THE STRUCTURES OF ENGLISH WOODEN SHIPS: WILLIAM SUTHERLAND'S SHIP, *CIRCA* 1710[1]

Trevor Kenchington

Introduction

Beginning early in the sixteenth century, English shipbuilding methods underwent a major revolution with the introduction of Mediterranean/Iberian carvel, or plank-on-frame, techniques in place of the earlier, northern European clinker or lapstrake approach. In the older method, the lower edge of each strake of the planking overlapped on the outside the upper part of the strake below, and clenches (turned over or riveted nails) were driven through this overlap. These fastenings provided much of the strength of the finished hull.[2] The southern method, which had its roots in the late Roman era but was not fully developed until the Middle Ages, depended on a rigid framework to which planks were subsequently fastened, there being no direct fastenings between adjacent strakes. The strength and rigidity of the frame allowed larger ships to be built and, perhaps more importantly, permitted them to carry heavy guns.[3]

Some three and one-half centuries after this revolution, an even more profound change began in which wood was replaced as the primary material for ship construction by iron. The new material encouraged wholly new structural arrangements, such **as** watertight bulkheads and longitudinal framing, and thus led to fundamental change **in** every aspect of ship construction.

Between these two eras of rapid technological change there was relative stability. Indeed, there is an unfortunate tendency in the current literature to suppose that this era was characterized by ***absolute*** stability of ship structures; in effect, to suppose that the structures of late Tudor ships differed only in detail from those of nineteenth or early twentieth century wooden hulls. This was not so.

This misunderstanding probably has its origin in the widespread contemporary disinterest in technical matters. Artists' patrons were generally concerned with ships as finished objects and not in the means by which they were built, **a** bias reflected in surviving paintings and models. The shipwrights rarely felt a need to commit their knowledge to paper: many were illiterate while most who could have described their skills in writing preferred to preserve the secrets of their trade. The few senior shipwrights who did prepare technical treatises often did so in private manuscripts, and even then most confined their explanations to the geometrical methods used to lay down the lines of their creations, avoiding complex structural accounts.[4] Historians of post-Medieval ships have understandably responded to this limited information by concerning themselves with shape, external appearance and rigging, for all of which they had useful sources, while largely leaving aside matters of hull structure and other internal detail.

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When they have ventured into the latter topics, they have had to interpret unclear technical sources, such as construction contracts. It is neither surprising that many errors have become accepted "facts" nor that many writers have filled gaps in their knowledge by extrapolating backwards from later, better documented shipbuilding practices.

With the advent of nautical archaeology, the lack of contemporary information could have been remedied by direct examination of surviving ship structures. Archaeologists, however, are no more likely than historians to be trained in technical nautical matters. Those who have excavated post-Medieval sites frequently seem to have accepted the popular view that ship construction did not progress after 1600 and hence that the broken and worm-eaten timbers on their sites could be ignored in favour of the smaller (and more human-oriented) artifacts with which they were more familiar. Those few who have probed deeper to make critical examinations of ship timbers have often encountered a further problem: the lack of accessible and authoritative historical accounts have left them with insufficient understanding of how they could expect ships to be built. Given the equivocal nature of much evidence from wreck sites, this lack has resulted in some highly imaginative, if improbable, interpretations and hence further confusion.

To resolve this, it is essential to return to primary sources, both archaeological and historical, and to re-examine the interpretations that have been placed on them. By so doing, a new understanding of the ways ships were actually built at various times may be achieved. As a first step in this essay, I aim to apply this approach to the structures of English-built wooden ships about 1710. The topic of this article is not shipbuilding ***per se*** but rather ship structure. It is not concerned with the numbers of hulls produced, the techniques by which shipwrights reduced timber to the required forms, nor the detailed fittings that turn a bare hull into a working ship. The shapes of ships' hulls and their designs impinge upon this analysis only peripherally. Instead, the focus is on the arrangements of pieces of wood that comprised ships' hulls and on the fastenings between those pieces.

William Sutherland and the Sources on Early Eighteenth-Century Ships

The earliest surviving English manuscript concerning ship structure dates from the late Elizabethan period, but the first published work did not appear until 1664. Indeed, it was not until the third such book that an adequate explanation of English ship construction appeared. This was ***The Ship-builders Assistant,*** first published in 1711 and written after a career in the Royal dockyards, particularly at Portsmouth and Deptford, by William Sutherland.[5] There is nothing comparable to this book and no earlier source that can serve as a foundation for a comprehensive description of an English ship structure. It is, therefore, a useful starting point for any re-examination of such structures.

Like other shipwrights of his time who tried to explain their art in words, Sutherland was largely concerned with the shape of ships and a host of matters that interest naval architects but are of less immediate importance to nautical archaeologists. Nevertheless, scattered throughout his book Sutherland provided detailed explanations of the ship structures with which he was familiar. Moreover, his explanations were generally clear and well-illustrated. In this essay, I collate and interpret these descriptions. Since some of the confusion surrounding wooden ship structures has arisen from the careless use of terminology, where possible I use Sutherland's terms, though with modern spellings for those that have endured. When they are essential to the clarity of an explanation, I have used entirely modern or artificial terms but these are consistently italicized.[6]

