

## Rigging the Pepper Wreck. Part 2—Sails

Filipe Castro

*Nautical Archaeology Program, Department of Anthropology, Texas A&M University, College Station, TX 77843–4352, USA*

Discovered in 1993 at the mouth of the Tagus River, the SJB2 shipwreck—or Pepper Wreck—was tentatively identified as the Portuguese Indiaman *Nossa Senhora dos Mártires*, lost there on its return voyage from Cochin, in India, on 15 September 1606. Its archaeological excavation led to a tentative reconstruction of the hull, based in contemporary texts on shipbuilding. Further analysis of these texts allowed us to propose a reconstruction of the rigging.

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*Key words:* Pepper Wreck, *Nossa Senhora dos Mártires*, Portugal, 17th-century India route, Portuguese *nau*.

The remains of a Portuguese Indiaman, commonly referred to as the Pepper Wreck because its timbers rested within a layer of peppercorns, were found during a survey at the mouth of the Tagus River near Lisbon, Portugal in 1994. Tentatively identified as the *nau Nossa Senhora dos Mártires*, lost in front of the fortress of São Julião da Barra on 15 September 1606 at the end of a nine-month return voyage from the East Indies, its remains were excavated between 1996 and 2000 by a joint team from the Portuguese Centro Nacional de Arqueologia Náutica e Subaquática and the Institute of Nautical Archaeology at Texas A&M University (Alves *et al.*, 1998; Castro, 2005a). A reconstruction of this ship's hull was attempted based on the archaeological data and a number of formulae and contemporary texts on shipbuilding, and is presented in Fig. 1 (Castro, 2003). The reconstruction of the dimensions of the masts and spars was also based on documents from this period and is presented in Fig. 2 (Castro, 2005b). All measurements in these documents are given in *rumos* (1.54 m), *braças* (1.76 m), *goas* (770 mm), *palmos de goa* (256.7 mm), *palmos de vara* (220 mm), and *dedos* (18.3 mm) (Castro, 2005a: 189–92).

The second part of this work consists of defining a plausible sail-plan, again based on contemporary evidence, both written and iconographic. Neither the shape and size of ships, nor their rigging arrangements, were standardized in the late-16th

century, and documents suggest ranges of values rather than precise measurements for spars and sails. Ship sizes were given in either tons burden or keel-length. In the late-16th and early-17th centuries India *nau*s had capacities of around 600 tons or keel-lengths of between 17 and 18 *rumos* (c. 27 m). Capacity and keel-length were directly related because the values of the maximum beam and length overall were derived from the length of the keel.

As mentioned in a previous article, while this reconstruction is only an educated guess, it seems to be the best way to understand the Portuguese Indiamen of the period under analysis (Castro and Fonseca, 2006). Looters and treasure-hunters are destroying these ships at a rapid pace and it is unlikely that either governmental or non-governmental organizations will react with any degree of efficiency before the last Portuguese *nau* is torn apart to retrieve artefacts or valuable metals for sale at auction or in antique markets. Therefore, in order to acquire a better understanding of this type of vessel, a model of such a ship has been developed, based on the dimensions retrieved between carpenter's marks on the bottom of the Pepper Wreck remains, compounded with information contained in texts from this period (Castro, 2003; 2005b). The plausibility of this model will be evaluated by mathematical models in the future (Castro and Fonseca, 2006). This article aims at the reconstruction of a plausible

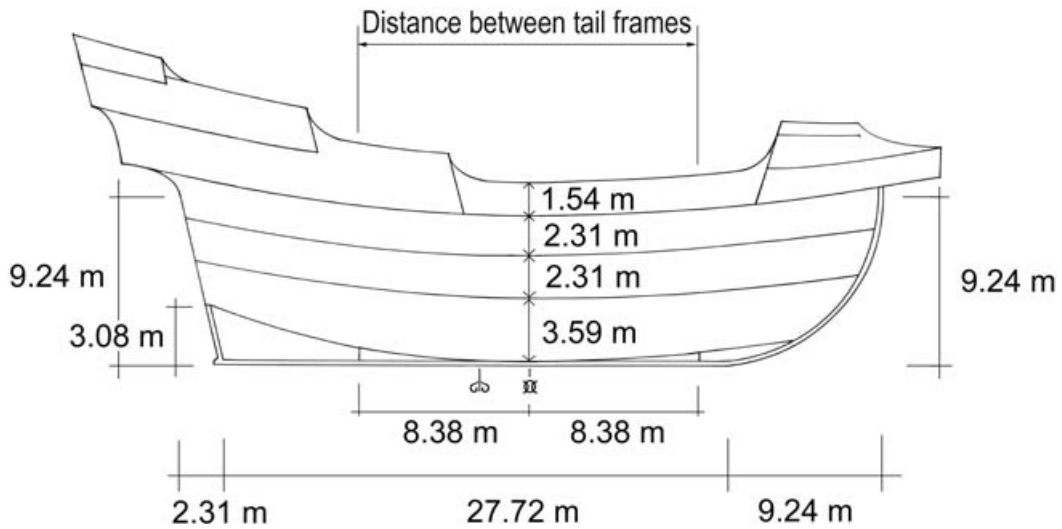


Figure 1. The Pepper Wreck hull reconstructed. (F. Castro)

