DIGITAL 3D RECONSTRUCTION OF BRITISH 74-GUN SHIP-OF-THE-LINE, *HMS COLOSSUS*, FROM ITS ORIGINAL CONSTRUCTION PLANS

A Thesis

by

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Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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May 2021

Major Subject: Anthropology

ABSTRACT

Virtual reality has created a vast number of solutions for exhibitions and the transfer of knowledge. Space limitations on museum displays and the extensive costs associated with raising and conserving waterlogged archaeological material discourage the development of large projects around the story of a particular shipwreck. There is, however, a way that technology can help overcome the above-mentioned problems and allow museums to provide visitors with information about local, national, and international shipwrecks and their construction. 3D drafting can be used to create 3D models and, in combination with 3D printing, develop exciting learning environments using a shipwreck and its story. This thesis is an attempt at using an 18th century shipwreck and hint at its story and development as a ship type in a particular historical moment, from the conception and construction to its loss, excavation, recording and reconstruction.

DEDICATION

I dedicate my thesis to my family and friends. A special feeling of gratitude to my parents, Ted and Diane Lewis, and to my Aunt, Joan, for all the support that allowed me to follow this childhood dream.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Luis Filipe Vieira de Castro, and my committee members, Dr. Chris Dostal, and Dr. Ergun Akleman, for their guidance and support throughout the course of this research.

Thanks also go to my friends and colleagues and the department faculty and staff for making my time at Texas A&M University a great experience. I would like to especially acknowledge my friends, Glen Grieco, TJ Frizzel, Ben Ioset and Paul Cochrane, for always being there for support, to answer any questions, and for editing my papers and thesis.

Finally, thanks to my mother and father for their encouragement, and to my Aunt Joan for her unwavering support of me during my time away.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supported by a thesis committee consisting of Professor Filipe Castro [Advisor] and Professor Chris Dostal of the Department of Anthropology and Professor Ergun Akleman of the Department of Visualization.

All work for the thesis was completed independently by the student.

Funding Sources

This thesis was partly funded by the Department of Anthropology, Texas A&M University, and could not have been started without their support.

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CHAPTER I

INTRODUCTION

Museums do not often display the physical remains of shipwrecks due to both space limitations and the immense cost of raising, conserving, and storing waterlogged archaeological material based upon the author's own personal observation. There is a way, however, that technology can circumvent this path entirely, while still allowing museums to provide audiences with information on shipwrecks and their construction. 3D modeling allows for the digital reconstruction of shipwrecks for the public. Additionally, models allow the public to interact with the ship in a manner that may facilitate their learning, based upon their own personal interests. Some of the nearly endless possibilities in these digital models include depictions of the vessel's original appearance, displayed together with its history, or perhaps interactive models to show the internal construction of these ships. High-end 3D models and augmented reality may provide sets of detailed and accurate renderings of a shipwreck site or remains, and partial or total reconstruction models can be used as learning environments that connect the public to the world where the ships under study existed. Once a digital 3D model of a ship is created, it can be turned into a virtual display or be printed to a desired scale. However, a 3D model is only as accurate as the information it was based upon, and the information it provides. Therefore, these models must ideally be developed from archaeological and documental evidence, and in scholarly projects it is important to make clear the parts that are accurate and those that are educated guesses.

This thesis will describe the author's use of an "off-the-shelf" 3D-modeling software, *Rhino 6*, to create a digital reconstruction of a 74-gun ship of the line, HMS *Colossus*. The model, produced using the original construction plans from 1787 provided by the Royal Maritime Museum, details the hull construction of the vessel up to point-of-launch. Due to time constraints, endeavoring for the same level of detail as a large-scale physical reconstruction was impossible, but the main purpose of this thesis was to experiment with the original drawings and – where possible – compare the historical data with the archaeological data available. This project therefore consisted of a detailed and scholarly reconstruction of an 18th-century shipwreck based on its original plans. The project attempted to answer the following research question:

1) Can a 3D ship model be developed from the remaining ship lines and plans originally used to construct the ship over 200 years ago? As plans are always insufficient in the detailed data, I used a comparative methodology to achieve this reconstruction. The present model is an educated guess and a plausible reconstruction of a complex machine that incorporated many adaptations determined by the availability of material. This is an extension of the work I developed in the ShipLab and includes the methodologies studied, as well as my own personal input based upon information gathered from a variety of literature and textual sources.

An important part of this thesis was the reconstruction of the process that led to the development of the 74-gun ship of the line and, based on that understanding, an interpretation of the drawings available to develop my model.

Implication of research

By developing a digital 3D model from original plans, ships that no longer exist can be brought back to virtual life, and museums can have a low-cost option to display accurate ship models of shipwrecks to the public. For instance, digital 3D models can be used by archaeologists for both analysis of the differences in construction techniques, and design logic between British built warships and British copies of French-built warships (Winfred 2007:84, Lavery 1991: 27-29). Another interesting outcome of this approach would be the analysis of the space appropriation in warships depending upon their nationality (Winfred 2007:84, Lavery 1991: 27-29). Additionally, digital 3D models can be used in publications, both as artistic renders for public consumption, in video games, or for illustrations in either scholarly publications or books for the general public.

Moreover, in order to understand how the *Colossus* was originally constructed, and to assess what information was possibly missing from the plans, due to the shipwrights already possessing the knowledge, the development of the present model was an interesting exercise (Winfred 2007:84, Lavery 1991: 27-29). In the process I researched the history of the 74-gun ship, in order to understand the concepts and design requirements that led to the development of the 74-gun ship of the line.

CHAPTER II

PREDECESSORS AND DEVELOPMENT OF THE 74-GUN THIRD-RATE SHIP OF THE LINE

Colossus was a 3rd rate 74-gun ship of the line (Gosset 1986:19; Murray 1798; Grocott 1997:64-65; Camidge 2017:10). This class of warship was the product of a long process of evolution in ship design that was neither simple nor linear. The 74-gun ship was a two-decker developed in France, during the mid-18th century, following a complex process of development of warships that led to the adoption of a large lower battery of 24 to 36-pounders, and an even larger battery of 18 to 24 pounders on the Gun Deck (Lavery 1988:16-20). Captured by the English during the War of the Austrian Succession (1740-1748), the 3rd rate 74-gun ship was adopted by the English and other European powers (Lavery 1988:20-22, 24). One of the first examples of this type in England was HMS *Invincible*, the first 74-gun English ship, built in France in 1744 and captured at the Battle of Cape Finisterre in 1747 (Lavery 1988:24). The navies of the European powers built 50- and 70-gun ships that both contributed to define the structure of the 74-gun ship, though both predecessors continued to be built and sailed after the 74-gun was adopted as a standard ship of the line in England (Lambert 2000:41; Winfield 1997: Table 85, p. 67). The result of this progression was a ship with a battery of 74 guns, slightly larger than the 70-gun ship of the line but inheriting certain features and functions of the 50-gun ship (Lavery 1983a 86-92; Konstam 2001:4-18). This chapter will examine the design and construction of the 74-gun ship of the line, based on the particular case of *Colossus* by examining its origins in both the 50- and 70-gun ships of the line.

Line of Battle and the Rating System

In order to discuss the 74-gun ship of the line, an explanation of the line of battle and the rating system needs to be presented first. The expression ‘line of battle’ is derived from the naval formation developed as early as the 16th century to make efficient use of the placement of naval artillery or guns along the sides of warships (Lavery 1983a:27-28; Konstam 2001:15-18). By the 18th century, ship design allowed the placement of heavy batteries on the sides of the vessels, or ‘broadsides,’ and the line of battle was a way to attempt to maximize their power in naval combat (Lavery 1983a:27-28; Lavery 1985:7-9; Konstam 2001:15-18). The line of battle was a formation in which warships sailed in a line each ship providing protection to the contiguous ship’s weakest points, the bow and stern, keeping them away from enemy fire (Lavery 1983a:27-28; Lavery 1985:7-9; Konstam 2001:16-17). Replacing the previous *mêlées*, in which ships engaged other ships in either single combat or tried to flank an enemy ship from both sides, the new line of battle allowed the two confronting lines of ships to sail in parallel routes, in opposite directions, and discharge the entire batteries on the enemy as they sailed past each other. The line-of-battle was a standard in naval combat by 1672 (Lambert 2000: 41).

The rating system was developed at first to determine the officer's pay and was based on the crew number. In the later 17th century, the rates were defined as standards for the formation of a fighting fleet, and based on the number of decks, the length on the main deck, and the size and weight of the battery (Lavery 1983a:86-95; Konstam 2001:16-18; Lambert 2000: 41). Eventually, warships ratings became associated with the number of guns and batteries carried by a ship. The 1st and 2nd rates were three-deckers carrying three superimposed batteries, the 1st rates arming 100 guns or more, and the 2nd rates carrying 90 to 98 guns. 3rd rates were the standard two-deck warships, carrying from 70 to 90 guns. After the 1750s 4th rates were used as flagships or in convoys, considered too small to be included in the line of battle; 5th and 6th rates were the classifications frigates and sloops of war, the actual rating dependent on the number of guns (Bruce 1998:303-304;Rodger 2004:51).

The Hull Shape of a 50-Gun Warship

In the Royal Navy 50-gun warships seem to have been a direct development from the single-deck frigates (Winfield 1997:7). The principles of their use and hull form were probably taken from the Flemish 'Dunkirkers,' privateer vessels used against the English in beginning of the 17th Century (Winfield 1997:7).

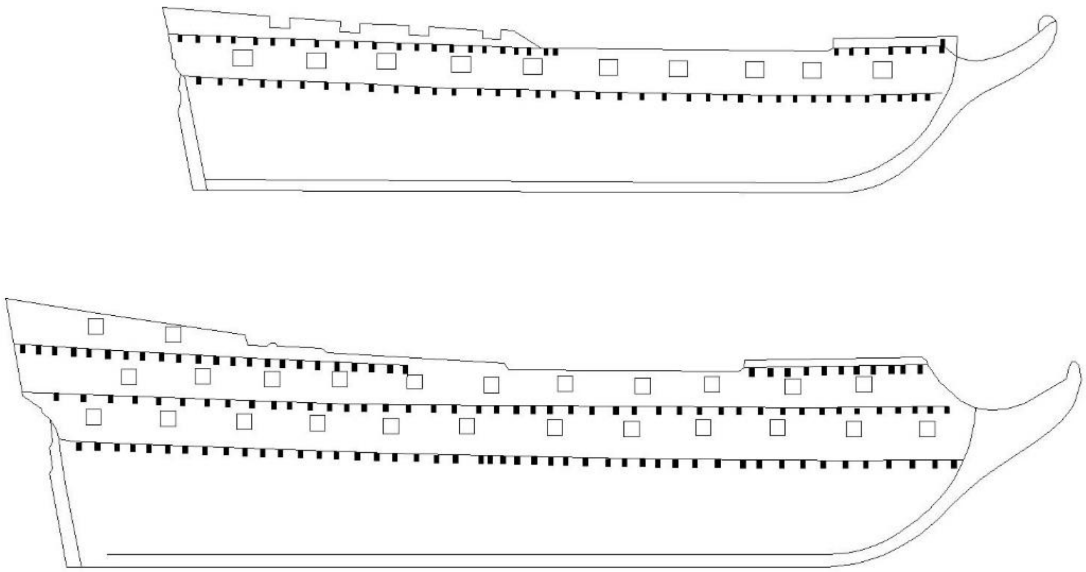


Figure 1. Comparison of early frigates (A) and 50-gun (B) profiles (M. Lewis, after Gardiner 1992:13).

These 50-gun ships were conceived as an enlargement of the frigates, with the hull form lengthened, and a second gundeck added, increasing the power of the battery (Figure 1) (Winfield 1997:7).

The frigate’s hull (Figure 2) was constructed for speed and maneuverability from the waterline to the keel, because the frigates duties consisted of cruising, patrolling and escorting (Winfield 1997:20-70; Konstam 2001:4-18; Lambert 2000:41). This was contradictory to design logic of the ships of the line where firepower and strength took precedence over that of speed and maneuverability (Lavery 1983b:28-46; Konstam 2001:4-18; Lambert 2000:41).

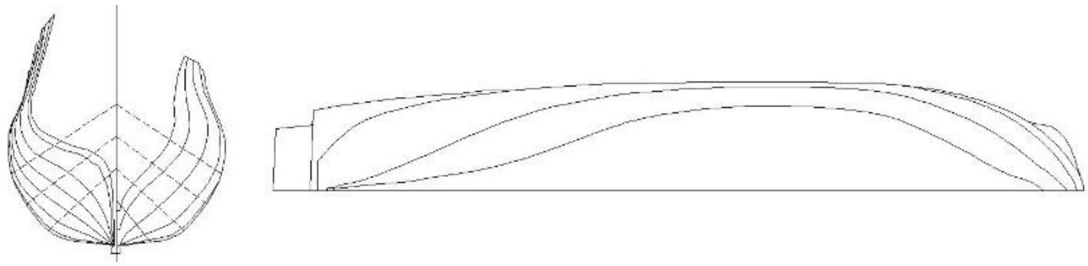


Figure 2. Line drawing of a 1705 Frigate (M. Lewis, after ZAZ3806, Collections, Royal Maritime Museum, Greenwich, UK accessed online Nov 20, 2018)

The concept of the 50-gun warship was that of an enlarged frigate (Figure 3), rather than that of ship of the line, since the 50-gun was also designed to be used for cruising, escorting and long-range expeditions (Winfield 1997:20-70).

Even though the 50-gun warship was not designed for inclusion in the line of battle, it was designed to possess a strong firepower, which would allow it to overwhelm any frigate or small vessel encountered, but be swift enough to escape from any larger and stronger vessel, due to its hull form, inherited from the frigate (Winfield 1997:20-70).

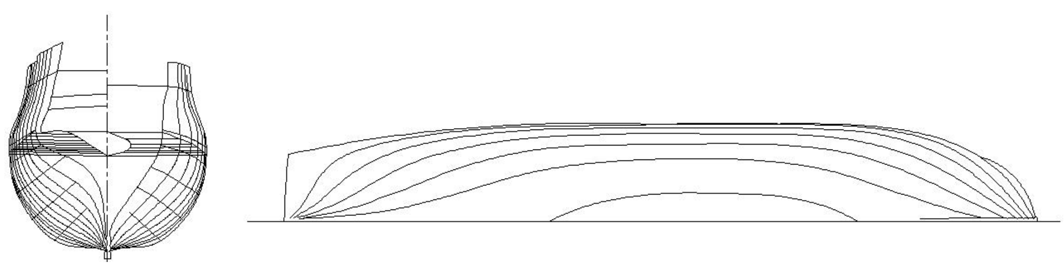


Figure 3. Line drawing for a 50-gun Warship (M. Lewis, after Ship Lines of 50-gun HMS Jupiter, Winfield 1997:68)

The stronger firepower of the 50-gun warship, provided by the addition of a second gun deck, came at a cost of increased instability, resulting from a high center of gravity in a relatively a narrow hull (Winfield 1997:69). The length to beam ratio of the early frigates and the 50-gun warships was a result of the need for speed. When the hulls were clean, wave resistance was probably higher than drag for the operating speeds of warships, and the compromise achieved in the development of the 4th rates resulted in a similar sheer line and length to beam ratio as that of the frigates (Winfield 1997:20-70). Early frigates had a length to beam ratio of 3:46.1 (Winfield 1997: table 2.*Nonsuch*:9), where an early 50-gun length to beam ratio was 3:13.1 (Winfield 1997: table 27.Spec.:28)(Appendix I). Soon 50-gun warships had their beam width increased (Winfield 1997:39), which allowed an increase in the gun battery weight. However, the increased weight made 50-gun ships slower and less operational, and the 50-gun eventually became obsolete, its duties performed better by vessels with superior firepower and sailing qualities, such as the 74-gun ship of the line. Thus, not only did the 50-gun contribute structural features to the 74-gun ship of the line, it also contributed to the definition of some of its functions, such as escorting and cruising (Winfield 1997:27; Lavery 1983a:107). The escort duties consisted of protecting trade routes, and convoying merchant vessels and troop transports (Winfield 1997:27,119-120; Lavery 1983a:107). Cruising meant patrolling, searching for and intercepting the opposition's merchant vessels, disturbing their trade routes, and ensuring safe troop movements in times of war (Winfield 1997:27, 119-120; Lavery 1983a:107). Although the 50-gun ship did not succeed as an escort and cruising vessel in the late 18th century, it represents an important step in the design of a warship for these capabilities (Winfield 1997:27,119-120).