What follows is based almost entirely on Sutherland's work but, in the few places where his text is unclear, I refer to other contemporary documents. One is an anonymous print, dating from 1712-1714 and dedicated to George St. Lo, that purports to show all the major timbers of a First Rate ship-of-the-line and is labelled with the names of those pieces, thus providing an illustrated key to some of Sutherland's terms.[7] This is referred to here as the "St. Lo print". A second supplementary source is a model in the National Maritime Museum, Greenwich, of the frame of a fifty-gun Fourth Rate warship which is conventionally dated from 17L5.[8] This not only shows the ship's ***skeleton*** in realistic detail (which no other known English model from before 1750 does) but also shows two different structures: the port side conforming closely to Sutherland's account while the starboard illustrates many features well known from later sources. Third, seme reference is made to the contract for the building of the ***Yarmouth,*** a seventy-gun Third Rate of 1059 tons, launched in 1695,[9] and one of the few major English warships of the time built in a commercial yard (and hence one of the few for which a detailed builder's contract was prepared). Finally, some information from the archaeological survey of the thirty-six-gun ***Dartmouth,*** built in 1655, is used.[10]

A Brief Introduction to Post-Medieval Wooden Ship Structures

While there were marked differences between the structures of Sutherland's ship and those built a half a century or more later, it is also true that the basic concepts involved in English wooden shipbuilding were relatively constant throughout the post-Medieval period. Thus, these structures were all founded on a central ***spine*** composed of a keel and an internal keelson, with a stem and sternpost at their ends. This ***spine*** bore transverse framing elements, analogous to human "ribs" (and composed of timbers called "floors," "futtocks" and "top timbers") that reached outward and upward from the keel to define the shape of the ship's bottom and sides. This transverse structure was covered, internally and externally, with fore-and-aft planking that provided both a ***skin*** for the hull and also much of its longitudinal strength. Beams spanned the gap between the sides and carried the deck planking. This much, but little more, Sutherland's ships had in common with both late Tudor galleons and twentieth-century schooners.[11]

Sutherland's Ship: The Centreline Structure

I here explore the ship structure described by Sutherland in the sequence: keel, stem, sternpost and associated structures; transverse framing of the bottom; transverse framing in the midships area; framing of the bow and stern; outer planking; inner structure and decks. Where specific scantlings are cited without further explanation, they are drawn from a list in ***The Ship-builders Assistant*** which refers to a 500-ton hull. Larger vessels would, of course, have had heavier scantlings and smaller hulls lighter ones.

As Sutherland described the process, once the shipwright had prepared his building slip, he began by constructing the ship's keel. This was of elm; in order to get sufficient length from the sizes of timber available, in all but the smallest vessels more than one piece of wood was required. A maximum of four was preferred in a 500-ton ship. The pieces were scarphed end-to-end, with the scarphs (four feet or more in length) cut vertically (see Figure 1)[12] and fastened by eight horizontal bolts 0.95 inches in diameter.[13]

Once pieced together, the keel was entirely straight and of virtually constant depth (see Figure 2). Amidships, it was square in section and sided fourteen inches[14]. Aft, it was tapered until it was 9.2 inches across at the sternpost. At its extreme forward end, the keel's upper surface swept up to make a fair curve with the inner face of the stem, while its lower surface continued straight to make a butt for the gripe. At each end, therefore, the keel was deeper than it was wide, though for different reasons. Along its sides, it was rabbetted to receive the garboard strakes.[15]

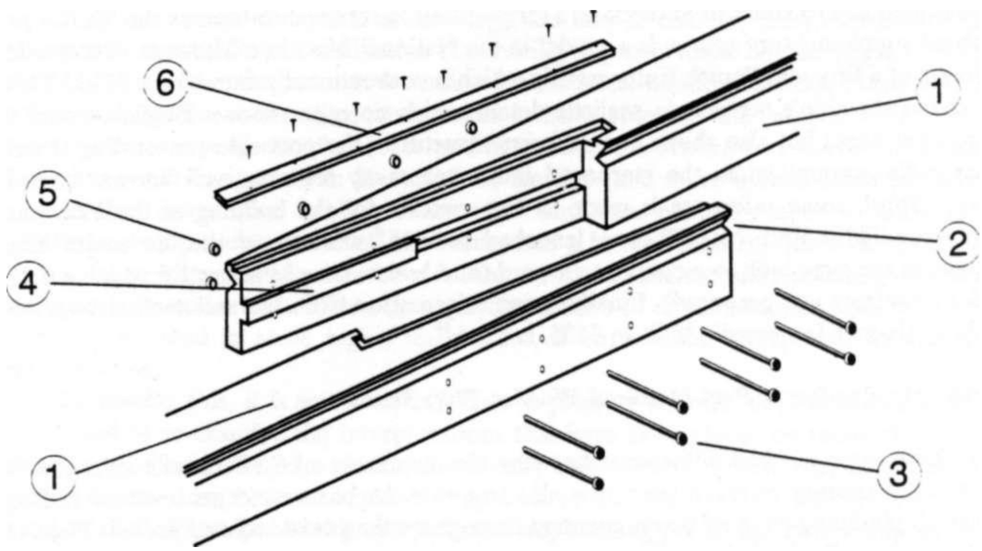

Figure 1: Exploded view of a keel scarph found on the wreck of the ***Dartmouth.*** 1: piece of the keel; 2: garboard rabbet (cut in side of keel); 3: bolt; 4: table (left proud of face of scarph); 5: rove (for end of bolt); 6: stopwater (to cover joint, fastened into matching groove by eight nails).

