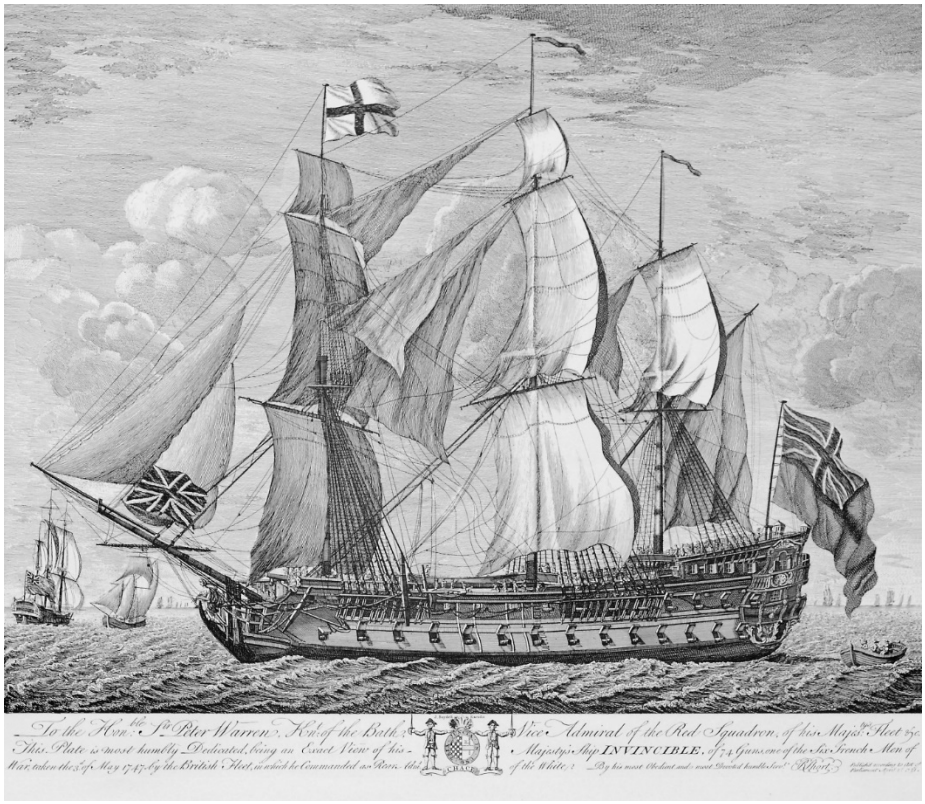
The Rigging of *HMS Invincible*



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Abstract

This research will catalogue and record the rig of the *HMS Invincible* at the time of its wrecking and compare and contrast findings with historical, iconographic and other archive records from the time in order to reconstruct the type of rigging it carried. The rigging is the most important part of the ship, allowing it to travel long distances and manoeuvre in battle and coming into port; however, as it is a rare survival in the archaeological record most of the information about rigging in the period has been taken from historical sources and ships models. However, it remains unclear how accurate historical records are, as they have never been tested against physical evidence with regard to these details; being able to compare rigging reconstructed from the rare primary archaeological evidence available from *HMS Invincible* with that documented historically will allow reconstruction of this crucial element of the ship and also demonstrate the accuracy of historical documents and thus how far archaeologists and historians can rely on these complementary lines of evidence in other contexts.

HMS Invincible offers a unique opportunity to validate the historical documents in this way due to the extraordinary preservation of the rigging from this shipwreck. Rigging is a rare survival on shipwrecks with the majority either being washed away in the wrecking process or recovered through contemporary salvage. Where rigging tends to survive it is usually in stores or trapped underneath the main wreck, meaning that most will not be discovered unless there is extensive excavation. Of the 305 Royal Navy wrecks lost between 1670 and 1770 only 24 have been archaeologically investigated, of these 24 of *Invincible w.*1758 and *Dartmouth w.*1690 have produced significant rigging collections with most sites producing no rigging or just tropical hardwood sheaves.

The *Invincible* is also of enormous significance as it marks a transition point in ship technology. *Invincible*'s career dates to an historical period right at the tail end of what can be best described as 'traditional' shipbuilding technologies and materials. Indeed, it has been argued that the drive to improve ship-building technology to remain competitive in an increasingly globalized marketplace (as well as to protect and defend national interests against competitors via warfare) was a major factor driving industrialization. Increasingly global trade also provided new materials such as tropical hardwoods from the colonies for use in hand-crafting individual rigging elements. Such changes that led to further technological developments, thus ratcheting technological development in this and other arenas. Tropical hardwoods appear in the archaeological records in *c.*1665 and by 1770 the Royal Navy adopted lighter machine-made blocks, making this period a turning point in shipbuilding technologies.

Although various part of the rigging has been individually recorded and described, this material has not been studied as a whole and the accuracy of historical documentation is debatable. This MRes will examine the archaeological evidence, reconstruct the likely configuration of the rigging *Invincible* carried based on this primary evidence, and compare that with evidence from the historical records for the time, focusing on the periods between the appearance of tropical hardwoods in ship manufacturing technology and the adoption of light machine-made blocks in 1665. The result will be a much greater understanding of the most important part of maritime technology at a critical point in the history of shipbuilding.

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Introduction and Background

This thesis aims to establish to what extent the rigging assemblage recovered from the wreck of *Invincible* can extend and inform us about early to mid-18th century rigging practices beyond what has been established from historical sources and ships' models.

This study focuses on the rigging materials recovered from *Invincible,* a Royal Navy warship, wrecked in 1758. It catalogues and records the rigging material recovered from the various excavations of the site between 1980 and 2019 and uses this data as well as historical accounts of the ships to attempt to reconstruct the rigging of the vessel and place the archaeology into the complex propulsion system.

The rigging is the most important part of the ship, allowing it to travel long distances and manoeuvre in battle and coming into port; however, as it is a rare survival in the archaeological record most of the information about rigging in the period has been taken from historical sources and ships models (Lees, 1979). It remains unclear how accurate historical records are, as they have never been tested against physical evidence with regard to these details; being able to compare rigging reconstructed from the rare primary archaeological evidence available from *Invincible* with that documented historically will allow reconstruction of this crucial element of the ship and also demonstrate the accuracy of historical documents are accurate and thus how far archaeologists and historians can rely on these complementary lines of evidence in other contexts.

The *Invincible's* significance is that it marks a transition point in ship technology. *Invincible*'s career dates to an historical period right at the tail end of what can be best described as 'traditional' rigging technologies and materials. Indeed, it has been argued that the drive to improve ship-building technology in order to remain competitive in an increasingly globalized marketplace (as well as to protect and defend national interests against competitors via warfare) was a major factor driving industrialization. Increasingly global trade also provided new materials such as tropical hardwoods from the colonies for use in hand-crafting individual rigging elements.

Although various part of the rigging have been individually recorded and described, this material has not been studied as a whole and the accuracy of historical documentation is debatable. This MRes will examine the archaeological evidence, reconstruct the likely configuration of the rigging *Invincible* carried based on this primary evidence, and compare that with evidence from the historical records for the time, focusing on the periods between the appearance of tropical hardwoods in ship manufacturing technology and the adoption of light machine-made blocks in 1665. The result will be a much greater understanding of the most important part of maritime technology at a critical point in the history of shipbuilding.

Introduction to Rigging.

The rigging is a series of ropes and blocks designed to support the masts of the vessel (standing rigging) and control the sails (running rigging). This complicated interconnected system forms the primary means of propulsion for the ship.

Although there is some debate on whether the whole system or a part can be considered rigging, for the purpose of this paper we will consider the whole system from the masts to the sails as they are all interconnected.

Archimedes' principle states that a ship will have an upwards buoyant force equal to the weight of water it displaces. For a large warship like *Invincible* this would amount to several 100 tonnes of water and vary depending on the volume of stores and men etc. Once the ship is floating the next step is to

get it to move, to do this it must displace the same amount of water. The larger the ship the more water it will need to displace and therefore the greater the thrust that needs to be produced.

Smaller vessels could be propelled by oars, but as ships got bigger wind power was harnessed using sails. Early sails in prehistory were probably simple ad-hoc ways of exposing the surface area of an object, such as a sheet, to the wind (McGrail, 2008, p. 218). This would have been sufficient for a small vessel in calm, sheltered conditions where the wind was blowing in a convenient direction. To expose a sufficient surface area of sail to effectively move the ship, masts became a permanent feature. Standing rigging developed to support this and running rigging to control the sails.

Uniquely with rigging, although there may be some minor regional differences, there seems to be a pan-European evolution with the various navies and shipbuilders following the major changes in rigs.

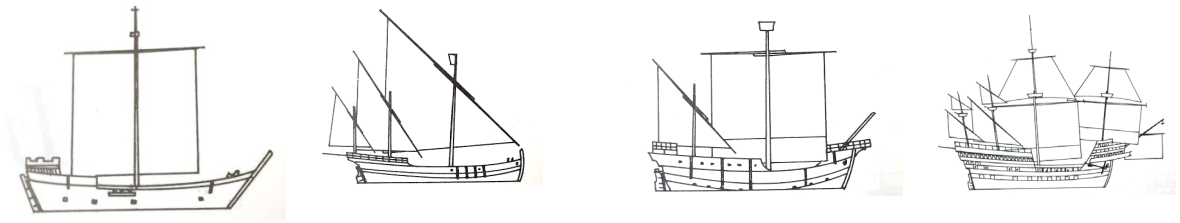
In Northwest Europe, the single-masted square-sailed, so called because its yard sat at 90° to the keel, vessel developed and became the standard up until the 14th century.

In order to effectively sail in a chosen direction, rather than just the direction of the wind, the sails must be angled to propel the vessel, become a type of wing or aerofoil with the wind flowing around the sail, generating lift and therefore forward momentum. With a single square sail this produced good performance and power, but it was limited in how close to the wind it could sail because of this. To get from A to B one has to tack, or zig zag, across the wind, increasing the time it takes to reach a destination.

In the Mediterranean sphere of influence a different type of rig was used, the yards would be rigged ‘fore and aft’, and a triangular lateen sail was hung from this. The lateen sail had less surface area, and therefore less power, but a more aerodynamic shape allowing it to sail closer to the wind. Another disadvantage of the lateen rig was that it was harder to manage, especially when tacking, as the yard would cross the mast and the rigging aft of the mast.

The next issue would be how to control the sails, which would not only weigh several hundred kilograms in addition to the added pressure of the wind. For this, simple machines such as levers and pulleys were developed and go far back as human history, with rigs appearing in iconographic evidence from ancient Egypt in 3500 BC and the first known blocks seen in Greek art in the 6th century BC. The oldest archaeological examples were recovered from the Kyrenia shipwreck lost in the 3rd Century BC (Howe, 2011).

Over the centuries ships and their rigging co-evolved, compromising between manageability and exposed surface area of the sails. This resulted in three-masted vessels with a bowsprit becoming the standard for the large European ships, such as carracks, in the 15th century that were engaged in trans-oceanic travel. The main and foremast of the carrack was square-rigged, providing the power and sharing the load and therefore the strain on the hull and the rigging. The mizen mast was rigged with a lateen sail, aiding in the manoeuvrability of the vessel. On the larger ships, such as galleons, a fourth lateen-rigged bon adventure mast was placed aft of the mizen. This increased the range and size of the vessels and meant they could sail closer to the wind, allowing for the long-distance travel that marked the beginnings of the overseas empires of the various European powers. By the 17th century the various naval powers started to build specialised warships, which differed in purpose to the previous merchant vessels, the emphasis being on armaments and manoeuvrability rather than cargo, leading to the development of the ship of the line (Unger, 1994).



Cog 1380 *Caravel 1450* *Nao 1450* *Carrack 1545*

Figure 1 Evolution of the Ship rig in the 15th century after (Unger, 1994)

As the world opened up, so did the market for new materials to improve on the technology of the age. Before the end of 17th century rigging blocks tended to be handmade from local timbers, for example the blocks recovered from the warships *Mary Rose* (w.1545) (Marsden, 2003) and London (w.1665) tended to be a mix of elm (*Ulmus sp*.), ash (*Fraxunus Sp.*), beech (*Fagus sp.)* and holly (*Ilex Sp.*) (Hazell & Aitken, 2019). Towards the end of the 17th century tropical hardwood imported from the Americas began to be used for rigging, this was imported under the name of *Lignum Vitae*[1]*,* but it could have been a range of similar timbers. Commissioner Thomas Middleton mentioned to Pepys in 1665 that this timber was not suitable (ADM 106/977/260), but by 1677 the Royal Navy (RN) had begun to outfit its ships with the new timber (ADM 106/321/434B). However old-style blocks were still in circulation with a mix of local wood and Tropical Hardwood sheaths being found on the *Dartmouth* 1690 (Martin, 1978) and the *Stirling Castle* 1703 (Whitewright, 2020). The historical rigging lists from Sutherland (1711, p. 119) also show a mix of ash and L*ignum vitae*. This suggest that a technology change in block-making occurred which allowed the use of the harder wearing blocks to become standard use in the Royal Navy in the sheaves and pins. The blocks would have essentially been made in the same way but using better materials for a stronger, longer lasting, self-lubricating block. However, as *Lignum vitae* is almost twice as heavy as ash this would increase the pressure on the masts and the rigging overall, therefore meaning that there would have to be an evolution in the rig and technology to cope with the excess weight.

The major change in ship design and rigging came at the very start of the 18th century where the ship's wheel first appears, replacing the whip staff, with the earliest historical evidence shown in 1703 (Harland, 1972). However, a fixed block recovered from the *Stirling Castle* lost in 1703 (Middleton, 2016) shows that these were probably retrofitted to British warships in the last decade of the 17th century. The change in rudder control systems was probably linked to the change in rigging technology with the stronger materials, mainly *Lignum vitae* which had the added benefit of being self-lubricating and therefore requiring less maintenance, making it possible to control the pressure generated whilst operating the rudder.

The change from rudder to wheel improved the ship handling and steering dramatically from the days of the whipstaff and therefore started to influence the rig of the ship. It has been suggested by RC Anderson (Harland, 1972) that the spritsail topmast, a vertical mast at the end of the bowsprit, began to be phased out, with an extension mast, or jibboom, becoming the standard for ship rigs across Europe because of this change.

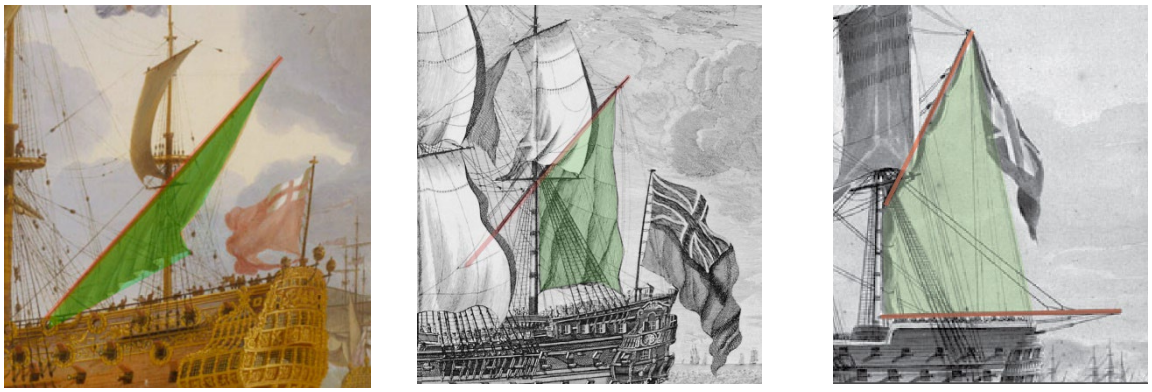
The change in materials from ash to lignum at the turn of the century also allowed for a stronger rig, which can be seen in the development in the sizes of the yards carried on British warships with the

[1] *Lignum Vitae is common name for timbers derived from the heart wood of Guaiacum Sp.* Although other tropical hardwoods are sometimes given the same label, exact species ID are beyond the scope of this paper

length of the top yards considerably lengthening between the start of the 18th century and the 1719 Establishments and again in the 1745 Establishments (Lavery, 1984, p. 73).

This can be seen in the changes between a 70-gun ship of 1692 and a vessel of the 1719 Establishment[2], the set of plans and equipment all Royal navy ships has to follow, where the topsail and topgallant yards were "considerably lengthened" adding square and larger upper sails. By the 1745 Establishments, they were further extended, and a jibboom was added to the bowsprit (Lavery, 1984, p. 73).

Another obvious change which comes with the improved manoeuvrability of the wheel-controlled rudder is the gradual phase or the Mizen course from a full lateen sail at the start of the 18th century to the Gaff of the late 18th century with a transitional phase of type of lug sail on the lateen spar with the fore edge laced down the mast (Figure 2). This would mean less surface area of sail but more working space on the deck making the sail easier to handle.



Royal Prince (van Beecq, 1679) *Invincible* (Short, et al., 1751) *Theseus* (Buttersworth, 1797)

Figure 2 The change in the mizen course throughout the 18th century from Lateen to Gaff

In 1756 Walter Taylor (d.1759) and his son purchased a block making company and began to develop smaller, lighter and stronger blocks, by changing the pin from *Lignum vitae* to iron and adding a metal coak, a type of bearing, to the sheaves. This reduced the amount of friction on the blocks (Clarke, 1976). The manufacture of these blocks also started to rely on machinery, allowing blocks to be produced faster and to a higher quality. Taylor's blocks were first tested by the Navy in 1770 on *HMS Centaur* and due to a fire at the Portsmouth block store shortly after this resulting in the loss of the whole supply of ordinary blocks, the Taylor blocks became the standard blocks used after this date. This monopoly held until 1802 when Brunel's steam-powered block making machines started to be installed at Portsmouth Dockyard (Coad, 2005). However, Taylor's blocks were still present on the *St. George* which wrecked in 1811 off the Danish Coast. Brunel's stronger and lighter blocks allowed the rigs of the warships to evolve, with an additional royal mast placed above the topgallant and the mizen-course being changed for a gaff-rigged spanker sail.

Invincible

With the advent of globalization and colonization by the major European powers it was clear that a new type of ship needed to be designed, capable of holding its own in battle whilst also having the sailing quality to travel the vast distances required to protect the countries' interests many thousands of miles away. British ship design stagnated with the cumbersome three-deckers built to the formal set of state approved designs known as the *Establishments*. However, French shipbuilders were given free rein with their designs with the French government only specifying the number of guns the ship

[2] The formal set of ship designs all Royal Navy warships had to follow

should carry (Lavery, 1988, p. 4). In 1737 the Toulon based shipbuilder Coulomb developed a new type of two-decked 74 by lengthening the hull, allowing for an extra two heavy guns per deck and eliminating the need for lighter arms higher up in the poop. He also increased the weight of the guns on the lower deck making his 74, *Terrible*, equal in weight of ordnance to all "but the largest three-deckers of the Royal Navy" (Lavery, 1988, p. 3).

The designer of *Invincible*[3], Morineau, appears to have had significant knowledge in ship design and improved on Coulombs' plans, increasing the length of the gundeck by 6ft to give more space for the men working the guns but shortening the keel to improve sailing performance (Lavery, 1988). The plans were approved by the French government and work began on the construction of the ship with its masts added in January 1744 (Lavery, 1988).

As with most large ships of the time *Invincible* was a three-masted fully rigged ship, a type which has a pan-European history back to the mid-15th century (Unger, 1994). Having three masts and a bowsprit on a vessel was seen as the most advantageous and manageable layout to give the most surface area of sail with square sails on the fore, main and top mast of the mizen and a lateen sail on the mizen (Steel, 1794). It is likely that in French service *Invincible* had a full lateen sail on the Mizen mast with the 'English' style of mizen course laced down the mast not becoming popular in France until the 1750s (Boudriot, 1987, p. 89)

Invincible spent three years in French service before finally being captured at the battle of Cape Finisterre in 1747. During the battle the main and foremast of *Invincible* were completely shot away, meaning that the ship had to be towed back to Portsmouth where they were surveyed by the Admiralty who deemed that "all the masts and yards except the bowsprit" had to be replaced (NMM/POR/D/9) "exactly the same as when she was taken from the enemy" (ADM 106/1044/16). This caused an issue, as *Invincible* did not fit into the Royal Navy Establishments. The Establishments mean that royal navy logistic supply was simplified with standardised with identical parts being used throughout the fleet. In some parts *Invincible*'s surviving rigging exceeded the established size of rigging for the 100-gun ship and in others it sat between the 100 and 90-gun ships (ADM/106/1046). As the Admiral in charge of the refit, Sir Peter Warren, did not understand the rules for masting, it was left to Pierson Lock the Master Shipwright of Portsmouth Dockyard to submit and calculate the size of the masts to be given to *Invincible.* Lock along with the other Master Shipwrights from the other Naval Yards were also involved in the final designs for the various rates of warships in the 1745 establishments. He chose to use masts slightly smaller than those standard for the 100-gun ship, but larger than those of the 90-gun vessels (ADM/106/1046).

This choice and layout of the masts caused issues throughout *Invincible's* career in the Royal Navy (Lavery, 1988, p. 35). It was found on the first trip out that the foremast, one recycled from old stock, was rotten. This led to Captain Lloyd noting that, due to the shipyard not wanting to stray too far from the Establishments, *Invincible* was "greatly overmasted" and it was "impossible to secure her masts in bad weather". He noted that if the issues were dealt with and *Invincible* was rigged correctly it would be one of the best ships in the navy (Lavery, 1988, p. 41). However even with these faults *Invincible* was still regarded as one of the fastest vessels in the Royal Navy at this time.

It was unclear if the rigging was changed during the great refit of 1754-56 as no progress reports survive, however we do know that *Invincible* lost its masts again during a hurricane in 1757 off the

[3] The ship was built as *L'Invincible* and retained the name throughout its service in the French Navy. Once captured by the British the ship was renamed *Invincible.*

coast of Canada during the first Louisbourg Expedition and had to be jury rigged for its return to Portsmouth (Lavery, 1988, p. 92).

On return *Invincible* must have been refitted with new masts and the associated rigging and was reequipped to return to Louisbourg and anchored at St. Helens Roads. At 0230 on the 19 February the order was given to weigh anchor (Bingeman, 2015, p. 20). However, *Invincible*'s anchor was stuck on the seabed and a series of calamitous events followed, leading *Invincible* to run aground on the Horse Tail sandbank.

Attempts made to lighten the load on the vessel and drive *Invincible* off under full sail failed and by the 22nd of February the ship fell onto its beam ends. Once it was decided that the vessel was a total loss a salvage program began, removing as many stores, arms and rigging as possible. These included items from the carpenters' stores such as the spars, and upper masts and a variety of blocks, ropes and sails (PRO/D/13). Salvage of the vessel continued with several gangs of shipwrights trying to save as much as possible, and on the last day of February the main mast was cut away (Whitehall Evening Post, 1758) most likely to prevent any leverage damage to the hull. Several other salvage attempts of the hull occurred, but a survey in May showed that the stump of the main mast had forced itself out of its step and the hull was greatly twisted and cambered (PRO/D/13), leading to the decision to declare *Invincible* a loss. After this more salvage took place over the summer, including the removal of the bowsprit and mizen mast, with the foremast being cleared in the September.

Archaeology

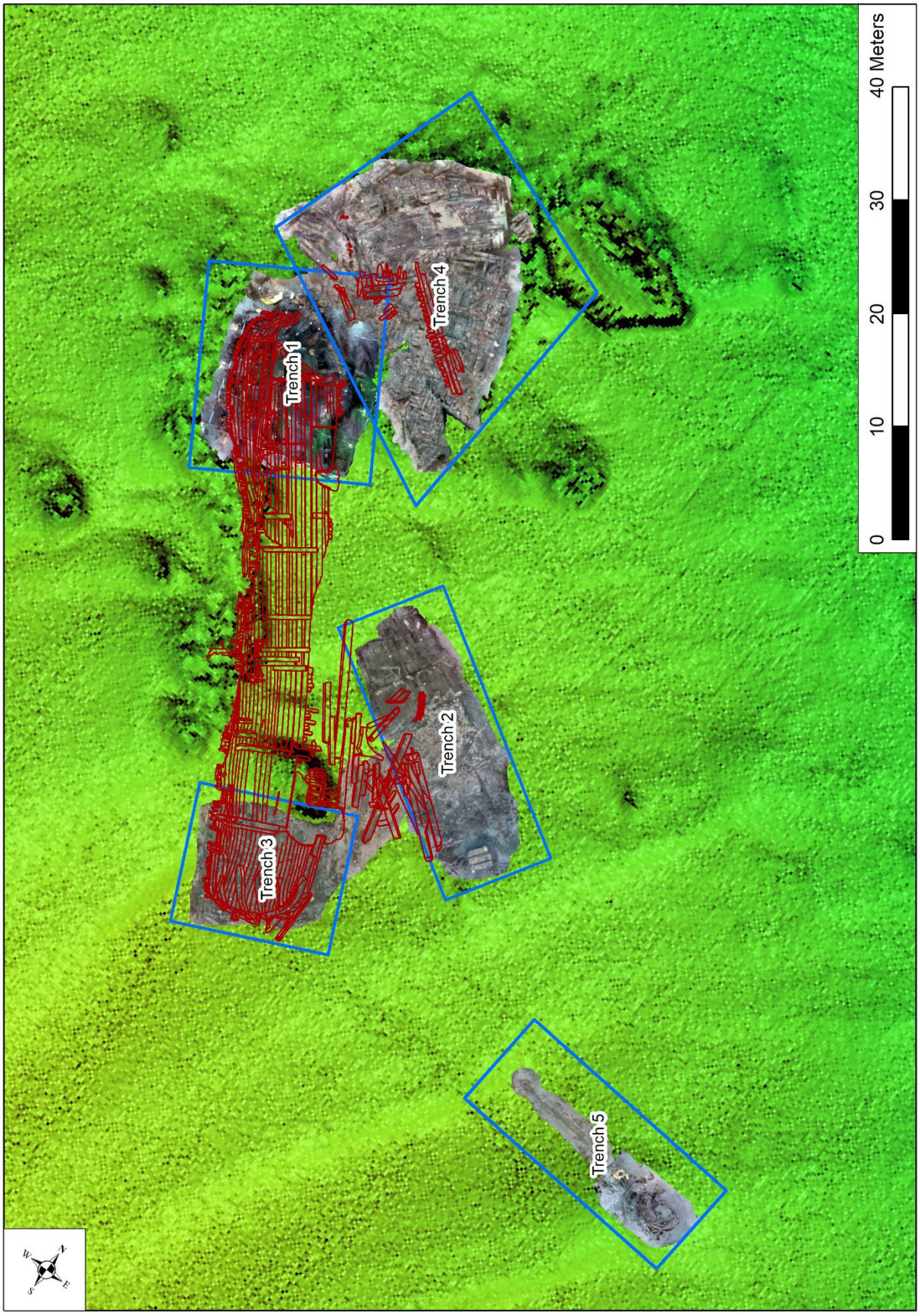


Figure 3 2019 site plan of Invincible (red lines mark the location of the 1980s excavations)

1980 excavations

The ship eventually began to break apart and was not seen again until discovered by Arthur Mack in 1979. John Bingeman joined the team shortly afterwards and they began a series of excavation of the wreck which lasted until 1991. During these excavations 664 rigging elements were reported to have been recovered and some basic measurements taken, including 94 items that were acquisitioned by Chatham Dockyard, the rest were either disposed of or sold to private collections. The majority of these finds were thought to have come from the bosun's store located on the orlop deck (Bingeman, 2015, p. 89)

Due to the construction of a sewage outfall 370m from the site all work ceased in 1991, with Bingeman remaining the licensee until 2010 when it was passed to Dan Pascoe who continued to monitor the site.