Structure of a 50-Gun Warship

As already mentioned, the design of the 50-gun warship contributed to the 74-gun warship's internal and structural features, in addition to the above described hull shape and capacity to perform the same duties.

The structural components of the 50-gun ship that contributed directly to the structure of the 74-gun ship of the line were tied into the addition of the second gun deck and a larger battery (Lavery 1985:7). These structural components, such as pillars, carlings, ledges, and hanging knees had similarities to those of the three-decker 1st and 2nd rates based upon the author's interpretation of a comparison of the illustration of these structural components from the reference materials consulted, (Winfield 1997:39-48; Lavery 1983a:27-28,86-92;Lavery 1983b:28-46). Although the weight of internal structures was not a fundamental concern, other than their impact on the ship's stability, it made the ships slower and a balance between strength and weight was the most important design concern of middle size ships such as the 3rd rates (Lavery 1985:7).

For the 50-gun warships on other hand, lightness of structures played a prevailing role in the design, since the concept of speed was a part of its design philosophy and anticipated roles. Although similar to the three-decker 1st and 2nd rates, these lighter internal structures were a design philosophy contribution to the structure of a 74-gun ship of the line (Lavery 1985:13).

The Structure of a 70-Gun Warship

As mentioned above, the 70-gun ship of the line is a direct precursor of the 74-gun ship of the line, and at one point it was considered the future successor of the 50-gun warship naval role, while designed to fit in the line of battle (Lavery 1988:1). After 1740, however, the appearance of the 74-gun ship offered a much better balance between size, weight, maneuverability and the strength that made the 70-gun ship obsolete. The 70-gun ship and the 74-gun ship owe their development to the arms race between the European naval powers, and are part of a long line of warships developed from the mid-17th century to the present, which culminated with the development of the Dreadnought Battleship in the early 20th century (Warner 1975: 30).

During the early 18th century the English navy had fallen into a state of stagnation in warship development (Winfield 1997:37-41). In 1719 they had experimented with increasing the firepower of the 50-gun warships by about 10 guns (Winfield 1997:41). The new 60-gun warships were created to increase the broadside weight in an effort to combat French and Spanish 50-gun warships, which carried 24-pound and 12-pound cannons, incomparably stronger than the 18 and 9-pounders carried by the English (Gardiner 1992:20;Winfield 1997:41). The French and Spanish responded by constructing vessels larger than the 60-gun ship (Winfield 1997:41). The English developed a heavier 58-gun warship that was an extended 50-gun warship, but it still carried fewer guns than the 60-gun French and Spanish warships (Winfield 1997:41-46). Although these new 58-gun experimental ships carried heavier guns, between 24 and 12-pounders, the enemy broadside weights kept growing and this new design proved useless in the line of battle (Winfield 1997:46). These improvements spanned the decades 1719-1739 and were the base for the development of the 74-gun ship (Gardiner 1992:19-20; Winfield 1997:39-48).

Once captured and copied by British shipwrights, the 74-gun ship set in motion a new chapter in ship design (Winfield 1997: 46; Lavery 1985:7;Gardiner 1992:18). The first step seems to have been the capture of the Spanish 70-gun ship *Princesa*, in 1740 (Winfield 1997: 46). This ship demonstrated how far behind British shipbuilding had lagged in ship development (Winfield 1997: 46). *Princesa* was larger than the comparable British 70-gun (Winfield 1997: 46), yet had a better hull shape, which probably allowed it to sail faster, although the exact details of this improved hull shape have been lost (Winfield 1997: 46). *Princesa*'s better design allowed it to open the lower gunports in rough seas, an issue that the British hull form failed to do (Winfield 1997: 46). The realization that they were far behind led the British navy to enter a phase of copying directly from foreign captured ships, as *Princesa*, and develop their own 70-gun ships from that model (Winfield 1997: 46). However, precisely in 1740, French shipwrights were launching a new warship that mounted 74 guns and could outfight and outrun the British copies of the 70-gun *Princesa* (Winfield 1997: 46; Lavery 1985:7; Gardiner 1992:18).

Development of the 74-Gun Ship of the Line

The history of the 74-gun ship of the line development diverges by country, since it was adopted by the navies of different European powers at different times (Lavery 1985:7;

Gardiner 1992:18). The French Navy designed and built the first 74-gun ships in the late 1730s as part of the naval arms racing that followed the War of the Spanish Succession (1701-1714), which was won by France and imposed a Bourbon king to Spain, making these two countries allies and effectively blocking the development of the British Empire (Lavery 1985:7; Gardiner 1992:18). With vast land borders to protect, prior to the 1720s France had focused on commerce raiding with small, fast ships, rather than on constructing a large battle fleet (Lavery 1985:7; Gardiner 1992:18). Hostilities with other European powers led to the construction of a new French battle fleet in the 1720s to 1730s, with a structure relying on two-deck (3rd Rates) ships of the line, which were designed to overwhelm their weaker opponents in the British navy (Lavery 1985:7; Gardiner 1992:18-20).

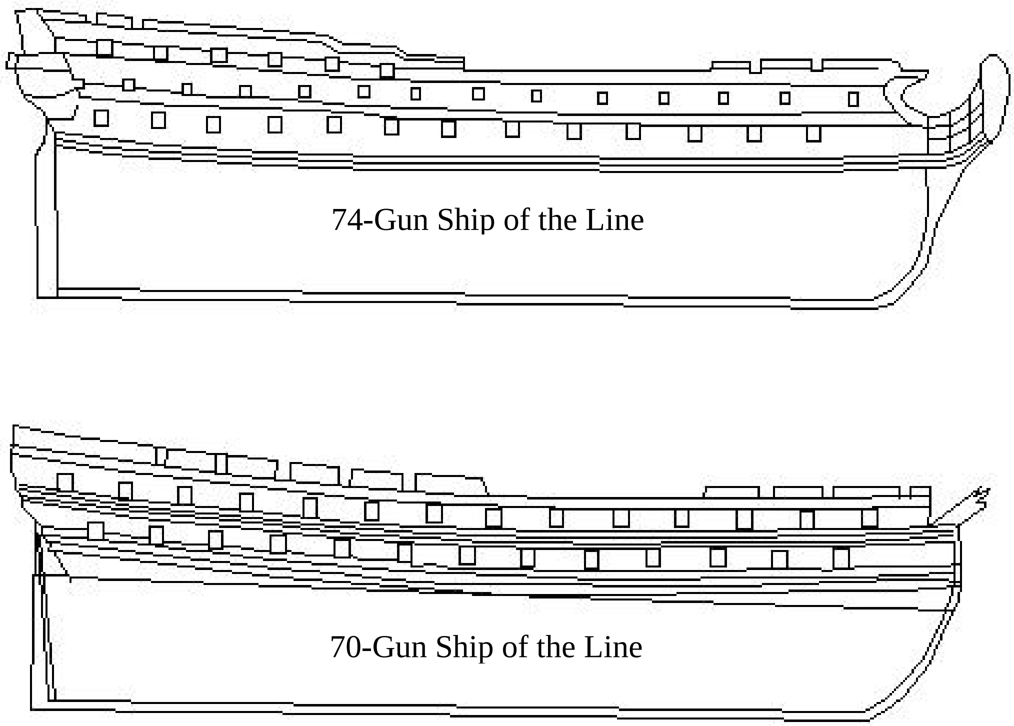


Figure 4. Profiles of 70-gun and 74-gun Ships of the line (M. Lewis after Gardiner 1992:19).

The key to the superiority of the French 74-gun ship design was its armament of twenty-eight 36-pounder guns on the lower deck, and thirty 24-pounder guns on the upper deck (Lavery 1985:7; Gardiner 1992:18). This powerful battery contrasted with the much weaker armament of the British 70-gun two-deckers, which mounted twenty-six 24-pounders on the lower Gun Deck (Lavery 1985:7). Moreover, at 51.8 meters (170 feet) the French 74-gun ships were also longer than the 45.7 meters (150 feet) British 70-gun ships (Lavery 1985:7). The French 74-gun ships had lower topside structures than the British, an advantage that gave them a low center of gravity (Lavery 1985:7). The lower center of gravity granted better sailing qualities, which besides allowing these ships to move swiftly on the water, permitted them to open their lower deck gun ports in rough weather, and thus make use of their heavy armament in battle (Lavery 1985:7).

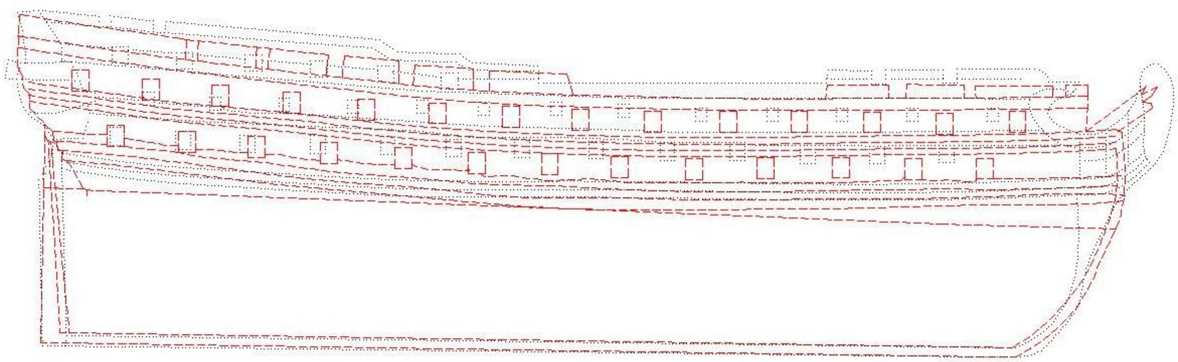


Figure 5. Comparison of 70-gun (Red) and Early 74-gun (Black) side profiles (M. Lewis after Gardiner 1992:19).

In 1747 the British discovered once again how far behind they were in the naval European arms race, after capturing some French 74-gun warships (Lavery 1988:20-22,24). One of these, l'*Invincible*, was immediately understood as a very well-designed ship, and taken into service by the British (Lavery 1983a:94: Lavery 1988:20-22,24).

The British development of the 74-gun and its service within their navy can be traced to the 1747 capture of l'*Invincible*, whose lines were copied to create the English 74-gun ships of the line (Lavery 1983a:94; Lavery 1988:20-22,24). Although the capture of l'*Invincible* is acknowledged as the source of the British 74-gun equivalents, shipbuilding methods varied from France to England, and the British shipwrights kept most construction features of their own 50 and 70-gun ships (Lavery 1983a:94-95;

Lavery 1988:20-22,24). In essence, the British shipbuilding traditions changed less than the ship design, which was copied from a more advanced country (Lavery 1983a:94-95; Lavery 1988:20-22,24).

The Structure of a 74-Gun Warship

As already explained, different navies developed different 74-gun ships. Local shipbuilding traditions, ways, and tastes determined differences between these vessels, in the overall dimensions, hull shape, and structural elements (Lavery 1983a:94-95; Lavery 1988:20-22,24; Fernández-González 2012:24). The dimensions and number of structural parts used by different shipwrights varied within the same shipyard and from shipyard to shipyard (Lavery 1983a:94-95; Lavery 1988:20-22,24; Fernández-González 2012:24). In the model developed for this thesis, which was based on the HMS *Colossus* original drawings, the author used its standard dimensions.

The keel was constructed in six to seven sections, scarfed and fastened together (Lavery 1985:12). Different navies developed different methods for scarfing and fastening timbers together (Lavery 1985:12; Fernández-González 2012:24). British ships used vertical scarfs with tables and coaks that were fastened with eight horizontal bolts (Fernández-González 2012:24). Spanish and French ships used horizontal keel scarphs and were fastened with eight vertical bolts driven through floors and the keelson (Fernández-González 2012:24). The false keel (F in Figure 6) was seven inches thick and secured to the keel with fasteners (nails or staples) (Lavery 1983b:43). The overall keel length varied across navies and time periods as shown in Table 1.

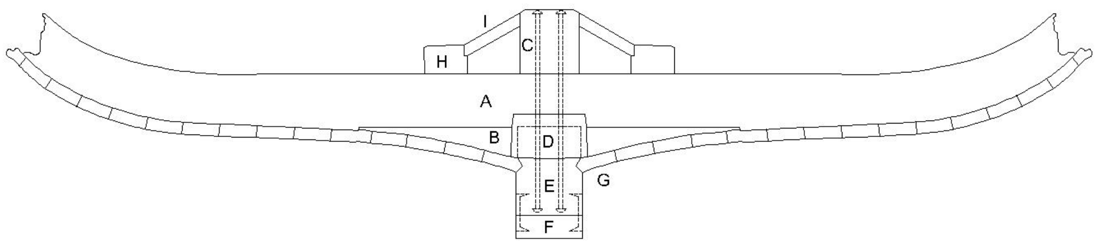


Figure 6. Cross section of keel and frames of 74-gun Ship-of-the-Line (M. Lewis after Lavery 1983b:43). Legend: A – Floor Timber, B - Chock, C - Keelson, D - Deadwood, E – Keel, F – False Keel, G – Garboard Strake, H - Limber strake, I – Limber Boards

Type	**Keel Length m/ (ft. in.)**
74-gun Warship – *Invincible* – French 1744	43.05m (141'-3")
74-gun Warship – *Bellona* – English 1760	42m (138')
74-gun Warship – *Colossus* – English 1787	43.36 (142'-3")
74-gun Warship – *Pompée* – French 1791	46.38 (152'-2")
74-gun Warship – *Montañes* – Spanish 1794	48.77m (160')

Table 1. Keel Length (See Appendix for full chart with associated references).