Source: Re-drawn after Martin.

Below the keel, there was a false keel, also of elm and moulded 3.15 inches. This presumably ran the full length of the keel and was intended to save it from damage rather than to provide additional strength, although Sutherland did not say so. He also did not make clear when the false keel was added, but its absence from his detailed account of setting up the keel suggests that this was late in construction, as indeed was the later practice.[16]

Once this keel structure was set up on the blocks (with or without the false keel), the sweeping curve of the stem was constructed of one or more pieces of oak (two in a 500-ton ship). These were of similar section to the keel low down but broadened upwards so that the top of the stem was as wide as the diameter of the bowsprit (about thirty inches). The pieces were scarphed end-on-end, as with the keel, but with the scarphs cut transversely instead of vertically. The lowest piece was scarphed onto the side of the keel. A rabbet was cut on either side of the stem to receive the hood (forward) ends of the planks.

Inside the stem was the lighter false stem, or apron, which matched the shape of the stem's inner curve and shared the same structure, although its scarphs may have been cut vertically. (In the Yarmouth, these scarphs were very much shorter than those in the stem and keel.) The false stem was moulded only 8.13 inches but was 22.9 inches in siding; thus, it was wider than the stem over most of its length, particularly near the keel. The false stem was presumably bolted to both the stem and the keel, although Sutherland did not confirm this. Indeed, with notable exceptions, he was generally silent on fastenings.[17]

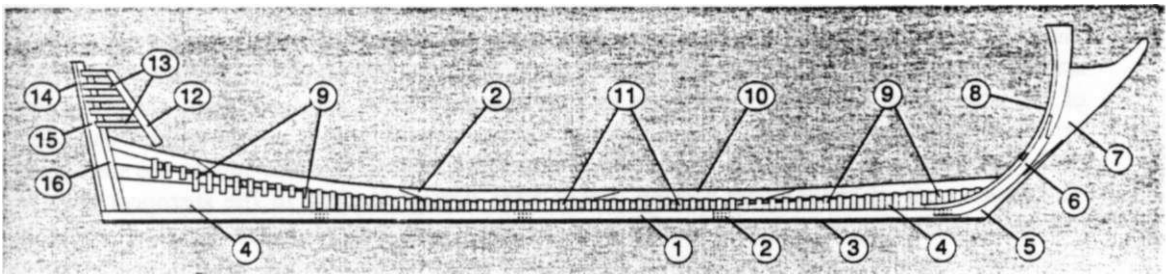

Figure 2: Diagram of the centreline structure of Sutherland's ship. 1: keel (at forward end and on side away from this view, upper surface follows curve of stem to limit of stem/keel scarph); 2: scarph; 3: false keel; 4: deadwood; 5: gripe; 6: stem; 7: knee of the head; 8: false stem or apron; 9: half-timbers (shown as projections of their heels onto the plane of the centreline); 10: keelson; 11: floors (seen in section at centreline); 12: fashion piece (projects out of plane of figure towards and away from direction of view); 13: transoms (project out of plane of figure towards and away from direction of view); 14: false post; 15: sternpost; 16: inner false post. A knee was fitted between the inner false post and the after deadwood but is omitted from this figure for clarity. The various rabbets are also not shown.

Sources: Prepared from the account given in the accompanying text with supporting information from the plates in Sutherland's book. Relative proportions drawn from Sutherland's ship design and his list of scantlings.

The sternpost was also added to the keel at this time. In contrast to the stem, being both straight and of great importance to the strength of the whole stern, the post was made of a single large piece of oak (thirty-two feet long, 17.25 inches square at its head, sided the width of the keel and moulded 25.8 inches at its heel). It was fastened to the extreme end of the keel by forming a tenon of its lower end and dropping that into a mortice cut in the keel. (There is nothing in Sutherland's book to suggest that the keel projected abaft the post, in the form of a skeg, to protect the rudder.[18]) The sternpost was accompanied by false posts both inside and out. The post itself was rabbetted to receive the hood ends of the lower planks.

This tripartite sternpost carried a number of transoms (transverse, forward-curving timbers fastened to the inner false post and conforming to the intended shape of the hull; see Figure 3), which were each moulded ten or 11.4 inches and set only thirteen inches apart, hence forming a substantial framework to bear the after planking. They must have been deeply scored about the post, and the inner false post must have been equally scored to receive them, or else their forward faces could not have spanned the forward face of the inner false post while their after ones conformed to the run of the planking. The uppermost was known as the "wing transom," while the one at the level of the gundeck, which probably supported the after ends of that deck's planks, was the "deck transom."[19]