2017 excavations

Between 2017 and 2019 Bournemouth University began a new phase of excavations recovering a further 225 rigging related artefacts.

This concentrated in five main areas:

Trench 1, which encompassed an area of the port side bow of the vessel which included a large rope store which has been interpreted as junk[4], coils of cable on the orlop deck and large structural elements such as the cutwater.

Trench 2, an area which covered the midships keel where several artefacts relating to the masts were located including mast caps and potentially the main mast step.

Trench 3, the port side stern of the vessel and Trench 4, three coherent section starboard hull which revealed little in terms of rigging.

Trench 5, (Figure 4) was located approximately 30m south east of main site, in the final days of the excavation, a small amount of rope was exposed which was immediately recognised as the mouse of the mainstay upon excavating area the complete main and preventor stays were uncovered as well as other artefacts related to the main mast top.

[4] Junk is the name given to any remnants or pieces of old cable, which is usually cut into small portions for the purpose of making points, mats, gaskets, sennit and gun wads (Falconer, 1769).

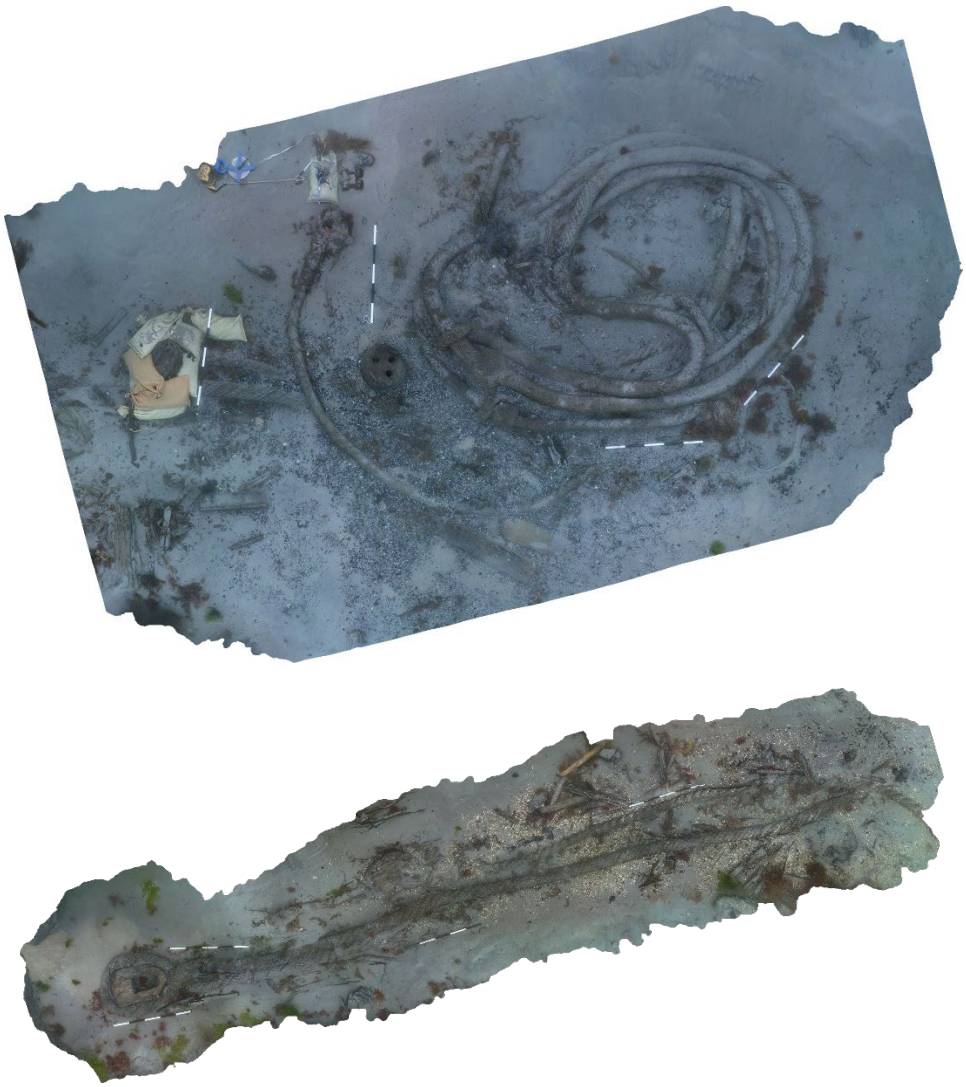


Figure 4 Upper and lower sections of Trench 5 showing the Main Stay and other associated lines (scales are 1m)

Significance of the *Invincible's* Rigging?

The various excavations of the *Invincible* have left us with an unparalleled collection of rigging material which currently sits out of its original context as the main complex part of the ships propulsion system. Several of the finds were likely to be spares kept in store to replace and repair *Invincible's* rig as and when it was needed.

The rigging is one of the largest categories of artefacts recovered from the site and the excavations by Bournemouth University have made it possible to record in detail these features and artefacts.

Prior to the advent of maritime archaeology our only insight into the rigging practices of the past come from historical texts such as those by Dean (Lavery, 1991), Sutherland (1711) and Steel (1794). All of these are shipbuilders rather than riggers, and as a result they tend to quote others rather than understand the issues themselves: for example, Dean states that rigging is more "proper for a master of attendant than a shipwright" to cover (Lavery, 1991, p. 81).

A second primary source of information is historical ships' models often built by the same people building the actual ship as a sort of proof of concept. Accurate models appear in the mid-17th century (Ball & Stephens, 2018); these focus mainly on the hulls but do include rigging and rigging features. However, due to issues with scaling and the constant repair, whilst the rigging is recorded it can't be

established whether the rigging had been repaired in antiquity and whether it was like for like or the ship was re-rigged using the techniques of the period during which it was repaired.

Most modern secondary sources on rigging were written before the advent of maritime archaeology and only draw on the above-mentioned sources. Lees (1979) notes that changes have occurred in the rigging practices, but does not go into detail about why, or about technological changes, as the primary audience for these secondary source such as Lees is for model makers rather than academic research with Lees himself stating that he will not go into great detail about elements of the rigging he does not consider to be "of any use to the modelmaker" (Lees, 1979, p. xi).

Rigging in the archaeological record tends to be rare, unpublished, and where mentioned, lacking details and consistency (Sanders, 2010). Shipwrecks as a rule tend to be disastrous events usually caused by running aground, striking an object or capsizing in bad weather. In all of these circumstances it is likely that the majority of the rigging would be lost either before the wrecking process in an attempt to save the ship, during the wrecking itself, or afterwards, due to salvage. An extreme example of the loss of rigging at sea comes from the East India Company ship *Halsewell,* which wrecked in 1786. The ship lost its mizen mast in a storm in the English Channel, and shortly afterwards the decision was taken to cut down the main mast to relieve the pressure on the hull, and finally the foremast was overcome. By the time of its wrecking, *Halsewell* was completely de-masted, and the site was heavily salvaged after the wrecking.

The survival of rigging beyond the initial wrecking is highly dependent on the site conditions. On sites with high preservation like the Swash Channel Wreck and *Invincible* it can be expected that rope, blocks and even sail can survive, but on more exposed sites this can be lost leaving only the more robust finds such as the tropical hardwood sheaves or brass coaks, leaving a survival bias in the record.

The wreck then needs to be found and investigated, and this includes only a very small sub sample. For example, of the 407 Royal Navy warships known to have been lost in the 18th century only 28 have had some form of investigation conducted (MAST, 2010). Of these, only four have been published in an archaeological journal and only one, *Invincible*, has produced a significant rigging collection.

Even on sites with good preservation that are excavated, much of the rigging is usually absent from the archaeological record, due to it not being contained within the wreck, where the concentration of work normally occurs. It is only by chance large rigging elements such as *Invincible's* main stay were located and excavated. This leaves the rigging that was in store, such as with *Dartmouth* 1690 (Martin, 1978) and which is thus out of its original context or association with other blocks or ropes.

In addition, the complexity of recovering, conserving and recording rope means that it has often been ignored (Sanders, 2010). For example for the *Mary Rose* discussion of the rigging makes up less than 30 pages of one volume, including the note that "much more research is possible after conservation" (Marsden & Endsor, 2009, p. 242) even though this work was published 27 years after the wreck was excavated and only recently has more work been published on the *Mary Rose'* rigging, notably the large cables (Sanders, 2019). In contrast to this, two whole volumes have been dedicated to the armaments of the ship.

Where rigging is published in archaeological records it tends to be out of context of the ships rigging and placed in a material category. One recent example is the publication of the *Stirling Castle*, which only records basic details of the artefacts within the material category of wood, whether or not this was just due to lack of material (Whitewright, 2020).

In more recent times it has become common for the rigging to be studied as part of a postgraduate dissertation for example the Newport Ship (McCarthy, 2012), *Vasa* (Howe, 2011), *La Belle* (Corder, 2007) and *Warwick* (Tsai, 2019). These ships are all of an earlier period than *Invincible* where there are less specific historic records available, and rigging was less regimented. The lack of comparative archaeological material published has meant that these reports do have to rely on limited data.

As a result of this under-representation in the archaeological record rigging tends to be understudied in maritime archaeology even though it was one of, if not the, most important element of a ship. Thus, it is important that the rigging material of *Invincible* is published in its correct context to allow for future study and comparisons.

Aims and Objectives.

The main aim of this project is to reconstruct a baseline rigging plan for the *Invincible*, to assess the extent to which the archaeological and historical, iconographic and other archive datasets align, and to aid archaeological assessment and interpretation of other, more limited rigging finds.

Objectives

- Catalogue and record the artefacts associated with rigging recovered from the various excavations of *Invincible* at the time of its wrecking.
- Review and synthesise historical, iconographic and other archive documentation relating the mid-18th century rigging and *Invincible*.
- Compare historical and archaeological lines of evidence.
- Reconstruct a rigging plan for *HMS Invincible.*
- Investigate how the archaeological evidence informs or challenges the current historic understanding of 18th century ships' rigging.

Methodology

Numbering Systems

Throughout the various excavations and museum accessions a variety of different numbering systems were used. During the original excavations finds were assigned a number based on the year they were excavated plus a unique ID for example "**86/0069**". These were added into a spreadsheet with a basic descriptions and dimensions. Off the finds that were accessioned by Chatham a new number was assigned in the format of **INV.XXX** for example the same find as above was renumbered "**INV.152".** The finds accessioned by Chatham had basic measurement and photographic records taken and can be accessed via their online collections catalogue: https://collection.thedockyard.co.uk/

During the BU excavations the find were assigned a tag with the site code "INV1744" followed by a unique identifier and recorded in a database, no differentiation was made between the various year of excavation.

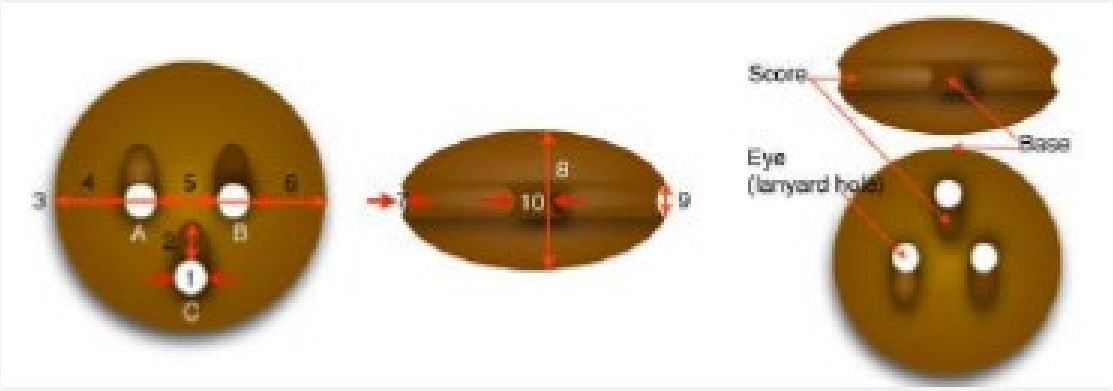
Finds Recording

During the 18th century, especially in the Royal Navy rigging became standardised and would have been described in relation to a key measurement in inches. For example, blocks would tend to have their heights in inches carved in roman or Arabic numerals (Figure 5). Rope on the other hand would have been recorded in circumference. For most of the finds from the 1980s excavations this is the only measurement that was taken however of the finds accessioned by Chatham photos and basic dimensions were also taken.

Figure 5 INV1744_3163 an 18" deadeye with carved XVIII

Further artefacts recovered by Bournemouth University (BU) in the 2017-19 excavation have been documented using set proformas taking key measurements of the artefacts these are then added to a matching database form within the site database. Referring to historical records of ship construction at the time allows us to use many measurements to inform on related artefacts. Using the deadeye as an example (Figure 6), measuring the score width and depth and the lanyards through measuring the diameter of the eyes allows calculation of the size of the shroud. Once conserved, the artefacts will have photographs taken and when feasible recorded via photogrammetry, however due to the ongoing Covid situation there has been a delay in this process.

Circular, 3 Eyed Deadeye Record Sheet



Feature No.		Finds no	3163	Timber ID	

Description	Deadeye
18" deadeye with XVIII inscribed on forehead	

Measurement No.	Description	Measurement					
1	Lanyard Diameter						60
2	Score Height						20
3	Diameter						450
4	Edge to Lanyardhole A						150
5	Distance between Lanyard Holes	A-B	120	5_B-C	145	5_C-A	145
6	Edge to Lanyard Hole B						290
7	Score Depth		32	Profile		Round	
8	Height						204
9	Score Width						78
10	Base Length						45
11	Is one eye flat/Unscored for stopper knot	☐					

Figure 6 Example proforma for recording deadeye INV1744_3163

Historical sources were sourced by searching the National Archives, and the National Maritime Museum, for any reference to the *Invincible* and general texts about shipbuilding and rigging in the 18th century, in particular the 1745 Establishments. Many of the general sources had also been synthesised by the secondary sources such as Lees (1979) mentioned above, which were also consulted.

Historical Evidence

General

Several contemporary sources in relation to the rigging that may have been on *Invincible* are known and have been heavily studied by historians such as Lees (1979) but as mentioned above these authors were not usually experts in rigging and were shipwrights like Sutherland or even poets like Falconer, leading them to repeat information that they may not fully understand (Sanders, 2010, p. 4)

Sutherland (1711) provides a rigging plan for a 60-gun vessel (Figure 7) and details the proportions of the rigging in relation to the masts and the size of the masts in relation to the ship's hull. However, his plan shows sprit topmast and no jibboom, elements that were obsolete by the time of *Invincible. S*o, although there will be some similarity with the *Invincible* there may be proportional differences. Sutherland published a second book in 1729 which gave and updated description of a variety of ships including one slightly shorter and narrower than *Invincible*.

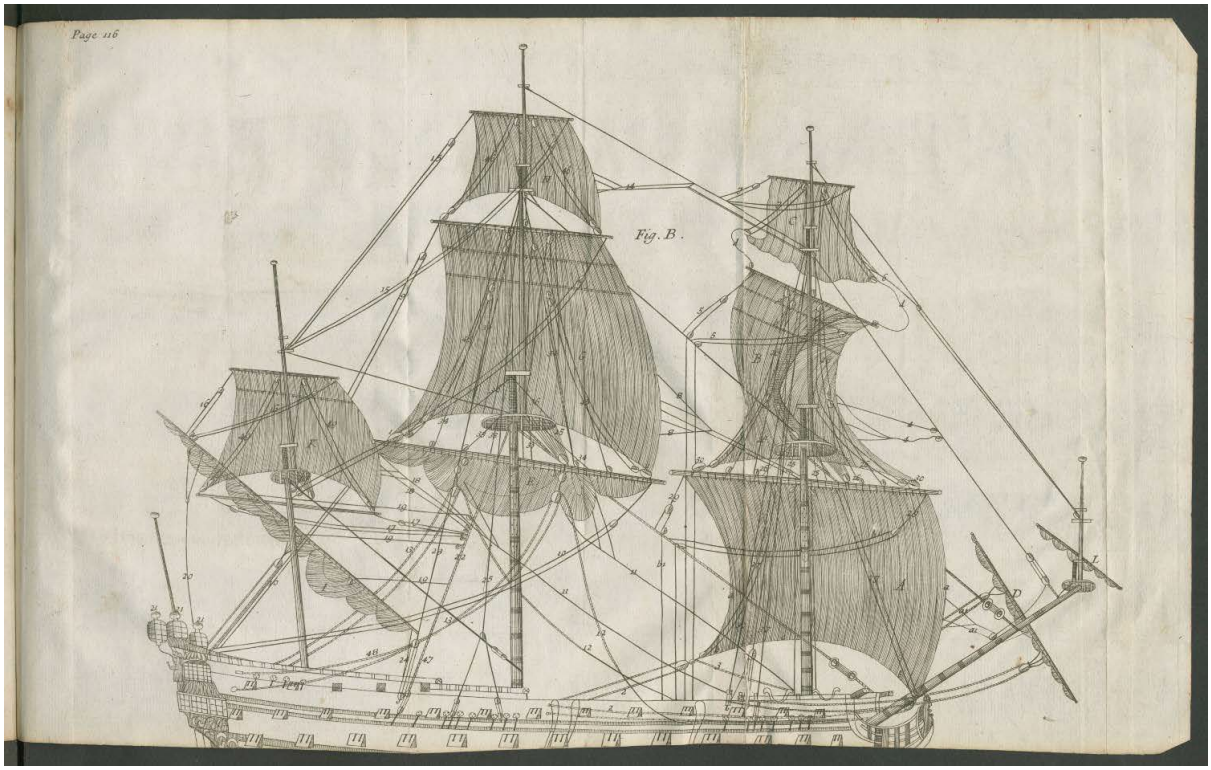


Figure 7 Sutherland (1711) running rigging plan for a 60-gun ship.

The formalised Establishments came into force in 1719, Lavery (1984, p. 171) list the exact size and lengths of the various rigging ropes used in a document from 1720 (BL Cup 651e, 28-31) however he believes that this document may be describing an earlier period pre-1680 as there are some obsolete elements such as bonnets included and other 18th century rigging like bobstays missing.

Lees (1979) includes the mast and spar sizes from several manuscripts and Establishments including the 1719 and 1745. He also includes two documents the Plymouth Yard manuscript from 1754 and

the 1773 establishment which includes the mast dimensions for the 74-gun ship Valiant, supposedly built on the lines of *Invincible*.

When *Invincible* was captured in 1747 the 1745 Establishments still applied, this still included the sprit top mast for the 80-, 90- and 100-gun ships; however, these are not included in the 1754 Plymouth yard manuscript, suggesting that the sprit topmast was dropped before the next set of Establishments 1773.

Capping off the 18th century, Steel's *Elements of Mast Making* (Steel, 1794) covers various aspects of Royal Navy warships; however, this is after the change to made masts, gaff mizens and Taylor blocks marking the next step in the evolution of rigging.

The 1745 Establishments

The Establishments have a general bad reputation with Lavery (1983) associating them with the stagnation of ship design in the Royal Navy and the politicising of the Navy Board with the dictation of the scantlings for each rate being rigidly adhered to. Whereas in comparison rival navies such as the French had the freedom to design their ships how they saw fit. Whilst this led to changes in design to create bigger and faster ships such as with *Invincible* the lack of uniformity and manufacturing processes would be a bigger issue for large organisations such as the Royal Navy. The Establishments would allow for a tested and approved ship design signed off by the master shipwrights of all the yards to be universal and interchangeable this would improve and allow for international logistics improved the overall efficiency of the Royal Navy.

The 1745 Establishments improved on the 1719 Establishments to produced larger and better designed ships (Lavery, 1988, p. 91). Within these Establishments the lengths and diameters of the mast and spars of each rate was dictated as well as the size of the tops (PRO/ADM/95/12). To complement these masting plans of the various rates were also produced by the Admiralty for each rate (Figure 8) these were part of the private Hillhouse collection acquired by the National Maritime Museum in the 1980s and feature some of the standing rigging of the lower masts.

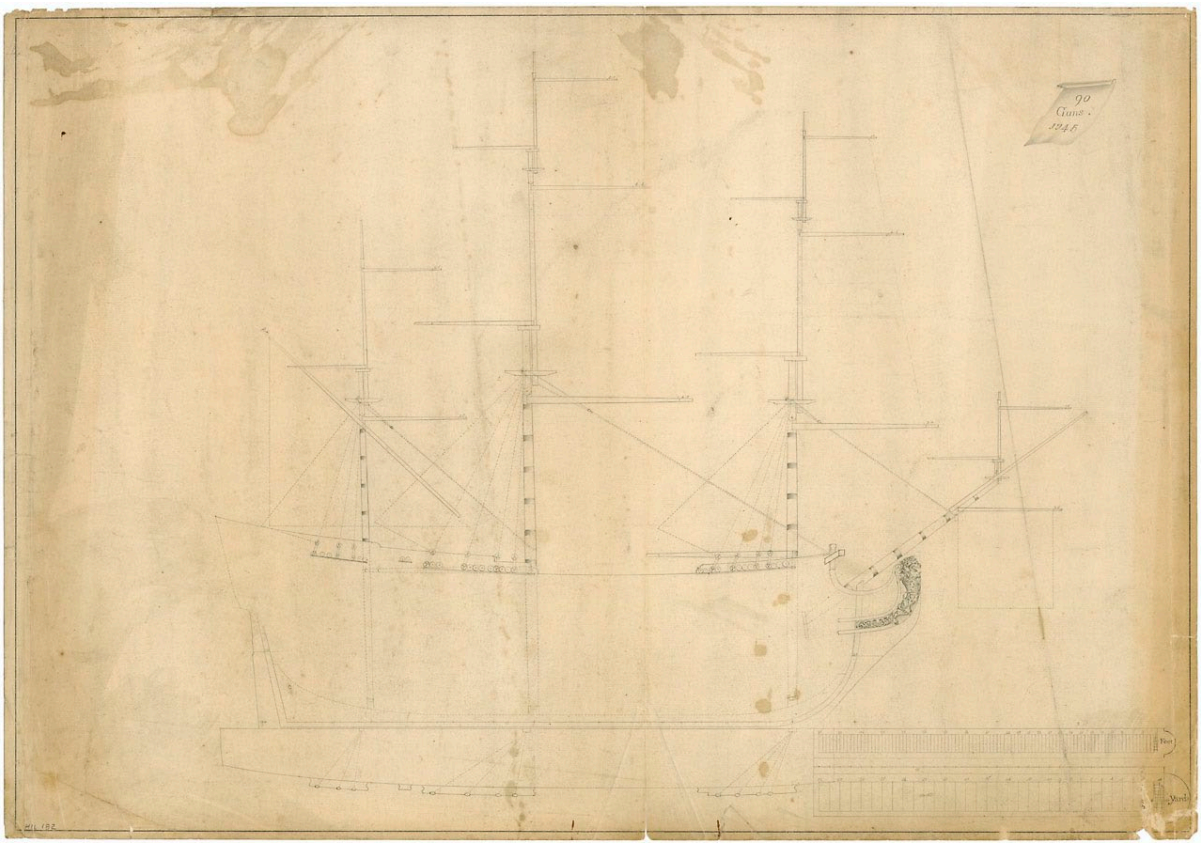


Figure 8 The Mast and Spar plan for a 90-gunship of the 1745 Establishment (HIL0179)

A more detailed rigging plan of a 60-gun ship of the 1745 establishment was in the Swedish Maritime Museum archives (Figure 9) although this is from a smaller ship and there are some obvious differences between this rigging plan and the archaeological and other historical data it provides a good overview of the rigging used in the period and how it all connects. This image was produced by FR Chapman (1721-1808) a Swedish shipwright who trained at various British shipyards between 1748-1753. The stated measurements in the rigging plan for the overall dimensions and tonnage as listed in the 1745 establishment but the masts are slightly longer when compared to the masting document and the lengths listed in the establishment book.