The frames of the 74-gun ship were assembled out of multiple futtocks (Figure 7) in close proximity to each other: double frames (Lavery 1983b:35). This effectively provided a solid wall of wood to protect the gun crews from incoming fire during combat engagements and was a standard feature for the ships of the line (Lavery

1983b:35). However, this close construction added weight to the hull, which resulted in a slower vessel (Lavery 1983b:35). The 74-gun ship hull construction dealt with this problem by adjusting the space between the pairing of frames, in order to minimize the weight of the hull while still acting as "wooden" armor (Lavery 1983b:35).

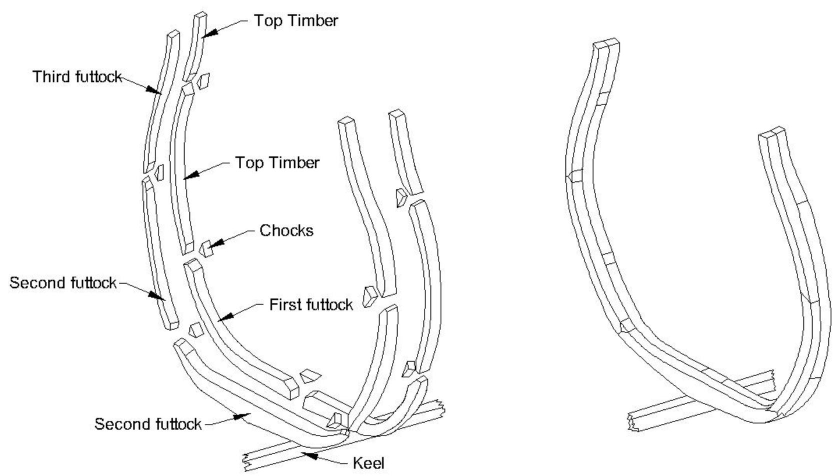
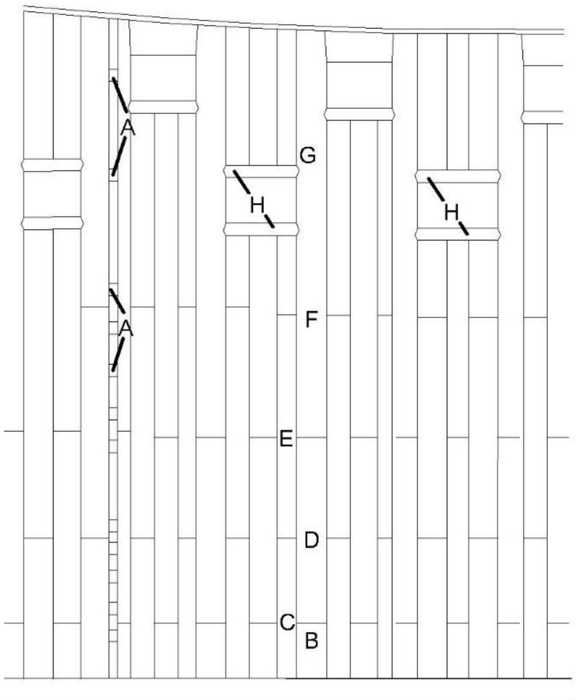


Figure 7. Frame Construction (M. Lewis after Lavery 1983b:35).



74-Gun Ship Framing Legend:

A – Small Chocks above and below deck level
These would be all along the sides.
B – Floor Timberheads
C – First futtocks
D - Second futtocks
E - Third futtocks
F - Fourth futtocks
G - Toptimber
H – Gunport sills

Figure 8. Framing of a 74-gun Warship (M. Lewis After Lavery 1983b:35).

The struggle between weight and speed is a tradeoff in shipbuilding and room and space varied in order to obtain faster and lighter hulls, or slower and stronger hulls (Fernández-González 2012:23). Later in the development of the 74-gun warship, to reduce the weight of the vessel and thus increase speed without reducing the hull strength, the Spanish decided to use wooden treenails as fasteners instead of the traditional iron fasteners (Fernández-González 2012:23). This allowed them to reduce the weight of the hull in the *Montañés* class by approximately 400 tons, (Fernández-González 2012:23) (Table 2).

As mentioned above, gundecks were reinforced to carry the weight of the batteries. The required reinforcements – stringers, stanchions, lodging knees, beams, carlings, and ledges – were reduced in scantlings as much as possible, and spaced at increasing distances to reduce the weight of the ship's structure (Lavery 1983a:94-95;Lavery 1988:20-22,24; Fernández-González 2012:24). This trend started during the development of the 50-gun warship and carried through into the development of the 74-gun ships (Lavery 1983a:94-95; Lavery 1988:20-22,24; Fernández-González 2012:24).

Type	**Keel Length [m/ft]**	**Beam @ Breath [m/ft]**	**Keel L:B Ratio**	**Draft [m/ft]**	**Displ. [tons]**
74-gun Warship – *Invincible* – French 1744	43.05m (141'-3")	15.01m (49'-3")	2.88:1	6.48m (21'-3")	1793
74-gun Warship – *Bellona* – English 1760	42m (138')	14.3 m (46'-11")	2.94:1	6.53m (21'-5")	1615
74-gun Warship – *Colossus* – English 1787	43.36 (142'-3")	14.55m (47'-9")	2.98:1	6.83m (22'-5"	1703
74-gun Warship – *Pompée* – French 1791	46.38 (152'-2")	14.95m (49'-0.5"	3.10:1	6.65m (21'-10")	1901
74-gun Warship – *Montaňes* – Spanish 1794	48.77m (160')	15.54m (51')	3.14:1	7.77m (25'-6")	1500

Table 2. Comparisons of Weights and Size of different ship of the line (M. Lewis see Appendix I for full chart with associated references).

Smaller scantlings had an obvious downside, reducing the amount of support provided to the hull, and it sometimes resulted in hogging of the hull. This problem was common to ship of the line and was further compounded when the hulls became longer, so that the length to beam ratio was maintained, and the consequent operational speeds improved. Methods to reduce hogging were continuously sought (Fernández-González 2012:23). Different methods were implemented throughout European shipyards, and the British seemed to prefer using an increasing number of pillars, in addition to riders, riding futtocks, stringers and hanging knees (Lavery 1985: 27). Spanish shipbuilders preferred to implement a girder structure, connecting deck beams and stringers to form diaphragms that supported the hull. A Spanish naval architect stated that: "*Strengthening the upperworks and joining the frame timbers side by side, and the waterway which is the fastening of the ship, especially in pitching as it links the whole length of the vessel, are the best we can desire for the moment*" (Fernández-González 2012:23).

Conclusion

The 74-gun warships were developed in the middle of the 18th century and became the mainstays of navies in the late 'Age of Sail' due to their performing well in a vast array of different functions, from standing in the line of battle to escorting convoys, and chasing frigates (Lavery 1983a:107; Winfield 1997:20-70). These ships were able to accomplish these tasks due to sharp entries and runs, cheeky bows and weight-saving strategies in the construction of the hulls. These ideas evolved from their early predecessors, the 50 and the 70-gun warships (Lavery 1983a:94-95; Lavery 1988:20-22,24; Fernández-González 2012:24).

The 50-gun warships contributed their hull shapes, which were taken from the early frigates, along with lightweight reinforcing structure need to mount guns on two-decks (Lavery 1985:7; Gardiner 1992:18). The 70-gun warships contributed with their increased strength and, paradoxically, with their design flaws, which caused the British naval authorities to wake up and realize how complacent their system had become, and how far behind they had fallen in the naval arms race of the 1720s and 1730s (Lavery 1983a: 90-95).

This realization led the British to directly copy the best of the captured foreign vessels and imitate their design concepts (Lavery 1983a:94-95). When faced with the improved British 70-gun ship, the French designed their first 74-gun warship (Lavery 1985:7; Gardiner 1992:18). After the capture of one of those by the British, their shipwrights had access to a better engineered ship and decided to copy and used it to their advantage in later wars (Lavery 1988: 31; Lavery 1983a:94-95). This practice of copying better ships became standard in the British navy and was the case of the HMS *Colossus*, a near direct copy of another captured French 74-gun ship, the *Courageaux* (Winfred 2007:84; Royal Maritime Museum (RMM) Drawings).

CHAPTER III

HISTORY OF HMS *COLOSSUS*, THE SITE, SURVEYS AND EXCAVATIONS

History of HMS *COLOSSUS*

The construction of the 74-gun *Colossus* started in 1782 at the Gravesend Dockyard and took five years to build, being launched in 1787 (Winfred 2007:85). These dates are known because of surviving textual records, solely focusing upon the costs, regarding the vessel's construction (Winfred 2007:85). Not only do these construction documents remain, but the original plans used in the construction of *Colossus* survived in English archives (RMM drawings). *Colossus* and her three sister ships are near direct copies of *Courageux* (Winfred 2007:84), a French 74-gun ship captured by HMS *Bellona* in 1761 (Lavery 1985:10; Winfield 2007:63).

As stated, the 74-gun ship of the line was a French innovation which was readily adopted by the British Navy (Lavery 1985:7; Gardiner 1992:18). For this purpose, the British admiralty created a strategy to examine the captured ships' hull forms and construction features and used the data collected to copy and adapt these new better ships to the British taste and construction technology (Lavery 1991:27-29). *Colossus* and her sister ships were considered near copies of *Courageux* because the British modified the layout of the storage of gunpowder and altered the internal layout, in addition to altering the size of the cannons mounted. The Royal Maritime Museum's plans of *Colossus* show these changes outlined in green (Winfred 2007:84; RMM Drawings). The changes in armament were due to the French preferring to mount 24-

pound cannons on the upper gun deck, whereas, the British preferred to mount 18-pounders cannons upon this deck, arguing that it increased sea-keeping by offsetting the decrease in broadside weight (Lavery 1991:173; Winfred 2007:85). However, all the changes between *Courageux* and *Colossus* were internal, and from the exterior there would be no difference in hull shape and form between the *Courageux* and *Colossus*.

Colossus had a short but eventful service life spanning 1787 to 1798, encompassing the earlier years of the French Revolutionary War (1793 to 1803) (Lambert 2000:151-169). *Colossus* was part of the Mediterranean fleet present during the siege of Toulon in 1793, and participated in the naval battle off Toulon, on March 13, 1795 (Gardiner 1996:116). The next battle that *Colossus* took part in was the Battle of Isle de Groix, June 30, 1795, (Gardiner 1996:49; Winfield 2007:85), after which it was repaired at Plymouth. The repairs took until July 1795, after which *Colossus* was dispatched under Captain George Murray to reinforce Admiral Jervis, prior to the Battle of Cape St. Vincent, on February 14, 1797 (Winfield 2007:85; Gardiner 1996:121). During this battle *Colossus* was damaged and crippled by cannon fire, suffering damage aloft (Padfield 2005:127). Following the battle of Cape St. Vincent *Colossus* was part of the blockading force off Cadiz (Gardiner 1996:134-135). *Colossus* was assigned to Nelson's command and sent into the Mediterranean in order to find the French Fleet, which Nelson later brought to battle at Aboukir Bay, perhaps better known as the Battle of the Nile (Gardiner 1997:18;Tracy 2006:257).

Because of the damage sustained during the naval battles mentioned above, *Colossus* was deemed unfit for involvement in the line of battle and detached and to participate in the blockade of Malta (Winfred 2007:85; Tracy 2006:257). *Colossus* later joined Rear Admiral Nelson's victorious squadron in Naples, and its Captain, George Murray assigned to return to England (Tracy 2006:258).

Colossus carried the wounded from the Battle of Aboukir Bay back to England, in addition to a cargo of pottery, and the body of Admiral Shuldham, shipped back for burial (Murray 1798; Tracy 2006:258). Before departing for England, Captain Murray transferred some guns and equipment, including *Colossus*'s spare bower anchor, to Nelson's flagship *Vanguard*, to replace guns and equipment lost in battle (Murray 1798). *Colossus* then left Naples, sailing to Lisbon where it joined a convoy bound for England (Murray 1798; Gosset 1986:19). Enroute, *Colossus* along with the convoy was caught by bad weather and took shelter in the St. Mary Roads anchorage, in the Scilly Islands (Murray 1798). During the storm an anchor cable parted and due to the spare bowler anchor having been transferred in Naples, *Colossus* was driven aground south of Samson Island (Murray 1798). Everyone in the crew and passengers, except for one sailor, where rescued by boats sent by the residents of the nearby island before HMS *Colossus* rolled onto its beam and started to break up under the relentless seas of the storm (Gosset 1986:19; Camidge, et al 2015; Murray 1798).

Work upon the Wreck of the *Colossus*.

Upon receiving news of the sinking via Captain Murray dispatch, (see appendix II) the British Admiralty sent the brig *Fearless* to salvage what items it could find and retrieve from the shipwreck, including the body of Admiral Shuldham, who was being shipped back to England for burial (Gosset 1986:19;Murray 1798;Grocott 1997:64-65).

Not all of the cargo was recovered, specifically the Greek pottery vessels in the 2nd collection of Sir William Hamilton (Gosset 1986:19; Grocott 1997:64-65; Tracy 2006:258). *Fearless* was able to recover some stores and some cannons before *Colossus* broke up and sank below the waves, on January 1799 (Gosset 1986:19; Grocott 1997:64-65).

Recovery and salvage work continued upon the wreck site after her sinking up until the early 20th century, with recovery work being conducted by Braithwaite and Tonkin in 1803-1806, the Dean Brothers in the 1830s, and possibly a company, *Western Marine Salvage* in the early part of the 1900s (Camidge, et al 2105). “Not much documentation remains of this a salvage and we do not know what actually happened” (Camidge, et al 2105).

In 1967 Ronald Morris, a marine salver, conducted a search for the remains of *Colossus*. In August of 1974, Morris located the debris that was associated with the wreck of *Colossus*,see figure 9, including a large amount of ancient Greek pottery. (Camidge, et al 2015:15).

These pottery fragments were the remnants of the 2nd collection of Sir William Hamilton and were recovered from the site and turned over to the British Museum (Camidge, et al 2015:15). Following the recovery of pottery by Morris, in 1984, the site had its designation removed from the Protection of Wrecks Act of 1973 (Camidge, et al 2015:15).

Archaeological Excavation

In 2001 local divers found exposed timber and cannons some distance to the east of the site excavated by Morris (Camidge 2017:10). These remains turned out to be the stern of *Colossus*, which was designated in July of 2001 as a protected site under the Protection of Wrecks Act 1973 (Camidge 2017:10). During limited excavations by the Archaeological Diving Unit in late 2001, a curved piece of timber was found which was discovered to be a part of the stern quarter-piece (Camidge 2017:10). This stern quarter-piece was recovered in 2002 and conserved by the Mary Rose Trust before being returned for display at the Island of Scilly Museum in Tresco, Scilly Islands (Camidge 2017:10). Additionally, in 2002 another limited excavation of the area around the stern was conducted to establish the extent of the structural remains and the status of preservation (Camidge 2017:10). The exposed timbers were found to be degrading, thus a two-year stabilization trial to slow down the deterioration was authorized by English Heritage (Camidge 2017:10).

Figure 9. Location of Wreck site (Lewis After Camidge 2015:8).

In 2004 and 2005, the Cornwall and Isles of Scilly Maritime Archaeology Society (CISMAS) conducted surveys around the wreck of HMS *Colossus* in order to assess the extent of the debris field, which was found to extend outside the area covered by the designation (Camidge 2017:10). In 2008 an underwater diver trail was established on the wreck site of the *Colossus*, and an underwater guidebook was developed, which were distributed to the local dive boats for visiting divers (Camidge 2017:11). This work was paid for by the English Heritage (Camidge 2017:11).