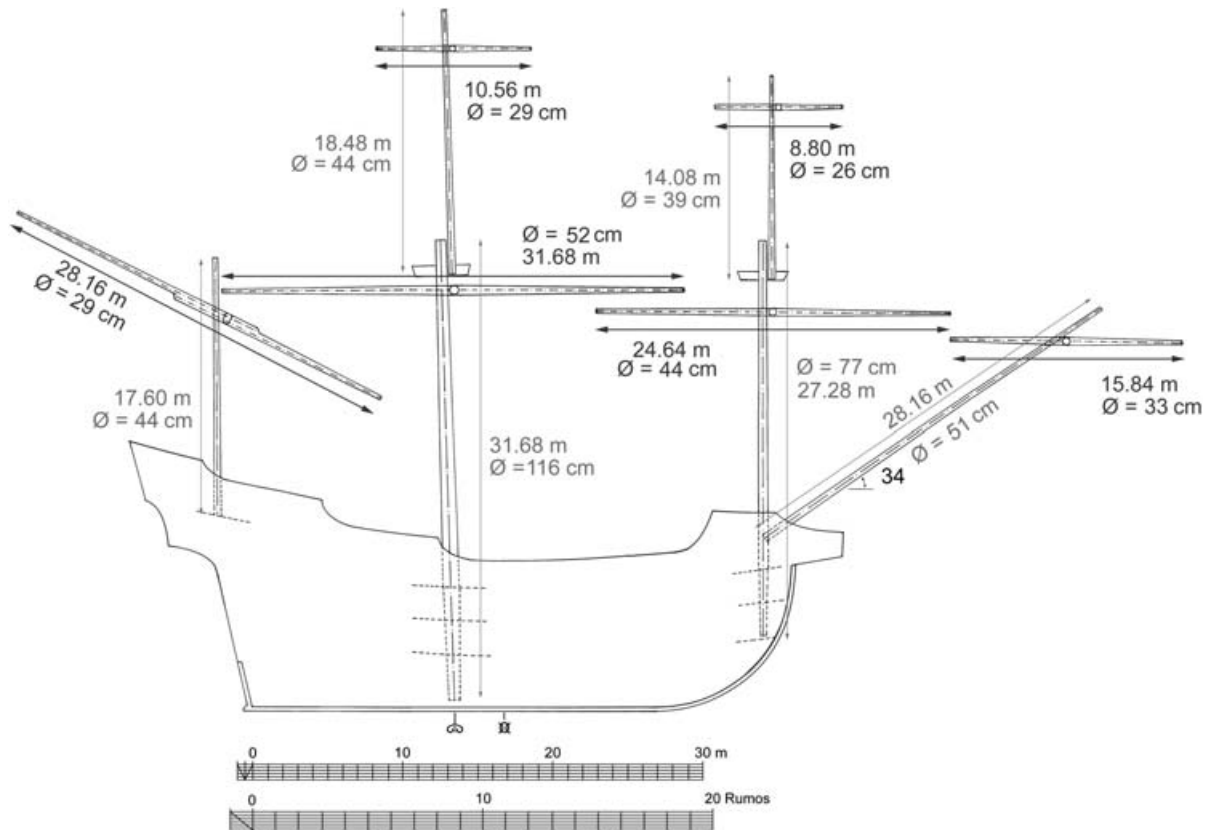


Figure 2. The Pepper Wreck masts and spars reconstructed. (F. Castro)

sail-plan. This is difficult because the shape and size of topsails seem to have evolved continuously during the 16th century. The dimensions given for the head and foot of the main and fore topsails of the Pepper Wreck reconstruction do not tally with any of the comparable vessels listed

in Tables 2, 3 and 4, presumably because topsail shapes and sizes evolved rapidly between the 1590s, when the data on which we have based the Pepper Wreck's rigging reconstruction was written down, and the 1620s, which is the period of the data presented here for comparison.

## Sources

The documents on which this reconstruction was based include: The rigging section of Garcia de Palacio's treatise, *Instrucion Nautica para el buen uso de las Naos, su traça, y gobierno conforme à la altura de Mexico*, dated 1587; The list 'Aparelhos de um galeão' from the Portuguese manuscript *Coriosidades de Gonçalo de Sousa*, dated to c.1630; Two lists (folios 38–41 and 178–81) from the first of the three volumes of the Portuguese codex of D. António de Ataíde, known as *Collecção de varios documentos e papeis régios e administrativos respectivos as armadas e expedições marítimas*, dated to 1624 and c.1630.<sup>1</sup>

A review of the best contemporary iconography helped to solve a few doubts, although only a handful of images have been drawn or painted with enough detail to allow the observation of ships' rigging arrangements (Table 1). Moreover, iconography always involves difficulties of interpretation, and care must be taken when it is used. Iconographic works consulted include the well-known Frans Huys etchings of Pieter Brueghel the Elder, mid-16th-century drawings (Gunn-Graham, 1998), as well as late-16th-century frescoes from the Spanish palaces of Escorial and Viso del Marques. One must always keep in mind the possibility that painters, engravers, and restorers made mistakes or placed anachronistic detail in their works (Barata, 1989; Tzalas, 1990; Barker, 2002).

The present reconstruction does not encompass the standing and running rigging, nor does it include the positions of the standing-ends and belaying-points of the running rigging on the reconstructed deck. At this point there are too many unanswered questions regarding these subjects. And again, the best advantage of the use of computers and 3-D modelling software is that all models are flexible and can be easily completed and corrected. Nevertheless, the development of this sail-plan took a basic rigging arrangement into consideration even if it is incomplete and not completely functional. For instance, at this point it seems difficult to rotate the lower yards in view of the position of the shrouds. The definition of the rigging has drawn extensively from 19th- and 20th-century sources<sup>2</sup> (Melo, 1836; Chavantes, 1881; Bandeira, 1895; Rees, 1970; Silva, 2003; Silva, 2005), as well as a number of other old and recent texts, such as the well-known anonymous early-17th-century *Treatise on Rigging* edited by Salisbury and Andersen (1958), Andersen's book on 17th-century rigging for model-makers (1974),

and the S. Tomé lists with rigging items by Barata (1989).