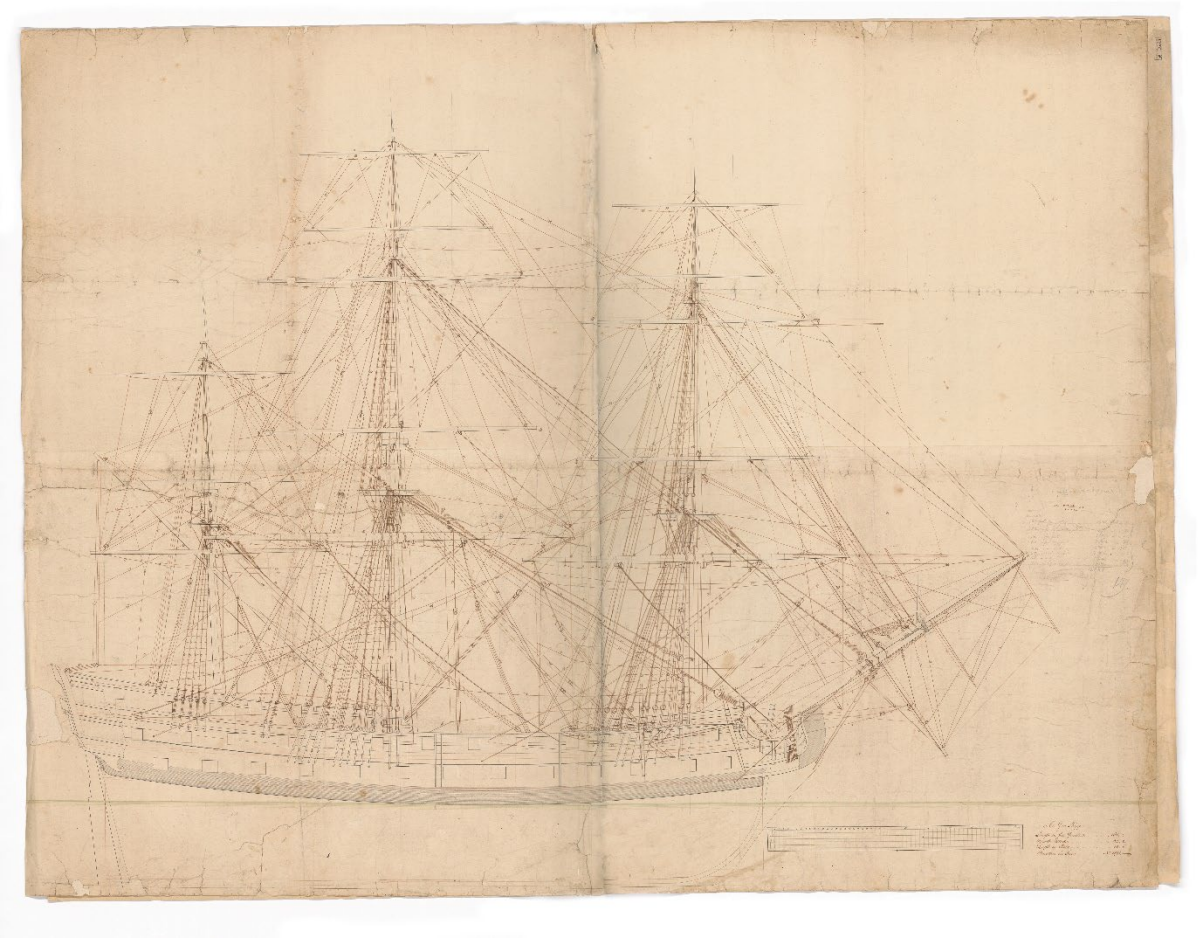


Figure 9 a Rigging plan of a 60-gun ship from the 1745 establishments (Sjöhistoriska museets arkiv OR 3003)

A further document in the archives which shed light on the specifics of the 1745 Establishment are the note of William Wilkins who began his apprenticeship at Chatham in 1745 (Wilkins, 1745) this book contains various notes and a copy of the 1745 Establishments which includes some of the sizes of the various rigging elements used on each rate of ship.

Invincible

In specific relation to *Invincible*, several sources mention *Invincible's* masts and rigging. The earliest documents are the survey of 1747 when she was captured (NMM.POR/D/9) and therefore document how she was masted as a French vessel. However, during the battle of Cape Finisterre most of its rigging was shot away making this record likely incomplete.

A second document in 1747 list the masts and yards that the dockyard attendants though to be the proper proportions for the ship (ADM 106/1046/75).

Once fully rigged and taken to sea the log of Captain Lloyd mentions several issues with the rigging and handling of the ship, (ADM 106/1059/171) in particular the foremast which caused several issues which were addressed in several letters held by the National Archives.

A further source is an illustration of *Invincible* under full sail (Short, et al., 1751) (NMM.PAI5887) (Figure 10); this shows the sails backed to the wind. Although partially obscured by the sails the masts, spars, standing and parts of the running rigging can be seen. This gives us an idea of the size and layout of *Invincible's* rigging and which sails she carried. However, all art is subjective and may not be 100%

accurate with issues of human error, perspective, and the time it takes to draw images meaning that other vessels or sketches could serve as a template.

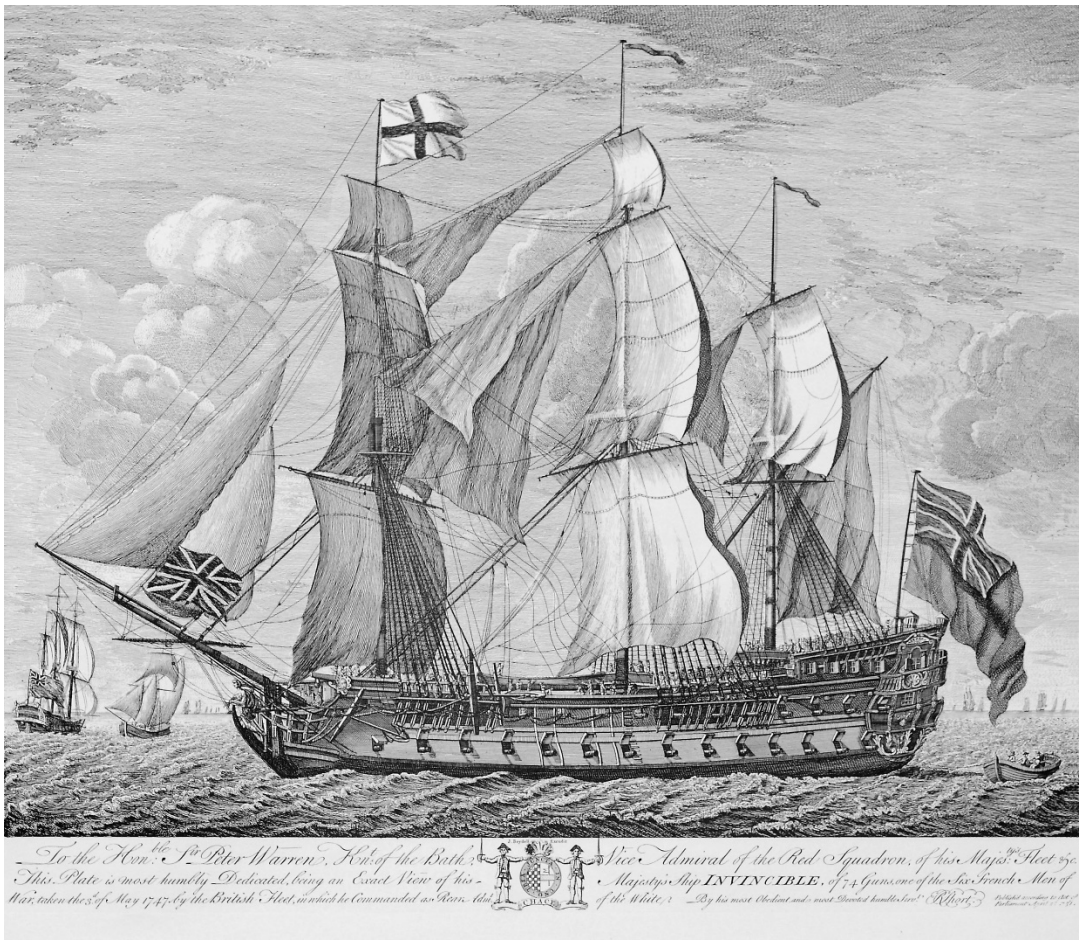


Figure 10 An Exact View of his Majesty's ship Invincible (Short, et al., 1751)

A second illustration made during the command of Sir John Bentley Kit in 1749-52 (Hood, 1749) (NMM.PAD8491) shows the *Invincible* without sails, showing the standing rigging on the port side of the ship and highlighting the masts, spars and standing rigging. The topgallant masts seem to be struck but with flag poles shown on each mast. Hood appears to be an accomplished shipwright and artist, having drawn several of the ships commanded by Kit but the same issues with art exist. However, the gammoning on the cutwater is shown to be different to the evidence obtained from the recovered cutwater shedding some doubt on the accuracy of this illustration.

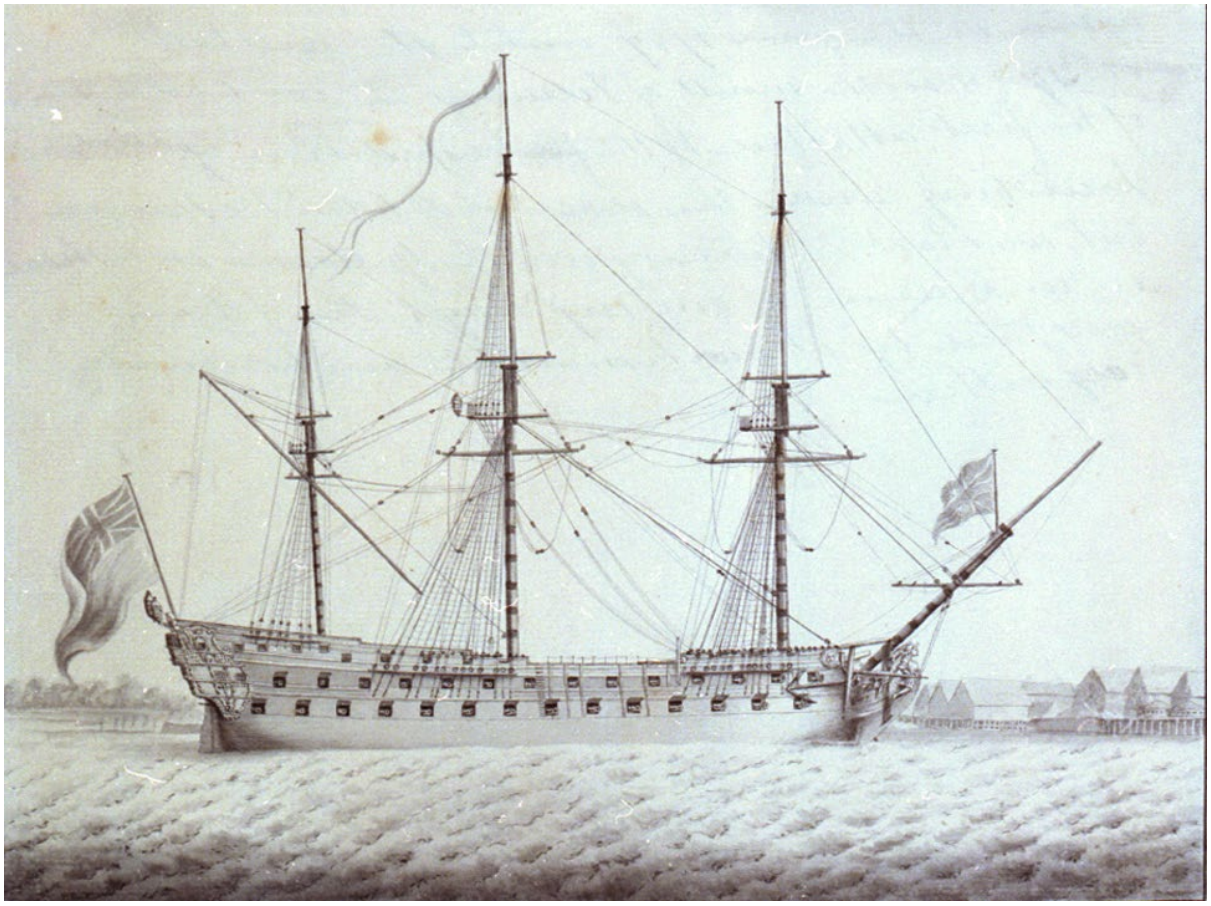


Figure 11 HMS Invincible (Hood, 1749)

Sources relating to the refit and repairs of *Invincible* have not currently been found however several documents relate to the salvage including one which list some of the material and rigging removed from the wreck (POR/D/13). Other newspaper articles over the summer of 1758 also mention the wreck and work that had occurred on the vessel.

By comparing the historic documents in relation to *Invincible* with the generic one of the 1745 establishments and the secondary sources such as Sutherland (1711) and Steel (1794), as well as Lees (1979) the proportions of the rigging *Invincible* may have had could be calculated - assuming it followed historic conventions - could be ascertained to create a provisional plan. The archaeological artefacts were then compared and combined with the historical data to understand how well the two lines of evidence can be considered complementary. We can begin to build up a picture of where the various rigging elements sit in the overall rigging plan and by using the archaeology, we can begin to find the sizes and dimensions of the various elements.

Results

The following section will consider the results of the archive searches as well as the archaeological information to try and recreate small elements of the rigging plan.

Masting

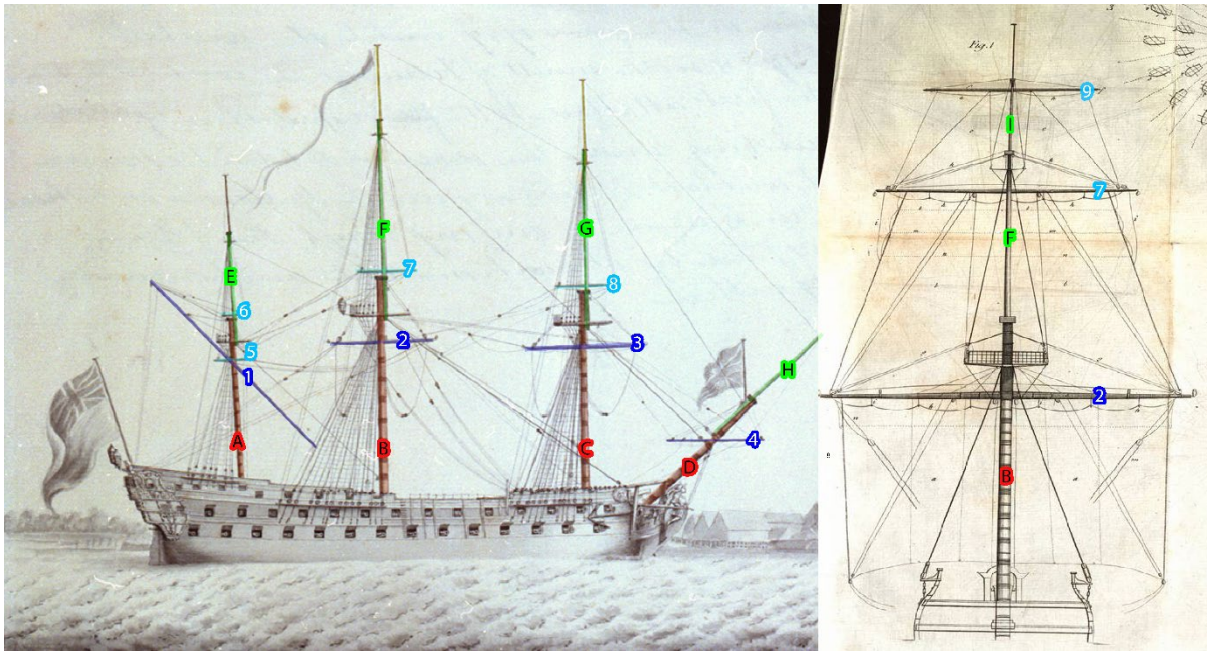


Figure 12 The Masts and Spars of Invincible.

Masts: A. Mizen, B. Main, C. Fore, D. Bowsprit, E-G respective topmasts, H. Jibboom. The main and fore would have had a topgallant mast above the main shown as I in the cross section. Spars: 1-3 Mizen, Main and Fore. 4. Spritsail yard, 5. Crossjack yard. 6-8 top yards. 9.topgallant yards.

All rigging on a ship is in proportion to the main mast, therefore by establishing the size of the masts that *Invincible* was equipped with we should be able to establish the size of the rest of the rigging, and likewise by recording the size of the recovered rigging we may be able to establish the size of the masts she carried when she was lost.

Invincible, like all large ships of the period, carried three masts and a bowsprit. The iconographic and historical evidence shows that *Invincible* did not have a mizen topgallant mast and there was no spritsail topmast, and although the records show *Invincible* carried a spritsail top yard it does not appear to be rigged in either of the images as it was generally considered an impractical sail and would have probably been rigged to the jibboom.

Invincible's masts were replaced at least four times in its career in the Royal Navy, once when captured, a refit in 1752, the major rebuild in 1754-6, and after a hurricane off Canada in 1757.

The first issue with masting in the Royal Navy was that of timber supply. It was the Navy's preference to use grown masts made from a solid stick of wood, however the British climate was not suitable for the growth of timbers in the size and quantity needed to equip all its warships, so the Royal Navy had to look overseas to the Baltic, Ukraine and the American colonies (Albion, 1952). As this was not a unique issue to the Royal Navy but one to the whole of shipbuilding there was increased pressure from across Europe both mercantile and military for this timber, leading to a vast reduction in the available masting timber (Albion, 1952). The British colonies in New England contained virgin forests, therefore providing trees of a suitable length and diameter for mast making but due to the quality of wood from New England the mast would have to be *c.*25% thicker in diameter to be the same quality and strength as those sourced from the Baltic (Sutherland, 1711, p. 109). However, the French did not have access to these resources and had to solve the issue they made composite masts from multiple sticks bound with iron, known as a 'made mast' or *mâture d'assemblage* (Albion, 1952). Made masts

were inferior to single sticks in many ways as they lacked the flexibility and resinous qualities of single sticks and were less durable. This meant that French ships had to have thicker masts and potentially carry less sail (Bamford, 1956), but it also meant new masts were more readily available. These issues with the timber supply led to the British reusing masts, as with the case of *Invincible*'s foremast. This issue came to head with the American Revolution (1774-1783) where the loss of the American Colonies ended the Navy's mast supply, causing the Royal Navy to go to sea with old and unsuitable masts. The Second *Invincible* (1765) lost its masts at sea in during a storm in 1778, whereas the French ships with their made masts weathered the storm unharmed (Albion, 1952).

To establish the correct size of masts needed for a vessel, several complicated formulae existed based on tonnage and various lengths of the ship. The French system was based on the maximum beam of the vessel, of which each mast and spar was a ratio (Boudriot, 1987, p. 58). This produced slightly longer and thicker masts than those used by the Royal Navy. The Royal Navy on the other hand added the length of the gundeck to the beam then divided this by two to give the length of the main mast (Sutherland, 1711, Steel, 1794, p. 39), with every other mast's dimensions based on the main mast.

When *Invincible* was captured in 1747, most of its masts were shot away or damaged but key dimensions of the mast and spars were taken in the survey of the vessel (NMR.POR/D/9). Comparisons between the inferred dimensions derived from Boudriot's (1987) formula and the dimensions at the time of capture (Table 2) taken shows very little correlation, suggesting that as with the construction of *Invincible* there was very little control from Paris with regard to the construction of the ship, and the dockyards may have used their own proportions or formulas for the masting of the vessel.

During the battle of Cape Finisterre *Invincible* suffered heavy damage and when brought into Portsmouth for survey it was deemed that "all the masts and yards except the bowsprit" had to be replaced, meaning that *Invincible* was "being in want of an entire suit of masts and yards" (ADM 106/1046/60). The Navy Board wanted to rig *Invincible* "exactly the same as when she was taken from the enemy" (ADM 106/1044/16), but this caused an issue with the British Establishment system, which although had its downsides made the rigging of Royal Navy ships inter-changeable and uniform and standardised the supply of blocks and rope etc. which is important as it belongs to a large system.

The dimensions of the captured masts and spars in some ways exceeded the size of the masts 100-gun ship, and in terms of the mizen yard significantly so (Table 2), even though *Invincible* itself was only slightly larger than the 90-gun vessel (

Table 1 Given dimensions of Invincible against the 1745 Establishments (measurements in metres)

Ship	100 Gun	*Invincible*	90 Gun
Keel Length	44.06	43.74	42.16
Gundeck	54.25	52.20	51.82
Breadth	15.54	15.22	14.78
Depth Hold	6.55	6.48	6.25
Tunnage	2000	1793	1730

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As the admiral in charge of the purchasing and refit did not "understand the proportion of masting ships" (ADM/106/1046) he decided to go with the proportions suggested by the dock yard attendants, which sat somewhere between the 90- and 100-gun vessel (Table 2).

Letters from the Portsmouth dockyard also suggest that the main mast of a 90-gun ship, HMS *Marlborough,* was re-used as *Invincible's* foremast. This was itself a reused mast from another ship to save time. The master shipwrights immediately noticed issues with the mast and the way it was stayed, causing it to bend forward, but these complaints were ignored by the Lieutenants (ADM 106/1059/172).

When *Invincible* put to sea in March 1748 Captain Lloyd noted that "the foremast was badly sprung" and the dock carpenters tried to hide the damage. He also noted that *Invincible* was "greatly overmasted, as we have found by experience, for she has worked all the oakum out of her seams, and its morally impossible to secure her masts in bad weather, her lower yards are much longer and squarer than any ships in the navy, and her topmasts are so taunt, that there is no securing them, for the angle the tops give are too acute". He recommended that she be re-masted as a 90-gun vessel, suggesting that then "she would… be one of the best ships belonging to his majesty" (ADM 106/1059/171). He also reflected that the smaller crew of 695 men was insufficient to run the rigging safely, meaning that there was a high possibility of losing the masts.

It is not clear if the Admiralty followed Lloyds' advice and have the *Invincible* fully re-masted, but they did allow him to stray from conventions and increase the size of the crew. However, by July 1748 *Invincible* was laid up in "ordinary", the naval term for taking a ship out of active service, only working with a minimal crew and rig. In 1751 the foremast was shown to be rotten again and the whole rig was replaced in early 1752 (Lavery, 1987, p. 61). Although no records of a change in the masting are known, the sailing report by Captain Bentley after this work shows *Invincible* to be an excellent ship with good qualities even with a reduced crew of 250, suggesting that the masts or the rigging had been altered to address the issues experienced by Captain Lloyd.

To add further confusion a letter from Admiral Lord Keppel to Prince William in regard to the rigging of *Valiant,* a direct copy of *Invincible*, written in 1790 (LBK/81/2) mentions that the mizen yard of *Invincible* was 28.23m long, with a diameter of 0.41m. This is over four metres longer than suggested in the 1747 document. The same document also gives the length of the mizen top yard as 12.19m, 1.75m shorter than the 1747 document.

Table 2 Comparison of the Masts and Spars Invincible may have had at differing times in its career. (dimensions in metres)

	Boudriot (1987)		Captured		1747		100 Gun		90 Gun		Ideal Masts (Lees 1979)	
Mast	**Length**	**Diameter**	**Length**	**Diameter**	**Length**	**Diameter**	**Length**	**Diameter**	**Length**	**Diameter**	**Length**	**Diameter**
Main	35.88	1.00	n/a	0.99	34.29	0.95	34.87	0.97	33.53	0.93	33.71	0.94
Main Top	21.53	0.52	22.12	0.65	20.30	0.51	20.93	0.52	20.12	0.50	20.22	0.51
Main Topgallant	11.91	0.25	n/a	n/a	9.88	0.27	10.06	0.28	9.65	0.27	9.91	0.28
Fore	33.22	0.92	32.31	0.92	30.43	0.85	31.22	0.87	30.00	0.83	30.34	0.84
Fore Top	20.09	0.49	20.42	0.51	18.52	0.51	18.82	0.52	18.11	0.50	18.20	0.51
Fore Topgallant	9.76	0.20	8.48	0.24	8.89	0.25	9.04	0.25	8.69	0.24	8.92	0.25
Mizen[5]	25.11	0.61	24.38	0.58	29.82	0.57	30.35	0.57	29.18	0.55	28.99	0.55
Mizen Top	14.35	0.35	n/a	n/a	14.61	0.34	14.86	0.34	14.27	0.33	14.16	0.33
Bowsprit	20.09	0.91	20.40	0.99	21.95	0.91	22.33	0.93	21.46	0.90	21.23	0.92
Jibboom	14.35	0.51	12.47	0.32	14.91	0.36	15.54	0.38	14.78	0.36	14.86	0.36
Yards												
Main	35.88	0.75	n/a	n/a	29.59	0.59	30.38	0.59	28.96	0.57	30.34	0.63
Main Top	21.53	0.40	21.51	0.40	21.29	0.38	21.87	0.39	20.88	0.37	21.84	0.38
Main Topgallant	11.48	0.19	n/a	n/a	14.68	0.25	15.09	0.25	14.40	0.24	10.92	0.18
Fore	28.70	0.60	n/a	n/a	26.09	0.52	26.92	0.53	25.50	0.51	26.54	0.55
Fore Top	19.13	0.36	19.35	0.40	18.62	0.33	19.10	0.34	17.48	0.32	19.11	0.33
Fore Topgallant	10.01	0.17	n/a	n/a	12.85	0.22	13.18	0.23	12.57	0.21	9.56	0.16
Mizen	28.70	0.48	28.58		24.26	0.37	24.92	0.39	23.80	0.20	25.28	0.38
Mizen Top	14.35	0.27	n/a	n/a	13.94	0.24	14.33	0.24	13.69	0.23	14.33	0.25
Bowsprit			21.41	0.40	18.62	0.33	19.10	0.34	18.24	0.32	19.11	0.33
Cross Jack	19.13	0.32	n/a	n/a	18.62	0.33	19.10	0.34	18.24	0.32	19.11	0.33
Spritsail Yard	21.53	0.40	n/a	n/a	12.85	0.22	13.18	0.23	12.57	0.21	13.19	0.23

[5] The French stepped their mizen on the gundeck and the British in the hold hence the difference between when she was captured and when rigged as a Royal Navy ship

As the masts were either cut down or removed during the original salvage there is very little direct evidence for the mast in the archaeological record however a few fixtures and fittings were uncovered.

Mast Steps

The Mast step is a large timber bolted over the keel with a square mortice in which the heel of the mast would have sat. The potential step for the mainmast was located in Trench Two amongst the contents of the shot locker that would have been built around the mast (Figure 13).

Figure 13 Main Mast Step

This measured *c.*2.2m by 0.96m and the mortice for the heel of the mast was *c.*0.6m2, suggesting that it would be suitable for a mast with a minimum diameter of 0.85m and a maximum of 0.96. which would be suitable for the main mast proposed in 1747 and the main mast of a 90-gun ship as shown in Table 2.

Mast Caps

The tops of the lower masts were cut into a square tenon, this would fit into a mortice on a thick block of timber fitted with an eye bolt each side, known as a mast cap, adjacent to a round hole through which the lower mast would be passed, allowing the masts to be struck in a telescopic fashion.