On either side, the forward ends of the transoms were linked by a diagonal fashion piece. In Sutherland's illustrations (which in this case are unsupported by any text) and in Figure 2, the lower ends of this seem unconnected to anything substantial. This appears unbelievable but is confirmed by the contemporary frame model. Below the lowermost transom, the fashion piece evidently extended diagonally forwards and downwards, where it was simply fayed into a few timbers (Figure 3). Since their outer surfaces had to be flush to receive the planking, the timbers and perhaps also the fashion piece must have been deeply scored at the joint.[20] It may be worth noting that this complex arrangement had a logical origin in the late sixteenth and early seventeenth centuries when ships had square tucks (see Figure 4): the sort of flat stern now known to yachtsmen as a "transom."[21] With a square tuck, the transoms provided horizontal framing for the flat of the stern, while the fashion pieces defined the edge of the flat area and received the hood ends of those planks which did not end on the sternpost. The lower ends of these older fashion pieces were firmly attached to the sternpost slightly below the waterline. In the mid-seventeenth century, when English shipwrights adopted the round tuck (in which the planks swept up in a fair curve to end on the wing transom), they seem to have simply curved the transoms forward to conform to the new shape. The fashion piece lost its function of receiving the hood ends of any planks; as well its strong connection with the sternpost but was retained, perhaps to brace the outer ends of the transoms. Lacking anything better, the shipwrights evidently adopted the arrangement illustrated by Sutherland. This rather unsatisfactory solution was abandoned not long after he wrote in favour of carrying the lower end of the fashion piece down to the keel. The starboard side of the frame model shows the later arrangement, almost as it remained in English warships until the round stern was introduced early in the nineteenth century.

Two deadwoods were then placed on top of the keel one immediately ahead of the sternpost and another well forward, spanning the scarph between the keel and the stem.[22] Each was about a quarter as long as the keel and was built of as many pieces of wood as convenient, all bolted together and to the keel stem, apron, post and/or false posts, as appropriate. Sutherland did not explain their purpose but presumably, as in later ships, they served to fill in the sharpest parts of the hull with solid timber and to bear the ends of the half-timbers that framed these parts of the ship's length (see below). The deadwoods thus gave adequate strength to these areas without demanding the extravagant use of oak required by the **earlier** practice of shaping extra-deep floors to frame the entrance and run. They no doubt also gave additional reinforcement to the joints between the keel and the stem and sternpost. In contrast to later practice, Sutherland's figures show their upper surfaces as forming a series of steps and flat faces rather than a single smooth curve.[23]

Some recent reconstructions suggest that these deadwoods were equal in siding to the keel throughout their height (except where they were scored to receive the timbers). If so, they would have appeared like vertical walls when first constructed. Once the planking was added, it would have had no direct contact with the deadwood. Instead, there would have been a series of narrow, tapering voids reaching almost to the keel, each bounded by deadwood, planking and two timbers. The frame model suggests that this was not the arrangement used, at least for the after deadwood. (The forward deadwood, if one exists in the model, is too small to be seen in the published photographs.) Instead, the heels of the after timbers end some considerable distance above the keel, being fayed into the sides of the deadwood, close to its upper surface. That surface must therefore have been much wider than the keel while the deadwood as a whole must have filled the entire volume within the planking, its sides being shaped to follow the curves of the inner faces of the planks, which (below the heels of the timbers) can only have been fastened to the deadwood directly. Sutherland said nothing in his text that might confirm or refute this conclusion while his figures were equivocal: in one crude plate, no timbers extend down the sides of either deadwood while in another some do but not all reach the keel. Since even the latter plate is not inconsistent with the deadwoods filling the spaces between the timbers, it seems best to accept the model's evidence for solid structure. The forward deadwood necessarily overlapped the apron which, since it was wider than the stem in this area, must have contributed to the bulk of timber forming the functional deadwood, although it retained its distinct name. Sutherland illustrated, but did not mention in his text, a large knee[24] bracing the angle between the sternpost and the upper face of the after deadwood. This would have strengthened the joint between the stern frame and the keel/deadwood unit.[25]

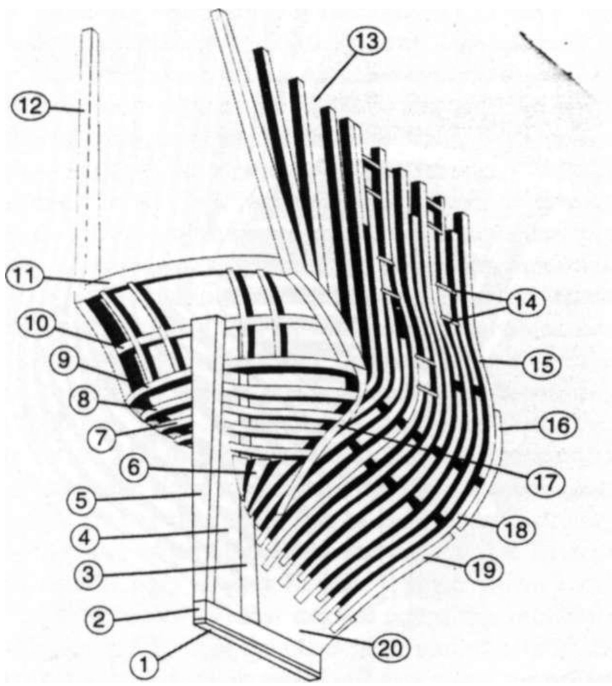

Figure 3: Orthogonal view of the structure of the stern and starboard quarter of Sutherland's ship. 1: false keel; 2: keel; 3: inner false post; 4: sternpost; 5: false post; 6: filling piece; 7: transom; 8: deck transom; 9: wing transom; 10: helm port transom; 11: counter rail; 12: stern timber; 13: space occupied at upper deck level by doorway to quarter gallery; 14: port sills; IS: top timber; 16: futtock; 17: fashion piece; 18: long timber; 19: half-timber; 20: deadwood (the arrangement of the various components is not indicated). The rabbets on the keel sternpost, and wing transom are not shown. Note that the irregular arrangement of timbers above the level of the gundeck is essential to reconcile the frame with the locations of the ports. [General arrangement follows accompanying text. The frame of the stern above the wing transom is somewhat speculative. Gaps between heads and heels of timbers are speculative. The frame of a real ship would probably have been much more irregular than is shown here.]