The uncertainty associated with this sail-plan is greater than with the hull reconstruction proposed. Evidence suggests that ships grew considerably in size during the first half of the 17th century, and the three- and four-masted ship's typical rigging was substantially altered by the addition of new sails and changes on the sizes and shapes of both lower and topsails. Data available on this subject is scarce. For example, there exist a few early-15th-century Italian documents, such as the book of Michael of Rhodes known until recently through a later copy titled *Libro di marineria* or *Fabrica di galere*, or the manuscript of Zorzi Trombetta from Modon (McGee, 2008). But until the late-16th century there are very few references regarding sail-making or the commerce of sailcloth. And even in the 16th century, only Garcia de Palacio seems to have written about sails and sail-making, if the drawings on pages 115 and 133 of Matthew Baker (c.1570) and John Wells's notes are to be excluded (Barker, 1986). There is a series of drawings with late-16th-century rigging-plans in the library of the Dutch Scheepvaart Museum (pers. comm. Wendy van Duivenvoorde, 2003), which this author has not yet seen.

## Sails

The model created displaces a minimum of 1100 tons and a maximum of 1600 tons, and weighs about 400 tons. A tentative sail-plan is presented in Fig. 3, based on the sizes of the masts and spars suggested previously (Castro, 2005b). The sails stretched from yardarm to yardarm and their height was dependent on the space allowed by the mast size and top arrangements (Garcia de Palacio, 1587, 25–30). Ataíde's codex is especially interesting because it contains, with few omissions, values for the sizes of all sails of the 1624 *nau S. Bartolomeu* with 20 *rumos* of keel (30.8 m), all the sails of a *nau Capitana*, and smaller *naus* of 600, 400, 300, 200, and 100 tons (Tables 2 to 8). These lists mention that all *papafigos*—main, fore and sprit sails—should be: when made of cloth from Flanders, with canvas *dobradas*; when made of Oporto cloth, ships should carry one set of sails *dobradas*, and one set *quarteadas*; when sails were made of canvas from France they only needed to be *quarteadas*; on 100-ton vessels all sails should be *singelas*.

It is not easy to make full sense of the words *dobradas*, *quarteadas*, and *singelas*. The first word

**Table 1.** *Relevant iconography*

Designation	Author	Date	Ship-types Represented	Reference
<i>Livro carmesim</i>	Anon.	c.1500	<i>Nau</i>	MS, Lisbon Municipal Archive (Garcia, 1996: 35)
<i>Livro das fortalezas</i>	Duarte d'Armas	c.1509	<i>Naus</i> , caravels and other	MS 159, Casa Forte do Arquivo Municipal da Torre do Tombo, Lisbon (Armas, 1997)
<i>S. João de Patmos</i>	Master of Lourinhã	c.1514	<i>Nau</i>	Painting, Museu da Misericórdia da Lourinhã, Portugal
<i>Breviário da Condessa de Bertiandos</i>	Anon.	1515–30	<i>Naus</i>	MS, Library of Academia de Ciências de Lisboa (Garcia, 1998: 39)
<i>Livro de Horas de D. Manuel</i>	Anon.	1517–26	<i>Naus</i> , caravels and other	MS, Museu Nacional de Arte Antiga, Lisbon (Garcia, 1998: 37)
<i>Retábulo de Sta Auta</i>	Anon.	c.1520	<i>Naus</i> , caravels and other	Triptych, Museu Nacional de Arte Antiga (Domingues, 1998).
<i>Portuguese Carracks off a Rocky Coast</i>	Attrib. to Patinier	1521–30	<i>Naus</i> , caravels and other	Painting, National Maritime Museum, London (Domingues, 1998).
<i>Roteiro do mar Roxo</i>	Anon.	1538–1540	<i>Naus</i> , caravels and other	MS Cott. Tib. DIX, British Library (Castro, 1991)
<i>Roteiro de D. João de Castro</i>	Anon.	1538–40	<i>Naus</i> , galleons, caravels and other	<i>Roteiro de Goa a Dio</i> , MS 33, Library of the University of Coimbra (Castro, 1988).
<i>Memória das Armadas</i>	Anon.	1566	<i>Naus</i> , caravels and other	MS, Library of Academia de Ciências de Lisboa, Portugal ( <i>Memória das armadas</i> , 1995).
<i>Livro de Lisuarte de Abreu</i>	Lisuarte de Abreu	1558–65	<i>Naus</i> , caravels and other	MS 525, Pierpoint Morgan Library, New York (Abreu, 1992)
<i>Leiden view of Lisbon</i>	Anon.	1535–70	<i>Naus</i> , caravels and other	Drawing, Library of the University of Leiden, Netherlands (Moita, 1983, fig. 16).
<i>Paintings of S. Roque Church</i>	André Reinoso	c.1619	<i>Naus</i>	Mural paintings, Church of S. Roque, Lisbon.