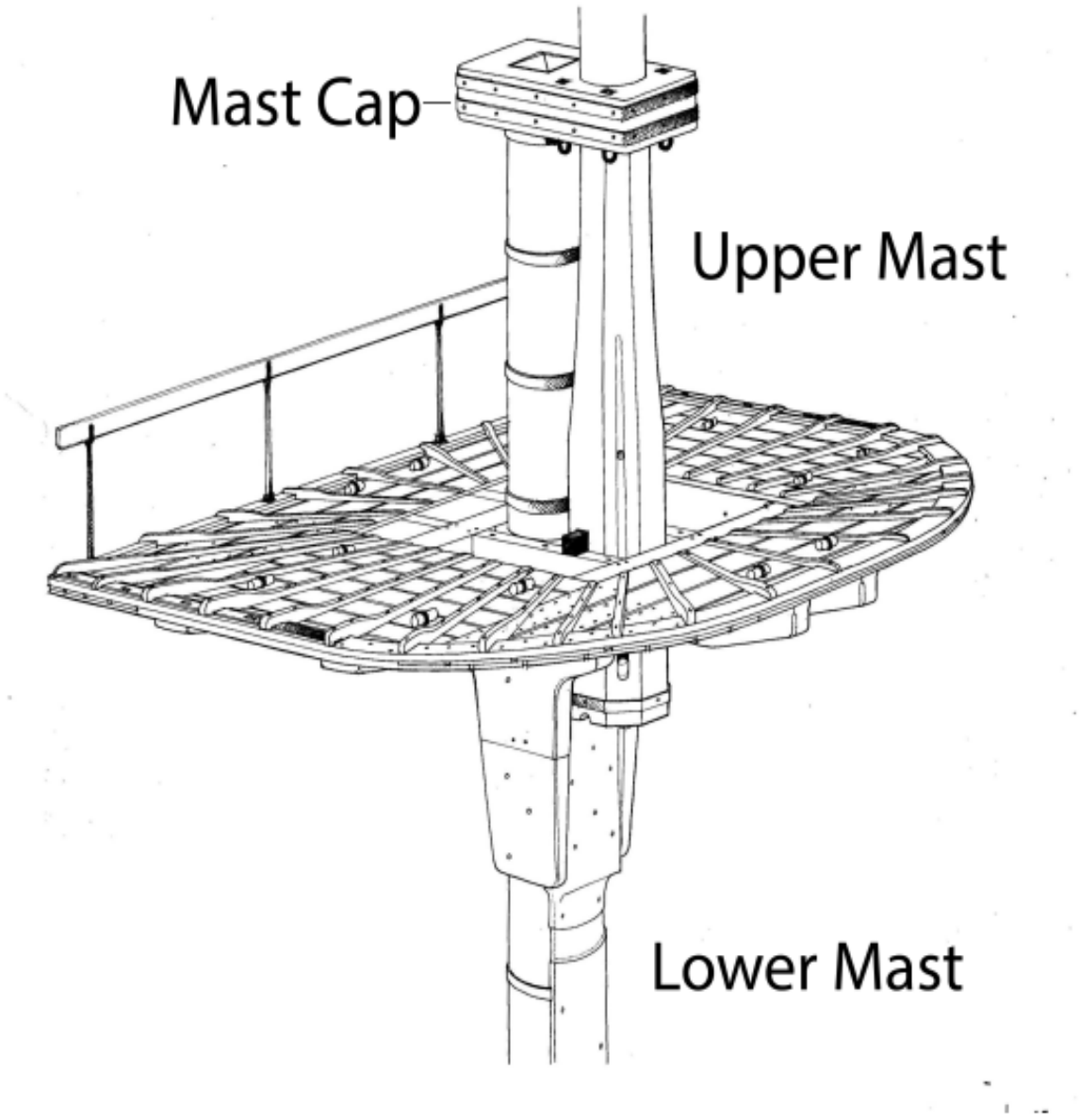


Figure 14 Mast Head after Boudriot (1987, p. 45)

Three caps were recovered from the wreck in 2018, all from the midship area of Trench 2. According to Falconer (1769) the breadth of the caps should be twice the diameter of the topmast, and four times the length. By applying these measurements to diameters of the masts given above, it is possible to use the size of the recovered caps to infer the size of the masts of *Invincible*.

INV1744_1461 & 1462 were both too small for *Invincible's* main rig with **1461** suitable for a mast of 6" (0.15m) diameter. It is likely that these caps were in store for the fitting out of *Invincible's* longboat or pinnace, whose masts were salvaged shortly after sinking. Wilkins (1745) lists formula for working out the length and diameter of the boats masts which suggests that that the largest longboats in use would have carried a 6" diameter mast suitable for this cap. It is unlikely that the longboats would have had topmasts or spars as they carried shoulder of mutton sails with a gaff (Figure 49), but the round hole may have been for the raising of a flagstaff.

Alternatively, they may have been attached to topgallant masts for flagstaff but the rigging plan for a 60 gun of the 1745 establishment only shows a cap for the flagstaff on the mizen topmast.

INV1744_2137 would have been suitable for a mast with a diameter of *c.*11 inches (0.28m) this would suggest that it would have coupled the top and topgallant masts of the main mast.

Figure 15INV1744_2137 Mast Cap

Boom saddles

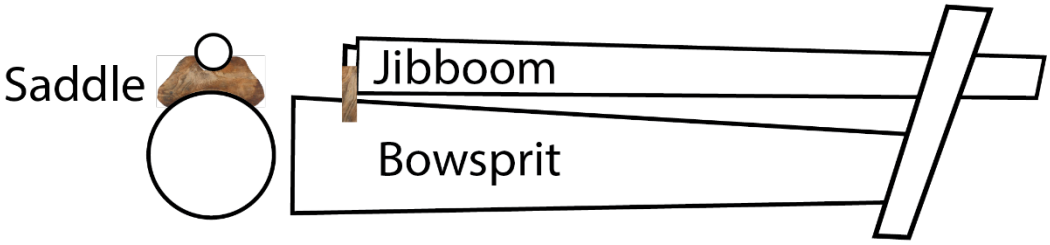


Figure 16 schematic of the boom saddle position

Boom saddles are a seat of wood with two semi-circular recesses to fit onto the masts. The larger lower, semicircle would be nailed on top of the bowsprit "one third of the length of the jibboom from the cap" (Lees, 1979, p. 9), with the heel jibboom sitting in the upper semicircle allowing it to lie parallel with the bowsprit.

Two boom saddles have been recovered from the site, the first in 1985, though at first it was incorrectly identified as a barrel stool (**INV.192**), and a second in 2018 (**INV1744_627**). No nail holes or fixings were present on either artefact, suggesting that they were held in store as spares.

Figure 17 Chatham boom saddle (Chatham Dockyard, 2018) and INV1744_627

The two recovered saddles were approximately the same size, with the diameter of the lower semi-circle *c.*1m and the upper *c.*0.31m. This would be suitable for a bowsprit and jibboom of the size given for the *Invincible*, as well as for 90- and 100-gun ships under the 1745 Establishments as seen in Table 2.

Yardarm Cleats

The 1980s excavation spreadsheet lists 35 cleats, but it is not entirely clear which type of cleat each one is.

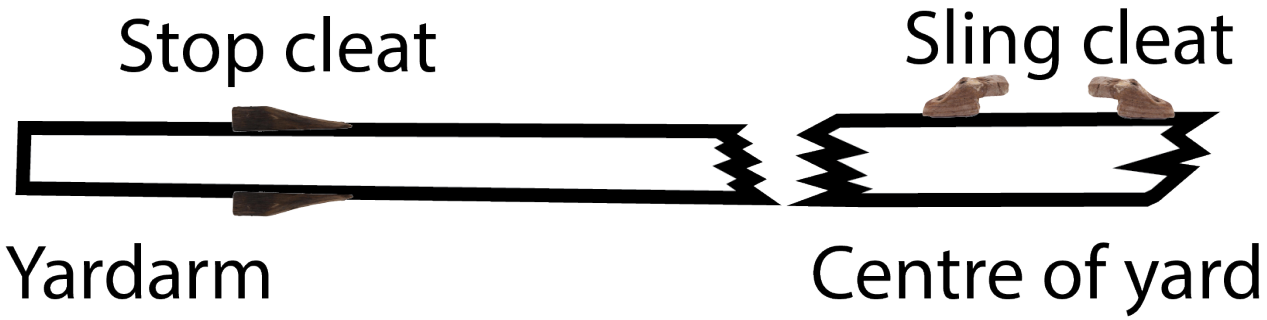


Figure 18 Stop cleats and sling cleats on a schematic of a yard (not to scale).

Stop cleats would have been added to the end of the yards, (known as the yardarm) to prevent the rigging from "moving in on the yard" (Lees, 1979, p. 13). Eight confirmed stop cleats were recovered, all from the 1980s excavation, of which five had given measurements (

Table 3). According to Lees (1979, p. 13) the length of these cleats would have been twice the diameter of the yard and a quarter of this in breadth. However, although the recovered cleats fit the 4:1 ratio the length would suggest that they are for yards with a much larger diameter than even the main yard of a 100-gun ship.

However, cleats were also used on the bowsprit to prevent the collars of the stays and the gammoning from slipping, and thus the larger stop cleats are likely to have been for this purpose.

Table 3 Stop Cleats, lengths, and predicted yard diameters.

Number	**L**	B	D
81/0154	No measurements available		
81/0155			
81/0156			
83/0162	392	100	60
87/0067	383	95	95
INV.1	306	75	55
INV.2	434	85	75
INV.405	170	45	37

Sling Cleats were placed in the centre of the yard and featured a single arm and were 1/20th the length of the yard (Lees, 1979, p. 13). All the slings recovered would be far too small for any of the yards on *Invincible*, making them more likely to be Thumb-Cleats which were used to "hang anything thereon" (Steel, 1794, p. 4).

Miscellaneous

INV1744-3189 is another object of unknown purpose. However, one theory is that it could have been used to support the spars when they are stowed on deck. The circular recess in the top of the object has a diameter of 200mm, which would be suitable for the spritsail yard or topgallant yards to rest in.

Figure 19 INV1744_3189 artefact of unknown purpose (scale is 200mm)

Standing rigging

The standing rigging is the system of ropes and blocks used to support the masts such as the shrouds, stays and back stays. Generally, this does not move, hence the name standing.

Stays

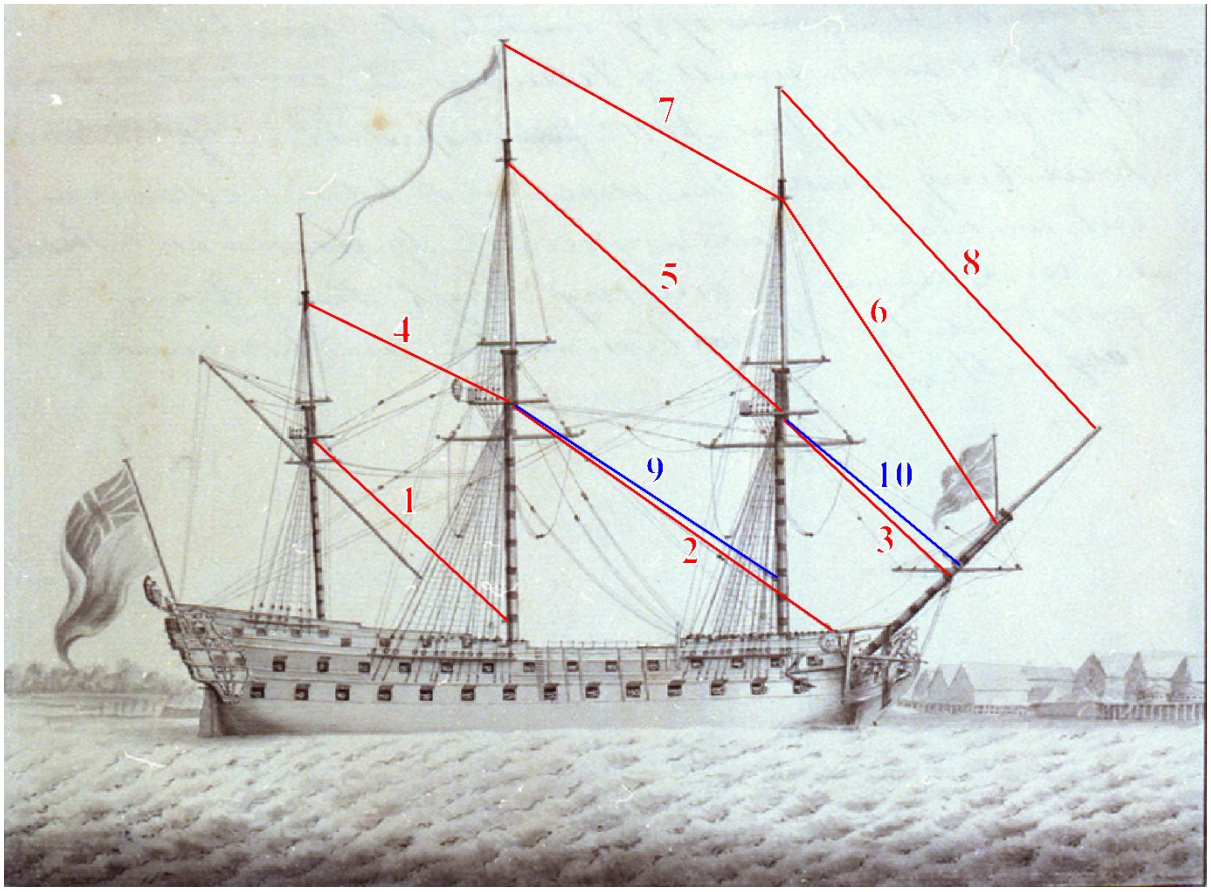


Figure 20 The Stays of Invincible

1.Mizen Stay, 2. Main Stay, 3. Forestay, 4-6. Topmast stays, 7-8. topgallant stays (note that for the purpose of this illustration we are treating the flag staffs as topgallant masts) 9-10. Preventor stays (blue) not it is possible that she carried topmast preventer stays in addition to these stays.

The stays are large strong ropes that run from the mast head supporting the masts forward. Other than the anchor line they would have been the largest ropes aboard the ship. At the upper end of the stay a slipknot was created by eye splicing the end of the cable around the body of the line; to prevent it seizing onto the mast, a large swelling was built up onto the line called a mouse. The amount of tension in the stay would need to be constantly adjusted to cope with changes in the weather and therefore pressure on the mast, on the lower stays a heart block, or a dead eye on the mizen stay, would have been seized into the lower end. From this a lanyard would have run between a matching heart that would have been seized into a collar, to a fitting on the hull for the main mast or the next mast forward. The upper masts would have been stayed to the heads of the next lower mast forward and tensioned through a pulley system secured to the deck at the base of said mast.

According to Lees (1979, p. 185), in all periods the circumference of the lower stays would have been half the size of the diameter of the mast. So, for the 1747 size listed in Table 2 the main mast diameter was given as 37 ½ inches meaning the main stay should be 18¾" in circumference. Likewise, the 100 gun should be *c.*19" and the 90 gun should be 18 $^{5}/_{16}$ inches. However, these measurements may not

be practical as rope was provided to the navy in ½ inch sizes as demonstrated by the salvage records (POR/D/13). The salvage records of the *Invincible* also mention the recovery of two deadeyes one 22" and the other 15" for the stays using Lee's (1979) formula of a deadeye being 1.6 times the size of the rope this would mean that there were stays of *c.* 13 ¾ and 9 ½ inches. However, as the largest dead eye recovered from the site was 18 inches it may be that this refers instead to hearts, which were often regarded as a "peculiar sort of dead-eye" (Steel, 1794, p. 158). As the main stay and its hearts were present on the seabed this would suggest that these could be the hearts for the forestay and its preventor. In addition to the recovered cable sizes of the main (18"), preventor (14") and orlop ropes (9") the salvage records indicate that there were cables of 11, 6 ½ and 4 ½", matching some of these predictions.

Table 4 Predicted sized of the various stays.

Rope	Circ. In inches
Main Stay	18
Preventor	14
Main Top	*9*
Main TG	*4 ½*
Fore stay	*17*
Fore Preventor	*12*
Fore Top	*8 ½*
Fore TG	*4*
Mizen	*11*
Mizen Preventor	*11*
Mizen Top	*6 ½*

Main stay

The main and preventor stays comprised one of the largest finds. These were found lying side by side *c.*25 metres west of the site in Trench 5, surviving from the stay collars to the heart blocks (Figure 4).

The mainstay was made up of four 8" Z twist hawsers (32mm diameter), S-twisted around a heart of loose yarns *c.*58mm in diameter to create an 18" four strand cable (73mm dia). This was heavily tarred and wormed with a 2" hawser (16mm) along its whole length. The stay was parcelled in canvas and served at the upper end with a single flattened strand of 11 yarns, for extra rigidity and protection.

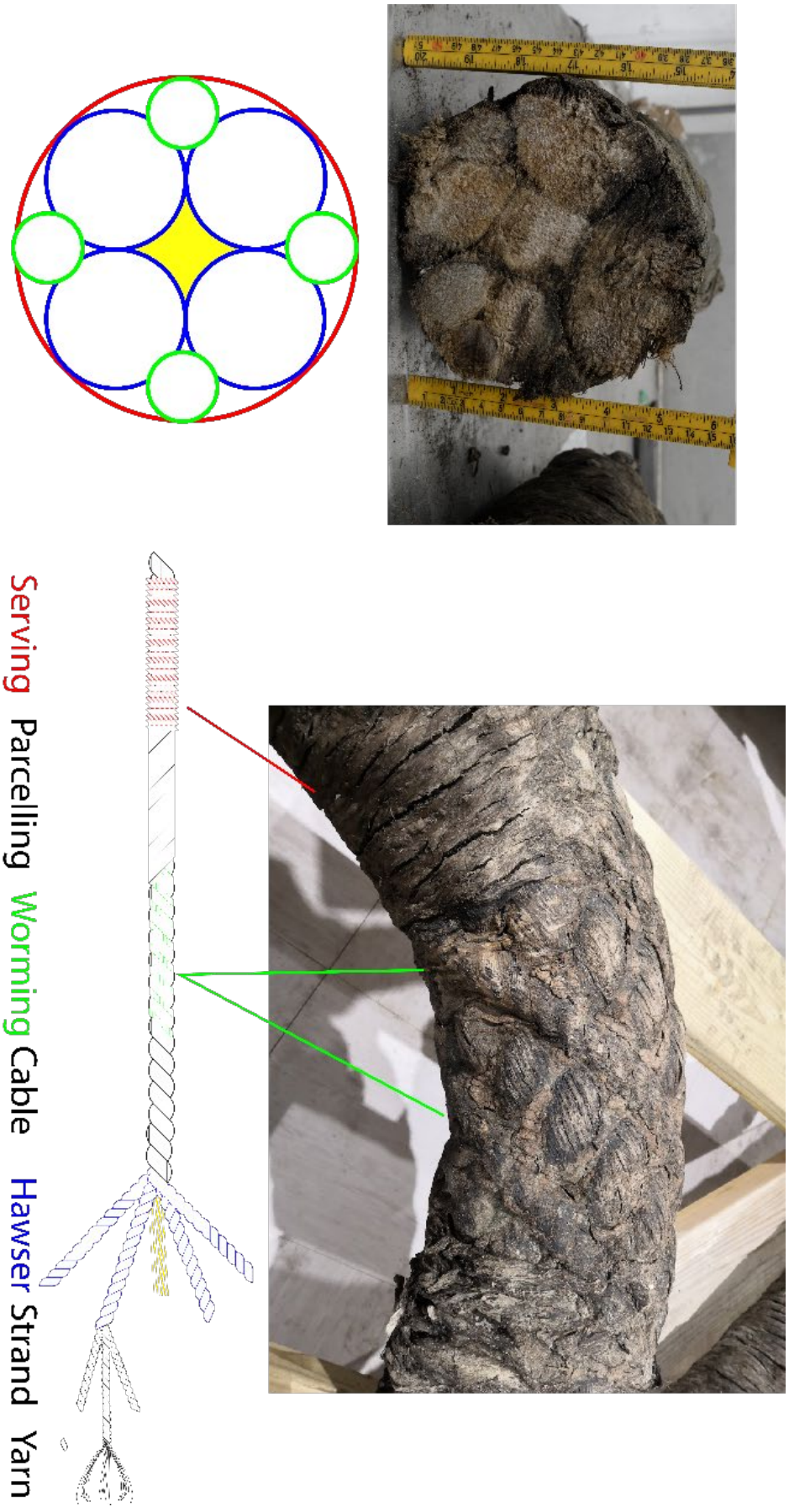


Figure 21 The mainstay with cross section and schematic view

At the upper end of the stays an eye splice is made around itself creating a slipknot. Due to the serving completely covering the stay, the exact method of splicing and number of tucks cannot be ascertained but it appears that the hawsers have been untwisted, with only two of the four looping around the stay, with the serving binding it all together.

To prevent the rope from seizing onto the mast, a mouse is created. Again, in the *Invincible* find the rope work is hidden by the serving but it appears that rope, likely the same 2" hawsers as the worming, was wrapped around the stay to create a ball. This was then tightly wrapped with several layers of tarred canvas. Ten mm diameter three-strand, three yarn hawser was then laid parallel with the stay, and then a warp made from the same line as the serving was weaved between these to create a basket work effect. The end of these line was secured with extra serving which blended into the rest of the stay.

Figure 22 The mouse and splice on the main stay

A heart block was turned into the lower end of the stay, using a throat seizing with the tail end lashed back on itself (Figure 23).

Figure 23 Lower end of the mainstay and schematic (scales are metres) Red is the main stay and green marks the lashings.

INV1744_3517 was made from a single piece of timber[6] from the centre of the trunk. As a result of this it was heavily split along the rings of the tree with two parts surviving, the heart block also featured multiple small broad arrows carved into the face and the roman numerals XX and III on the two halves either side of the split. It is likely that they originally read 'XXVIII' (28) which is the length of the block in inches.

A second heart would have mirrored this turned into the main stay collar with a lanyard one third the size of the stay rove between the two hearts to provide the necessary tension on the stay (Figure 24). According to Lee (1979, p. 40) this lanyard would have been spliced into the stay around the upper heart. There is no evidence of this on the recovered upper heart but a small area of serving alongside the block could mark where the lanyard was attached to the stay. French and English systems differed slightly with the French mainstay collar passing either side of the foremast to be connected to the gammoning knee and the English to a hole in the beak.

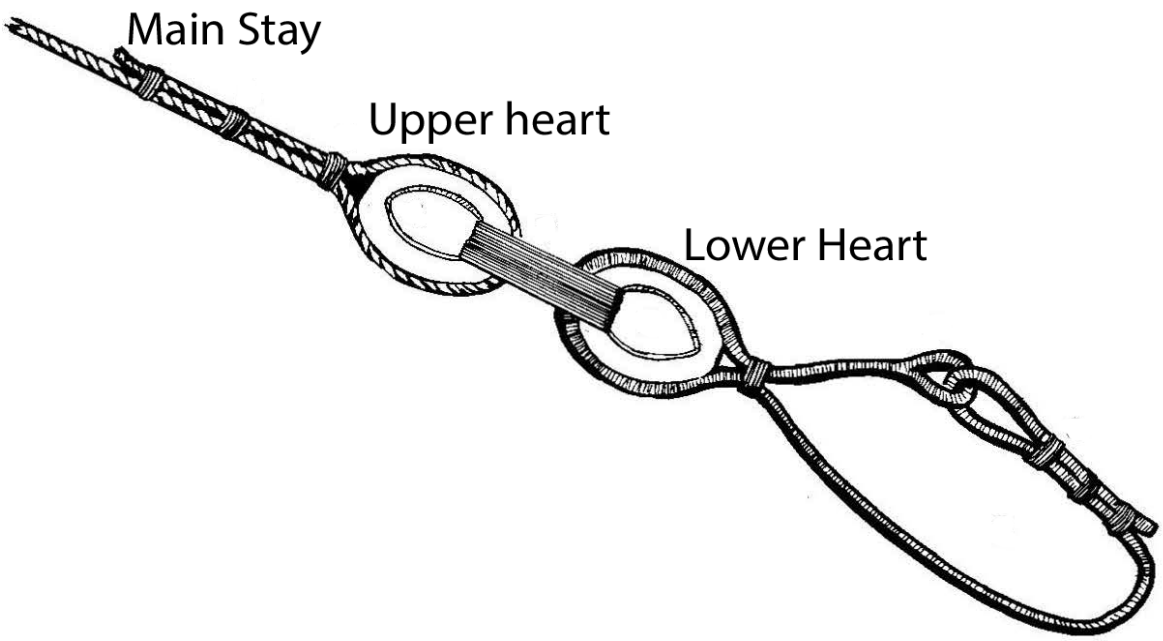


Figure 24 Representation of the lower end of the main stay after Lavery (2003)

Preventor Stay

Running above the main stay was the preventor stay. This smaller 114mm diameter (14" circ.) cable was made from three 7" hawser. This differs from the later sources which show the preventor stay to be made of four hawsers (Steel, 1794).

Unlike the main stay it only appeared to be wormed and served at the upper collar and did not appear to be parcelled. Preventor stays were generally unique to warships, providing a backup in case the main stay was shot away, the two stays would have been connected with a line lashed between them in an alternating zigzag fashion known as snaking, therefore if one section of the stay was hit it was still supported. The snaking is not shown on the 1749 drawing (Hood, 1749) but it can be clearly seen in the 1751 drawing of *Invincible* (Short, et al., 1751) (Figure 25). However, it was not present on the seabed although a small section of lashing can be seen on the alternating on the main and preventor

[6] Species ID is yet to be confirmed

stays (Figure 26), suggesting they were still snaked together when the rigging was cut down, explaining the position of the two lines on the seabed.

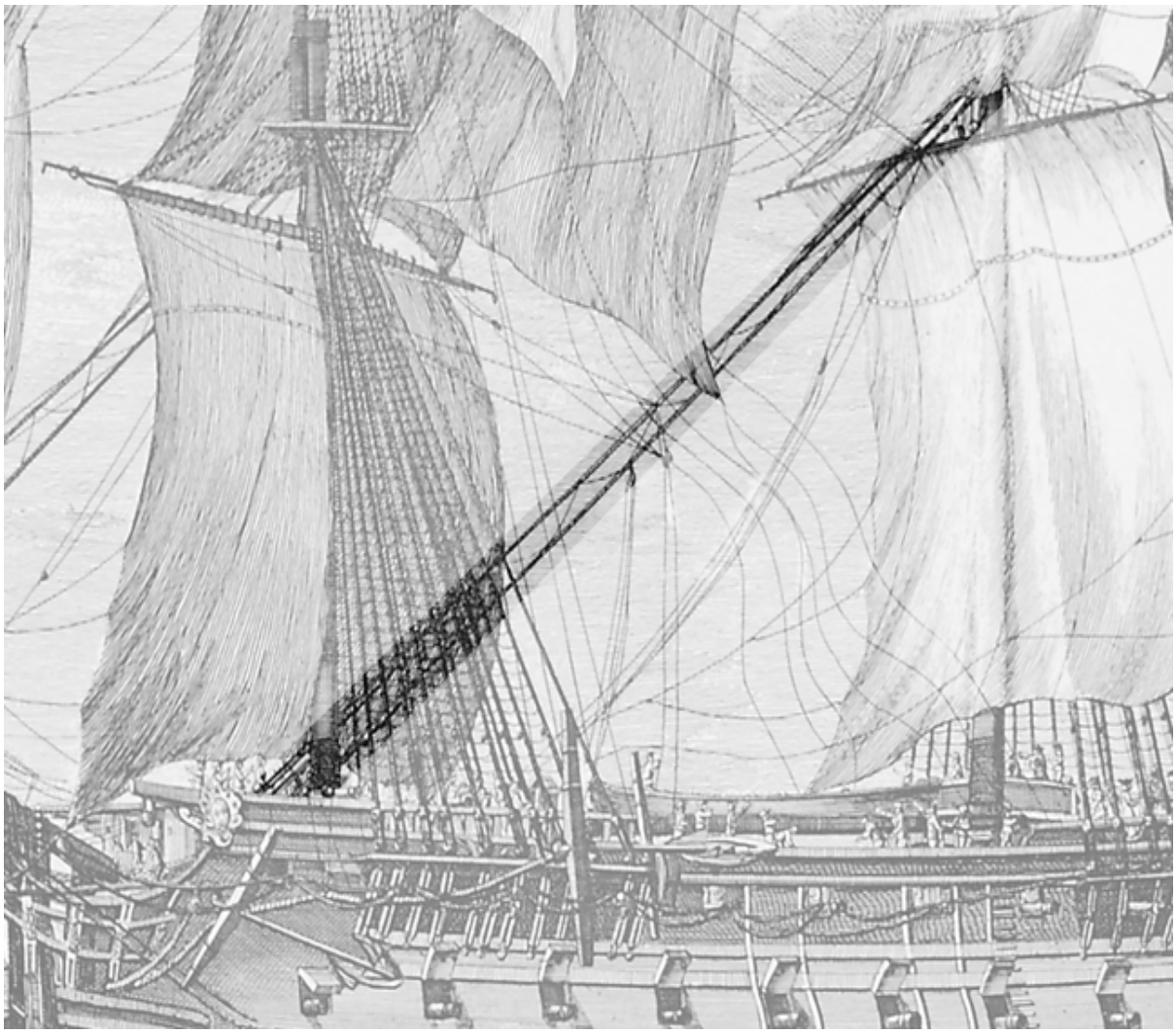


Figure 25 Snaking between the mainstay and its preventor as shown on Short (1751)

Figure 26 Lashing seen on the main and preventor stays.