Further archaeological work on the shipwreck site took place in 2012, 2015 and 2017 (Camidge 2017:10). In 2014, during maintenance work on the dive trail, new material from *Colossus* was found to have been exposed by wave action (Camidge 2017:11). During the 2015 excavation, these were recovered and conserved (Camidge 2017:10-11). Included amongst these items were several parts of a 9-pounder gun carriage, one of which had the name of the vessel, *Colossus*, inscribed on it (Camidge 2017:10).

Conclusion

The wreck of *Colossus* is a rarity in archaeology. Not only do the original construction plans of the ship survive, but so does a letter, written by the captain of the vessel, describing the events leading up to the sinking, in addition to an account of the sinking and the rescuing of the crew. Moreover, the wreckage of the vessel has been located, salvaged, looted, surveyed and excavated, and today a layer of sand is still protecting part of the wooden remnants of the hull. Although not adding directly to the digital reconstruction of *Colossus*, this chapter has provided a background to history of the vessel and context of the site.

CHAPTER IV

DIGITAL RECONSTRUCTION OF THE SHIP

The methodology of this ship's reconstruction can be divided into five steps: acquisition of a digital image of the construction plans, creation of a set of working drawings in *AutoCAD*, the insertion of the *AutoCAD* drawings into *Rhino 6*, tracing and conversion of the working drawings into 3D objects, and the assembling of the 3D objects into a structural reconstruction of the vessel.

The first step in the project was to gain access to the archaeological site reports and permissions from the CISMAS in the United Kingdom. Following this critical step, physical copies of the original ship construction plans were acquired from the Royal Maritime Museum in Greenwich, United Kingdom. These physical plans were then scanned to create a set of digital files in PDF format.

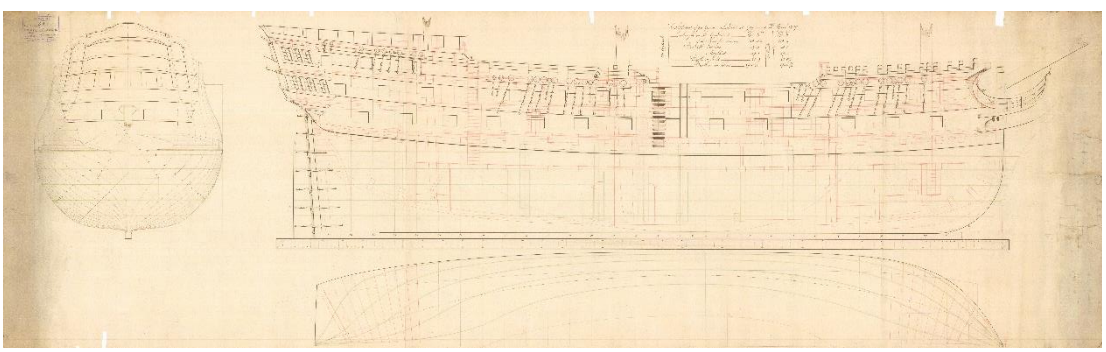


Figure 10**.** Copy of the scanned HMS Colossus Original Ship plans purchased from the RMM by the author (M. Lewis).

These digital files were then inserted into *Autodesk ACAD 2018*, in order to develop a set of ship lines and working drawings that would allow the production of a reconstruction of the vessel. Although these are the same plans which were used to construct 74-gun ship-of-the-line HMS *Colossus* in 1787, information such asthe size of the structural timbers, the frame spacing, and the keel attachment, was found to be missing or lacking. This missing information is where the shipwright's own knowledge, acquired through their apprenticeship would have been used. Unfortunately, this information has been not passed on and therefore it had to be recreated from other sources. Luckily, there has been information assembled in different books that describe part of the missing information.

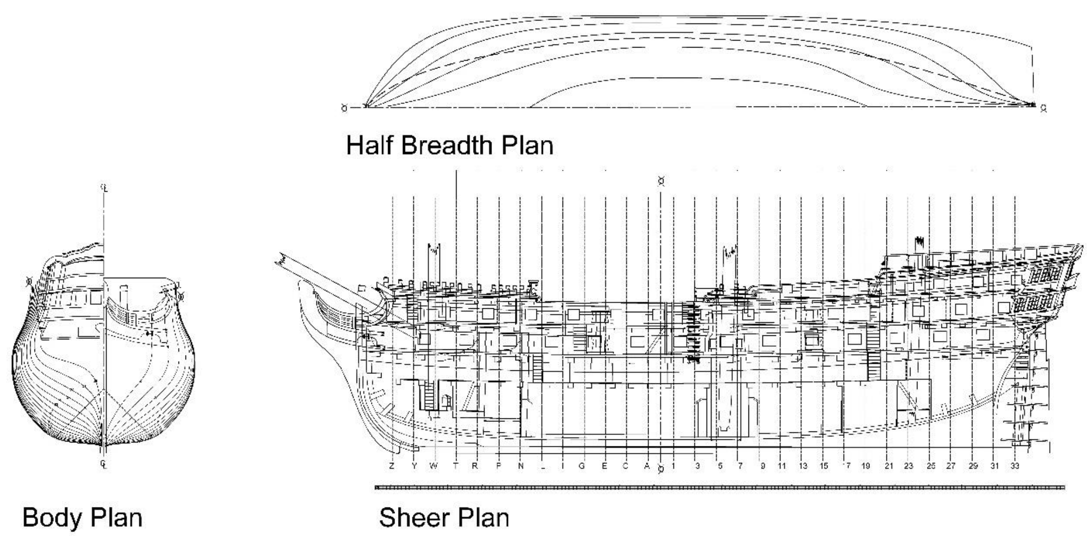


Figure 11. Working drawing of HMS Colossus, Ship Lines (Drawing: M. Lewis).

The book *Invincible* provides details about the construction and internal layout of a 74-gun ship of the line based upon that of a French ship that was captured and put into service by the British in the 1740s (Lavery 1988: 24). Brian Lavery's book, *Building the Wooden Walls*, about the construction of the ship *Valiant* was also consulted.

Additionally, *Building the Wooden Fighting Ship* and *The Seventy-Four Gun Ship, Vol 1.* provided more missing construction details.

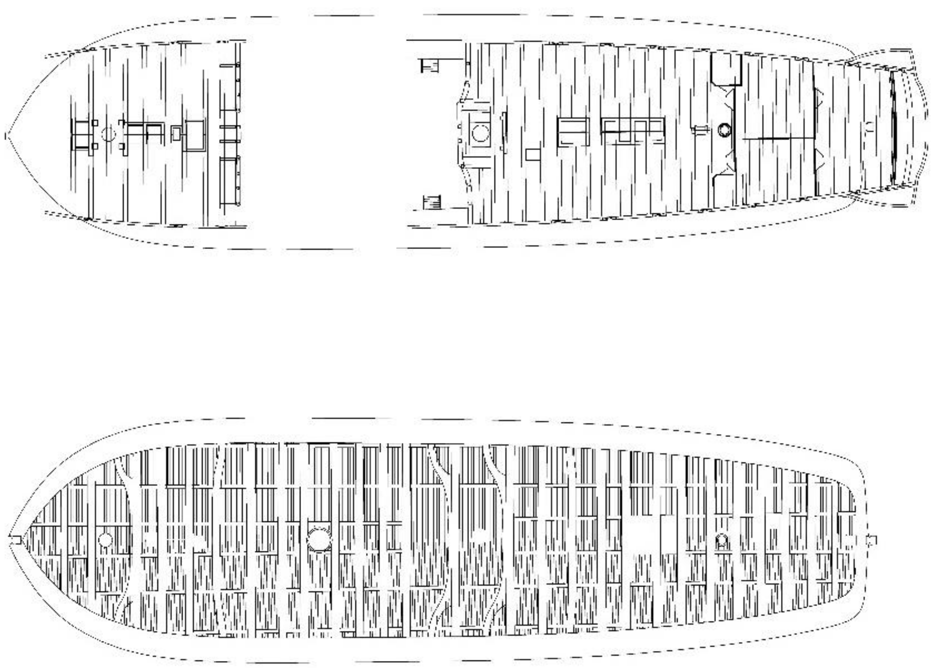


Figure 12. Quarterdeck and Upper Gun Deck Plans (M. Lewis).

These missing details and the sources for the information used to replace them will be explained further on. This technical information was gathered in order to develop a set of working drawings (Figures 11-13) which would include the missing information and provide a basis for creating a 3D reconstruction of the vessel prior to launch without planking attached.

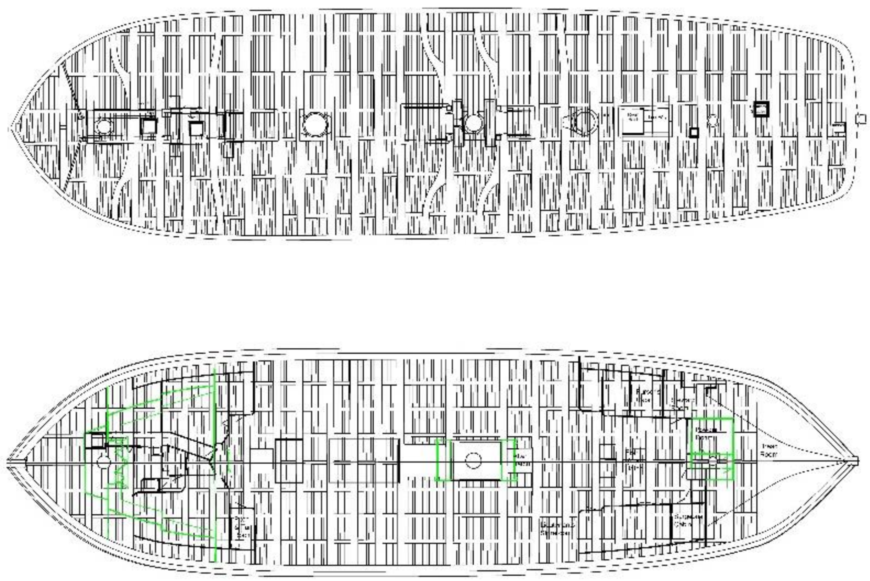


Figure 13. Lower Gun Deck and Orlop Plans (Drawing: M. Lewis).

The working drawings were inserted as a bitmap background into *Rhino 6*, using the insert bitmap background command. The working drawings were drawn at a one to one scale. Thus, the bitmap did not require any scaling prior to work starting on the conversion of the 2D drawings and working into a 3D representation of the vessel. This was done by first tracing the frames associated with section lines that were taken off from the half-breadth plans (Figure 11).

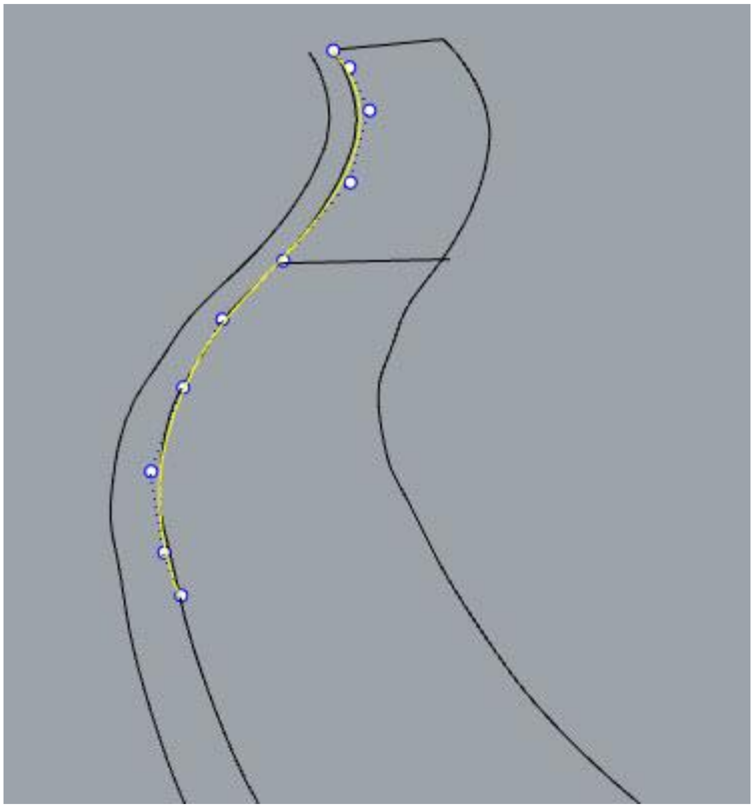


Figure 14. Tracing of frames (Drawing: M. Lewis).

The tracing of the frames was done by using ‘curve interpolate points’ or ‘line’ commands, singularly or in combination. The ‘curve interpolate points’ allows the curvature of the frames to be traced, while the ‘line’ command allowed for straight lines to be traced. Once the outline had been traced, the resulting line, which could consist of 4 or more separate lines, was combined into a single closed curve, using the ‘join’ command (Figure 15).

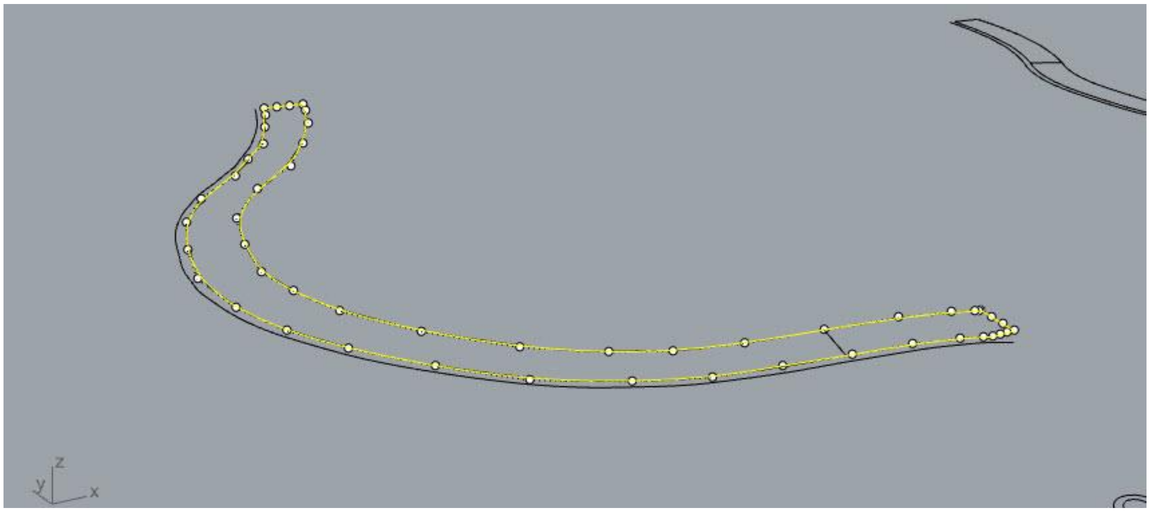


Figure 15. closed curve (Drawing: M. Lewis).

Once the tracing was combined into a single entity, the closed curve is extended using either the extend command or by using the gumball function within *Rhino*, and by double clicking the mouse button on the center ball and entering the measurement that the frame is to be (Figure 16).