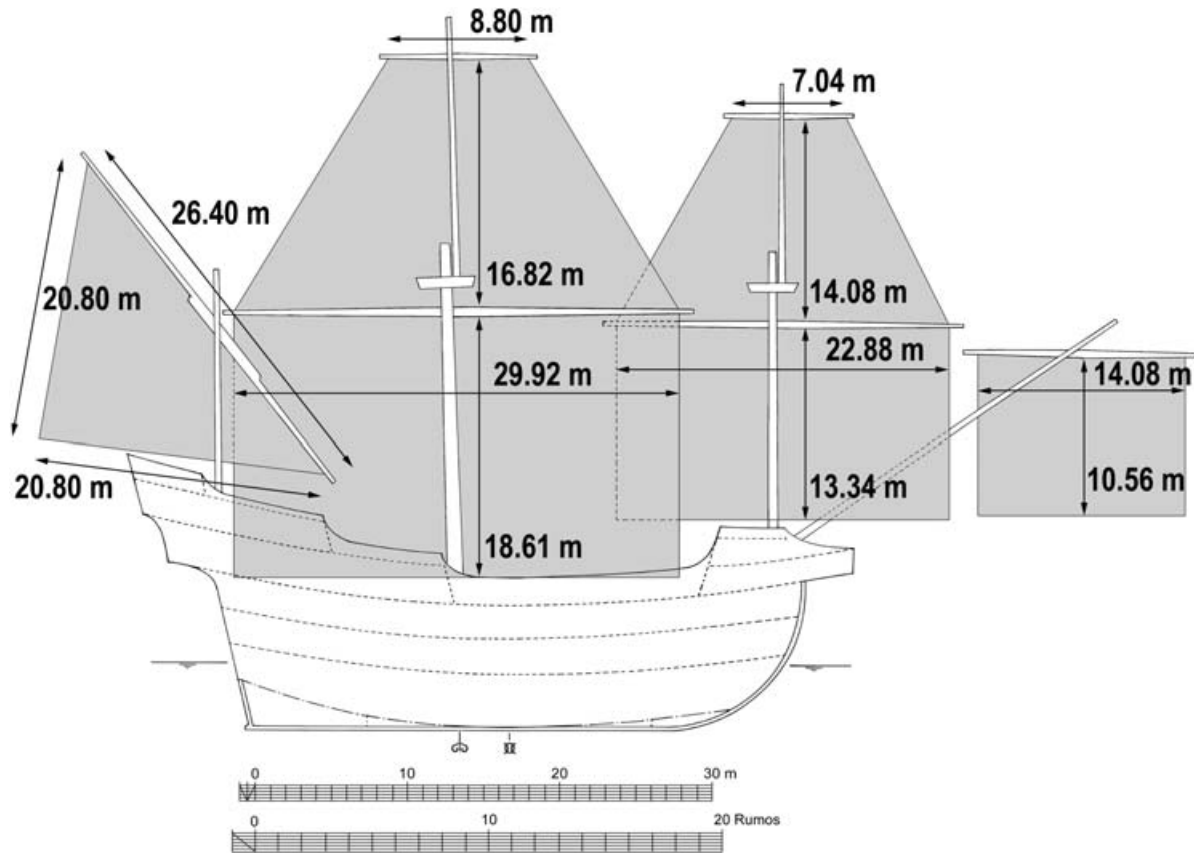


Figure 3. The Pepper Wreck sails reconstructed. (F. Castro)

Table 2. Sails of the nau S. Bartolomeu

Sail	Head (m)	Foot (m)	Height (m)	Area (m <sup>2</sup> )
Main	29.92	29.92	13.2	395
Bonnet	29.92	29.92	5.28	158
		total	18.48	553
Main top	11.88	29.92	18.04	377
Fore	22.88	22.88	10.56	242
Bonnet	22.88	22.88	4.4	101
		total	14.96	342
Fore top	10.12	22.88	14.08	232
Spritsail	15.84	15.84	10.56	167

Table 3. Sails of a nau capitana

Sail	Head (m)	Foot (m)	Height (m)	Area (m <sup>2</sup> )
Main	29.92	29.92	14.08	421
Bonnet	29.92	29.92	5.28	158
		total	19.36	579
Main top	12.32	29.92	17.6	372
Fore	21.12	21.12	11.44	242
Bonnet	21.12	21.12	4.4	93
		total	15.84	335
Running foresail	21.12	21.12	8.8	186
Fore top	10.56	21.12	14.3	227
Spritsail	16.72	16.72	11.44	191

literally means doubled, the second either divided in quarters or reinforced on the four corners, and *singelas* meaning made in a single layer (Barker, 2002). A scheme of the ship's sails and main dimensions is presented in Fig. 4. Neither Palacio's text nor the *Vasa* archaeological remains suggest that sails were made with more than one layer of sailcloth. In the *Vasa* there were reinforcements in the zone of the five buntline cringles to better

distribute stress (Bengtsson, 1975: 36). The word *dobradas* suggests that these sails, meant to withstand six-month voyages, may have been reinforced in a much heavier way than those of the *Vasa* or the Spanish New-World-Route vessels, perhaps even to the point of sewing each band of sailcloth folded in two.

Some of Ataíde's lists (folios 41 and 178) mention both the length of sailcloth necessary to

**Table 4.** *Sails of a 600-ton nau*

Sail	Head (m)	Foot (m)	Height (m)	Area (m <sup>2</sup> )
Main	23.76	23.76	11.44	272
Bonnet	23.76	23.76	?	?
		total	?	?
Main top	12.32	23.76	17.6	318
Fore	21.12	21.12	9.68	204
Bonnet	21.12	21.12	?	?
		total	?	?
Running foresail	?	?	?	?
Fore top	9.68	21.12	14.08	217
Spritsail	16.72	16.72	8.8	147

**Table 5.** *Sails of a 400-ton nau*

Sail	Head (m)	Foot (m)	Height (m)	Area (m <sup>2</sup> )
Main	21.12	21.12	10.12	214
Bonnet	21.12	21.12	3.52	74
		total	13.64	288
Main top	10.56	21.12	15.4	244
Fore	17.6	17.6	8.36	147
Bonnet	17.6	17.6	2.2	39
		total	10.56	186
Running foresail	?	?	?	?
Fore top	8.8	17.6	11.88	157
Spritsail	12.32	12.32	8.36	103

**Table 6.** *Sails of a 300-ton nau*

Sail	Head (m)	Foot (m)	Height (m)	Area (m <sup>2</sup> )
Main	16.72	16.72	7.92	132
Bonnet	16.72	16.72	2.64	44
		total	10.56	177
Main top	7.92	16.72	13.2	163
Fore	14.08	14.08	7.04	99
Bonnet	14.08	14.08	2.2	31
		total	9.24	130
Running foresail	?	?	?	?
Fore top	7.04	14.08	10.56	112
Spritsail	10.56	10.56	7.04	74

make each sail (in *varas*) and the sail dimensions (in *braças*), together with the type of sailcloth recommended and whether it should be *singelo*, *quarteado*, or *dobrado*. Based on these figures, and considering the values indicated above for *varas* and *braças* (1.10 m and 1.76 m respectively), a series of consistent values for the sailcloth widths