Sources: The lengths of the half-timbers and long timbers follow Stalkartt's explanation of 1787 and may not be correct for 1710. Detailed distribution of timbers in the frame taken from frame model. Scantlings taken from Sutherland's list.

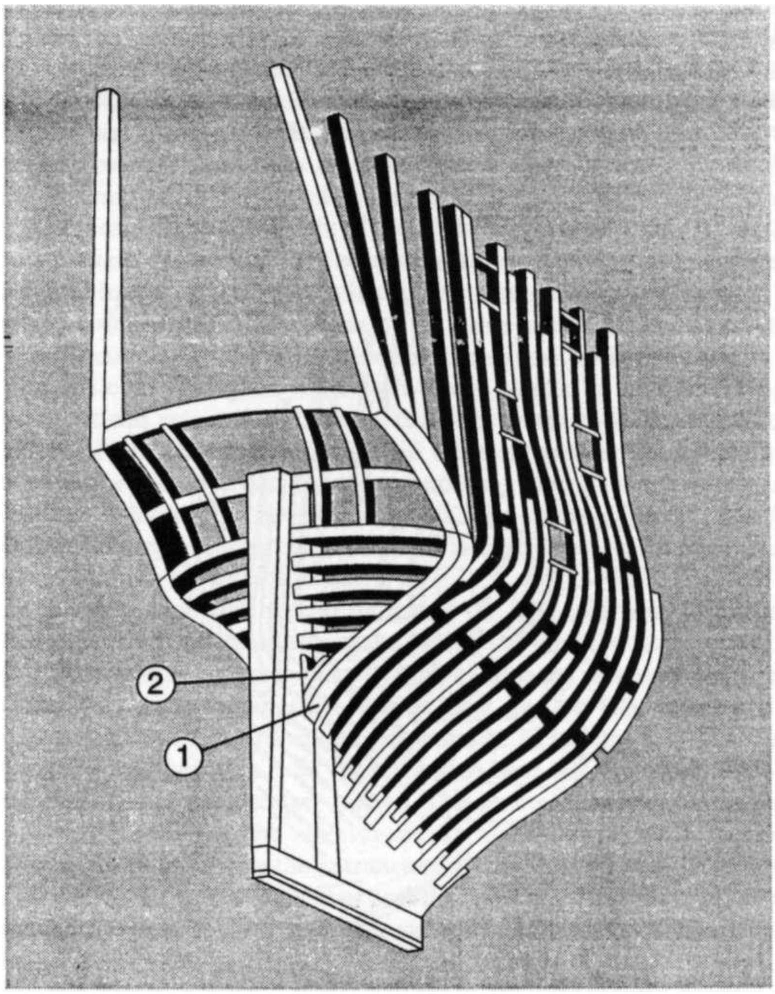

Figure **4:** Orthogonal view of the structure of the stern and starboard quarter of a ship similar to Sutherland's but with a square tuck, illustrating the structure of the latter. 1: fashion piece; 2: knee (hypothetical). Other items are as labelled in Figure 3. [Note that in this late form of the square tuck, the transoms are slightly curved. In reality, by ***circa*** 1710 English shipwrights had all but abandoned the square tuck for two-decked ships. Thus, this figure is of a purely theoretical hull structure.]

Forward of the stem, many ships carried an elaborate, decorative head. Its basic structure comprised two pieces fastened onto the forward face of the stem by through bolting. The knee of the head swept forward and upward (ultimately to carry the carved figure) while the gripe reached down to the level of the keel (forming the cutwater and giving the ship a better grip on the water when working to windward). Both were as thick as the stem where they were attached to it but tapered forward to ease their passage through the water. The ***Yarmouth's*** gripe was attached by a stirrup.[26]

The keelson and mast steps, though clearly parts of the centreline structure, are discussed below, since they cannot be understood without reference to the floors.

Transverse Structure of the Bottom

Once the keel stem, sternpost and associated structures were set square and well-shored, the shipwright began to lay the floors across the keel (see Figure 5). As with more recent ships, the floors were the principal transverse framing timbers of the bottom. Unlike nineteenth and twentieth-century construction, however, each was added to the growing structure as a single piece of wood and not after being built into a complete, multi-part frame.

Each floor was more or less rectangular in cross-section (sided 9.4 inches and moulded fourteen inches at the keel). Its lower surface curved upwards from the keel to its heads, matching the designed shape of the hull while its upper surface curved less sharply to allow a slight taper in its depth (moulded eleven inches at its heads). The floors of the frame-timbers[27] were set up first and bolted to the keel. These might be alternate floors or only every third or fourth. Presumably, they corresponded to the sections worked out geometrically and either drawn on the shipwright's draught or recorded in his table of offsets. With these floors in place, the shipwright ran a ribband (or "ribbon" as Sutherland spelled it—a length of relatively thin wood) around their heads and across the sirmarks (points defined when preparing the draught and marked on each timber when it was shaped; the shipwright would already have checked that these lay on a fair, three-dimensional curve). Assuming that the ribbands followed a fair curve while touching every sinnark and that all was symmetrical about the keel the ribbands were fastened firmly (though temporarily) and the remaining floor timbers were added, reaching from ribband to ribband across the keel and lying between and parallel to the frame-timber floors. Together, these would frame that part of the bottom between the deadwoods. They were set on 21.5 inch centres (in Sutherland's terms, the "room and space" was one foot, 9.5 inches) and were sided 9.4 inches. Thus the space between adjacent floors was 12.1 inches, or only slightly greater than the siding of each floor.[28]