The upper collar and mouse are made up in the same way as the main with only two hawsers, served together forming the eye splice and the mouse built up and then covered in woven rope.

At the lower end of the stay the upper heart was heavily fragmented, making it unclear how it was turned into the stay but there was no evidence of the tail being lashed back on itself like the mainstay. A smaller *c.*4" line was present in this area and was interpreted as the lanyard leading to the lower heart which was *c.*480 x 280mm, making it likely to be a 19" heart.

Although not fully excavated the lower heart's collar appears to be eye-spliced back on itself to seize the heart in the bight, like the way the rope was spliced at the mouse, with the rope continuing parallel to the main stay. This is at odds with the standard method of seizing the heart within the middle of a rope which would then be made off around the foremast (Lees, 1979). From the heart the stay collar was served and wormed, a splice can be seen at the end of the tail, but it is not clear if it is back spliced or there was an eye or cunt splice that has eroded away. It is not clear how this would have attached to the main hull of the vessel. According to Lees (1979), Royal Navy standards for the period would have had a strop with an eye splice in each end and the heart seized into the middle with the two-ends lashed around the foremast. He believed that the style of seizing the stay with and eye splice did not come into effect until the 1840s (Lees, 1979, p. 40) when the end of the preventor joined the main stay with being made off on the beak.

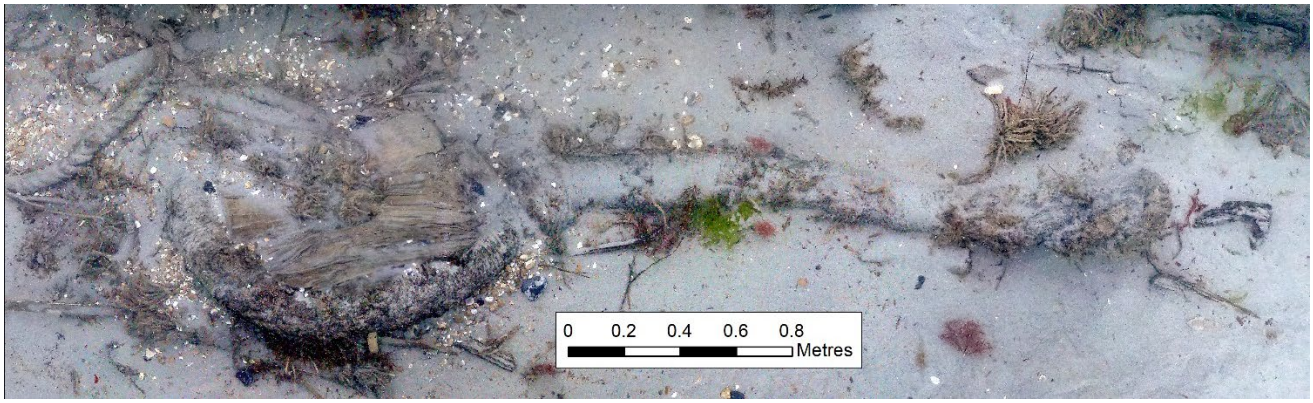


Figure 27 The lower heart of the preventor stay.

The 1749 drawing of *Invincible* seems to show the preventor and its heart blocks ending on the fore mast and the main continuing down into the fo'c'sle, supporting this view (Figure 28). However, the 1751 drawing show both stays continuing into the fo'c'sle, suggesting there may have been a change to its rigging as it was known at this point that there was a problem with the foremast.

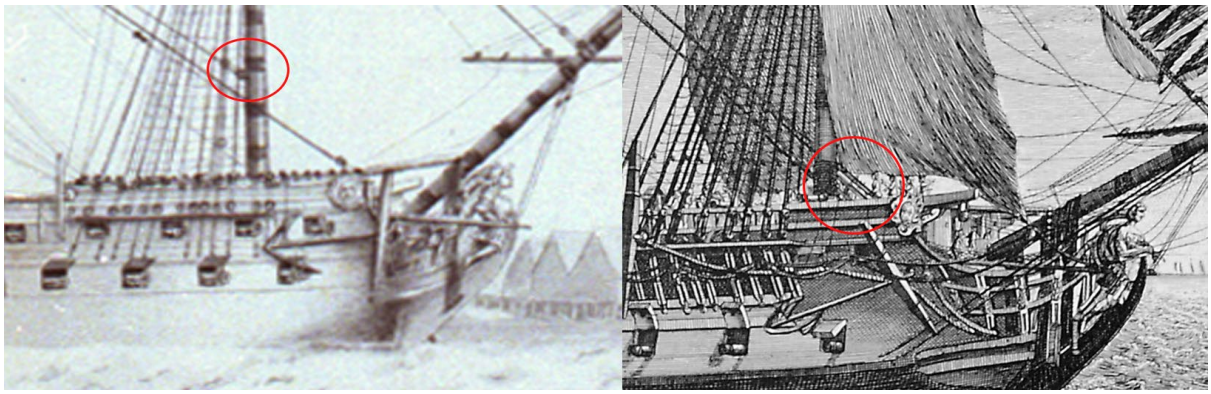


Figure 28 Change in the position of the mainstay and preventor.

Orlop rope

Two large coils of three-strand cable were located on the orlop deck. There were two different sizes 9” and 12” and heavily tarred. Attached in the coil was a tally stick, **INV1744_574**, on which inked writing was present in which the words main stay could be ascertained. The 12” cable was of similar construction to the preventor stay, but two inches shorter suggesting that it could be used for the preventer stay of the foremast.

As predicted in Table 4 the Topmast stay would have been 9”, it could therefore be hypothesized that these cables were the spares to repair any damaged stays.

Bobstays

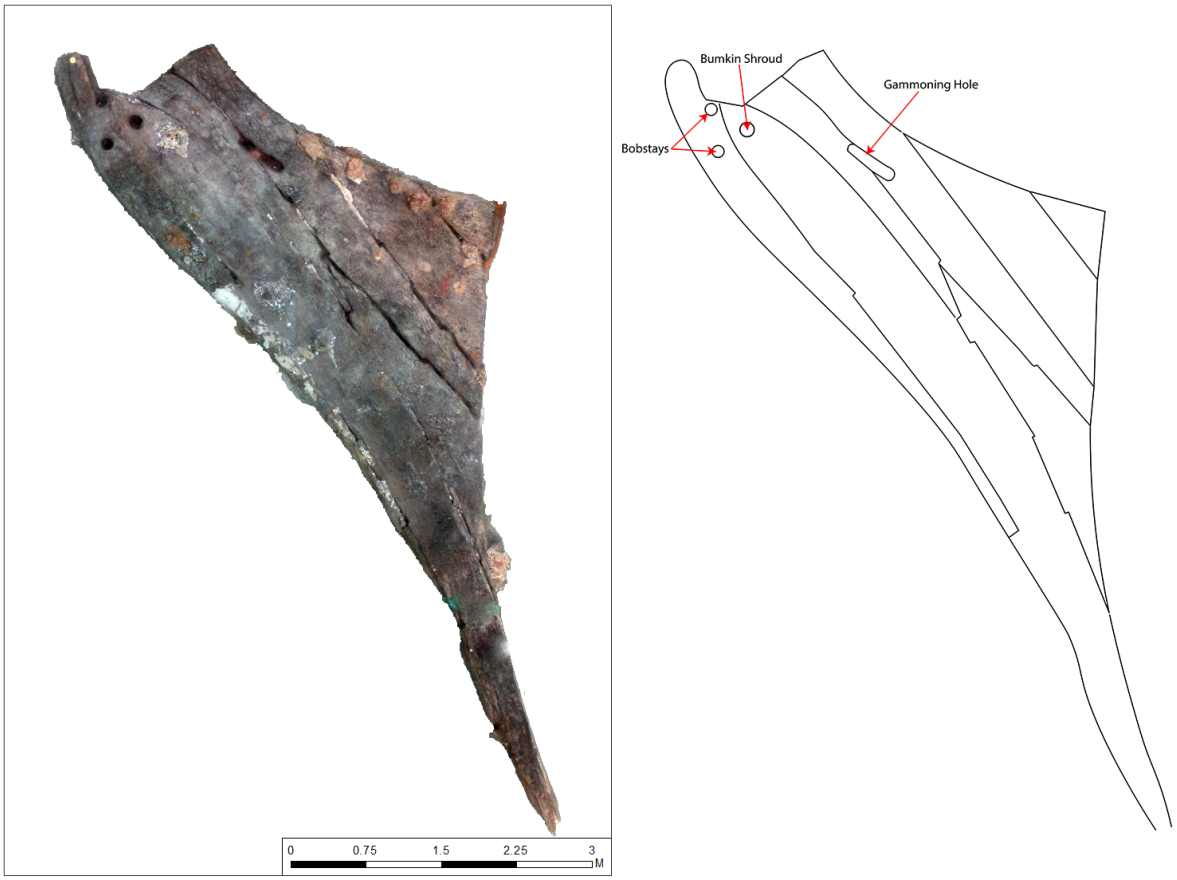


Figure 29 orthomosaic of the cutwater and schematic view

Bobstays are used to confine the bowsprit to the stem. A hole is bored through the cutwater from which the bob stay is run through and spliced to create a continuous strop. A deadeye of a heart is seized into the end which in turn is partners with another deadeye seized onto the bowsprit beneath where the fore stay collar is attached, helping to counteract the strain of the forestay. A second bobstay would have run from the cutwater to the position on the bowsprit where the fore preventor stay connected.

The cutwater of *Invincible* featured three holes *c.*130mm diameter holes for the bobstays suggesting the cable would have been a maximum size of 15”. Lees suggest that the Bobstays would have been half the size of the forestays. Using the predictions above this would make them 8.5”, the same size as listed for a similar tonnage 74 in 1799 (Steel, 1794).

The third hole is likely to be for the stay of a bumkin, although neither of the contemporary images are clear enough to see if the artist included the bumkin they were standard on ships from around 1710 (Goodwin, 1987, p. 223).

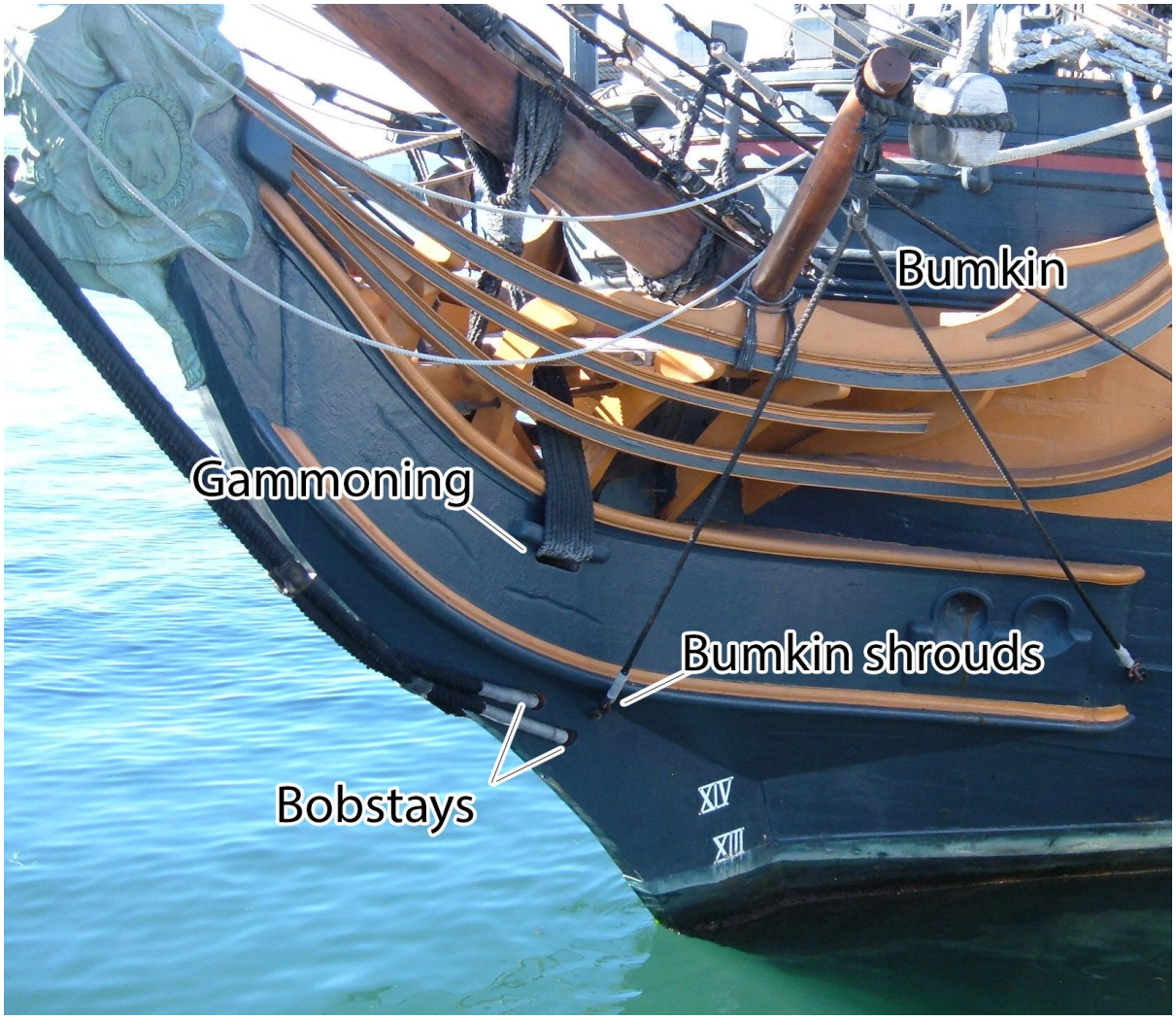


Figure 30 The rigging attached to the cutwater on the replica of HMS Surprise after (BrokenSphere, 2008)

Gammoning

The gammoning is the rope that binds the bowsprit to the stem. A rectangular hole was present in the cutwater measuring *c.*100 x 585mm which has been interpreted as the part of the stem which the gammoning would have been lashed through. The maximum size of the gammoning would therefore be 12 ½ inches but this would only allow for five turns around the bowsprit. Lees (1979) states that the gammoning should be 44% of the forestay making it 7 ½ inches, allowing for almost exactly 10 wraps.

Hearts

Figure 31 The Heart blocks from Invincible (not to scale)

In addition to the three hearts observed on the mainstay, five further heart blocks were recovered in the 1980s excavation. These are all of an un-uniform shape and size, but two heart blocks (86/0089 & 86/0340) did feature broad arrows and their size in inches.

The 14" (86/0340) and 13" (INV.142), hearts are similar in shape to the hearts of the main stay and it preventor but appears to be in a much sounder timber. INV.142 also featured four grooves for the lanyard to sit in, suggesting that its lanyard was originally 4" rope, which in turn suggesting that it was turned into an *c.*8" cable. A third heart (86/253) measured 12", but was it was more round in shape with a triangular hole.

By the end of the 18th century the only place on a 74-gun ship which had hearts other than the main and fore stays were the bobstays and bowsprit shrouds both of which were equipped with 14" hearts (Steel, 1794) it could therefore be suggested that these hearts are for this purpose and the exact inch height may not have been adhered to.

The smallest heart recovered 80/177 was only 8" high but no other records or photos are known.

Shrouds

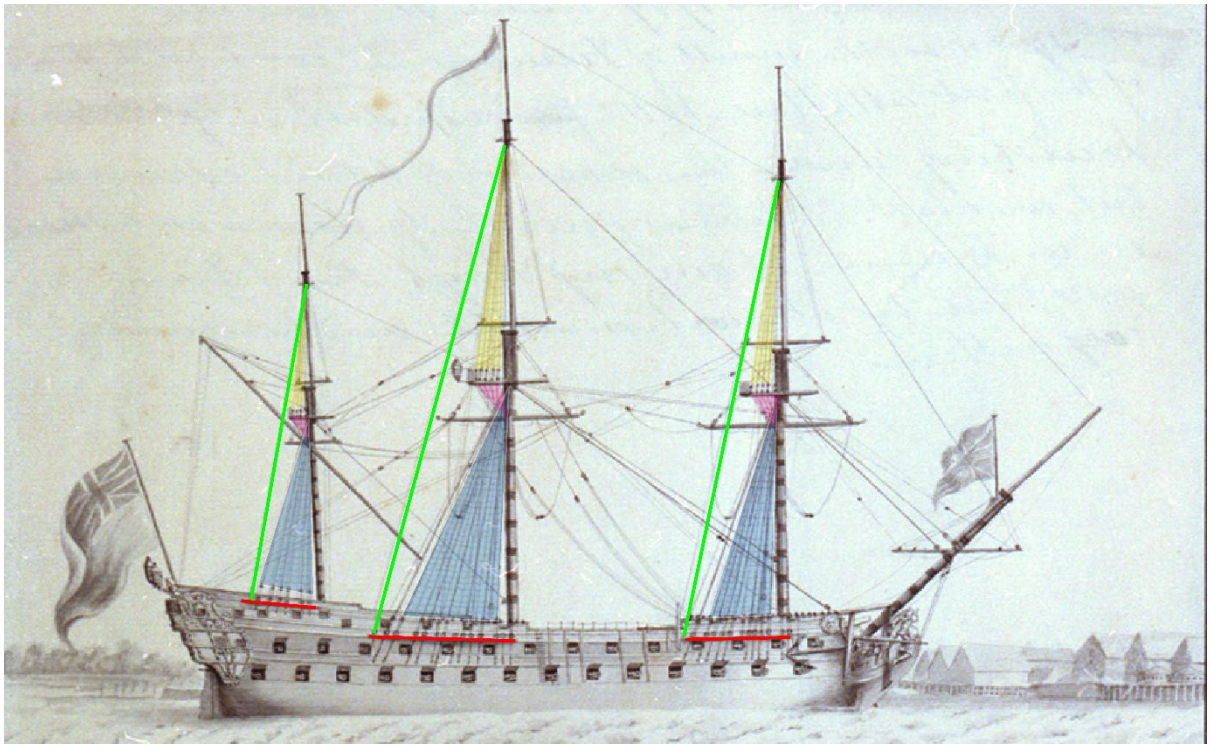


Figure 32 The Shrouds and Backstays

Red = Channels, Blue = shrouds, Pink = Futtock Shrouds, Yellow = Top shrouds, Green = Backstays (not the topgallants are omitted from this picture)

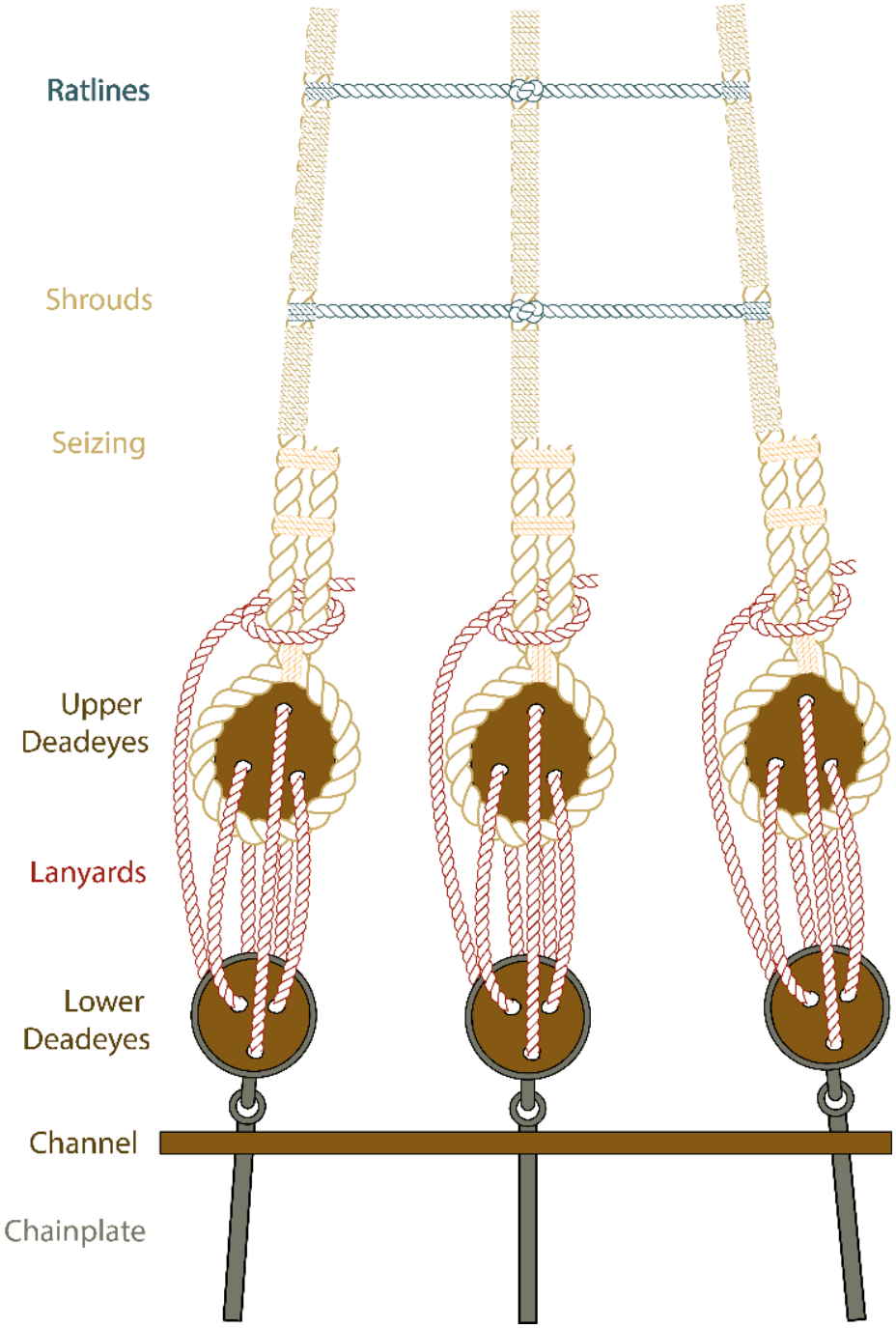


Figure 33 Schematic of the lower shroud layout

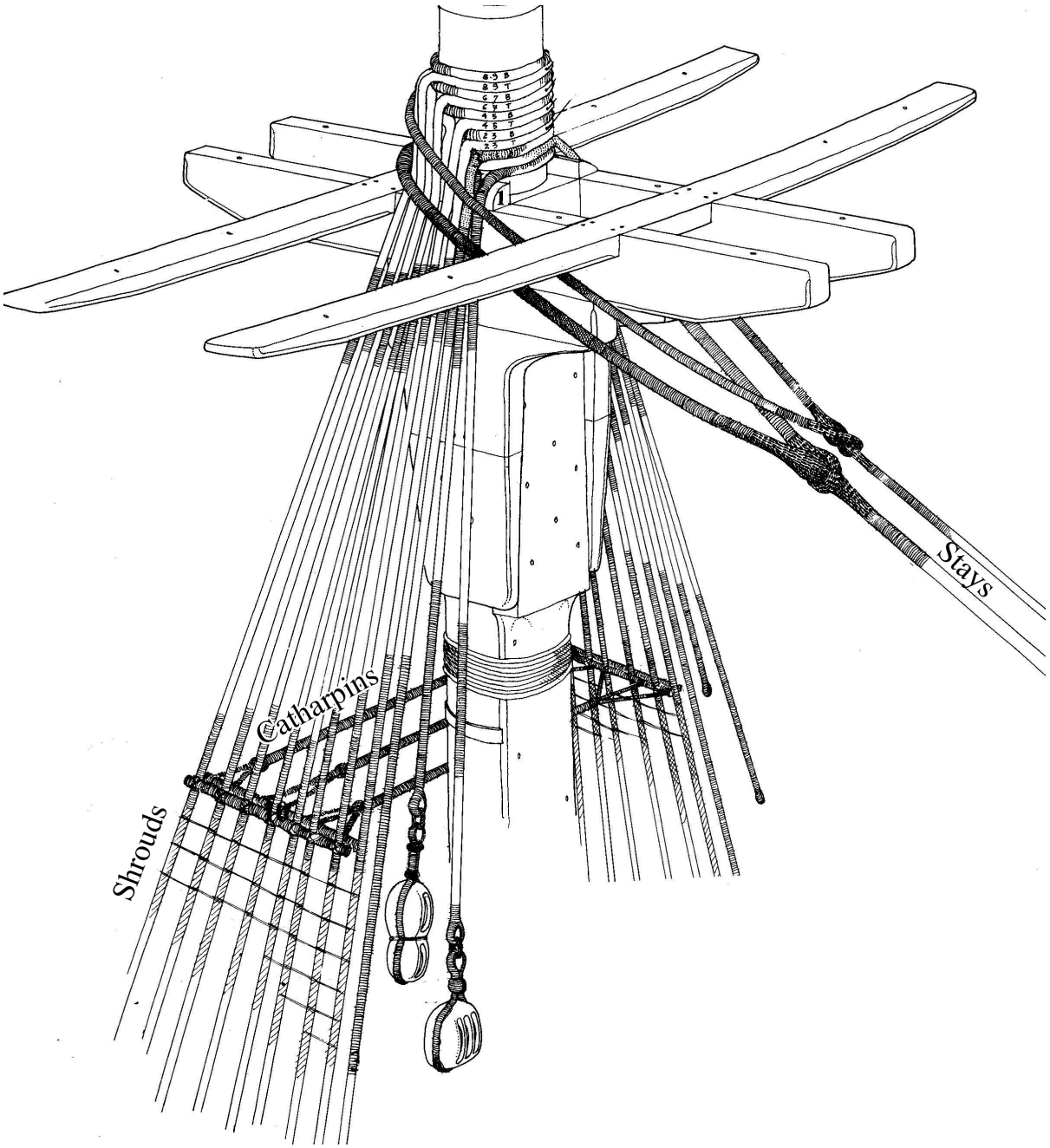


Figure 34 The upper mast showing the Stays, shrouds and catharpins after Boudriot (1987. p130)

The majority of the rope recovered from *Invincible*, came from Trench 1 and it's thought to have been in store as junk for the creation of gun wads, although several ropes interpreted as shrouds were recovered in this collection they could have come from any ship and therefore they are not included as part of this study. Trench 5 however did reveal several ropes associated with the main masthead.

