lines plan will be compared with the digital values and historical evidence. Following comparison, the 3D model will be adjusted to fit a design more suited to its function as an American China trader. Finally, the ultimate model will be used as a base for recreating the construction of Rapid in 3D. This paper focuses on the initial creation of a 3D model.

The program used for the 3D reconstruction was Rhinoceros 5, a computer design software based on the NURBS mathematical model. This program provides a 3D platform along with the Orca Plugin, which is designed to assist marine architects in 3D design projects of ships and other structures. In this case, its most useful feature is a hydrostatics calculator that computes dimensions, displacement, and coefficients. This tool proved useful in analyzing the 3D reconstruction of Rapid and allowing for adjustments to the initial model.

A number of steps were involved when converting a 2D representation to a 3D model. A base layer was created by placing the reconstructed lines plan as a background image in each viewing panel. The image was set to a 1:1 scale using the measuring tool and aligning it with key features, especially the length and breadth of the ship. The section lines on the body plan were traced in the ‘Right’ view panel. This placed the section lines on an even vertical and horizontal plane, but the lines were still only a 2D representation. To move them to a 3D representation, the section lines were moved horizontally along the traced keel line, stem, and sternpost. The section lines were adjusted on a smaller scale to ensure they connected with the keel line. When this was confirmed, an initial 3D rendering was attempted.

This produced two issues that required troubleshooting. Part of the stem forward of the first section needed to be set as a separate line to allow a fair flow to the rendered model.

The original lines plan did not have a section placed at the stern end of the rabbit line. However, it does show on the plan view. As a result, a line was placed at the end of the rabbet line to mirror this final stern transom line as much as possible. This allowed for the creation of a completely rendered model (Figure 2).

After rendering, the model was orientated so that the longitudinal center of buoyancy (LCB) point was set at the origin point in the Rhino model (x=0, y=0, z=0). This orientation allows for the most accurate analysis of a model. The subsequent analysis yielded the following
results: A length of 111 ft., a beam of 31 ft. 3 in., and depth of 23 ft. 2 in. Displacement was calculated at 476.05 long tons. These values differ markedly from those claimed in the historical documents.

**Evaluation of 3D Model**

The discrepancies between these values may reveal issues with the initial lines plan. Most notably, they call into question the accuracy of the depth used in the initial lines plan. As mentioned by Hutchins in the tonnage equation above, the lack of this measurement resulted in a hypothetical lines plan based on the notion that the depth simply equaled half the beam. While this method may provide for a historically accurate reconstruction, the convenience of simply halving the beam does not yield a model that is also scientifically accurate. As a result, some adjustments still need to be made.

This project is still underway and the model is far from complete. The lines are not fair, especially at the sheer waterline where the top of the section lines do not allow for a smooth line. This is most prevalent at the first, second, and third waterline. More work and accurate adjustments of the model will result in a fair model that can form the basis of future work in which Rapid’s final dimensions and shape may be revealed.

**Future Work**

Creating a basic 3D model paves the way for several opportunities of future research. From a basic lines model, the progression to a full 3D model of the ship’s interior and structure is entirely possible. Timber measurements, feature drawings, and profile measurements all provide the archaeological data required for further digital reconstruction. Archival research also reveals comparative options of similar ship plans or contemporary artwork that would assist in reconstruction efforts. Promising datasets may be at the Peabody Essex Museum, which focuses on the China trade and the Massachusetts-built ships involved in the trade. International comparisons to similar ships could also yield significant results including the smaller East Indiamen of contemporary European nations. More work is planned for refining the 3D model and testing hypotheses related to dimensions and shape along with historical research into the design of American China traders.

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U.S. NATIONAL ARCHIVES
1810 Boston Customhouse Register, Charlestown, 23 December 1807, ship Rapid, No.246.

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