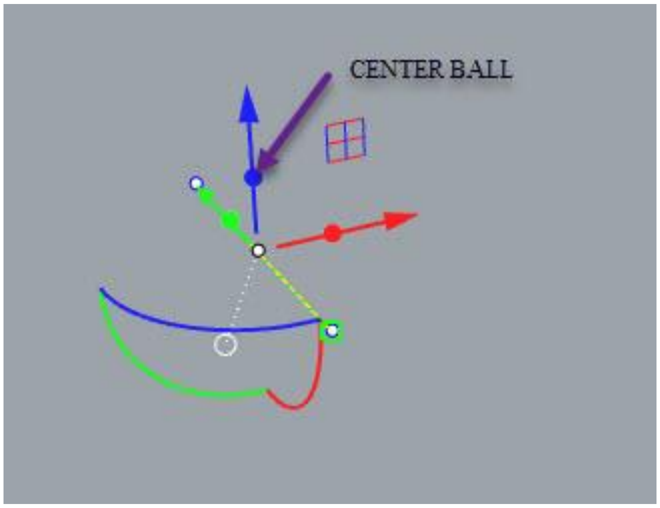


Figure 16. Gumball function, with center ball labelled (Drawing: M. Lewis).

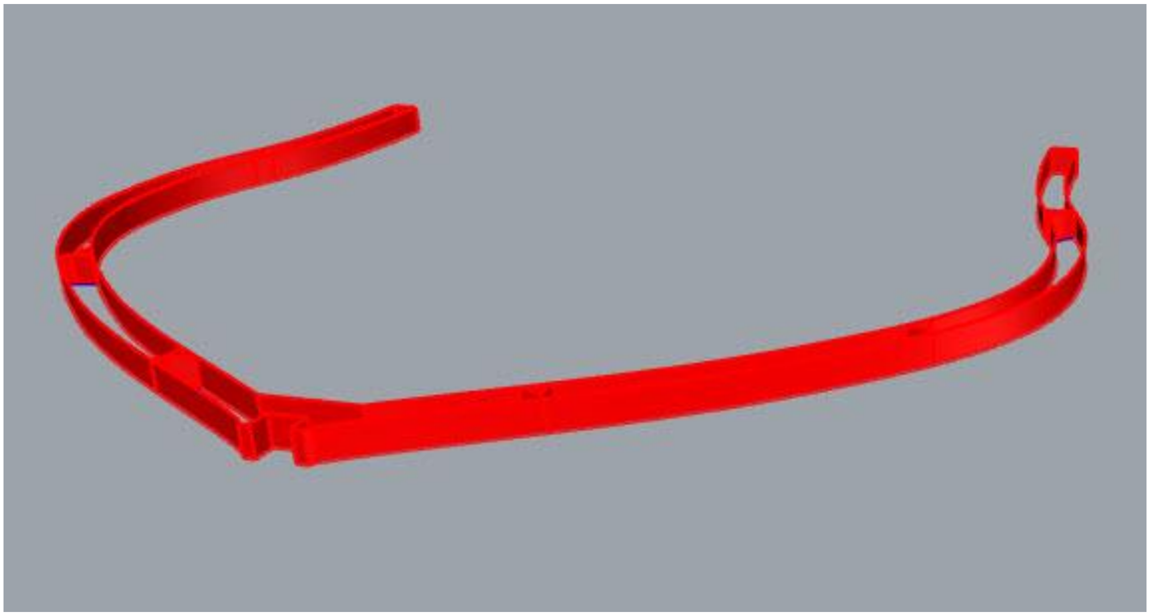


Figure 17. Extending the closed curve (Drawing: M. Lewis).

After the closed curve, which is a tracing of the tracing of a drawing of the frame, has been extended, the entity can be finished off and capped using the cap command to create a solid entity. The chock joints of the frames are included in the tracing and extension; thus, the joints show up, but the entire frame is actual a single entity, and can moved around as such. This will speed up the assembly of the reconstruction and ensure the components of the frame are perfectly aligned (Figure 20).

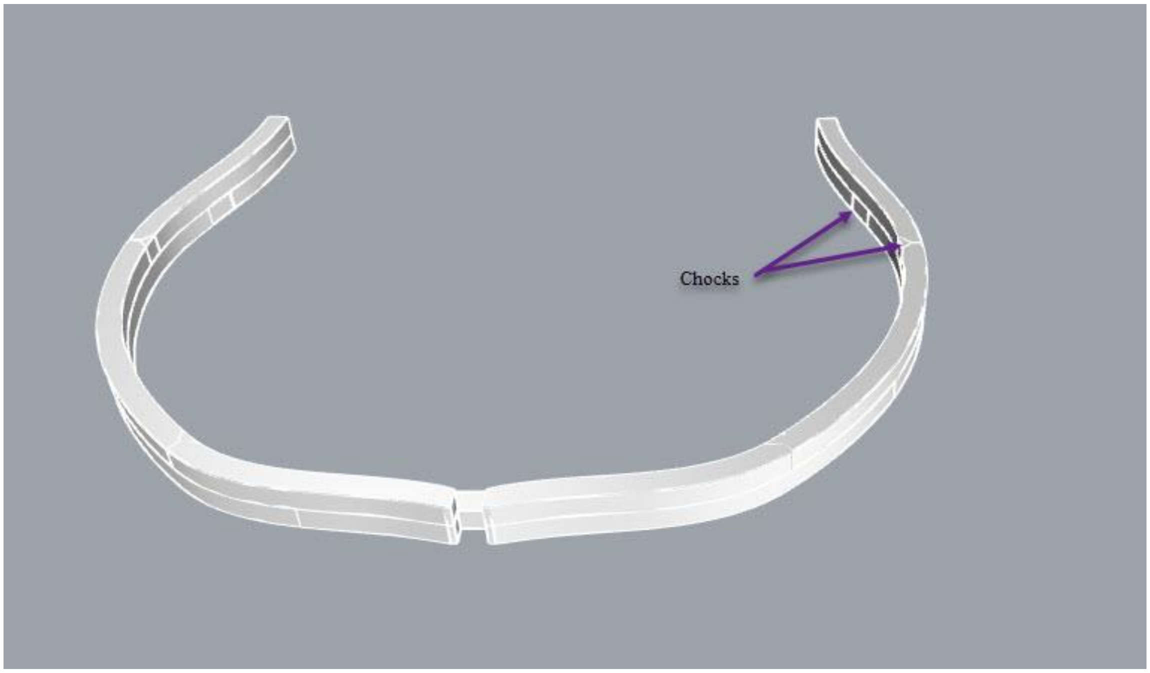


Figure 18. Frame with the chocks labelled. (Drawing: M. Lewis)

Once each full frame had been created into a single entity, it was placed on to its associated half frame and then the entire assemble of full frame and half frame was joined together (Figure 19). Using the gumball controls, the double frames were 3D rotated into standing up position. Each of these previous steps were then done again for all 31 of the double frames that were developed from the section lines of the half berth plan (Figure 20).

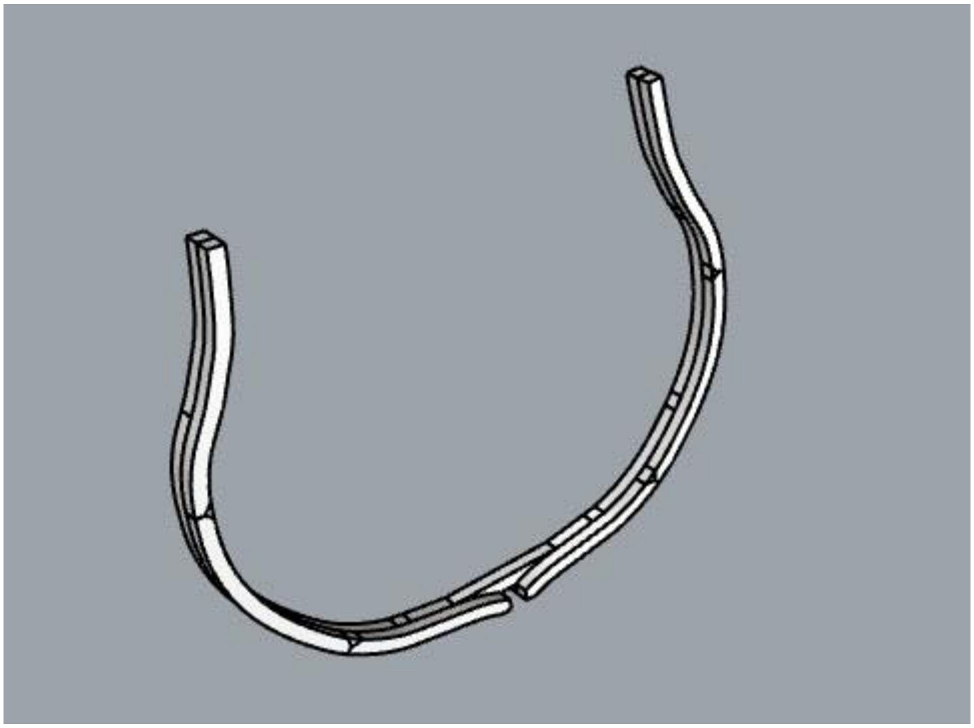


Figure 19. Double frames (Drawing: M. Lewis)

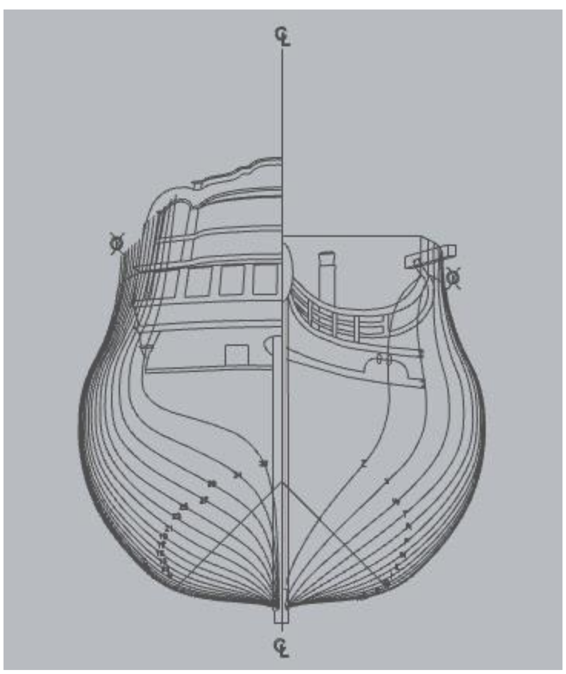


Figure 20. sections lines used to develop frame shapes (Drawing: M. Lewis).

Once all of the double frames had been rotated into an upright position, each double frame section was moved into its corresponding position on the sheer plan.This was to align with the ship’s section lines, using the center joint of the double frame as the alignment point (Figure 23). Once this operation was repeated for each double frame, the results provided a facsimile of the rough outline of the vessel. (Figure 24)

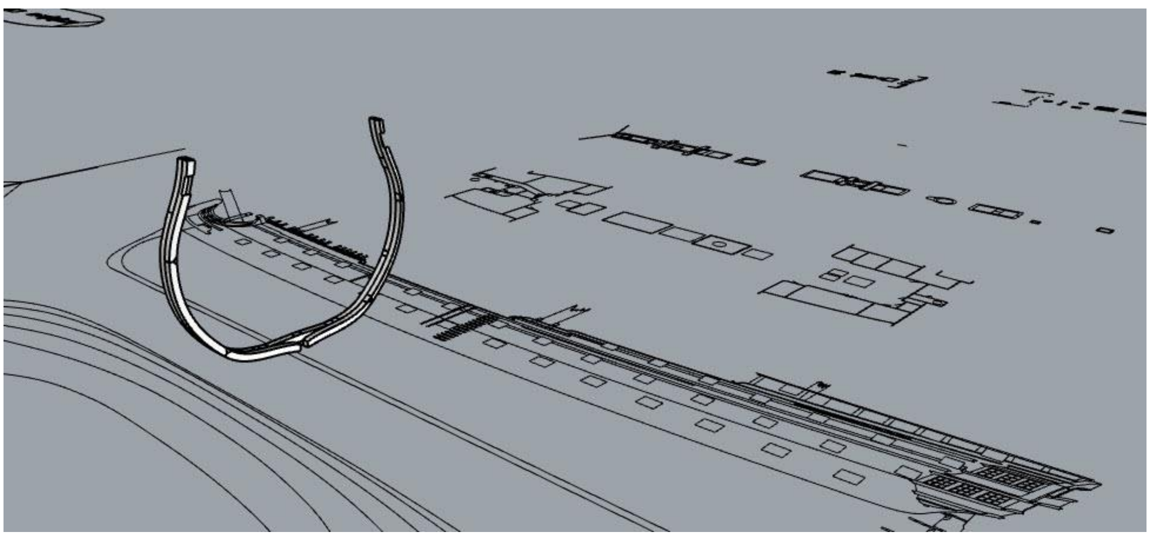


Figure 21. positioning of the double frames on the sheer plan (Drawing: M. Lewis).

The outline of all the structures of the six decks: orlop, lower gun deck, upper gun deck, main deck, forecastle and poop deck, were traced off the working drawings developed from the construction plans. After the outline of the decks had been traced in, using the same methodology as was used on the frames, a ‘closed curve’ was created.

The deck beams were extruded to the correct dimension required, dependant upon which deck the beams were located upon.

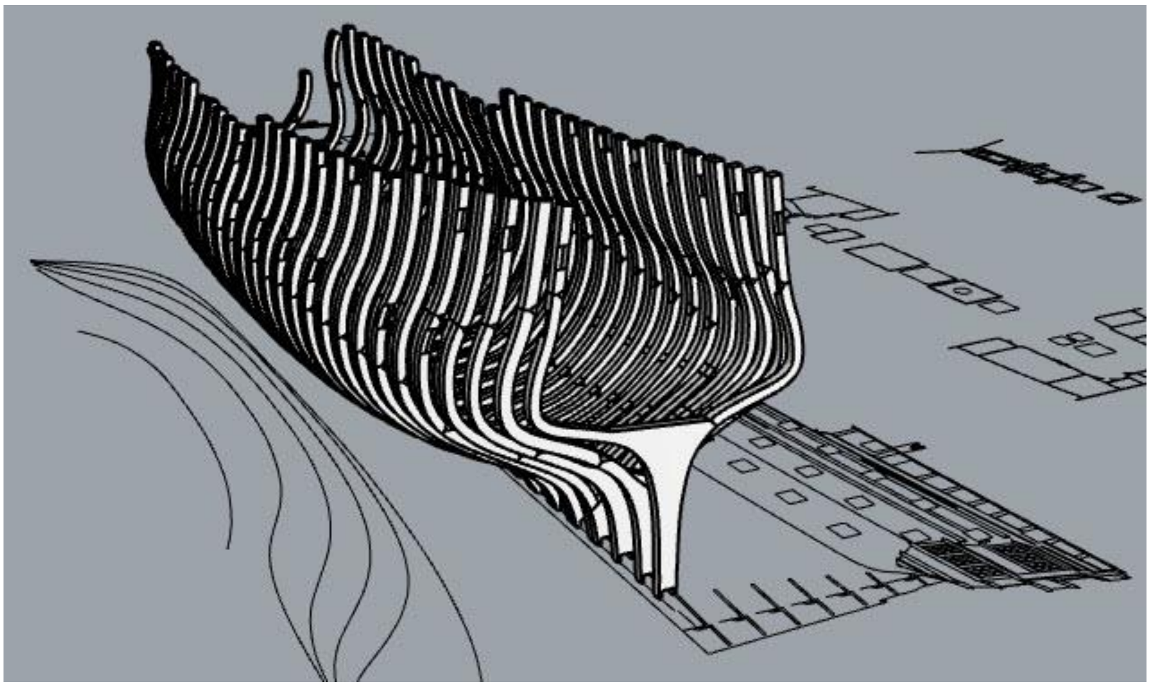


Figure 22. All double frames placed on the sheer plan in alignment of their section lines (Drawing: M. Lewis)

Orlop Deck

The Orlop Deck beams were 39.4 by 39.4 cm (15.5in. by 15.5in.) in section, with the length dependent upon the position in the vessel (Lavery 1991:119-123). The carlings, the structure running perpendicular to the direction of the deck beams, were extruded at 22.9 by 22.9 cm (9in. by 9 in.) (Lavery 1991:119-123). Finally, the ledges, the support structures running parallel to the deck beams, were extruded to create an object that was 12.7 by 12.7 cm (5in. by 5in.) (Lavery 1991:119-123), with the spacing between consecutive faces dependent on their location within the ship, but with a minimum 22.9 cm (9 in.) and a maximum of 30.5 cm (12 in.) between carlings and ledges (Lavery 1991:123).