Next came a step about which Sutherland was unclear. He advised shipwrights to "let in all the Half-timbers, and then get in your Kelson."[29] Some modern archaeologists use the term "half-floor" to mean a piece of wood that extends across the keel like a floor but projects much further on one side of the ship than the other. Alternatively, Sutherland might be telling us to fit short floors across the keel between the true floors, thus preparing for modern-looking framing in which the first futtocks extend to a short chock set across the keel. In fact, he had something very different in mind.

As shown by the St. Lo print, "half Timbers" (labelled as such) were literally half-length floors, each extending from the centreline to the ribband ***on one side of the hull only.*** As noted above, true floors were not fitted near the ends of the hull where the lines were too sharp for a floor to be cut from any normal tree without excessive wastage. However, the space that should be occupied by a floor could be filled by two separate pieces on either side of the centreline, plus the deadwood between them. This of course was much less strong than a single floor, but by 1710 it was (and remains) the only viable option in building a ship. Thus, by "letting in the Half-timbers," Sutherland meant mounting these half-length floors at either end of the ship. More specifically, he probably meant letting them into the sides of the deadwoods by cutting an appropriately-sized groove, but we cannot be certain of this.

Sutherland's figures are ambivalent about both whether there were any true floors set across the top of the deadwoods near their low, midship ends, and whether the heels of the half-timbers butted onto the upper faces of the deadwoods or were let into their sides, as was the later practice and his text is unfortunately silent.[30] The frame model suggests that the heels of the after half-timbers were set well above the keel and only a little way below the tops of the deadwoods whereas those forward extended to the top of the apron or keel. The exact arrangements cannot be determined from photographs alone, however. The remains of the ***Dartmouth*** are more informative, but are best left until later since they require careful interpretation.

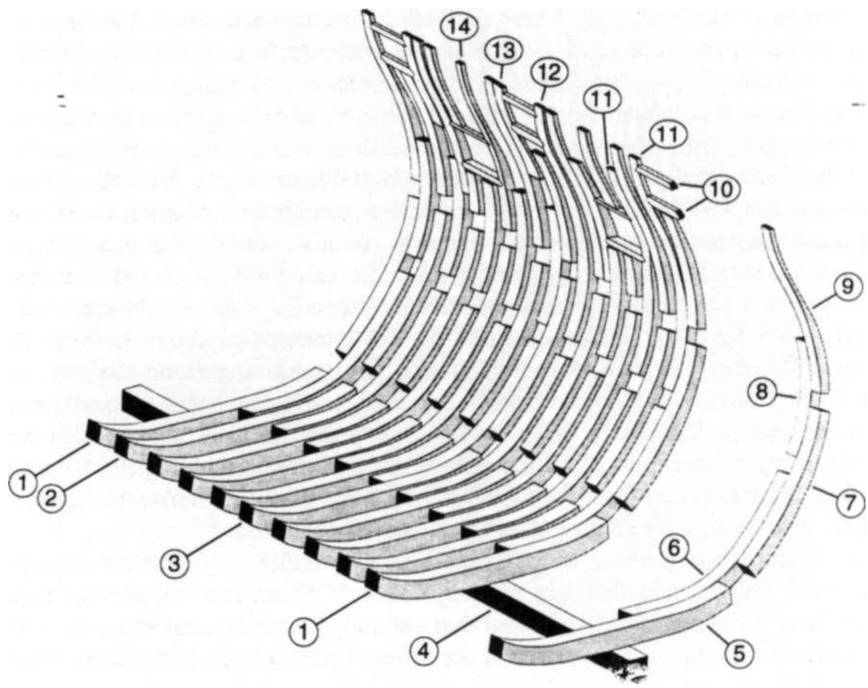

Figure 5: Orthogonal view of the port side of the frame amidships, from the first frame-timber abaft the midship frame-timber to the second one forward of it (the timbers between the first and second frame-timbers forward of the midship frame-timber are omitted for clarity). 1: frame-timber; 2: extra floor, second futtock and top timber (allowing reversal of floor/futtock orientation); 3: midship frame-timber; 4: keel; 5: floor; 6: first futtock; 7: second futtock; 8: third futtock; 9: top timber; 10: port sill; 11: side-round futtock; 12: extra-long futtock; 13: extra piece; 14: narrowed top timber. The false keel is omitted for clarity. Note the lack of contact between most futtocks and also the irregular arrangements of the timbers to accommodate the ports. [Gaps between heads and heels of timbers are speculative and, for emphasis, are here drawn larger than they probably were in a ship of 1710. The frame of a real ship would probably have been much more irregular than is shown here. The frame is drawn as though the deadflat extended over the whole area shown. In a real ship, there would have been more longitudinal curvature.]

Sources: General arrangement and scantlings follow accompanying text and Sutherland. Detailed distribution of timbers above the heads of the second futtocks taken from frame model.