**Table 7.** *Sails of a 200-ton nau*

Sail	Head (m)	Foot (m)	Height (m)	Area (m <sup>2</sup> )
Main	15.84	15.84	7.92	125
Bonnet	15.84	15.84	2.2	35
		total	10.12	160
Main top	7.92	15.84	11.44	136
Fore	13.2	13.2	5.72	76
Bonnet	13.2	13.2	1.76	23
		total	7.48	99
Running foresail	?	?	?	?
Fore top	6.16	13.2	10.12	98
Spritsail	9.68	9.68	6.16	60

**Table 8.** *Sails of a 100-ton nau*

Sail	Head (m)	Foot (m)	Height (m)	Area (m <sup>2</sup> )
Main	12.32	12.32	5.28	65
Bonnet	12.32	12.32	1.76	22
		total	7.04	87
Main top	6.16	12.32	9.68	89
Fore	10.56	10.56	4.4	46
Bonnet	10.56	10.56	?	?
		total	?	?
Running foresail	?	?	?	?
Fore top	5.28	10.56	7.92	63
Spritsail	8.8	8.8	4.4	39

has been obtained. This naturally considers that all the sailcloth in the inventories would be applied to the sails, not taking into account any wasted cloth or overlapping. Unfortunately there was not enough data pertaining to mizzen sails.

The actual widths in which these sailcloths were fabricated are not known. Several types are mentioned: from *Pindavi* or *Pindavir*, a French town in Finisterre actually named Pouldavid, near Concarneau (pers. comm. Leoner Freire Costa, 2007); from Noyal, near Rennes, also in France; and generally from France and Flanders. None of the widths of these cloths are given in the *Ataíde* manuscript, with the exception of *pano de treu*, a type of cloth that is referred to as *pano de treu* (*treu* cloth), *treu estreito* (narrow *treu*), and *treu real da Maia* (royal *treu* from Maia, a city north of Oporto). According to the dictionary, *treu* was a very durable type of cloth produced in the region north of Oporto (Maia, Vila do Conde) in extremely narrow widths of 1 *palm* (*de vara*) and two *dedos*, or  $220 + (18.3 \times 2) = 256.7$  mm (Leitão and Lopes, 1990).

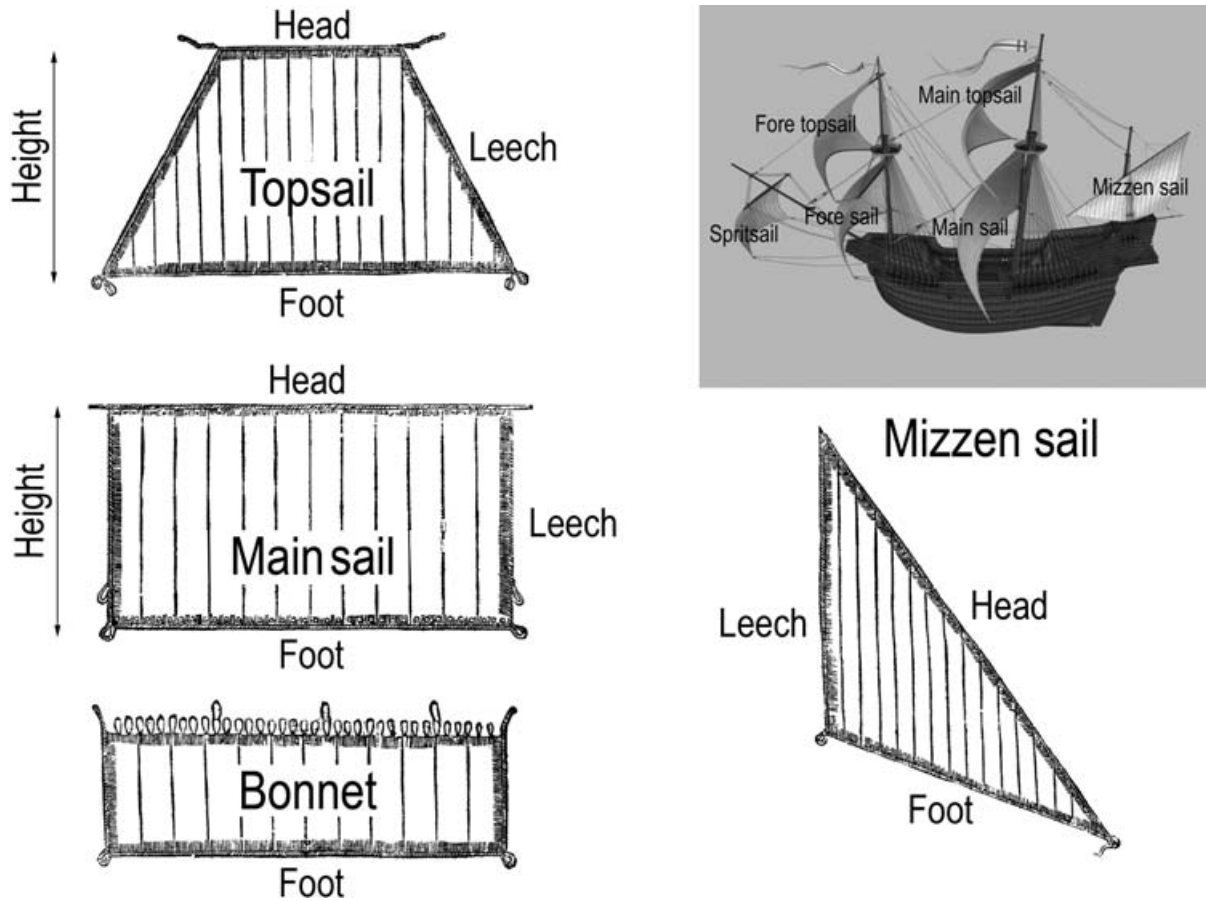


Figure 4. The Pepper Wreck sails, basic shapes. (after Garcia de Palacio and virtual reconstruction by Audrey Wells)