All the carlings and ledges were raised up to the same elevation as the deck beams to ensure the deck was level, again using the gumball command (Figure 23).

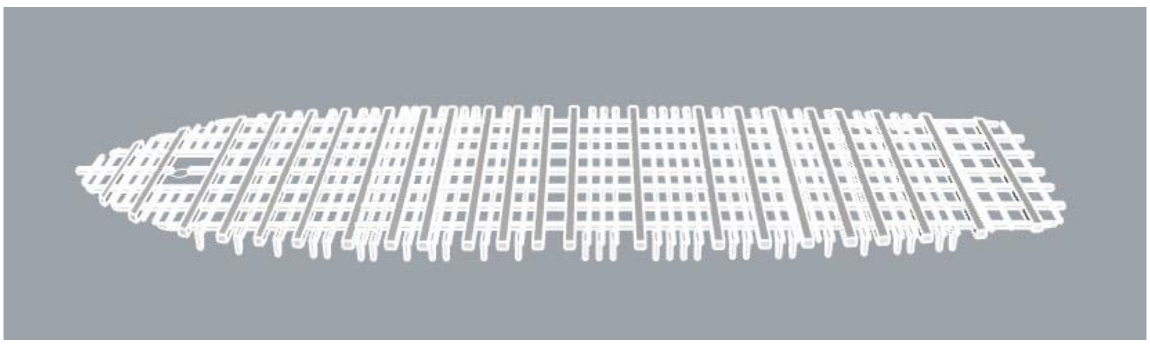


Figure 23 Orlop Deck showing the deck beams, carlings and ledges. (Drawing: M. Lewis)

The deck beams for the lower gun deck (Figure 26) and upper gun deck (Figure 27) were 41.9 by 41.9 cm (16.5 in. by 16.5 in.) in section, and the carlings and ledges were designed with the same dimensions and spacing as the Orlop Deck ones. However, unlike the Orlop Deck, which was built to stay below the waterline and was flat for that reason, all decks above it had a sheer to allow water to flow toward the bilge pumps

(Lavery 1991:123). Additionally, they had a camber to them where the mid-point of the beam would be high point.

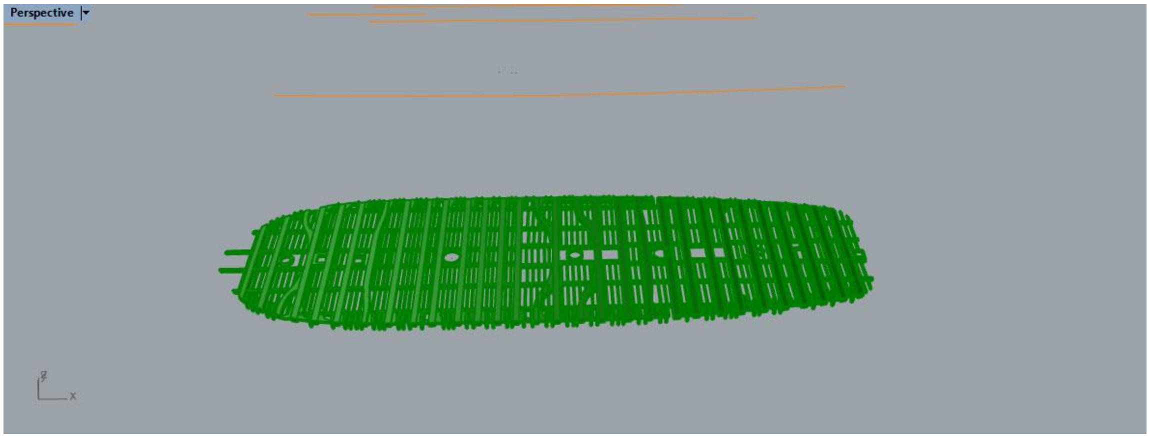


Figure 24. Lower Gun Deck with deck beams, carlings and ledges – flat (Drawing: M. Lewis).

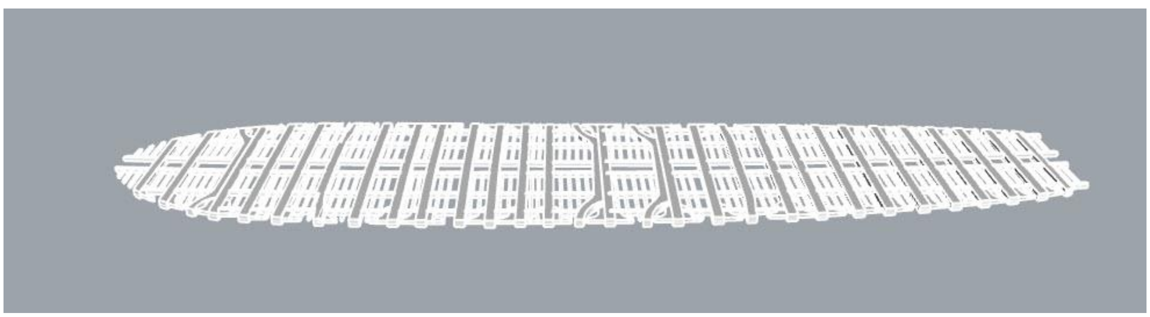


Figure 25. Upper Gun Deck with deck beams, carlings and ledges. (Drawing M. Lewis)

To alter the gundecks (Figures 24 and 25) and those above to both these curvatures, the ‘flowalongsurface’ command was used. The steps for this command require the drawing of both a level plan surface and a plan surface that matches the curvatures needed, and for both surfaces to be the same size. The level plan is placed under the existing deck, and by selecting upon the level surface first, then on the curved one, the deck is altered to match (Figures 26 to 28).

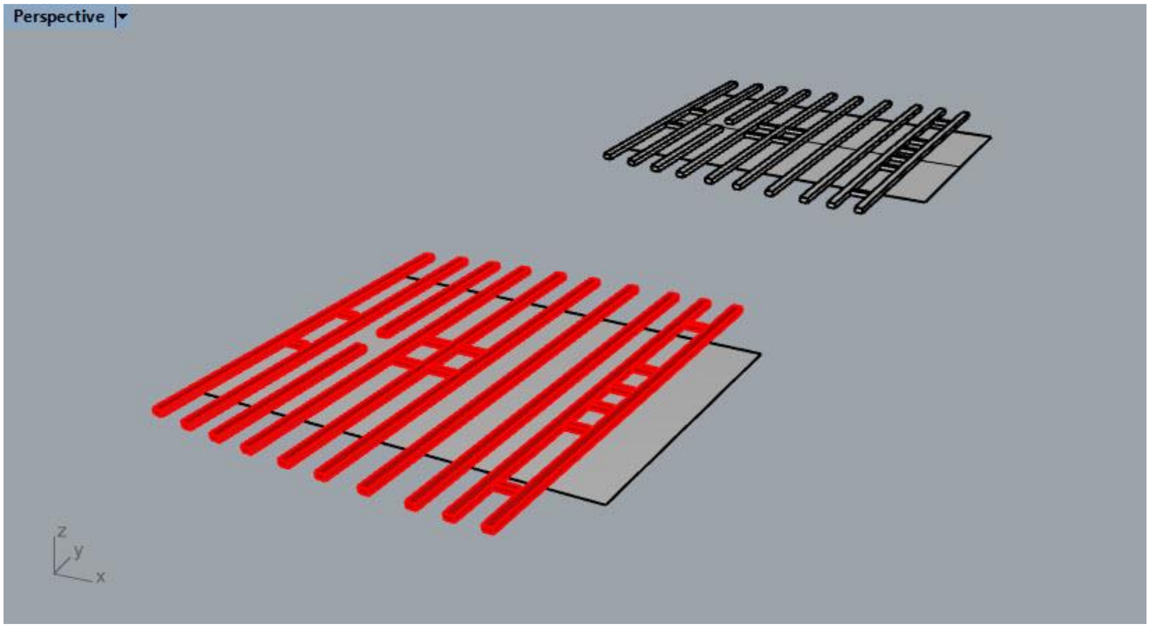


Figure 26. ‘Flowalongsurface’ command red is before, white is after. (Drawing M. Lewis)

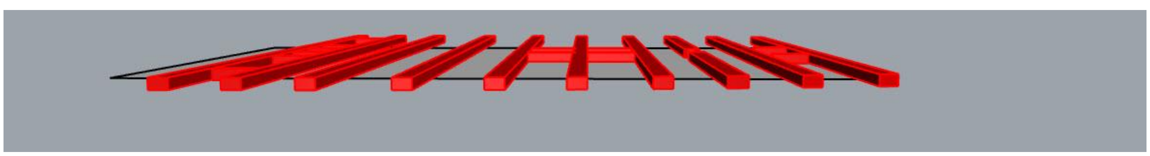


Figure 27. ‘Flowalongsurface’ flat deck. (Drawing M. Lewis)

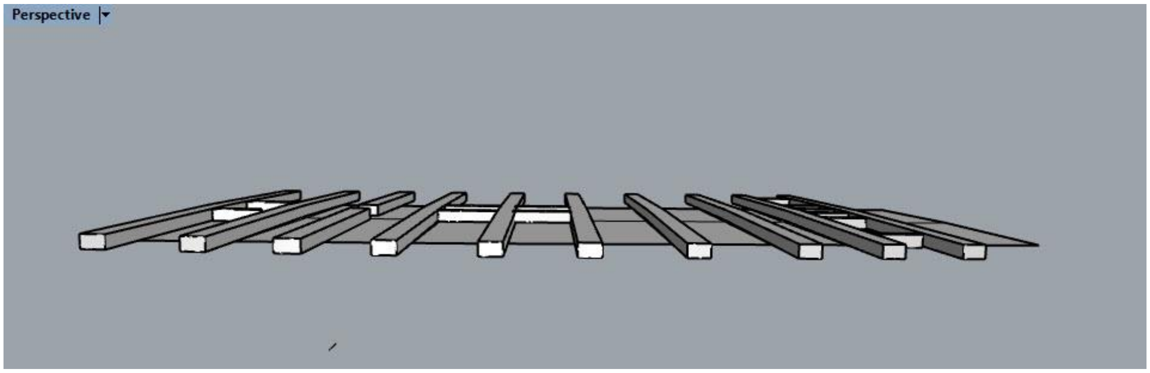


Figure 28. ‘Flowalongsurface’ curved deck. (Drawing M. Lewis)

The armament on the main deck (Fig 29), was 9-pounders (Winfred 2007:85) so the deck beams were reduced in size, in comparison to the lower- and upper-gun decks. The main deck beams were 31.1 cm (12.25 in.) sided and 41.3 cm (16.25 in.) molded, as measured from the working drawings. The carlings and ledges once again were sized and spaced as stated above.

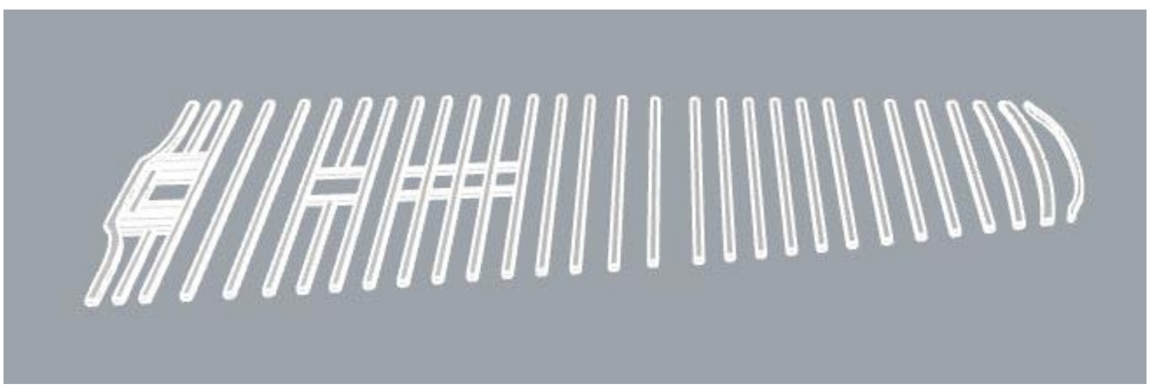


Figure 29. Main Deck with deck beams, carlings and ledges. (Drawing M. Lewis)

The forecastle and poop deck's beams (Figure 30) were 17.8 cm by 14 cm (7 in. by 5.5 in.) (Lavery 1991:119-123). These carlings and ledges once again were sized and spaced as stated above.

Figure 30. Forecastle and Poop Deck with deck beams, carlings and ledges (Drawing: M. Lewis).

Other support structures associated with the decks, the hanging knees and the lodging knees, were added to the decks prior to the use of the 'flowalongsurface' command. The working plans and the deck plans were used for the placement. The thickness of these support structures' features was 21.6 cm (8.5 in.) for hanging knees and 19.7 cm (7.8 in.) for lodging knees (Lavery 1985:14, 50-51).

Following the attachment of the hanging knees and the placement of the lodging knees, all decks were elevated using the gumball tool, using the bottom of the keel as the base point. The Orlop Deck was raised to 5.58 m (18 ft. 3.5 in.) above the base point. The Lower Gun Deck up to 7.86 m (25 ft. 9.25 in.), Upper Gun Deck up to 9.82 m (32 ft. 2.25 in.), Main Deck to 12.12 m (39 ft. 9 in.), Forecastle up to 12.12 m (39 ft. 9 in.), and

Poop Deck to 14.88 m (48 ft. 9.75 in.). The distances for the spacing between decks were based upon the RMM Sheer plan.