The shrouds are the lines which support the masts port and starboard. Large iron straps are bolted to the hull of the ship, typically just above the lower deck so as not to impede the operation of the main battery. These travel up through the channels, "a thick horizontal plank projecting from the side of a vessel and used to support the shrouds and keep them clear of the bulwarks" (Steffy, 1994, p. 269) and this would then wrap around the lower deadeye. The upper deadeye would be turned into the shroud rope which would in turn continue around the top of the mast above the trestle trees and then lead back down to the next dead eye along. A lanyard would then be passed through each of the eyes to provide tension using a mechanical advantage of six. Ratlines would then be tied between the

shrouds to create a ladder to allow the sailors to go aloft. The swifter was the aftmost shroud in the group and would end in an eye splice going directly onto the mast, meaning that there should be an odd number of shrouds each side although this is not always the case.

For the topmasts, the pattern would be repeated but with the lower deadeyes attached to the tops. Futtock shrouds would then go from the chains or the topmast deadeyes back to the lower mast head. Deadeyes were used rather than standard blocks as the pressure generated by the shroud's lines would be too great for pin and sheaves. Back stays would have also run from the top of the topmast to the main hull channels in the same fashion as the stays.

The exact number of shrouds *Invincible* would have carried is not known as although the contemporary drawings show the shrouds, they are not 100% clear. The 1749 drawing appears to show 13 dead eyes on the main channel although not all of them appear rigged. The 1751 drawing is slightly clearer and shows 15 dead eyes in the channel, the aft most two appear to be for the back stays and two deadeyes in the centre are unrigged likely for the setup of preventer shrouds in bad weather.

The two illustrations have differing numbers of shrouds for each mast, and neither is clear enough to make out the topgallant shrouds. Falconer (1769) shows the top gallant shroud as extending to the cross trees of the topmast, but it is not clear if they have blocks. According to Lees (1979 p.61) Royal Navy ships stopped using deadeyes for the topgallant shrouds in 1719 but they are shown on the 1745 establishment rigging plan for a 60-gun ship (Figure 9) however deadeyes of the same size were still used on the standing backstays. The two illustrations also show the aft most backstays as being in the same channel as the shrouds whereas ships of the 1745 establishment have these back stays in a separate channel further aft and slightly higher in the ship to give a better angle.

Falconer (1769, p. Plate VI) shows the main mast set up for a 74 (although it should be noted that most Royal Navy 74s were smaller than *Invincible*), which shows 11 shrouds, and by the time of Steel (1794) they are reduced to nine a side. *Valiant*, said to be a direct copy of the *Invincible*, shows 11 shrouds on the main and fore and seven on the mizen. Although it should be noted that the 60-gun which Wilkins (1745) list as having eight shrouds on the fore mast has 10 full size deadeyes in the plan, one of these is unrigged and the other is partnered with a smaller deadeye for the back stay.

This number of deadeyes is like the number listed by Wilkins (1745) (Table 5) for a 100-gun ship suggesting *Invincible* may have been rigged the same.

Table 5 Number and size of deadeyes on a 100-gun ship after Wilkins (1745)

Mast	Number of Deadeyes a side	Size (inches)
Main	11	17
Fore	10	16
Mizen	7	11
Main Top Backstay	3	11
Main TG Backstay	1	8
Fore Top Backstay	3	10
Fore TG Backstay	1	8
Mizen Top	1	8

Within Trench 5 next to the stay collars several sections of served cable with an approximate diameter of 100mm was noted in the area, the largest of which terminate in a concretion where another section of the same size cable changed direction. Within this concretion was the remains of 12” three strand cable which showed no evidence of worming seized around this was an 8” hawser that was both wormed and served. This is likely the remains of a Catharpin a line which braced the shrouds behind the yards adding to the interpretation of these lines as the shrouds. Unfortunately, no significant lengths of these ropes were recovered.

According to Lees (1979) The main shrouds would have been 60% of the size of the stays, so knowing the size of the main stay it is possible to predict the main stay would be made from 11” cable. This measurement can also be used to work out the size of the dead eyes for each shroud which would be 1.6 time the size of the rope (Lees, 1979, p. 189). An estimated size and number of shrouds is displayed in Table 6 with the measurement rounded up to the nearest half inch.

Table 6 estimated number of shrouds aside and diameters of the deadeyes (the backstays would be the same size as their appropriate shroud).

Shroud	Size	Deadeye
Main	11	18
Main Top	*7.25*	12
Main Topgallant	4.5	7
Fore	10	16
Fore Top	6.5	10
Fore Topgallant	4.25	7
Mizen	9	14
Mizen Top	5.5	9

Deadeyes

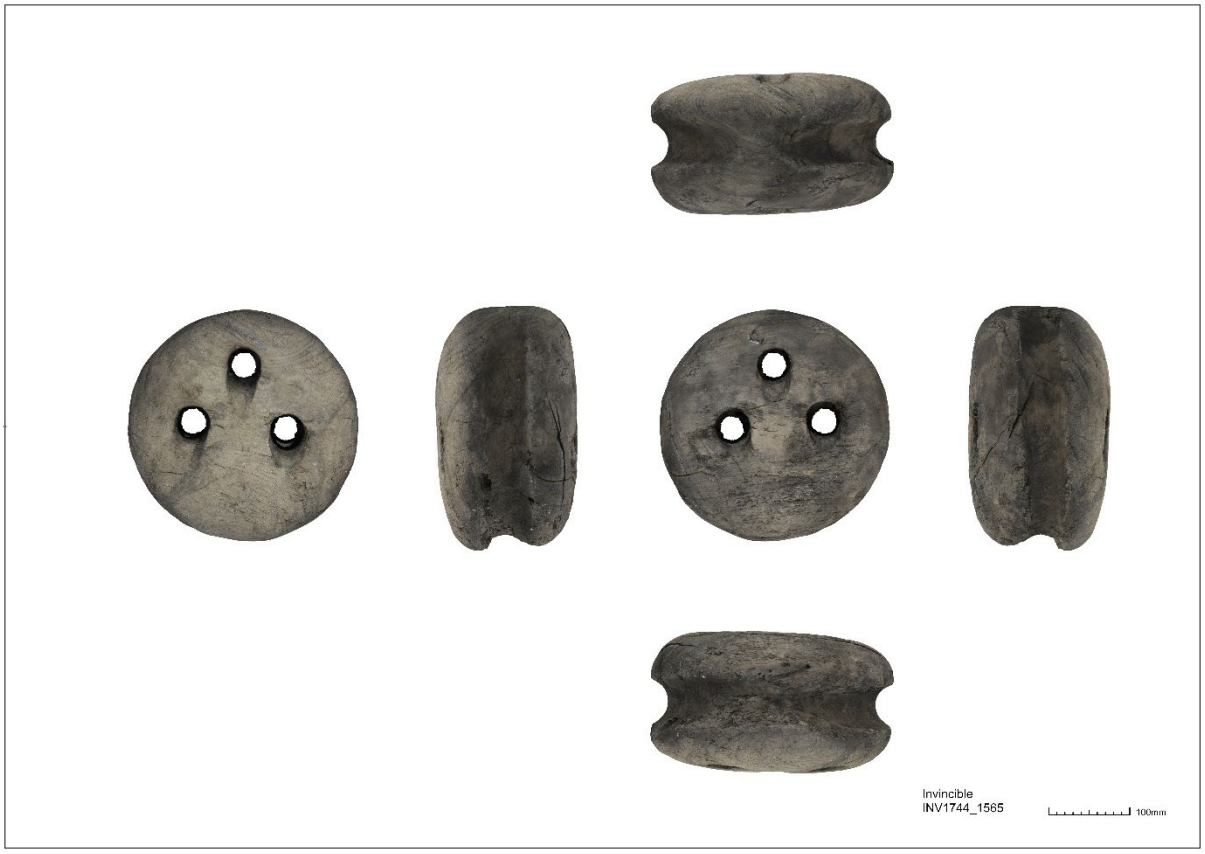


Figure 35 INV1744_1565 A 12" Deadeye

Eight deadeyes were recovered during the 2017-19 excavation with an additional 40 in the 1980s ranging in diameters from 89mm to 457mm (3½ to 18 Inches) many of which had their size in inches carved into them either in Arabic or roman numerals, suggesting a standardisation throughout the Royal Navy (Table 7).

Table 7 Sizes and numbers of the deadeyes recorded on the site.

Size	Salvaged 1757	Recovered	Mast
18	23	4	Main
17	2		Fore
16		1	
14		3	Mizen
12	1	6	
11		7	
10	42	5	Top masts
9		5	Mizen Top
8		2	
7		12	TG Backstays
5		1	Ships Boats
3.5		1	

The largest deadeyes recovered from the site were 18-inch diameter; these were likely from the main mast shrouds. Three of these have been recovered, all marked with 'XVIII', and a possible fourth recovered in 1981 was measured at 17 inches but is heavily degraded. The score width and depths support the hypothesised shroud size of 11", and the holes suggest a 7" lanyard. This matches the predicted size of the main shroud as 60% of the main stay. The deadeyes in the 16-17" range could possibly be for the foremast and the 14" for the mizen topmast. The largest collection recovered in 1758 were 10" likely suitable for both the fore and main topmasts.

The 12", 11" and 8" do not fit into the predicted size of deadeyes for use on *Invincible* but both the 12" and 11" had their lengths inscribed in roman numerals suggesting that they would have had a purpose aboard the ship, potentially as spares for the top mast shrouds.

The two 8" are likely anomalous with 87/0115 being described as heavily concreted and INV.190 being of made in a non-standard shape and material (Figure 36).

Figure 36 INV.190 (Chatham Dockyard, 2018)

The smallest deadeye recovered the 5" and 3.5" likely for the rigging of ships longboat or pinnace.

The fact that there are at least 12 different sizes of deadeyes known to have come from the wreck when it would only require six different sizes suggests that the rig was not as standardised as thought. By the end of the 18th century the number and type of deadeyes was rationalised down with only four sizes with the fore and main having the same size shrouds and deadeyes and the mizen using the same as the topmasts of the main.

Given the vessel only survives to the gunports on the main deck it is likely that if the lower deadeyes were left on the hull, they, or part of the chains, may still be present in the areas to the southwest of the wreck where no excavation has occurred.

Euphroe

One 28” Euphroe was recovered from the bosuns store in 1986, it was used to spread the crow-foot from the stay up to the mast top, these prevented the topsail “striking violently and fretting against the edges of the tops” (Falconer, 1769). The euphroe would have had a tackle consisting of two single blocks attached to the preventor stay to provide the tension, with the crowsfoot consisting of a single line running through the holes in the top through the euphroe and back. The block had sixteen 20mm diameter holes, which would be suitable to 2” line. Crowsfeet can be seen on all the lower masts in the 1751 image (Short, et al., 1751).

Figure 37 INV.167 Euphroe

According to Lees (1979, p. 168) the block would have been quarter the length of the appropriate mast head. This would mean that the euphroe recovered from *Invincible* would have been suitable for a 112” or 2.85m long mast head far smaller than any of *Invincible’s* lower masts, meaning it is more likely supporting an awning to protect the officers and crew from the weather (Falconer, 1769). However Steel (1797) lists the Euphroe for the foremast of his 74 as only being 13” and his mizzen at 24” meaning that this block may have been a spare of either of these masts, he also list a 34,24 and 22 kept on board for awnings and that they are rarely used on the stays except in smaller vessel, suggesting that *Invincible* one have been one of the last ships rigged with euphroe before the changes in the late 18th century.

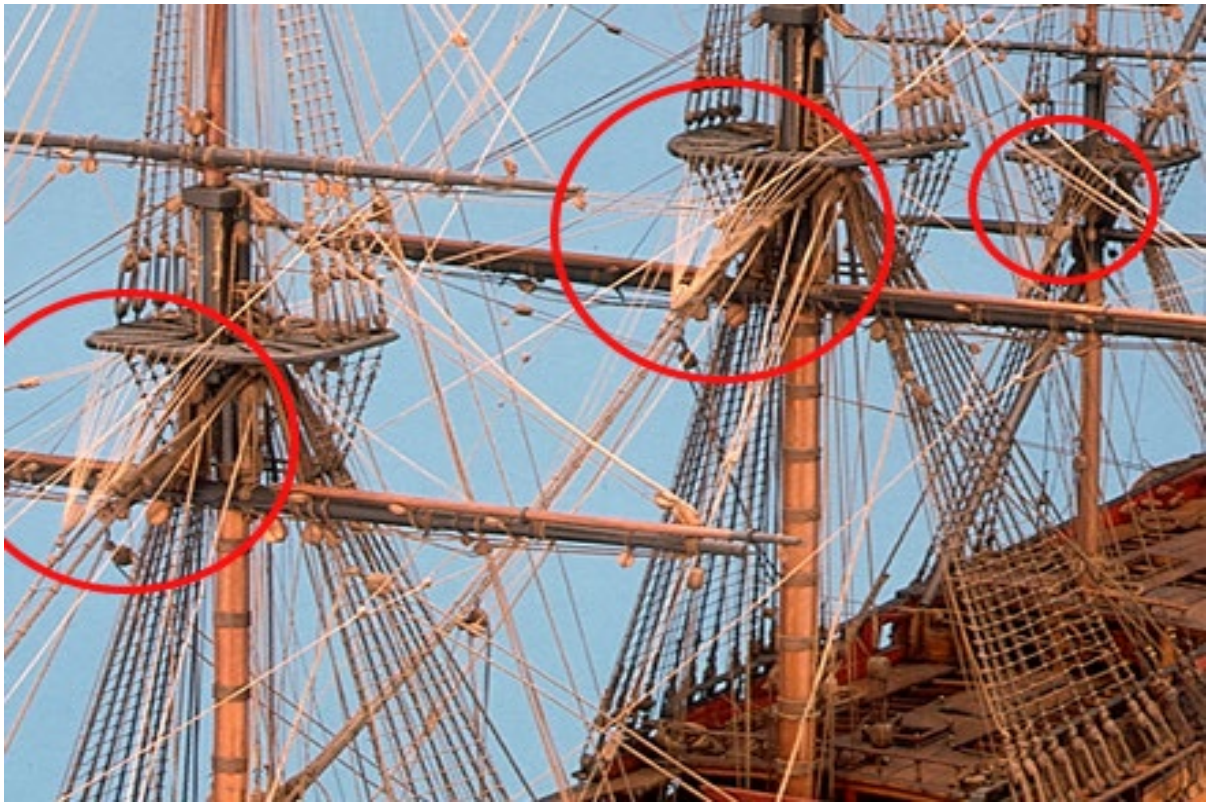


Figure 38 The Euphroes and crowfeet on 64 third rate c.1774 (NMM, 1775)

Running Rigging

The purpose of the running rigging is to hoist the spars up the masts and control the sails. This was made easier through mechanical advantage provided by block and tackles reducing the force needed to hoist the heavy weights.

139 objects relating to the running rigging were recovered between 2017 and 2019 and over 500 artefacts were recovered in the 1980s. It should be noted that although block and tackles were primarily used for the running rigging, their usefulness expanded to any heavy work such as handling any cargo or guns; therefore, some blocks may not be for the rigging.

Due to the conditions on the site the vast majority of finds in the running rigging category are individual *Lignum vitae* sheaves and pins, it is not clear if these were once complete blocks where the elm shells have eroded away or spares in store. The sheaves ranged in diameters from 330mm down to 95mm, some of the pins showed heavy wear as *Invincible* was on the outward journey and the rigging was recently replaced it would suggest that the shells had degraded as there would be no need to keep old stock aboard the ship where space is paramount.

Common Blocks

Common blocks as the name suggests are the most common type of blocks abord the ship, these are non-specialist blocks with simple oval shells and a single strop and would have been used for multiple purposes aboard the ship. These would have not been limited to the rigging but for any task that required mechanical advantage such as moving the guns or cargo, making it hard to assign any artefact to its intended purpose.

101 Common single blocks were recovered from the site ranging in sizes from 5” up to 20” in height. 36 of these blocks had their hights carved into one of the faces and multiple broad arrows. Of these 101 blocks

Only 29 common double blocks were recovered from the site ranging from 8 to 15” and of these 20 were the 10” blocks thought to be for the gun tackle. The small number of double blocks would suggest that in terms of the rigging when a luff tackle was needed the long tackle block was preferred.

INV1744_379 Single Block

INV1744_3147 Double Block

Figure 39 Two 10" normal blocks though to be spares for the gun tackles.

Long Tackle Blocks

Long tackles or fiddles are double blocks with one sheave above the other rather than side by side as in common blocks, with the lower block three quarters the size of the upper block to create a “fiddle” like shape. These would usually be rigged to a single block in a luff tackle. They maintain the mechanical advantage of normal double blocks although there would be more friction due to the smaller lower sheave.

Figure 40 INV.146 Fiddle Block (Chatham Dockyard, 2018)

These would have been used in positions where having the wider side by side blocks could foul up.

These blocks would have been used on the lifts of the lower yards of the fore and main mast where they would have been attached to the mast caps. Wilkins (1745) lists the size of the lifts on the main yard on a 100-gun as 4.5 inches meaning that the swallow of the block would need to be larger than 36mm in diameter.

They were also used on various tackles on the yard, where they would be seized into a pendant around the yardarms and fall to an ordinary block with a hook for lifting boats and supplies in and out of the vessel (Figure 41). Although it should be noted that the Mainstay Tackle of *Invincible* was an ordinary 14" double block.

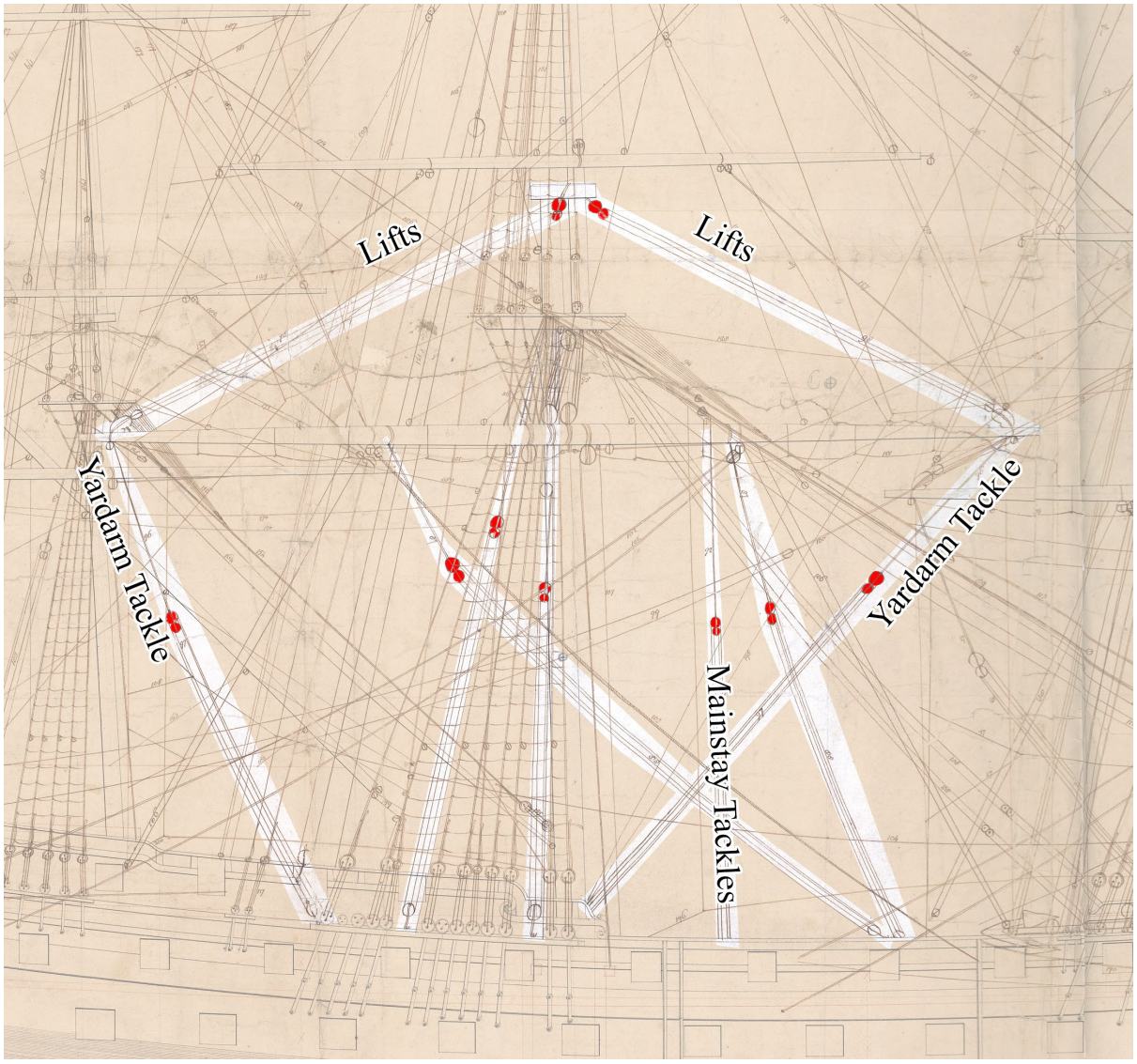


Figure 41 Various long tackle blocks shown on the rigging plan of a 60-gun ship of the 1745 Establishments (Sjöhistoriska museets arkiv: OR 3003)

Four fiddle blocks were recovered in the 2017-19 season and 15 were recovered in the 1980s, several of these were marked with their lengths in roman numerals along the face. These ranged in size from 24" to 34". A 28" fiddle block (**85/080**) was recovered along with a strop terminating in a short loop (Bingeman, 2015, p. 100) it could be that this was a lift block seized into an eyebolt on the cap.

Double Scored Blocks

Double scored blocks would have two strops running either side of the centre, these would have been used where there was a need for the block to be connected to a yard, with one strop longer than the other ending in an eye splice which would have gone around the yard and lashed to the second strop.

The most common use was in the jeers, the tackle system for raising and lowering the yards, double blocks would have been used on the yard going up to ordinary blocks attached to the mast head. They were also used for the topsail sheet blocks.

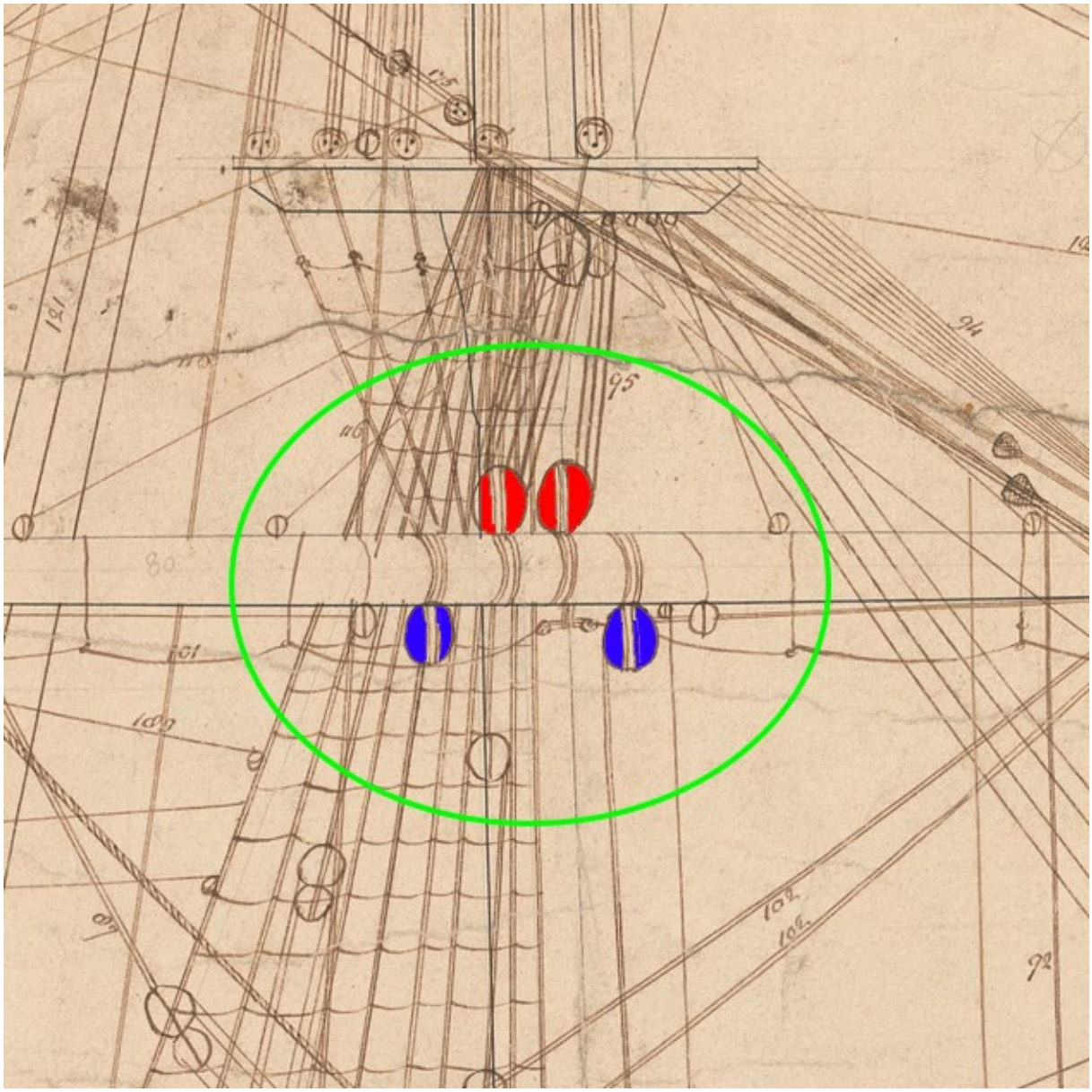


Figure 42The Jeers blocks (red) and top sail sheet blocks (blue) on the main yard (Sjöhistoriska museets arkiv OR 3003)

Single, double, and triple double scored blocks have been found on the site.