It is known that during the 16th and 17th centuries Portugal imported hemp sailcloth from Flanders and France (Costa, 1997). During the 18th century in France, canvas from Noyal, near Rennes, and Port David (Pouldavid?) was fabricated in bolts measuring 21 inches (569 mm) by 50 ells (59.4 m), and in several different weights. Depending on how many threads of the warp were passed through the weft, the sailcloth could be triple-threaded (only made in Brest and Angers), double-threaded, double *mélis*, single *mélis*, and single-threaded, thus presenting different character-

istics in terms of weight and resistance. Canvas weight therefore varied immensely from nearly 1.2 Kg/m<sup>2</sup> in the best triple-threaded cloth, used in the main courses by the French Navy, to about 400 gr/m<sup>2</sup> in the average single-threaded lining canvas (Boudriot, 1987: 64–7). The values obtained for the effective widths of cloth used in each sail—again, considering a *vara* of 1.10 m and a *braça* of 1.76 m—are indicated in Tables 9 to 17.

Following the indications of the Ataíde manuscript it was decided to consider in the calculations of the weights that the main and foresails were

Table 9. Mainsail

Mainsail	<i>S. Bartolomeu</i> <sup>1</sup>	Capitana	600 t.	400 t.	300 t.	200 t.	100 t.
Area [m <sup>2</sup> ]	394.94	421.27	271.81	213.73	132.42	125.45	65.05
Length of cloth [m]	1283.7	957	605	462	302.5	275	121
Width, Noyal cloth ( <i>dobrada</i> )	0.31	—	—	—	—	—	—
Width, Flanders cloth ( <i>quarteado</i> )	—	0.44	0.45	0.46	0.44	0.46	—
Width, single cloth	—	—	—	—	—	—	0.54

1. The nau *S. Bartolomeu* was built in 1632 with 20 rumos (30.8 m) of keel (values in folio 41).

**Table 10.** *Main sail bonnet*

Mainsail bonnet	<i>S. Bartolomeu</i>	Capitana	600 t.	400 t.	300 t.	200 t.	100 t.
Area [m <sup>2</sup> ]	157.98	157.98	—	74.34	44.14	34.85	21.68
Length of cloth [m]	294.8	319	242	165	110	88	55
Width, Noyal cloth	0.54	—	—	—	—	—	—
Width, Flanders cloth ( <i>quarteado</i> )	—	0.50	—	0.45	0.40	0.40	—
With, single cloth ( <i>pano singelo</i> )	—	—	—	—	—	—	0.39

**Table 11.** *Main topsail*

Main topsail	<i>S. Bartolomeu</i>	Capitana	600 t.	400 t.	300 t.	200 t.	100 t.
Area [m <sup>2</sup> ]	377.04	371.71	317.50	243.94	162.62	135.91	117.13
Length of cloth [m]	3436.4	1389.3	2860	2310	1562	1034	990
<i>Pano de treu</i>	0.11	0.27 <sup>1</sup>	0.11	0.11	0.10	0.13	0.12

1. Odd value, considering the range of values obtained for all the other cases.

**Table 12.** *Foresail*

Fore sail	<i>S. Bartolomeu</i>	Capitana	600 t.	400 t.	300 t.	200 t.	100 t.
Area [m <sup>2</sup> ]	241.61	241.61	204.44	147.14	99.12	75.50	46.46
Length of cloth [m]	839.3	528	453.2	352	242	198	79.2
Width, Noyal cloth ( <i>dobrada</i> )	0.29	—	—	—	—	—	—
Width, Flanders cloth ( <i>quarteado</i> )	—	0.46	0.45	0.42	0.41	0.38	—
With, single cloth ( <i>pano singelo</i> )	—	—	—	—	—	—	0.59

**Table 13.** *Foresail bonnet*

Foresail bonnets	<i>S. Bartolomeu</i>	Capitana	600 t.	400 t.	300 t.	200 t.	100 t.
Area [m <sup>2</sup> ]	100.67	92.93	—	38.72	30.98	23.23	—
Length of cloth [m]	172.7	231	165	115.5	88	77	44
Width, Noyal and Pindavis cloth	0.58	—	—	—	—	—	—
Width, Flanders cloth ( <i>quarteado</i> )	—	0.40	—	0.34	0.35	0.30	—

**Table 14.** *Running foresail* (traquete de correr)

<i>Traquete de correr</i>	<i>S. Bartolomeu</i>	Capitana	600 t.	400 t.	300 t.	200 t.	100 t.
Area [m <sup>2</sup> ]	—	185.86	—	—	—	—	—
Length of cloth [m]	—	550	550	385	275	220	—
<i>Dobrado</i>	—	0.34	—	—	—	—	—

**Table 15.** *Fore topsail*

Fore topsail	<i>S. Bartolomeu</i>	Capitana	600 t.	400 t.	300 t.	200 t.	100 t.
Area [m <sup>2</sup> ]	232.32	226.51	216.83	156.82	111.51	97.96	62.73
Length of cloth [m]	2226.4	858	1925	1518	1045	968	770
<i>Pano de treu</i>	0.10	0.26 <sup>1</sup>	0.11	0.10	0.11	0.10	0.08