Once all of the floors and half-timbers were in place, the kelson (now "keelson" and fourteen by fifteen inches in section) was placed on top of the floors, parallel to and above the keel. It was made of several pieces scarphed together in much the same way as the keel (but perhaps with the scarphs cut transversely instead of vertically) and was bolted to the latter through alternate floors, the remaining floors being bolted only to the keel. The keelson was scored so that the floors projected one inch into it or, conversely, so that it hung one inch into the gaps between adjacent floors. Its ends presumably overlapped the ends of the deadwoods and it may have run all the way to the stem and the sternpost, as the ***Yarmouth's*** was required to do, although Sutherland did not **confirm** this. If it ran to the post, its arrangement relative to the knee between the post and the deadwood is unclear.[31]

Transverse Structure Amidships

With the skeleton of the ship's bottom complete from stem to stern, the next step was to extend it upwards to the rail. This involved structural arrangements that differed in several important ways from later construction. Although the frame-timber floors had been placed across the keel first, by the time the keelson was added, the floors and half-timbers formed an unbroken series. In common with later eighteenth-century shipwrights but unlike modern ones, however, Sutherland continued to regard the frame-timbers as special. He therefore added the corresponding futtocks and top timbers to the frame-timber floors before doing any further work associated with the ***intermediate*** floors. In small hulls, this construction was immediately taken to the height of the rail, while large ships were initially framed only to the height of their maximum breadth and were raised to the rail in a second phase. Sutherland gave few details but we may surmise that the process was to take the hull's designed section at each frame-timber and to cut curving pieces of wood (called "futtocks," except for the uppermost, which was the "top timber") to match that shape. The number of futtocks per floor needed to reach from near the keel to the top of the hull depended on the shape and size of the ship. Three on each side plus a top timber were required for Sutherland's hypothetical 500-ton hull.

Those in the lowest tier ("first futtocks") would be set up, each with its lower end between two adjacent floors, overlapping much of their length, and with one side in direct contact with the side of the appropriate frame-timber floor. Unlike later construction, at this time the heels of the first futtocks did not reach the centreline, ending nearly twelve inches from the keel. Once each was in place, the corresponding second futtock was positioned beside it so that the second futtock's heel butted onto (or at least closely approached) the head of the corresponding floor (see illustration of isolated frame-timber in Figure 5). Subsequent futtocks and the top timbers followed in sequence, each butted onto (or approaching) the head of the next-but-one below, with the next-bellow acting to scarph this joint.[32]

In more recent construction, the heels of the second futtocks, for example, were in direct contact with the heads of the floors but it is far from sure that this was so in Sutherland's day. He did illustrate the second futtock mould as being continuous with the floor mould, suggesting that the various pieces abutted one another. Likewise, he wrote that "you may observe the Timbers to be equally scarfed, the Middle of one Timber being in the Wake of the Head and Heels of the others,"[33] which clearly suggests that head and heel were close together, if not actually touching. In his table of scantlings, however, he required only that the various futtocks should scarph (i.e., overlap) by a minimum of five and one-half feet. Since the first futtocks amidships, for example, projected about seven feet beyond the heads of the floors, this gives considerable scope for gaps rather than butt joints. Similarly, in his glossary, he defined "wrung head" (later "rung head" and usually synonymous with head of the floor) as "that part between the Floor-timber head and second Foot-hook HeeL" implying such a gap.[34] The alternative sources are of no help in resolving this uncertainty. The frame model shows the floors and second futtocks (and similar joints higher in the hull) as continuous timber with a line scribed on the surface to suggest a butt joint. This may, however, have been nothing more than a simplification to aid the model builder. Conversely, the ***Yarmouth*** contract called for the "middle futtock" (the second) to have six and one-half feet of scarph on the "navel timber" (first futtock), which agrees with Sutherland's scantlings and their suggestion of a gap. It may be that during Sutherland's career there was a gradual tendency to place the ends of these timbers closer together without actual contact becoming a requirement. If so, he offered a confusing snapshot of this change, making no mention of the scarphing chocks that were sometimes fitted into these butt joints later in the eighteenth century.[35]

Given three tiers of futtocks (Figure 5), there was clearly a top timber butted onto, or perhaps set close to, the head of every second futtock and reaching up to the rail. In contrast to some later construction arrangements, there does not seem to have been a second, shorter top timber butted onto the head of each third futtock. Sutherland neither mentioned such a timber nor provided a length for one in his table of scantlings. Nor indeed did the third futtock itself extend to the rail; its head lay little higher than the line of maximum breadth of the hull.[36] Similarly, the St. Lo print shows only one top timber per floor, along with uppermost futtocks that were too short to parallel the whole length of those timbers. Most convincingly, the frame model shows the futtocks ending at the level of the gundeck ports, leaving only one top timber per floor to frame the upper topsides.

In a final complication, clearly visible in the frame model, the first futtocks of the frame-timbers forward of amidships he abaft their corresponding floors whereas those abaft amidships lie forward of their floors. The orientation of the higher futtocks and top timbers is reversed in the same way. This peculiar arrangement has parallels in much older construction[37] and was probably followed in some manner by Sutherland, although he nowhere said so.