Figure 43 Double Scored Block INV1744_3022

Two 20” treble blocks of this type were recovered in the 1980s (INV.351 & INV/86/338). Treble blocks were rarely used on board with the first rate using them on the standing part of the Jeers and therefore

unlikely to be double scored. The relatively small size of the block would also mean that although it would have had a strong mechanical advantage it was likely used with a relatively thin 5” line whereas the Jeers and sheet blocks of a 100- and 90-gun ship were 7.5-8” in diameter needing a 30-32” block. It is therefore likely that these two blocks may have either been undersized for the job or are part of a winding tackle for lifting heavy cargos like the long tackle blocks or the mainstay tackle.

At least two double blocks (INV.258 & INV/86/110) were recovered in the 1980s both measuring *c.*27” and one in the 2017-9 period (INV1744_3022) measuring 21” high. Likewise, with the 20” block these are still too small for the main or fore jeers but the 27” block may be for the mizen jeer which was 6” (Wilkins, 1745)

A wooden tag was recovered alongside INV/86/110 featuring the initials TB, Bingeman (2015, p. 96) hypothesises that this may stand for “top block” however both Falconer (1769) Steel (1794) describes a top block as being bound in iron with a hook which would connect to the caps to raise and lower the upper masts so it is unlikely to be this.

Three single, double scored blocks were recovered INV.183 & INV1744_1210 & 1500 measuring 21” and 18” respectively again these are too small for the ships main rig if using the historical calculations.

Main Sheet Block

Main sheet blocks are long tear drop shaped blocks with a hole at one end to secure the block to a strap. The pin was the same length as the block allowing the fall of the line to be belayed onto block if needed. These were used for the sheet-tackle of small vessels suggesting that this was part of the longboat or pinnaces’ rigging. A similar shaped 11” block but without the extended pin was recovered in the 80s (INV.54).

Figure 44 Main Sheet Block (INV1744_1320)

Clue Garnet Blocks

Clue or clew garnet blocks were seized into the lower corner of the sails (known as the clue or clew). They are single sheaved and feature a distinctive hood through which the strop passed through. These allowed the sails to be furled easily against the yards.

A total of 11 clue garnet blocks were recovered from the site between the two excavations, these all featured their length in inches carved into the face. Seven of these were 16”, four were 14” and one 11”. INV1744_1158 and INV.150 still featured part of their stop which consisted of a served rope. These would have been attached to the yards with the fall leading to another clue block seized into the clue of the sail.

Figure 45 Clue Garnet block INV1744_3144

Topsail Halliard Blocks

Topsail Halliard blocks are large flat single sheaved blocks used to raise the topyards. Three different sizes of block have been recovered 28, 25 and 20”. These could represent the halliard lifts of the top mast of each yard. The 20” block INV1744_536 shows evidence of repair where a section of the shell has been doweled in.

Parrels

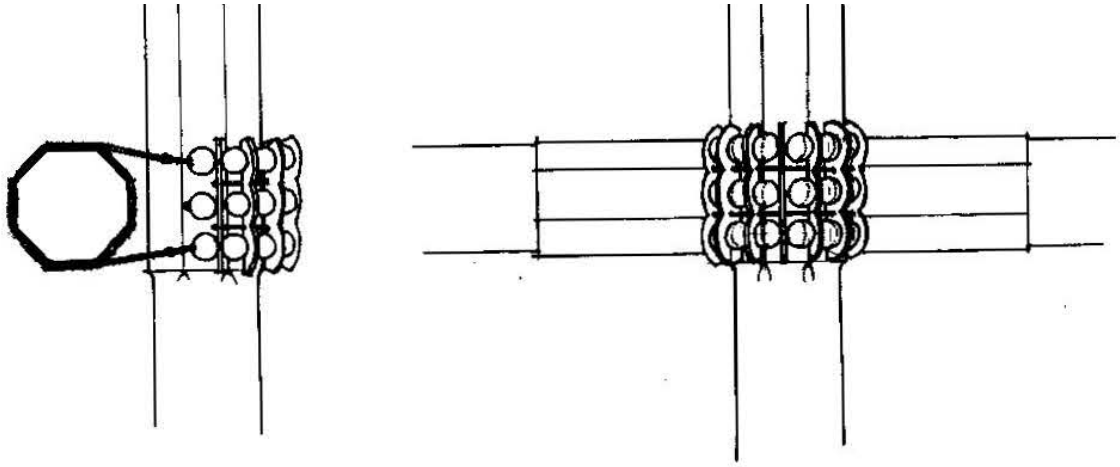


Figure 46 parrels trucks and ribs on the topmast (Boudriot, 1987, p. 162)

To raise the spars a bearing, known as a parrel was made up of ribs and trucks connected by rope, the trucks would roll up and down the masts allowing the spars to raise smoothly, a total of 69 trucks have been recovered ranging from 6" to 2" in diameter and 37 ribs including single fragments, 18" double and 37-9" triple ribs.

According to Lees (1979, P.168) the ribs would have been 1.5x the diameter of their yard in length, except for the topgallant yards which would have been twice the diameter in length. The trucks would have been a fifth of the rib's length in diameter for the triples and a third for the doubles. By applying this formula to the mast's sizes in Table 2 the following predicted sizes can be made (Table 8).

Table 8 Predicted Length of the Parrel Ribs against their Yards after Lees (1979)

Yard	Rib Length	Truck Diameter
Main	34 2/3	7
Main Top	22 1/2	7.5
Main Topgallant	19 1/2	6
Fore	30 3/4	6
Fore Top	19 1/2	6.52
Fore Topgallant	17 1/4	5.75
Mizen	22 1/8	4.5
Mizen Top	14	4.75
CrossJack	19 2/3	6.5
Spritsail Yard	13	4.25

However, the majority of the ribs recovered did not fit into this pattern, this may be due to *Invincible*'s masting not following the Establishments and making do with the nearest size of mass-produced rigging gear.

Table 9 Rib and Bead sizes recovered from the wreck.

Bead Size	Count	Rib Length	Count
6	9	39	1
5.5	2	37	1
5	6	36	2
4.75	1	30.25	1
4	14	28	4
3.75	13	27	2
3.5	2	22	4
3	9	20	2
2.75	6	18	7
2	1	14	7
		13	2
		12	5

The exact method the parrels were connected to the mast and spars is not known (Lees, 1979, p. 66) and they were replaced by truss pendants on the lower masts in *c.*1760 making *Invincible* one of the last warships to be rigged in this way, the use of parrels did continue on the upper masts and the mizen.

Rack Block

Figure 47 Rack block INV.147

One complete and one partial 58” rack block was recovered in the 1980s, these would have been lashed on either side of the gammoning on the bowsprit to lead the running ropes for the sprit yards. By the end of the 18th century, they are “seldom used” (Steel, 1794).

Miscellaneous rigging

Shroud Trucks

Shroud trucks were wooden tubes which were lashed to the lower shrouds to act as a guide for the running rigging to pass through them, over 100 have been recovered from the wreck, these are all of a similar size of around 4” (90-100mm) high with a central hole of *c.*35mm in diameter allowing a 4” circumference line to comfortable pass through.

They have one vertical groove which sat against the stay and two horizontal groves which would allow them to be lashed to the stay using 2.5” circumference line.

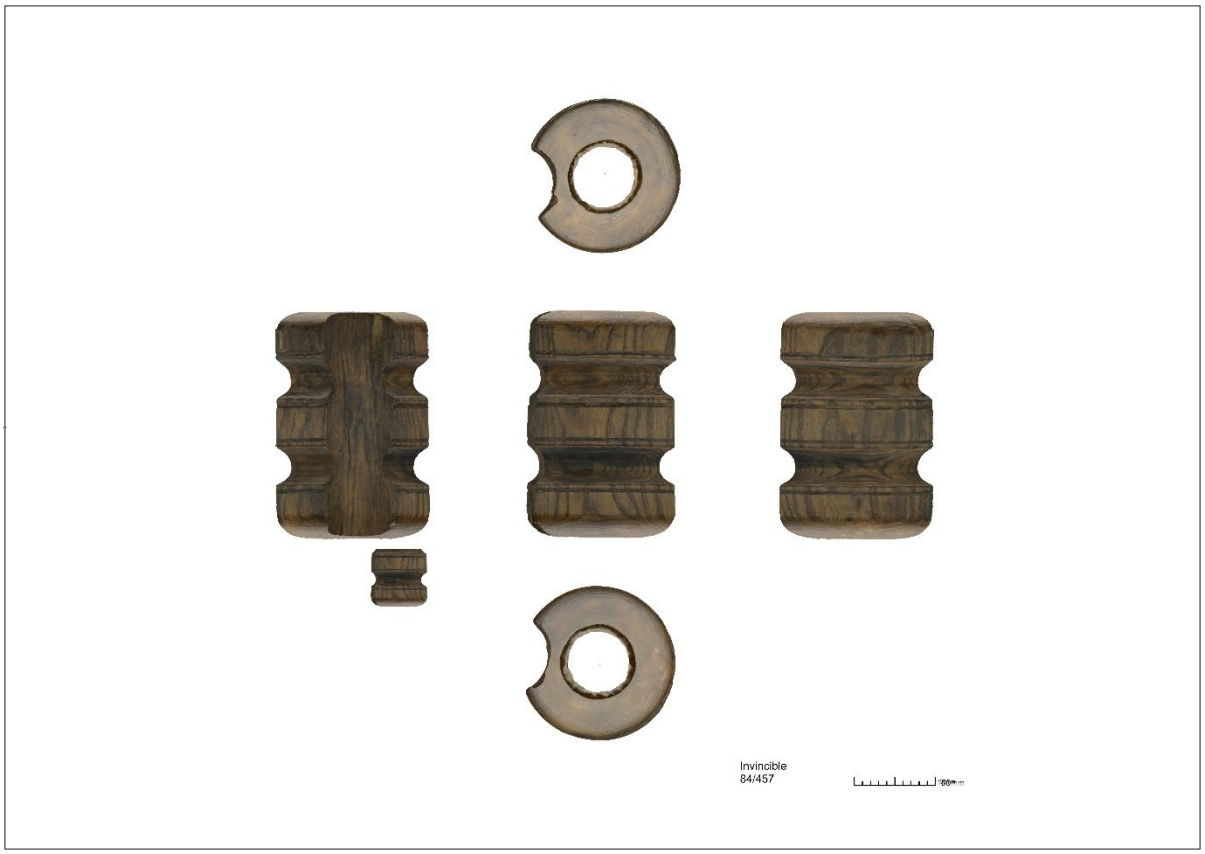


Figure 48 Shroud Truck 84/457

Mainstay Tackle

A 14" double block was seized just below the serving on the mainstay, this would have formed part of the mainstay or winding tackle used for bringing heavy loads into the ship such as provisions and cannons and would have been positioned above the main hatch on the deck. Leather parcelling was laid around the mainstay, and the strop of the block, also parcelled in leather was seized on the stay with no pendant. It is likely that this would have been partners with a single block of a similar size with a hook seize onto its strop in a luff tackle.

This differs from the examples shown in Lees (1979, p. 47) which show fiddle blocks seized onto the stay using long pendants. Steel (1794, p. 177) describes a double block but also mentions the pendant which the *Invincible* mainstay tackled lacked.

Ship's Boats

Boats had to operate independently from the main ship, but the ship had to carry spares and supplies to outfit each boat therefore not every rigging element recovered from the ship, especially those in store, are for the main rig but rather for the rig for the boats.

Several of the smaller rigging elements such as the small mast caps (**INV1744_1461 & 1462**) and the 5" & 3.5" deadeyes are far too small for *Invincible's* rigging, as well as specialist blocks such as the main sheet block. This would suggest that they are the spares for the ship's boats. The Establishments for boats in 1746 list a total of five boats to be issued to 100- and 90-gun ships with an additional Deal Cutter added in 1755 (May, 1999, p. 56). The salvage records mention a mast for the pinnace and longboats were recovered but no other details were given. Using Wilkins (1745) formula the largest longboats of the time had a main mast of 9.37m long and a diameter of 0.15m (*c.*8.5 yards and 6"). This would suggest a stay of 3" for the longboats and therefore a deadeye of 5" matching the sizes

recovered. This is corroborated by Steel's (1790) rigging list for the 74-gun ship which lists the longboat as having 5" deadeyes on the shrouds and stays. Steel does not list the standing rigging for the longboat's foremast or for the pinnace, but it could be assumed that the 3.5" deadeyes is for this or a smaller longboat.

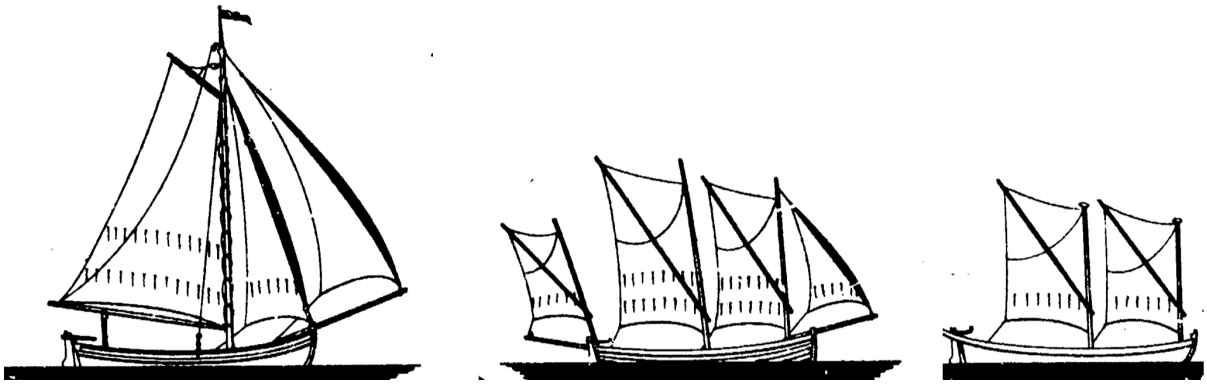


Figure 49 The rigging on a Longboat, Deal cutter and Pinnace after (Chapman, 1768)

Figure 50 Main stay Tackle Block

Discussion

The main aim of this project was to reconstruct a baseline rigging plan for the *Invincible* to assess the extent to which the archaeological and historical, iconographic and other archive datasets align, and to aid archaeological assessment of other, more limited rigging finds.

However, it was not ultimately possible to accurately create a specific rigging plan for *Invincible* as the archaeological record does not fit 100% with the historical one. Only a generic mid-18th century rigging plan could be produced such as Figure 9.

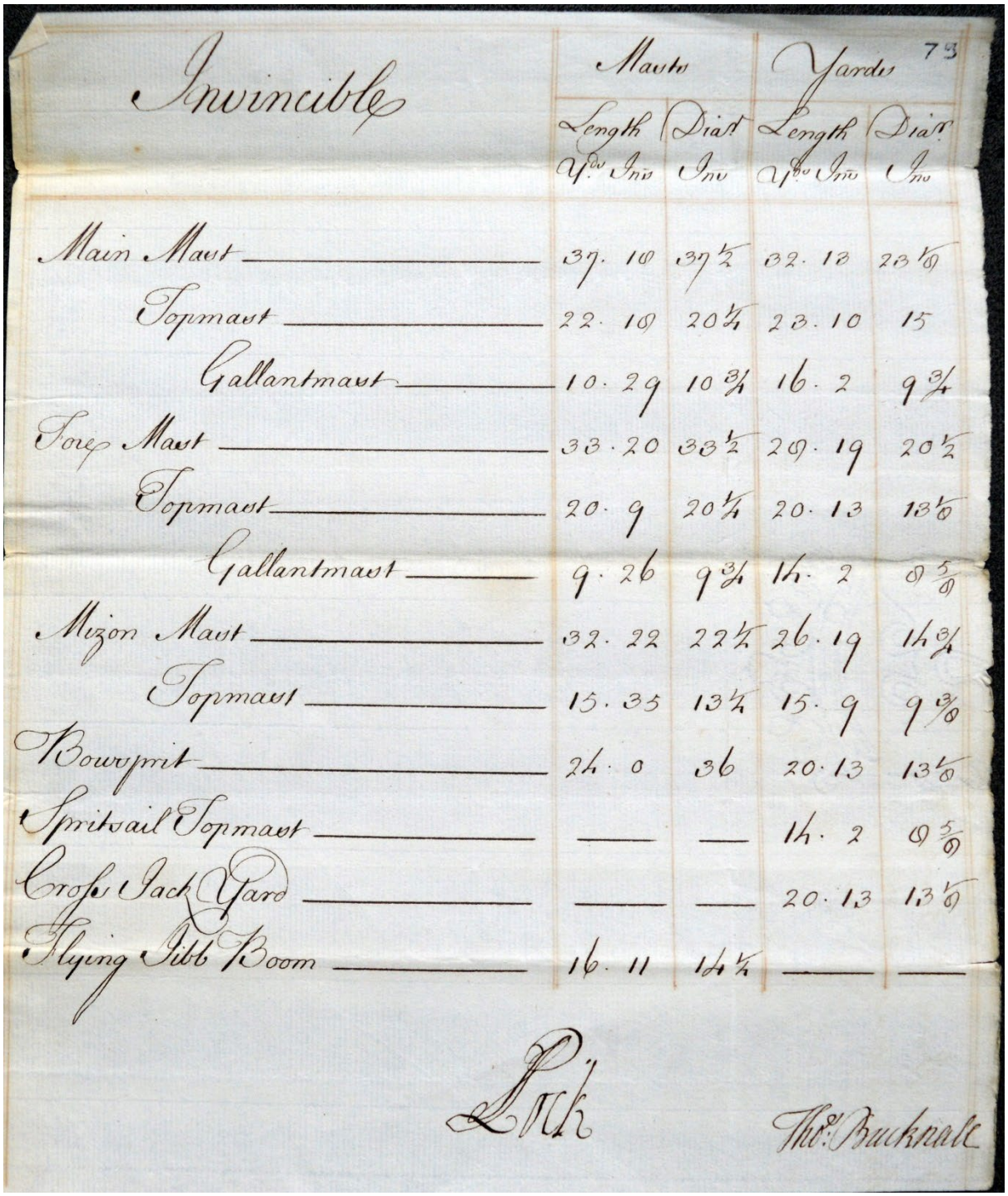
The complexity of a full rigging plan can be seen in the 60-gun plan in Figure 9 with each line overlapping and obscuring each induvial element, making it hard to pick out individual elements. Although superficially resembling the way *Invincible* would have been rigged there are some significant differences between the plan, the archaeology and other historic records as *Invincible* was over 600-tons larger. For example, the position of the channels, the lack of the bumkins and the

deadeyes instead of heart blocks make it hard to fit the archaeology directly into a scaled-up version of this plan as many archaeological elements could fit into multiple places aboard the ship.

Indeed, it is commonly quoted that a 74-gun ship would have needed over 1000 blocks of various types, as well as miles of rope and rigging (Cooper, 1984). Thus, with just the small cross section of artefacts raised, representing only a fraction of the full complement, reconstructing a complicated complete rigging plan is near impossible, leading to an over-reliance on historical and secondary sources.

In terms of building an accurate rigging plan for *Invincible*, the main source is ADM/106/1046 the assigned mast and spar sizes for *Invincible* when she was commissioned into the Royal Navy (figure 50) which includes a table showing the mast and yard sizes the dockyard thought *Invincible* should carry (Figure 51) and the plans for the *Valiant* (1759) which was said to be built on the same lines as *Invincible*. By comparing this to the established formula for the sizes of masts in relation to the size of the ship, we can see that these masts would have been suitable given the knowledge and technology of masting at the time but using the formula of (length x breadth)/2 as laid out in Sutherland (1711) and Steel (1797), the main mast is approximately 0.5m longer than it needs to be. Under the 1745 Establishments a 100-gun's mainmast should be 2.24 times the ship's beam and the 90-gun, 2.26 times the ship's beam. The dimensions given in ADM/106/1046 are approximately 2.25 times the ships

beam, suggesting that as *Invincible* sat between these two rates in size the multiplication factors were averaged to give the ship comparable mast sizes and therefore comparable rigging sizes.



Invincible

73

	Masts		Yards	
	Length Yds Ins	Diat Ins	Length Yds Ins	Diat Ins
Main Mast	37. 10	37½	32. 18	28 9/10
Topmast	22. 10	20¼	23. 10	15
Gallantmast	10. 29	10¾	16. 2	9¾
Fore Mast	33. 20	33½	29. 19	20½
Topmast	20. 9	20¼	20. 13	13 9/10
Gallantmast	9. 26	9¾	14. 2	9 5/10
Mizon Mast	32. 22	22¼	26. 19	14¾
Topmast	15. 35	13¼	15. 9	9⅜
Bowsprit	24. 0	36	20. 13	13 9/10
Spritsail Topmast	—	—	14. 2	9 5/10
Cross Jack Yard	—	—	20. 13	13 9/10
Flying Jibb Boom	16. 11	14¼	—	—

Thos. Bucknall

Figure 51 The Masts and Spar sizes for Invincible ADM/106/1046

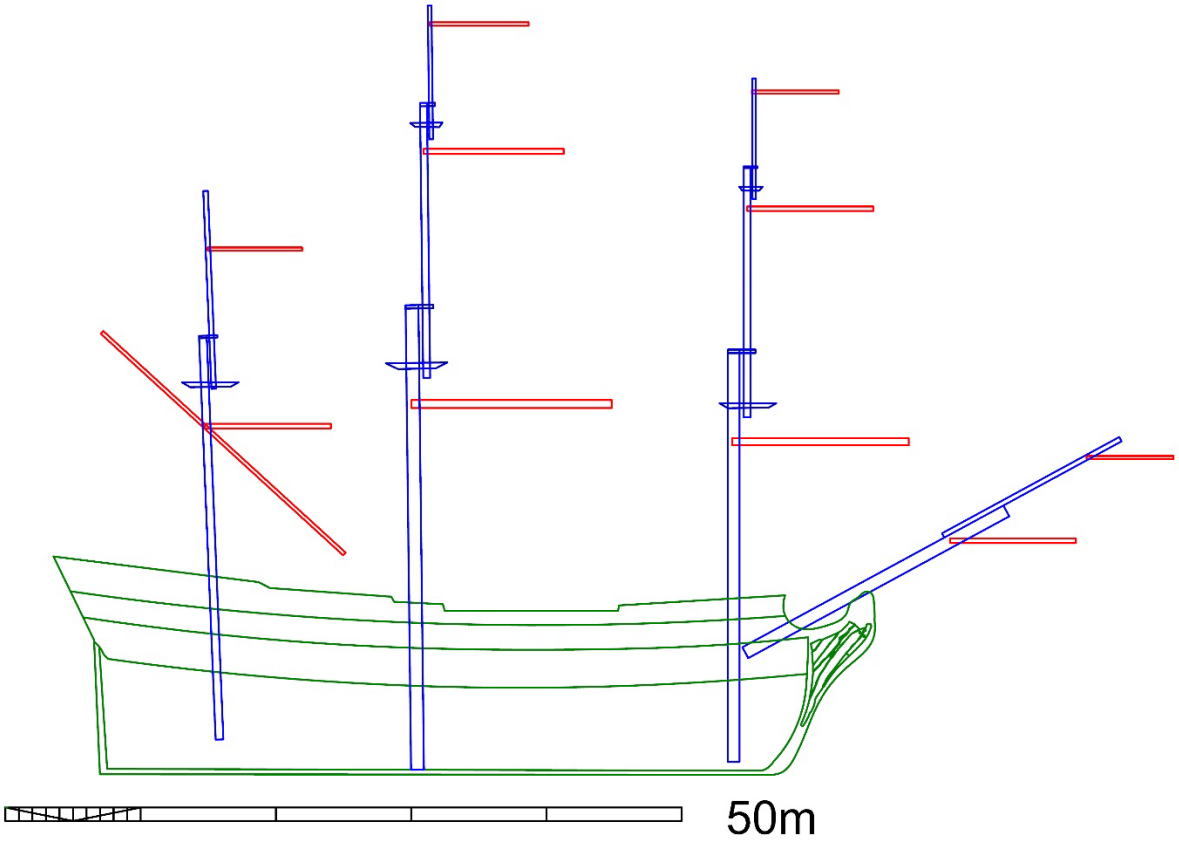


Figure 52 Details of ADM/106/1056 placed onto a masting plan.

However, there are issues with only knowing the lengths and diameters of the masts and trying to fit the ship into the Establishments. For example, we do not know if Establishment sized tops for a 90 or 100 were used or whether bespoke tops were made for the masts, and we cannot tell what the rake of the main, mizen and bowsprit would be.

Evidently when *Invincible* was first put to sea as a Royal Navy ship, the captain, Lloyd, and sailing master had several issues with the rig, as noted in the captain's letters (ADM1/2043) where Lloyd states that the ship was "greatly overmasted" with the pressure of the masts working the caulking out of the ship. He also felt that it was "morally impossible" to secure the masts, and the lower yards were longer and squarer than any other ship in the navy. But as we have seen from Table 2, and by comparing the masts sizes to the ones given for the *Valiant*, a ship built and rigged on the lines of *Invincible,* we can see that the yards are appropriate for a ship of the time. This issue may be down to Lloyd having only commanded a small sloop before given command of one of the largest ships in the Navy and therefore being unaccustomed to handling larger ships, or alternatively *Invincible* was not masted to the dimensions given in ADM/106/1042.

Lloyd also states the angle the tops give is too acute, suggesting that they are not the correct size for the masts. Lloyd suggests the issues are due to *Invincible* being two decks, while the 100 and 90-gun are both three decker ships, leading to the masts being tighter by 7ft.

As the mast dimensions are based on the length and beam of the vessels and not the height, the number of decks should not affect the size of the masts. However, the distance between the top of the mast and the deck would differ and therefore to maintain the best angle the distance would be further and therefore longer lines would be needed.