Keel, stem and stern post

The keel, the stem, and the stern posts were traced and extruded to the measurements taken off the RMM plans. The keel was 43.6 m (142 ft. 3 in.) long and 48.8 cm (19.2 in.) sided, and consisted of 6 pieces connected with scarf joints (Figure 33). Along the length of both of its faces was a rabbet in which the garboard strake of the planking was placed. Attached to the forward part of the keel was the forefoot, a curved piece that joins the keel assembly and stem assembly together.

The False Keel mounted below the keel was 17.8 cm (7 in.) molded and had the same sided dimension as the keel (Lavery 1985: 13). This False keel was used a sacrificial piece to prevent damage to the keel during a possible grounding (Lavery 1985: 13).

Figure 31. Keel Assembly (Drawing: M. Lewis).

Stem Assembly

The stem was installed above the forefoot and was 12.2 m (40 ft.) in length, 20.3 cm (8 in.) Sided and 47.2 cm (18.6 in.) molded. The stem was composed of two timbers that had been scarfed together. The Apron was the wooden structure that reinforced the interior, between the forefoot and the stem. Information for the stem was gathered from the working drawings.

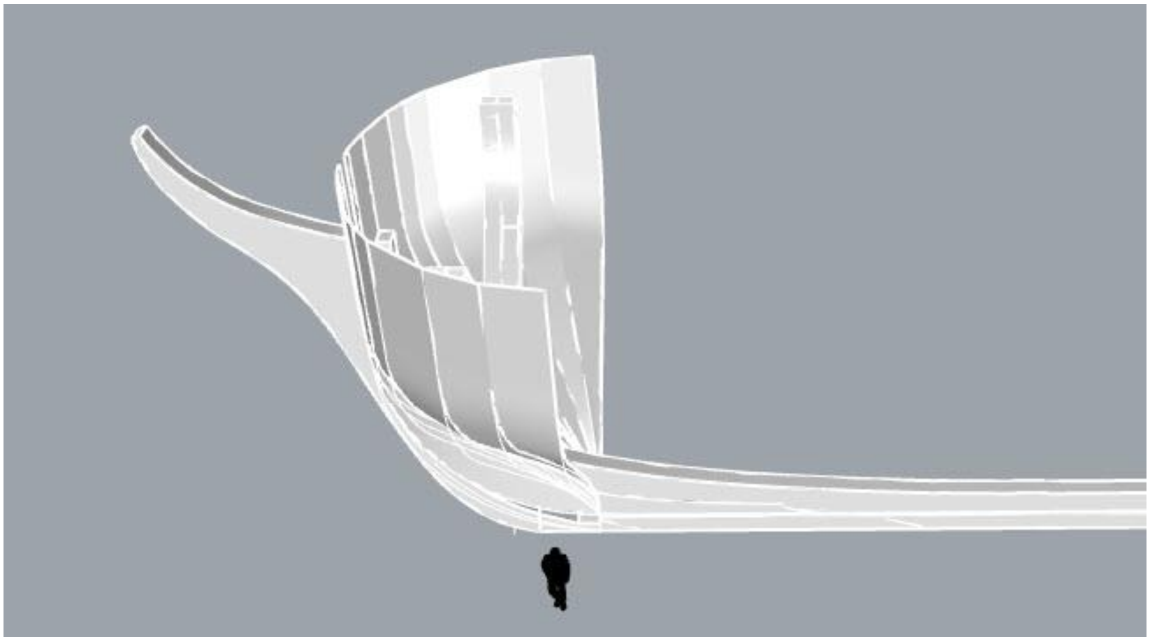


Figure 32. Stem Assembly (Drawing: M. Lewis).

Sternpost

The sternpost attached to the keel at the stern of the vessel. The sternpost raised up and was capped by the wing transom. Fashion pieces are drawn to match the stern profile and are raised into position conforming to that, as shown on Figure 35 (Lavery 1991:92-93).

Figure 33. Sternpost (Drawing M. Lewis).

Deadwood

The deadwood was the structural wood that was used in the entries and runs, at both the bow and stern of the vessel to provide support for the planking. The curvature of the deadwood was what allowed the planking to conform to the shape of the hull (Lavery 1991:82).

The methodology of following the original construction process was altered when it came to the 3d drafting of the deadwood. Instead of requiring the deadwood to assist the development of the curvature, the curvature of the exterior and interior hull planking could be digitally developed off working plans frames. The methodology of the creation of the planking profile will be explained in the next section. Once the profile was developed, the trim command was used to shape the deadwood, in addition to all the frame and half frame interior edges.

Exterior and Interior Planking

The profile of the planking, both interior and exterior, were created by using the curvatures of each segment of the hull frames (Figure 36). The tracing of each main frame was copied, and the exterior and interior placed upon its own layer. Each of these frames were then rotated and placed onto the associated section line. Once all the segments of the hull frames had been placed onto the associated section line the interior planking layer was then hidden, as well as all the layers in the drawing except the exterior planking layer. The loft command was used to create the exterior planking profile. Using the loft command, each of the section line curves were combined into a single polygon surface that matched the shape of the hull profile from the working drawings (Figure 37). After the exterior planking profile had been developed, the interior hull planking layer was unfrozen and the exterior planking layer frozen, and the process of using the loft command to develop the interior hull planking profile repeated. The one structural element that has been omitted are the wales. The channel wale would be in-line with the bottom of the upper gundeck and were made of timbers 14.0 cm (5.5 in.) thick. The main wales were located between the top of the Orlop Deck and the bottom of the lower gundeck and were made of timbers 21.6 cm (8.5 in.) thick (Lavery

1991:99). The justification for the omission of the wales is that they are a part of the planking and I envision that the planking would be a texture file showing the planking pattern.This is due to the lack of information on the *Colossus*'s planking pattern; a pattern which varied between ship and by shipyard and material availability (Lavery 1991:98-111). The planking pattern differs between the *Invincible, Valiant* and *Bellona,* so any pattern used on the *Colossus* reconstruction would only be hypothetical. The 3D model currently has a polysurface that is in the shape of the hull planking. By using a texture pattern instead of creating individual planks on the 3D model, any changes to the pattern can be undertaken without modification to the actual 3D model.

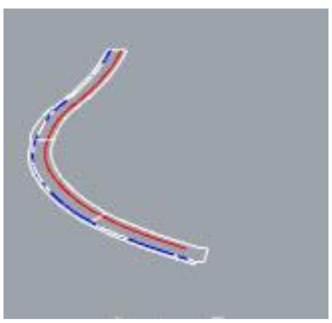


Figure 34. frame curvature used to develop planking profile (Drawing: M. Lewis)

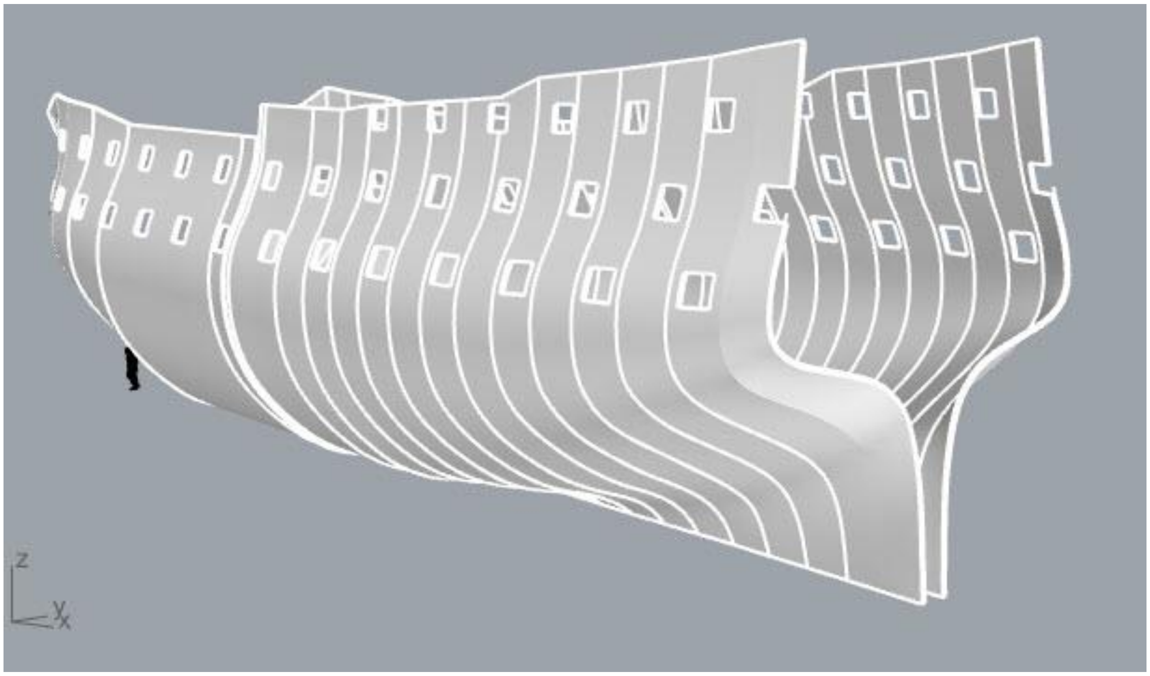


Figure 35. Exterior hull profile (Drawing: M. Lewis)

Results

The 3D reconstruction was divided into 5 steps or phases; acquisition of a digital image of the construction plans, creation of working drawings in AutoCAD, the insertion of the AutoCAD drawings into *Rhino 6*, tracing and conversion of the working drawings into 3 dimensional objects, and the assembling of the 3D objects into a structural reconstruction of the vessel. The method of assembly attempted to follow the construction sequence that was used on the original ship, *Colossus*, during its construction, but doing it digitally instead of physically. However, occasionally the construction sequence deviated from the original sequence, when using the computer proved more advantageous. When working with wood, the shipwrights could remove more wood during construction to ensure a close-fitted joint, since the wood would determine the final shape of the hull. When doing reconstruction digitally, this ability to fine tune the shape of the wooden hull is not available. However, the shape of the hull can be determined before the internal structure of the vessel has been drafted. This allows the person doing the reconstruction to deviate from the construction sequence in order to complete the 3D model in a reasonable timeframe. Although the construction sequence deviated from the original sequence, the end result still looks appropriate of the ship's name, *Colossus* (Figure 38).

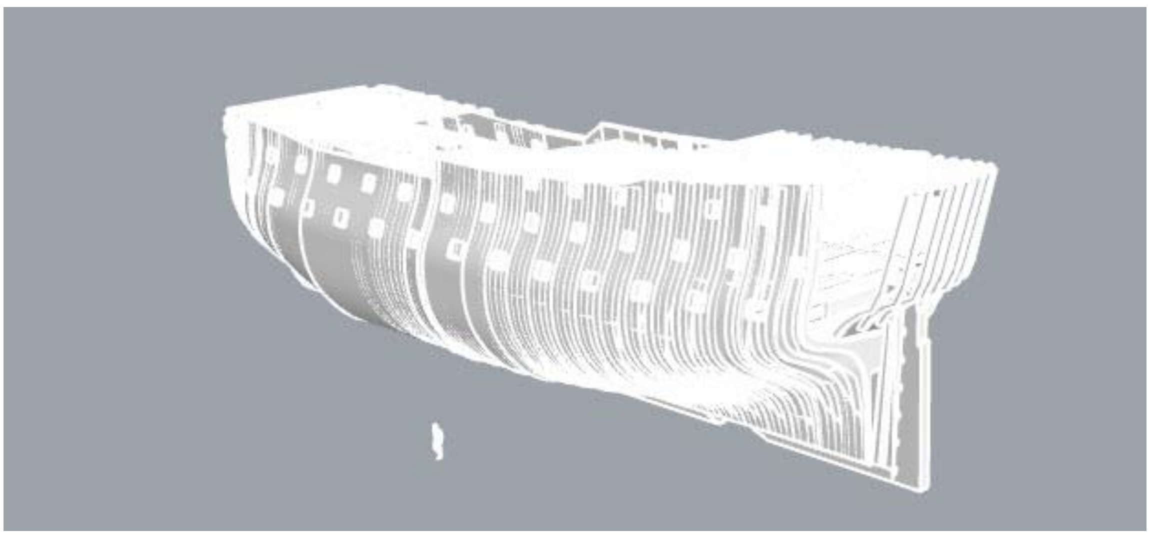


Figure 36. 3D reconstruction perspective viewpoint. (Drawing M. Lewis)

CHAPTER V

CONCLUSION

This thesis describes the author's use of an "off-the-shelf" 3D-modeling software, *Rhino 6*, to create a partial digital reconstruction of the HMS *Colossus*. As time and resources did not allow for a more detailed reconstruction, the model developed was used to propose a basic reconstruction that could easily be refined, step by step, to incorporate smaller details, since it was developed in a 1:1 scale.

The answers we asked in the beginning of this project can be easily answered, namely:

1) Can a 3D ship model be developed from the remaining ship lines and plans originally used to construct the ship over 200 years ago? and
2) Can this 3D model – given the required amount of time and resources – be as accurate, and provide the same quality, or even better details, than a wooden model of the same ship?

As we mentioned above, as original plans are always insufficient in the detailed data, the answer is yes, although incorporating a number of educated guesses, that is larger as we attempt to include small details. The present model is rather simple, but it is already an educated guess and proposes a plausible reconstruction of a complex machine that incorporated a lot of adaptations determined by the availability of material.

In that sense, augmented reality can be the proper tool to address the more difficult questions, or separate the details retrieved from the archaeological excavation and allow the designer to produce a model where it is clearly demonstrated – with color codes, for example – which solutions were taken from documental evidence and which were taken from archaeological research.

The accuracy of the present 3D model in comparison with that of a wooden model needs to be evaluated on two different plans. On one side it is obvious that a real size virtual model allows a much better representation of a ship than a scale model. On the other hand, bending timber is difficult in a virtual environment, even if the software uses splines to simulate the stresses in bent timbers.

As mentioned above, it was not withing the scope of this thesis to render the model to a plausible color and texture, or to include the repairs, imperfections, and plausible deviations from the original project that would be expected of a full scale model.

Since there is no wooden model of this ship we can only compare in abstract the advantages of a wooden model in relation to a virtual one. The case for virtual models and augmented reality is easy. A wooden model would have been far more expensive and have its accuracy limited by time, current knowledge of the vessel, and the scale factor. The time limitation on accuracy is directly related to the time needed to construct the model provided by the client; for this example, we will assume a museum. Wooden models built to scholarly standards require years of work. Even though, often details will have to be omitted. Although the aesthetic pleasure that wooden models – especially old ones – convey cannot be matched by virtual models, virtual reality has the potential to create different experiences, which may be better from a pedagogic viewpoint.

Moreover, virtual and scale models these are not mutually exclusive solutions, and depend only on space and financial resources.

A good example is the *Belle* project. The actual archaeological remains are available, together with a number of scale models, some of which were developed under scholarly standards at Texas A&M University by Glenn Grieco. It is conceivable that a virtual model could enhance the Austin Bullock Museum exhibition and provide the visitors with a full immersion experience in a real size virtual reconstruction.

As already mentioned, the present thesis describes the development of a real size model and points directions into the options available to the model developer.

The model developed in this thesis can be enhanced and modified in several ways, of which these seem to be the easiest and cheapest with the technology available from the shelves.