1. Odd value, considering the range of values obtained for all the other cases.



**Table 16.** *Spritsail*

Spritsail	<i>S. Bartolomeu</i>	Capitana	600 t.	400 t.	300 t.	200 t.	100 t.
Area [m <sup>2</sup> ]	167.27	191.28	147.14	103.00	74.34	59.63	38.72
Length of cloth [m]	—	946	348.7	220	154	132	66
Width, Noyal and Pindavis cloth ( <i>dobrada</i> )	—	—	—	—	—	—	—
Width, Flanders cloth ( <i>quarteado</i> )	—	0.20 <sup>1</sup>	0.42	0.47	0.48	0.45	—
With, single cloth	—	—	—	—	—	—	0.59

1. Odd value, considering the range of values obtained for all the other cases.

**Table 17.** *Mizzen sail*

Mizzen sail	<i>S. Bartolomeu</i>	Capitana	600 t.	400 t.	300 t.	200 t.	100 t.
Length of cloth [m]	935	495	1045	935	770	660	550

**Table 18.** *Square sails: proposed basic dimensions*

Sail	Head	Foot	Height	Area	Weight
Mainsail (doubled)	29.92 m	29.92 m	18.61 m	557 m <sup>2</sup>	836 Kgf
Main topsail ( <i>Treu</i> cloth)	8.80 m	29.92 m	16.82 m	326 m <sup>2</sup>	163 Kgf
Foresail (doubled)	22.88 m	22.88 m	13.34 m	305 m <sup>2</sup>	458 Kgf
Fore topsail ( <i>Treu</i> cloth)	7.04 m	22.88 m	14.08 m	211 m <sup>2</sup>	106 Kgf
Spritsail	14.08 m	14.08 m	10.56 m	149 m <sup>2</sup>	112 Kgf

**Table 19.** *Lateen sail: proposed basic dimensions*

Sail	Luff	Foot	Leech	Area	Weight
Mizzen	26.40 m	20.80 m	20.80 m	216 m <sup>2</sup>	162 Kgf

made with a double layer of sailcloth, and all other sails made of a single layer of cloth. Again following the indications of the manuscript the topsails were considered made of *treu* cloth. The canvas weight was set at an average of 0.75 Kgf/m<sup>2</sup> and the *treu* cloth 0.5 Kg/m<sup>2</sup>. These weighs include tabling, bolt-ropes, reef-bands, and all extra weights inherent to the making of a sail. The sails' widths were obtained considering yardarms with half a *braça* (1.76 m) long on each side, and the sails' heights measured from yard-to-yard or yard-to-deck, minus one *braça*. The values were obtained from a previous article (Castro, 2005b) and are indicated in Tables 18 and 19.

The areas obtained for the reconstructed Pepper Wreck match closely with those indicated in Ataíde's lists, namely the one for *nau S. Bartolomeu* dated to 1624, and the lists from

folios 178–81, which are not dated but are bound between a document dated to 1633 and another dated 1629. Comparing the reconstructed Pepper Wreck with the values indicated for the *nau S. Bartolomeu* of 1624, the *Capitana*, and a *nau* of 600 tons from the second list, the Pepper Wreck values are very plausible results for each sail area (Table 20). The *nau S. Bartolomeu* had a keel-length of 20 *rumos* (30.8 m), 2 *rumos* longer than the reconstructed Pepper Wreck, and it is understandable that most of its sails were larger than the Pepper Wreck ones. There are no values for the size of a *nau Capitana* around 1630, but it was probably larger than the reconstructed Pepper Wreck. The best matches should be the sails of a 600-ton *nau*, although no values of the length of the bonnets are given for this ship and therefore it is not possible to compare the main and foresail's values. However, it should be noted that the main and foreyards of the 600-ton *nau* are shorter than those of the Pepper Wreck.

When the documents are consulted together, a trend towards enlarging the topmasts and reducing the widths of the lower yards becomes clear. The ships of the 1630s were very different

**Table 20.** Sail areas expressed in % of the areas of the reconstructed ones

Ship	Mainsail	Main topsail	Foresail	Fore topsail	Spritsail
Pepper Wreck	100%	100%	100%	100%	100%
<i>S. Bartolomeu</i>	99%	116%	112%	110%	113%
<i>Capitana</i>	104%	114%	110%	108%	129%
<i>Nau</i> of 600 t.	—	98%	—	103%	99%

from those of the 1590s, whose values were used to reconstruct the 1606 Pepper Wreck. This trend can also be observed in the iconography of the period: between the earlier and later treatises (*c.*1570 to *c.*1630) topsails became taller and less trapezoidal, and larger in relation to the lower masts and sails. In fact, the sizes of the main and foresails of the 600-ton *nau* can be estimated, based on the values presented for other ships: *S. Bartolomeu's* bonnets were 42% of the mainsail and 40% of the foresail areas, respectively; the *Capitana's* were both 38% of the respective sail's areas; and the next values available, those of the 400-ton *nau*, were 35% for the mainsail, and 25% for the foresail. In smaller vessels—the 300, 200, and 100-ton *naus*—all bonnets are very close to 30% of the sail length. Considering the length of the bonnets of the 600-ton *nau* to be 35% of the length of the main and foresails, they would result in something much smaller—about 30% and 10% respectively—than the equivalent Pepper Wreck sails. Only further research will allow a better understanding of the values under analysis and the trends that they suggest.

Although the document from *Coriosidades de Gonçalo de Sousa* mentions a spritsail topsail it is unknown whether the *Nossa Senhora dos Mártires*,

built in 1605, carried such a sail, which is generally considered to have appeared around 1600. As it is today, the model of the so-called Flemish Galleon of Felipe II (1556–1598), in the Museo Naval of Madrid, has topgallants and a spritsail topsail and is said to have been offered to him while his father (Charles V, d. 1558) was alive. Such sails were not included in the sail-plan because most evidence indicates that they do not show in any other ship representation, Spanish, Portuguese, or from any other nation until the beginning of the 17th century. The Portuguese ship iconography from the period of Spanish domination is neither abundant nor very reliable, and so far it has not yet been extensively studied from the naval point of view.