The rigging plans for ships usually give the circumference of the rope and in length in fathoms (Sutherland, 1711) for example Steels (1797) 1799-ton 74's mainstay has a given length of 22.5 fathoms, where his 100 and 90's mainstay are both half a fathom shorter. This may explain why the foremast was "so badly forced forwards by the stays that it would be crippled" (ADM/106/1059/172). By comparing the distances between the top of the foremast and the bowsprit of the 90 gun plans of the 1745 establishment with the given mast size for *Invincible* against the hull of *Valiant*, it can be seen that *Invincible* would have needed a forestay 1.5m longer than a 90. Likewise, the shrouds of the lower masts would also have to be longer by about a metre to adequately secure them.

It is therefore likely that this was the cause of *Invincible's* rigging issues early on its career when trying to fit generic establishment sized lines into a unique sized ship.

This may also go some way to explaining why although a large proportion of the rigging blocks recovered had their sizes carved into them, suggesting a uniformity across the Navy with supply and manufacturer, there are some anomalies within the archaeological collection. For example, 12 different sizes of deadeyes were recovered including some of irregular shape and materials such as INV.190 (Figure 53) whereas later ships would only carry four sizes (Steel, 1794).

Figure 53 INV.190 an 8" deadeye made from Beech. (Chatham Dockyard, 2018)

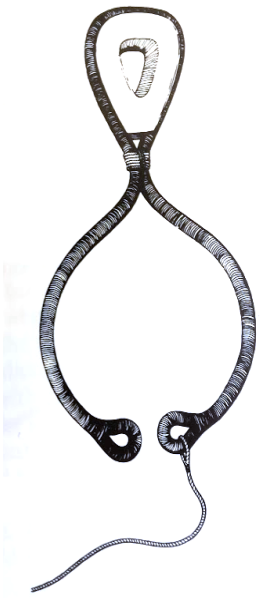
Given the size of *Invincible*'s masts you would expect the sizes of the shrouds and deadeyes to fit between the two ships, but we can see that *Invincible* carried larger deadeyes than the historical record for a 100-gunship on several of the masts (Table 10). This may be due to the historical documents or Lee's formula for working out the size of the shrouds not being as correct, but as four

18” deadeyes are in the archaeological collection and the contemporary salvage records state and extra 23 were also recovered this would suggest that *Invincible* did have 18” deadeyes on the main shrouds. The fact they are also marked with their sizes would also suggest that Wilkins (1745) may have used a different formula to work out the ideal deadeye size for his ships which was different from what was practical or regularly used.

Table 10 Predicted deadeyes against the sizes given by Wilkins (1745)

Shroud/Backstay	*Invincible*	100	90
Main	18	17	16.5
Main Top	12	11	10
Main Topgallant	7	8	7
Fore	16	16	15.5
Fore Top	10	10	9
Fore Topgallant	7	8	7
Mizzen	14	11	10.5
Mizen Top	9	8	7

Likewise, the heart blocks are all of a non-uniform size and shape, in particular the lower heart of the main preventer stay. According to Lees (1979) the standard way of setting up the lower collar of this stay up to 1793 was to seize the block into the centre of a line with two eye splices in either end so it could be fixed tight to the foremast (Figure 54). However, the lower heart appeared to be seized into the bight of long strop with an eye splice similar to the way the upper collar was seized before the mouse. The remains of another splice were seen at the other end of the stay collar suggesting it was either spliced around the fore mast or onto another rope or attachment on the deck in a non-standard fashion. This would have been a simple way to extend the length of the length of the line using simple methods already known to the sailors.



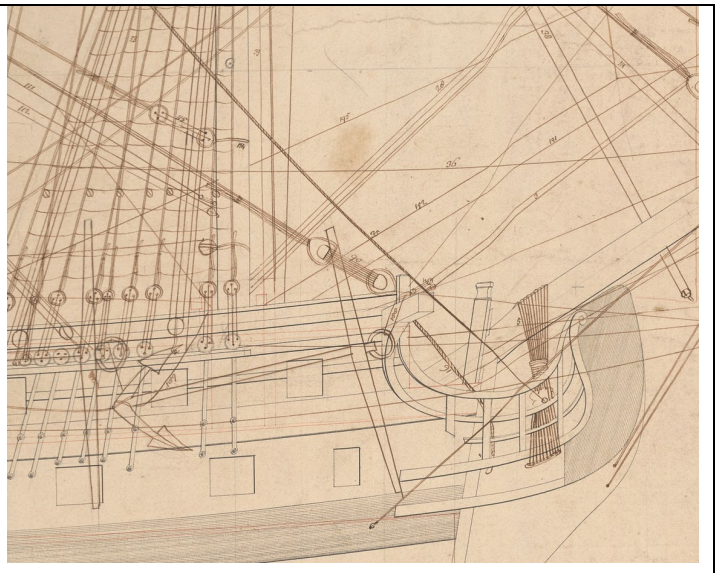


Figure 54 Preventer Stay Collar (Lees, 1979, p. 45) and shown attached to the foremast of the 1745 establishment rigging plan for a 60 gun (note this is a smaller rate of ship which appears to use deadeyes rather than hearts for the preventor stay) (Sjöhistoriska museets arkiv OR 3003)

Evidently there was a large issue with the rigging of *Invincible*, given the ship lost some or all its masts and rig on nearly every outing, which would mean constant repairs and replacements. For a standard ship of the Royal Navy this would be less of an issue as the Establishments allowed for set sizes which could be kept in store across all the dockyards and could be shared between ships. This is most evident with the ship's weapon system where everything was labelled with the size of the gun and appears to have a high degree of organisation. Whereas the rigging collection contained a mix of marked and unmarked blocks, suggesting that as elements were replaced, they were replaced with what was available. This is slightly evident in the letter from Admiral Keppel regarding the fitting out of *Valliant* (LBK/81/2) although written 30 years after *Invincible's* loss the ship was launched in 1759. Keppel states that the lower yards were too long and found it necessary to cut about 4ft from the length of the yards and the same off the topmast. As first glance this could suggest that, as Lloyd stated at the very start of *Invincible's* career as a British warship, it was over masted. However, Keppel goes onto say the mizen topmast was only 12.19m long whereas the original masting document stated that it should be 14.6m. Keppel returned the size of this mast to within a few inches of the 1747 document which is the same size given in the 1773 establishments for a ship of *Valliant's* class). He also mentions the mizzen yard as being over 4m longer than the original documents suggest. This suggest the at some point in *Invincible's* career that the size of the masts and spars were all changed, likely during the 1754-6 rebuild, or the original masting suggestions were not followed.

The historic documents point towards the begins of standardisation in the 18th century, with the introduction of the Establishments, but as everything was still handmade it may not have applied to all Royal Navy ships and only when they were built or refitted and with alterations and supply issues, we cannot say that each dockyard followed the standardisation to the letter and much more research and comparison need to be done to establish this.

These issues mean that it was not possible to reconstruct a complete, accurate rigging plan. However, it has highlighted that the Establishments probably weren't as rigid as first believed and adaptations had to be made, this is particularly important when considering that the capture of enemy warships was encouraged with 38 captured between 1741-1759, although the Establishment set out the design for new or rebuilt British ships other captured vessels would have had similar problems to *Invincible* and therefore compromised would have been made on the ground.

This project thus demonstrates why archaeology is an important complement to historical datasets, especially with rare objects such as the rigging, allowing us to see how ships worked rather than how they were supposed to work. Thus, further excavation of wrecks and studies of the rigging when recovered should be encouraged.

Further research

As with all archaeological projects, further investigation on the seabed with the knowledge gained from this study would be greatly beneficial. In particular the excavation and recording of the lower preventer stay and further excavations in Trench 5 would reveal a great amount of evidence regarding the standing rigging of the main mast.

Ships models are another source of information which could not be fully integrated as part of this project. These were often rigged contemporary with the ship they were representing and therefore provide a unique three-dimensional representation of the ships rigging making the deciphering and interpretation of the two-dimensional confusing contemporary rigging plans an easier task. Analysis of the models may also give us a better idea of where some of the odder blocks fit and decipher the various names in the historic records and isolate individual systems allowing us to fit the archaeology in to a plan with more confidence.

Due to the fragility and complication of recording these finds, and issues of access, interpretation of these models has relied on pre-published photographs and sources such as Ball and Stephens (2018), which inevitably did not cover the areas of interest to this paper with only general overviews and no detailed shots or specific areas which relate to the finds found on the wreck. Further study and three-dimensional recording of contemporary models and artistic representation may give a better idea of the changes in ship rigs throughout the 18th century adding to the interpretation of the archaeological material.

Further research into the archives of Europe may also reveal more rigging plans copied from the British. The highly detailed rigging plan for a British 60-gun in the Swedish archives would suggest that somewhere in the National Maritime Museum or Royal Navy archives, plans of this detail or complexity exist for the other rates of ships in the 18th century that have yet to be catalogued correctly. This may be further suggested by example Lees (1979 Plate 49) which shows the rigging plan of a 60-gun ship from 1719 but gives no references: it is not listed in the Maritime Museum collection. Likewise, a 30-gun plan of the same establishment was found hidden within a folder of eight plans dating from between 17th and 19th centuries (NMM: ANNB0002).

Further work also needs to be done on the recording of the artefacts post-conservation. The original material from the 1980s excavation could also be recorded to the same standards but except for the Chatham collection most of this material is in private hands. By recording the finds in groups at the same time more evidence may be revealed about the manufacture and standards of each element. For example, if all the deadeyes were re-recorded together patterns of manufacture and smaller variations in the size would be clearer and better conclusions could be made when establishing the rig as a whole.

Sails and Sail cloth

One of the largest sections omitted from this report on the rigging of *Invincible* are the sails themselves and the cloth they are made from. The historic records can give us the number size and shape of the sail allowing us to theoretically see the power generated and put upon the whole rig.

Several fragments and element of *Invincible's* sails were recovered in the 2017-19 excavations which are currently undergoing conservation in order to stabilise the extremely delicate material. This material includes the parts of the stitching, cloth and ropes that make up the sail.

The move from handmade to machine made cloth in the mid-18th century, in particular the flying shuttle in 1733 lead to stronger selvages and a tighter weave in the sail cloth used aboard British ships this allowed the type of seam to change and therefore increased the overall strength of the cloth (Bartoš & Sanders, 2012).

Very little sail cloth has been excavated, analysed, and published from nautical excavations, once stabilised the material should be analysed using the methods of Bartos & Sanders (2012) this would allow us to make judgements on the technological standards of the mid-18th century in terms of cloth manufacture and origins. This could be further supplementing by studying and analysing the *Victory* sail (NMRN, 2015) to see if and how the sail technology evolved by the end of the 18th century.

Conclusions

Overall, the archaeological record has shown that *Invincible* did not follow the historic sources as rigidly as first thought with adaptations having to be made to fit into the Establishments. As a result, it has not been possible to construct an accurate rigging plan for *Invincible* but just a generic one for the mid-18th century. Although technically correct, it is likely that in reality, the rigging of the early to

mid-18th century was not as standard as first thought, due to the manufacturing capabilities of the time. It is likely that true standardisation did not come into force until the 1770s when Walter Taylor managed to mass produce blocks and become the sole supplier for the Navy, and fully occurred in 1805 when Brunel's block mills were outputting 1420 standardised blocks a day (Alder, 1997, p. 237). Therefore, the need for a standardised rig in combination with the textile industry for the production of sails was one of the largest factors in the beginnings of the industrial revolution and therefore Britain's projection of power across the globe. *Invincible* wrecked just as industrialisation was coming into force, it is likely that its sails were already machine made and the gunnery and supply system was already well into standardisation.

Although the archaeological record on its own is not sufficient for re-creating rigging plans for a ship, as it is extremely rare to ever recover a complete system, it can answer some of the biggest questions the historical sources and secondary sources derived from these seem to omit. The three main historical sources for the 18th century are Sutherland (1711 & 1729), Falconer (1769) and Steel (1794). Sutherland and Falconer both give general overviews of the rigging with Falconer stating that.

> *"To explain the track of every particular rope, through its different channels, would be equally useless and unintelligible to a land reader: to mariners it was superfluous: and even the youths who are trained to the sea, would reap little advantage from it; because their situation affords them much better opportunities of making these minute discoveries." (Falconer, 1769, p. i)*

This suggest that the rigging was considered too complicated a system to explain in words and better studied as a vocational and practical subject. Steel covers rigging in more detail than the previous authors but at the time of his writing rigging had evolved again creating stronger and more efficient systems than would have been on *Invincible*. Other historic sources such as the Establishments can give us general dimensions of the mast, but it appears it may have been up to the riggers in the dockyard with their practical knowledge to apply the theory to reality.

The secondary sources such as Lees (1979) lists to his best guess when certain elements of the rigging changed or evolved, based on his personal study of ships plans and models in the Maritime Museum Collection with several of the other secondary sources such as Boudriot (1987) and Lavery (1983) drawing on Lees for details rather than source material. These sources list the changes and when but do not mention why the rigging changed or the technology involved. The archaeology of rigging can contribute somewhat to answering these questions with the presence of differing materials such as *Lignum vitae* appearing in the archaeological record on the *Dartmouth* (1690) but not on earlier ships such as *London (*1657*).* Historical sources suggest the ships wheel appears in 1703, even though the technology and science behind the wheel would have been known centuries earlier (Harland, 1972). Archaeological work on the *Stirling Castle (1679)* has shown that the wheel was probably adopted earlier than thought at the end of the 17th century, and any delay in adoption may have been due to the stronger materials needed rather than the theorical knowledge. This in turn likely led to changes in the rig such as the removal of the sprit topmast and the change in the mizzen. Harland (1972) dismisses this theory, as sprit topmasts are still mentioned in Steel (1794) and indeed the 1745 Establishment still has Sprit topmasts on the three largest rates of ships. This may be due to the larger vessels needing extra power to help manoeuvre or simply as the masting document for *Invincible* shows that the topmast yard is likely for the Jibboom.

Archaeology therefore in combination with the history can show more details on how material and technological changes go hand in hand, with the use of *Lignum vitae* leading to stronger blocks and overall rigs as well as fundamental changes in ship design.

In addition, several features observed or recovered from the site do not match the historical documentation. This shows that there were compromises made in the fitting and rigging of ships to increase their efficiency and not just the rigid sticking to the Establishments suggested by Lavery (1988) and other authors.

The recording of the rigging even at the most basic level is thus extremely important, providing a vital complementary line of evidence to historical sources. The more sites and periods investigated, the better we will build a picture of pan-European maritime technological changes, not just for navies, but for the merchant services and how they affected trade and power of each nation.

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Appendix 1 – Basic Rigging Finds Catalogue

FN	Label	Dia	L	W	H	Description
79/0014	Block single				254	Marked 'X'.
80/0002	Block double				254	Shell extensively eaten away by marine worm.
80/0006	Parrel truck				76	
80/0009	Block sheave	190			38	Chipping around edge of 1 face.
INV.17	Parrel rib				360	Marked 'XNH' = 'X1111'.
80/0069	Block single				127	Treated with linseed oil by A Mack.
80/0073	Rope		203			Course fibre interwoven - possibly coconut fibre.
80/0087	Block sheave					
80/0109	Fid		412			Debated whether it was a 'Fid' or 'Belaying Pin'. Two broad arrows.
INV.18	Mallet serving					Broad arrow on head.
INV.153	Fid	140	720			Size = Admiral Fid
INV.72	Deadeye				132	Unused.
80/0131	Deadeye					Some gribble worm attack on handle.
INV.55	Parrel truck				76	
INV.162	Deadeye				180	
80/0143	Block double				254	Casing twisted.
INV.532	Block single				254	
INV.203	Block sheave	328			40	Marked with broad arrow. 2 small cracks within grain, some chipping around edge.
80/0148	Block sheave					
80/0149	Belaying pin					
80/0158	Parrel truck	70			70	
80/0159	Parrel truck	70			70	

80/0160A	Parrel truck	70			70	
80/0160B	Parrel truck	70			70	
INV.57-60	Parrel truck	70			70	
INV.57-60	Parrel truck	70			70	
80/0163	Parrel truck	100			100	
80/0164	Parrel truck	101				
80/0165	Parrel truck	101				
80/0166	Parrel truck	100			100	
80/0167	Parrel truck	100			100	2 grooves around outside. 1 groove running through length.
80/0168	Parrel truck	100			100	Grooves around outside with groove running along length.
80/0171	Parrel rib		500	95	45	Originally sold at Christies Lot 13. Broad arrow.
80/0172	Parrel rib		460	86	42	
80/0173	Parrel rib		305			No markings.
80/0174	Parrel rib					
80/0175	Parrel rib					
80/0177	Block heart		203			
80/0180	Block double		254			
80/0181	Block single				304	
INV.64	Belaying pin rack					3 holes for belaying pins, the rack cut away at each end for lashing into rigging.
INV.65	Belaying pin					
	Block sheave				160	
INV.204	Block pin					
80/0202	Block double		254			Slightly damaged on 1 edge.
80/0207	Block single		254			

80/0208	Block single				203	
80/0210	Block double		254			Crack in one end made in antiquity.
80/0211	Block single		254			
80/0217	Parrel truck					
80/0218	Shroud truck	70	95			Conserved. Immaculate. Polished. Mounted on a piece of Victory rope with manila running through centre. Removed from Victory rope and re-lashed to Invincible rope.
80/0219	Deadeye				244	
80/0221	Block double		254			Slightly damaged at one edge.
80/0223	Block single				203	
80/0238	Belaying pin					
80/0279	Block single		254			No markings.
80/0307	Block fiddle				863	Gribble worm attack at large end.
81/0001	Block single					
81/0004	Block single				152	Used.
81/0006	Block single				152	Stamped with number 6.
81/0040	Block pin		209		52	Slight crack in small end.
81/0054	Shroud truck					
81/0055	Shroud truck					
81/0056	Shroud truck	68	92			
81/0057	Shroud truck	68	100			
INV.92	Tally stick		190			Words "Invincible Flying Jib" "26 x 26 No 6".
81/0061	Parrel rib					
81/0062	Deadeye	340				Iron band round outside. Very badly eroded and many splits.

81/0063	Block pin	68	340			Small strip light sap wood 150mm long at narrow end.
81/0071	Shroud truck	90	65			
81/0072	Shroud truck	96	73			
81/0073	Block pin	45	125			Worn slightly in centre to a width of 45mm. Thin crack over entire length.
81/0076	Block pin	50	260			
81/0080	Shroud truck	97			70	
81/0082	Block sheave				240	
81/0084	Parrel rib				355	
179	Sheave	320			40	
227	Sheave	97		22		
228	Sheave	190		30		
229	Cheek	250	254	190	34	one cheek of a block
267	Sheave	158		30		
269	Pin	23	95			spare pulley pin flared end 25mm
310	Double Block		273	205	85	Heavily eroded
314	Parrel Bead	100	125			
317	Cleat		92	36	37	Small wooden knee cleat.
379	Single Block		260	210	100	
405	Large rope					
406	Large rope					
407	Large rope					
408	Large rope					
409	Double Block		225	170	220	2 sheaves. Cheek length = 225mm. Cheek width = 266mm. Central fitting = 30mm. X2 sheath width 35mm.
416	Sheave	157		30		Centre hole = 32mm. Curve = 10mm.
417	Pin	44	141			Spare Pin 44mm up to 50mm
431	Shroud Truck		90	70		rigging element
495	Sheave		150	150		
517	Senate rope					possible slow match?

522	Parrel Bead	78	75			
523	Parrel Bead	91	125			
534	Fiddle Block		670	340		fiddle or long tackle block, in design they were a large and a small block joined on below the other. The smaller sheave (250mm) larger sheave 340mm
535	Block		602	432	298	swallow large 100mm
536	Topsail Halyard block	500	490	490	149	The seat portion of the shell is missing, tapered gribble damage from the seat to the pin, some structural repair work to the cheek can be seen with an extra pin attaching a section of the cheek
539	rope					
567	Clew Garnet Block		360	290	130	Clew garnet block, 14 inches. Roman numerals (XIV) and broad arrow visible.
575	mainstay halyard tally stick					
627	Boom Saddle					SADDLES.
630	Cheek					Partial Cheek with pin
639	rope	180				
657	Cheek		330	215		in 3 pieces
660	Pin	51	248			Diameter 51mm flared 57mm
673	Pin	39	88			broken at one end
707	Cheek				47	
709	Single Block		250	184	90	
710	Sheave					
1010	Toggle	24	145			
1038	Sheave	127				
1045	Two Sheave Gun Tackle		250	200	170	
1052	Fid	22	140			Possible Fid
1074	Sheave					
1075	Single Block					
1085	sheave	102			20	
1086	Double Block		240	130		

1135	Senet Hanks					
1136	Senet Hanks					
1137	Senet Hanks					
1146	Cringle					25mm diameter eye splice surviving to 3 tucks
1158	Clew Block		340	247	143	XIIII Clue Block with served rope pendant
1160	Single Block		457	355	194	18-inch Single Block with XVIII carved onto face
1161	Sheave	305			41	
1162	Single Block		220	180	90	fall hawser approx 30mm diameter made from 3x 10mm strands c. 9 yarns
1165	Pin	37	244			
1169	Fiddle Block					
1189	Served rope					
1199	Sheave	199			38	pin dia 40mm
1206	Sheave	188			35	
1210	18 Double strop block		470	345	200	large cut marks in the side of block appears to be done by axe or similar
1214	Cheek		330	260	34	
1220						
1235	Pin	59	190			
1250	Served Rope					
1275	Parrel Bead	150			150	rope hole 55mm
1280	Sheave	101			20	
1302	sheave	330			39	
1305	Sheave					
1308	Cleat		560	79	150	
1310	leach line hole	41				rope ring made from 5mm dia line likely an inner ring of the leech line hole
1320	Main Sheet Block					
1332	Sheave	158		30		
1333	sheave					

1338	Sennit Hank					
1345	Sheave	160				
1374	rope Strop					
1379	Pin	48	240			
1389	Sheave					
1390	Double Block					
1418	Sennit Hank					
1419	Sennit Hank					
1420	Sennit Hank					
1421	Sennit Hank					
1422	Sennit Hank					
1423	Sennit Hank					
1433						
1440	Cheek Fragment		279	381		
1461	Mast Cap		612	299	129	Mast cap
1462	Mast Cap					Mast Cap
1476	Sennit Hank					
1480	Sheave	150	32			
1488	Double Block		253	202	171	possible double gun block, associated line given number 1822
1490	Deadeye	270			140	
1491	Sennit Hank					
1497	Pin	70	260			
1500	Single sheave double pendant block					
1501	Sennit Hanks					
1502	Sennit Hanks					

1505	Pin	27	95			
1517	Stop Cleat		111	31	24	
1531	Cheek fragment		160	30		
1538	Pin	51	248			
1539	Sennit Hank					
1565	Deadeye	300			175	would be suitable for an 8.5" shroud and 5" lanyard
1566	Single Block		350	279	151	small fragment of leather INV17 2001 Found associated
1596	Stop Cleat		160	37	24	
1605	Stop Cleat		175	40	30	
1607	Single Block		495	357	189	
1608	Sheave	95				
1611	Deadeye	225			100	
1765	Served strop					
1849	Shell		166	68	35	Shell fragment
1866	Pin	24	145			
1879	Sling Cleat		172	50	33	
2008	Bullseye Cringle	80		45		
2011	Cheek		225		33	
2012	Pin					
2013	Sheave	140				
2015	Parrel Rib		350	140	60	
2137	Mast Cap		1110	465	325	fits the dimensions for the upper mast of the main or fore
3008	seized Strop					
3012	Parrel Bead	140	150			
3013	Cheek fragment	30	204	10		
3014	Cheek Fragment		282	110	38	One half of a cheek fragment
3015	Pin	48	131			

3021	Single Block		404	300	175	heavily eroded on one side
3022	Double Block		550	390	340	large double block
3023	Tarred Rope					
3025	Sheave					
3026	Single Block					
3028	Single Block					
3030	unknown object		200	35	12	small fragment of timber with 4 indents/recess possibly relating to rope
3031	Pin	75	626			eroded pin shows sign of use
3032	Sheave					
3033	Single Block					
3034	Stop Cleat					
3035	Cheek					
3037	Block strop					
3044	Pin					
3047	Cheek		250	200	60	Cheek of a block
3048	Sheave					
3049	Sheave	155			32	pin 34mm
3050	Sheave	155			32	pin 34mm
3051	Sheave	162			30	pin dia 32
3060	Sheave	226			46	
3062	Sheave	160			31	
3063	sheave	155				
3064	Cheek		250	208	20	Cheek of block
3067	Parrel Bead					
3068	Single Block					small heavily eroded block
3069	Sheave	157			24	half a small sheave
3070	Pin	30	120			
3075	Pin					
3086	Block					
3087	Single Block					Heavily eroded single block
3088	Sheave	160			30	
3095	Deadeye	250			113	

3097	Single Block		370	227	145	Damaged single block
3100	Sheave					
3102	Cable					
3103	Timber rope					assorted collection of wicker or willow braded into three twist rope ranging from 50mm to 38mm in circumference with a Z twist of 40deg
3113	Shroud Truck					
3118	Single Block		360	285	155	
3119	Deadeye					
3120	Deadeye	350			190	
3122	Parrel Bead	120			115	central diameter 53mm
3123	Parrel Bead					
3124	Sheave	155			24	
3125	Sheave	165			32	
3126	Sheave	259			49	
3127	Sheave					
3128	Sheave					
3131	Fiddle Block					upper sheave 270mm lower sheave 380
3132	Single Block					
3136	Sheave					
3138	Sword Matting					knitted woollen fabric in 5 pieces in a stocking stich, edges visible in three places
3139	Shroud Truck					
3140	Rope					
3144	16 Inch Clew Block		405	320	170	
3147	Double Block		252	192	170	Double block degraded on one side, small amount of rope was present inside the swallow
3148	Fiddle Block		390	340	140	top half of a fiddle block
3149	Truck	400			153	
3156	Strop					

3157	Single block					
3161	Sheaves					
3163	Deadeye	450			204	18" deadeye with XVIII inscribed on forehead
3194	Single Block		266	202	103	
3209	Parrel Bead	80			75	
3217	Double Block		260	212	98	broken double block
3224	Single Block					
3225	Strop					strop from 3224
3244	Rope Sample					
3245	Stays					
3248	Sheave	232			44	
3249	Sheave	160			30	
3250	Sheave	160			34	
3251	Sheave	155			30	
3252	Sheave	165		29		
3253	sennet	20				sennet rope found associated with shroud truck 3139
3414	Parrel Rib		950	55		37" long by 2" wide, holes or parrel rope 2.5" and smaller holes 3/4" small hole at end 1"
3513	Parrel Rib					39" long by 2.75" wide. holes 2 1/4"
3515	Main Stay					Main Stay
3516	Main Preventer					
3517	Main Stay Heart					