1) It can be provided with masts and spars, sails, running and standing rigging;
2) It can be rendered and with realistic textures and colors and provide a plausible image of the real ship;
3) It can be completed with coatings and sheathings, the planking seams enlarged and caulked, and the surfaces battered and provided with a realistic fowling;
4) It can be fitted with accessories and the space divided in a plausible way;
5) It can be populated and provided with the mobiliary that made everyday life possible aboard; or
6) It can be divided and shared in separate spaces, easier and cheaper to bring to life.

Special effects, more expensive and outside the scope of this thesis could enhance this model in countless different ways, by calculating the ship's weight, its intact stability for several loading arrangements, analyse its sailing abilities, develop mechanisms of collapse, study the ship's demise, or adding light, noise and scent to the model.

Perhaps the main advantage that a digital model has over a wooden model is that it can be altered if new information has been gained and that it can be always be further refined and improved.

The weakness of my methodology of relying upon a visual evaluation for accuracy is that it makes the assumption that the viewer evaluating is knowledgeable about the construction of the vessel in order to determine if all the details are present, and what, if any, have been omitted. The strength of the methodology is its simplicity. A checklist of details could be drawn up and the two models could be directly compared. However, in this case there is no wooden model to compare to. Therefore, in order evaluate the accuracy, I will have to rely upon my 20+ years of model building experience to know what details would be provided upon a wooden model at any given scale, and what details would have been omitted, in order to allow a determination of the accuracy of the digital model in comparison to a non-existent physical model. So does the 3D model answer these research questions. If the time and knowledge factors are equal, the digital model is more accurate due to the ability to construct it to a 1:1 scale.

Can a 3D model of a ship be developed from the remaining ship lines and plans originally used to construct the ship over 200 years ago? The answer to this is a simple yes. By using the original ship plan and by using information from other ships of the line that we possess more information on, such as the *Bellona*, *Valiant*, and the *Invincible*, a plausible reconstruction of the *Colossus* can be completed.

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APPENDIX I

CHART OF WARSHIPS SIZES

Type	Keel Length m/(feet)	Beam @ breath m/(feet)	Keel L:B Ratio	Draft m/(feet)	Displacement – Tons	Source
Early – Frigate (1635)	29.87m (98’)	8.63m (28’-4”)	3.46:1	4.32m (14’-2”)	418	Winfield 1997: table 2: *Nonsuch*:9
50-gun (early - 1690)	30.48m (100’)	10.21m (33’-6”)	3.13:1	4.11m (13’-6”)	597	Winfield 1997: table 27: Spec. :28
50-gun (late - 1745)	35.88m (117’-8.5”)	12.50m (41’)	2.87:1	5.38m (17’-8”)	1152	Winfield 1997: table 59:51
50-gun (late - 1790)	37.98m (124’-7.5”)	12.50m (41’)	3.04:1	5.38m (17’-8”)	1106	Winfield 1997: table 79:62
60-gun (1726)	39.34m (117’-7”)	11.89m (39’)	3.01:1	5.01m (16’-5”)	1000	Winfield 1997: table 50:42
64-gun	37.80m (129’1”)	13.46m (44’-2”)	2.93:1	5.76m (18’-11”)	1299	Gardiner 1992: *Northumberland*:25
70-gun (1668)	37.80m (129’1”)	12.14m (39’-10”)	3.12:1	5.59m (18’-4”)	1406	Lavery 1983a: *Edgar*:106
70-gun (1730)	50.29m (165’)	15.14m (49’-8”)	3.32:1	6.78m (22’-3”)	1709	Gardiner 1992: *Princessa*:25
74-gun – early *Invincible* – French (1744)	43.05m (141’-3”)	15.01m (49’-3”)	2.88:1	6.48m (21’-3”)	1793	Gardiner 1992: *Invincible*:26
74-gun – *Bellona* – English (1760)	42m (138’)	14.3m (46’-11”)	2.94:1	6.53m (21’-5”)	1615	Lavery 1985: 30
74-gun – *Colossus* – English (1787)	43.36m (142’-3”)	14.55m (47’-9”)	2.98:1	6.83m (22’-5”)	1703	Author’s Collection, *Colossus* -Ship Plan – Print J3067 RMM
74-gun – *Pompée* – French (1791)	46.38m (152’-2”)	14.95m (49’-0.5”)	3.10:1	6.65m (21’-10”)	1901	Gardiner 1992: *Pompée*:26
74-gun – *Montañes* – Spanish (1794)	48.77m (160’)	15.54m (51’)	3.14:1	7.77m (25’-6”)	1500	Gardiner 1992: *Montañes*:26
100-gun Victory English (1765)	46.13m (151’-4”)	15.80m (51’-10”)	3.01:1	8.76m (28’-9”)	2142	McGowan 1999

APPENDIX II

THE CAPTAIN'S ACCOUNT OF THE LOSS

ADM1/2136

Duplicate

St. Mary's Scilly December 12th

Sir

It is with great concern that I am to request you will inform their Lordships of the loss of His Majesty's Ship Colossus, late under my Command on the night of the 10th Inst. In my letter of the 8th I informed you of my having put into St Mary's with the Convoy, the wind being from the Eastward – on the 9th it blew strong from the ESE & SE but as the wind was from the shore and the water in consequence smooth I had not the smallest apprehension that he ship would drive – On the 10th the wind considerably increased – I sent the master of sound for some distance round the ship, to see if there was any foul ground – he returned with an account of its being perfectly clear, and that it shoaled very gradually toward each shore, we were then in eleven fathom water & apparently good holding ground, with a whole Cable out, which cable had never been used before – The Top Gallant Masts were struck & the other two anchors were ready for letting go – The third anchor having been supplied to the Vanguard at Naples – about four in the afternoon the Cable parted – the small Bower was immediately let go, & after Veering to a Cable she bought up, having then the Sheet anchor only left, & every appearance of its' continuing to blow hard – I wished to go to sea, but the Pilot told me it was impossible, as we should not have daylight to go through the Rocks – In this case it became necessary to prepare the ship for riding the Gale out – The Sheet anchor therefore was let go, & the Yards & Top Masts struck – I flattered myself with the Cables & anchors would then hold, but about half past five, the Small Bower anchor came home, & we were obliged to veer & let her ride between both – About six she struck the Ground – but not so hard as to be of consequences – The throwing the Guns overboard & cutting the Masts away was then an object – I therefore consult Captains Peyton & Draper, the first Liut. & the Master - & having taken everything into consideration, we were all of opinion that it would be better not to throw the guns over, as the ship might beat on them, or to cut the Masts away, there being a prospect of getting to Sea at daylight with the flood tide, should the wind either off the Shore, or even not get more to the Southward – It was likewise taken into consideration that should she bulge the tide might flow over her - & by keeping the Masts, the lives of the People might be saved by hanging in the rigging & tops till relief could be got – About 8 O'Clock the Wind unfortunately drew more to the Southward, by which she tailed in Shore. It then blew a very hard Gale of wind – we still kept her free with our pumps & I had hopes by heaving on one Cable & bousing in the Slack of the other, as the tide ebbed to keep her afloat – having then seven fathom water under her Stern, & knowing, by having tried with the Boat, that there was more water ahead of us, as the water decreased we continued to heave till we go to near half a Cable on each anchor, when she again struck with great violence & shortly after gained on our Chain Pumps – We then man'd all the pumps baled with half-tubs & Buckets. About Midnight the Rudder went, it still continuing to blow very hard, & the night very dark – Signals of distress were repeatedly made from the first of our driving, but situated as we were, we could expert no relief till daylight. The ship was now gaining on us very fast, and we were apprehensive should the Ebb force the ship to the Southward, that the next flood might be over the ship. The Masts therefore became a serious object to keep for the reasons I before stated – before daylight in the Morning, I had assembled the people on the Quarter Deck & Poop – the water then being up to the Cills of the Ports of the Upper Deck, & with her rolling frequently struck on the Quarter Deck with great force. About 8 we saw Boats coming to our assistance & as the saving of the People then become the only object, I directed the Sick & Invalids to go in the first Boat, and the People by Division in the other Boats as they came. By the exertions of the People belongings to the Islands of Scilly in bringing their Boats to our assistance, I am happy to say, that before three O'Clock in the afternoon I saw the last safe out of the Ship, one only having drowned, who had feel overboard in the night – had we waited another hour, we could not have got away, as the People of the Boats said they could not have stayed there without almost a certainty of being lost. The whole of the Crew were landed on St Mary's except about one hundred which I obliged to send in the Ship's Boats to the Island of Bryer – that island being to Leeward, & the Boats not being able to pull to windward – I directed the Officers to come to St Mary's with the People, as soon as the weather would permit, but the Gale not having abated, I have not yet heard from them. At Daylight this morning I observed the Ships on her beams ends, so that she must have fell over early in the night. I am happy in the reflection that the People were all safe out of her before this took place, as no Boats could have gone to assistance to-day. Whenever the weather moderates, I hope many of the Stores may be saved as well her Guns. I feel myself much obliged to Captains Peyton & Draper for the great assistance I received from them – every exertion was made by the Officers & Ship's Company, & it is not possible for any Crew to have behaved more orderly & Obedient. I beg you will inform their Lordships, that had I not been for the great energy & attention of Major Bowen the Commanding officer of the Fort, in sending Boats to our assistance the moment the signals of distress were heard, many must have Perished. He has likewise been unremitting in his services since we have landed in allotting houses to receive the People & procuring food &c for them on their landing. I shall send to the Commanding Officer of the Ships that may be at Falmouth, to acquaint him with our situation & to request some ship may be immediately sent to take off part of the Crew, & shall await their Lordship's order for my further proceedings with the remainder. Whenever their Lordships may think proper to order a Court Martial to inquire into the lost of the Ship, I request they will be pleased to direct that Captains Peyton & Draper may attend- & flatter myself that the result of the enquiry will acquit me in their Lordships Opinion of any neglect or blame.

I have the Honor to be

Sir,

Your Obedt humble Servt

Geo Murray

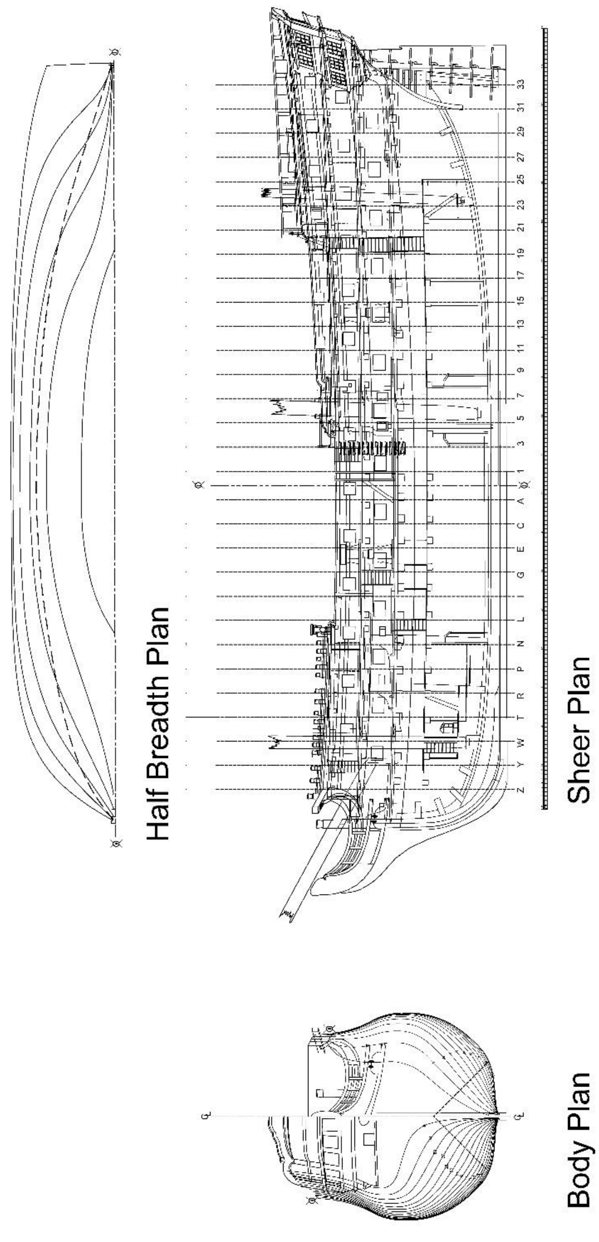
December 14th

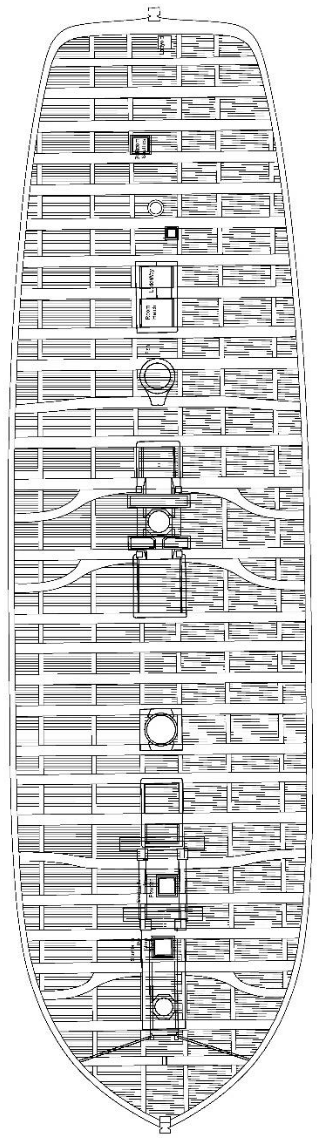
P:S: - As no boats has yet been able to get out, I have further to observe, that since my writing the above. The Colossus's Main Mast is gone, part of her Larboard side appears beat in, & the Guns of course fell over. I am therefore apprehensive there will not be many of her stores saved.

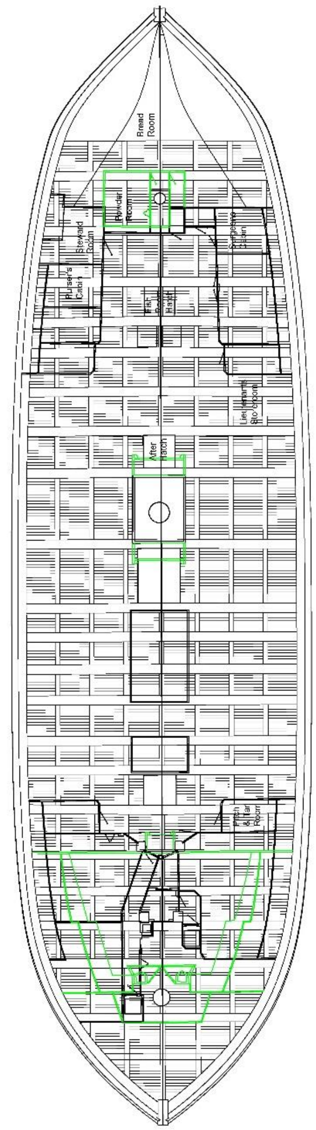
GM

APPENDIX III

WORKING DRAWING






Bread Room
Powder Room
Steward Room
Purser's Cabin
After Hatch
Pitch & Tar Room