## Conclusions

A better understanding of this tentative sail-plan will be acquired once the planned model is built and tested in a wind-tunnel; afterwards it will be ready for trials and tried on the ship's hull, under a number of different loads and sailing conditions. Only then will a better feeling for the ranges of values indicated by the written documents and iconography be acquired.

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1. I am greatly indebted to Richard Barker, who showed me the second of these lists a few years ago.
2. Chavantes's book was shown to me by António Teixeira (and is also cited by Silva, 2003), and Rees's book by Glenn Grieco.

## References

- Abreu, L., 1992, *O livro de Lisuarte de Abreu*. Lisbon.
- Alves, F., Castro, F., Rodrigues, P., Garcia, C., and Aleluia, M., 1998, Arqueologia de um Naufrágio, in S. L. Afonso, *Nossa Senhora dos Mártires: A Última Viagem*. Lisbon.
- Andersen, R. C., 1974, *Seventeenth-Century Rigging*. Hertfordshire.
- Anon., 1995, *Memória das armadas*. Macau.
- Armas, D., 1997, *Livro das fortalezas*. Lisbon.

- Ataide, A., 1588–1633, *Codices of D. António de Ataíde*, 3 vols., Ms. 4794f of the Houghton Library of Harvard University (microfilm at Lisbon's Biblioteca Central de Marinha).
- Baker, M., c.1570, Manuscript in the Pepysian Library of the Magdalenean College, Cambridge University, CB3 OAG—PL 2820 (microfilm at Texas A&M University's Nautical Archaeology Program library).
- Bandeira, J. S., 1895, *Tratado do aparelho do navio*. Lisbon.
- Barata, J. G. P., 1989, Achegas para a arqueologia naval portuguesa do século XVI, colhidas em documentos respeitantes à Ilha de S. Tomé, *Estudos de Arqueologia Naval*, 2 Vols., Lisbon.
- Barker, R., 1986, Fragments from the Pepysian Library, *Revista da Universidade de Coimbra* 32: 161–78.
- Barker, R., 2002, 'Showing the flag in 1521: wafting Beatriz of Savoy' from <http://home.clara.net/rabarker/Showing-the-flag-web.htm>, accessed May 2007.
- Bengtsson, S., 1975, The Sails of the Wasa, *IJNA* 4.1: 27–41.
- Boudriot, J., 1987, *The Seventy-Four Gun Ship*. 4 vols, Rochester.
- Castro, F., 2003, The Pepper Wreck, *IJNA* 32.1, 6–23.
- Castro, F., 2005a, *The Pepper Wreck*. College Station, TX.
- Castro, F., 2005b, Rigging the Pepper Wreck. Part I: Masts and Yards, *IJNA* 34.1, 112–24.
- Castro, F. and Fonseca, N., 2006, Sailing the Pepper Wreck: A Proposed Methodology to Understand an Early-17th-Century Portuguese Indiamen, *IJNA* 35.1, 97–103.
- Castro, J., 1988, *Tables des Routiers de l'Inde de D. João de Castro*. Lisbon.
- Castro, J., 1991, *Roteiro do Mar Roxo*. Lisbon.
- Chavantes, O. J., 1881, *Compêndio do aparelho dos navios*. Rio de Janeiro.
- Costa, L. F., 1997, *Naus e Galeões na Ribeira de Lisboa*. Cascais.
- Domingues, F. C., 1998, *A Carreira da Índia*. Lisbon.
- Garcia, J. M., 1998, 'Poder, história e exotismo na iluminura portuguesa quinhentista', *Oceanos* 26, 39.
- Garcia de Palacio, D., 1587, *Instrucion Nautica para el buen uso de las Naos, su traça, y gobierno conforme à la altura de Mexico*. Mexico. (Partially transcribed by C. F. Duro in *Disquisiciones Nauticas* (1880), Vol. V, 7–36. Madrid)
- Graham, T. I., 1998, The Marine Engravings of Peter Brueghel the Elder, *American Neptune* 58.4, 329–41.
- Leitão, H. and Lopes, J. V., 1990, *Dicionário da Linguagem de Marinha Antiga e Actual*, (3rd edn), Lisbon.
- McGee, D., 2008, The Shipbuilding Text of Michael of Rhodes, in H. Nowacki and W. Lefèvre (eds), *Creating Shapes in Civil and Naval Architecture*, Max Plank Institute Preprint 338, Vol. II, 79–104. Berlin.
- Melo, J. F. P., 1836, *Tratado prático do aparelho dos navios*. Lisbon.
- Moita, I., 1983, *Lisboa Quinhentista*. Lisbon.
- Rees, A., 1970, *Naval Architecture* (1819–1820). Trowbridge and London.
- Salisbury, W. and Anderson, R. C. (eds), 1958, *A Treatise on Shipbuilding and a Treatise on Rigging Written about 1620–1625*. London.
- Silva, A. M., 2003, *Sail Power*. Lisbon.
- Silva, A. M., 2005, *Quem vai pró mar . . .*. Lisbon.
- Sousa, G., c.1630, *Coriosidades de Gonçallo de Sousa*, ms 3074, Biblioteca Geral, Universidade de Coimbra.
- Tzalas, H. E., 1990, Kyrenia II in the Fresco of Pedoula Church, Cyprus. A Comparison with Ancient Ship Iconography, in H. Tzalas (ed.), *Tropis 2 Proceedings of the 2nd International Symposium on Ship Construction in Antiquity*, 323–7. Athens.