In the frame-timbers, the first futtocks would have been in direct contact with the corresponding floors. There may even have been temporary fastenings between these timbers but, until the planking was added, the futtocks were mainly supported by the ribbands and shores. Indeed, in contrast to later practice, there can have been no strong fore-and-aft fastenings between a floor and its associated first futtock since the adjacent floors (already in place and fastened to the keel before the futtocks were added) would have prevented them from being driven. Higher in the hull, the futtock/futtock and futtock/top timber scarphs in the frame-timbers could have had fore-and-aft fastenings, since these pieces were added before the intervening timbers. Thus, Sutherland wrote that it was normal "to fit or join all the Foot-hooks and Top-timbers together"[38] in a small ship or only the futtocks for a large one, which may imply some sort of permanent fastenings through these scarphs (though it could equally refer only to a building sequence). Elsewhere, however, in one of his more curious comments, he was concerned that the disposition of timber in the frame of the hull was even; that is, that the pieces should not be close together in one place and further apart in others. To this end, he wrote that "after the Frame-timbers are up in their places, and truly set, they may be parted without Prejudice, and equally spaced, as the Ship is planked."[39] If this really means what it seems to, it confirms that nothing more than a temporary attachment can ever have been made between the adjacent timbers in a frame-timber, all other support being via the ribbands and, later, the planking and inner structures of the hull. That being so, in the finished hull it might be hard to see that the various timbers had ever been directly attached. Such temporary attachment and subsequent displacement of the futtocks might go some way towards explaining both the disarticulated appearance of the timbering in many wrecks and the excessive numbers of treenails commonly seen in their timbers. Nevertheless, it seems a peculiar way of working, involving movement late in construction of substantial pieces of wood, and it may not be what Sutherland really meant.

Once all the frame-timbers were complete to the height of maximum breadth or to the rail, further ribbands were run around the "breadth sirmarks" (points taken from the plans corresponding to the widest point of the hull at each section) and presumably at other heights above the keel. All was then carefully levelled and squared ("horned," as later shipwrights called it) before building proceeded. Presumably, the next step was to add the remaining futtocks and top timbers (those above and beside the ***intermediate*** floors and hence interspersed between the frame-timbers).[40] These were shaped to follow the curves defined by the ribbands. They were probably almost indistinguishable from the futtocks and top timbers of the frame-timbers, with the important exception (if the frame model is to be believed) that an intermediate second futtock, for example, was evenly spaced between the first futtocks on either side and never touched either the first or the third futtock with which it was associated (see Figure 5). It was certainly not fastened to either. Unfortunately, Sutherland did not make any of this clear.

When adding these ***intermediate*** timbers, the shipwright had to maintain a regular alternation of floors and first futtocks along the length of the ship, despite the reversal of orientation of the frame-timbers noted above. This required some adjustment of the sequence near midships.[41] In the frame model, it was achieved by placing a fourth floor (and its accompanying second futtocks and top timbers) but only three first futtocks (and their accompanying third futtocks) between the midship frame-timber (itself oriented like those forward) and the next frame-timber aft. Elsewhere there were consistently three floors and three first futtocks between adjacent frame-timbers (see Figure 5).

In an unarmed ship, there need have been no further complications to the frame amidships but a ship with gun batteries required ports between the futtocks and top timbers. If the maximum number of guns were to be fitted into the available length of deck, they had to be close together. The sizes and positions of the ports were thus fixed by the requirements of the batteries and the ship's frame had to conform. Later shipwrights solved this by coordinating the room and space of the floors with the spacing of the ports so that the frame-timbers ran from keel to rail between the ports. Sutherland made no such concession, resorting instead to a complex of ***ad hoc*** arrangements.

He did recommend against cutting the top timbers to make the ports but he must have cut some since the space between adjacent timbers was far too small to accommodate the muzzle of a gun. What he probably sought to avoid was cutting the top timbers that were parts of the frame-timbers. Wherever possible, he suggested using the top timbers to make the sides of the ports, where they could take the lashing bolts for the guns and could "give Scarph to the Port-holes,"[42] implying that the length and strength of these timbers could best compensate for the weakness resulting from cutting a large port in the side of a ship. Since he did not coordinate room and space with the spacing of the ports, however, straight top timbers would only form the sides of the latter by chance. Thus, he allowed the use of timbers that curved forward or aft (termed "Side Round-timber") to help reconcile the frame to the ports, although he seems to have preferred to move the top timbers forward or aft relative to the futtock below, if that gave sufficient adjustment. (Sutherland was otherwise opposed to the use of side round timber and insisted that even those which had to be used be set square to the keel presumably in those parts of their length that did not curve forward or aft.)[43] The frame model, on which this aspect of Figure 5 is based, suggests that even these expedients were insufficient to reconcile the frame with the battery. Rather, it shows a highly irregular arrangement that includes extra-long third futtocks, unusually narrow top timbers, top timbers fayed into the sides of futtocks and even short filling pieces, in addition to side round timbers. Sutherland may well have built his ships in a similarly complex way, while setting out in his textbook ideal arrangements for which other shipwrights could aim. This weakness and the lack of coordination between the hull structure and the batteries are rather surprising, considering that by Sutherland's time English ships had been pierced for guns for more than 150 years. In that long period, the shipwrights had evidently not adapted their practices to the new realities of naval warfare.

As a last aspect of these timbers, Sutherland noted that the practice in earlier times had been to place the floors and first futtocks very close together, giving the ship an almost solid bottom. This, however, encouraged rot; by bis time some air spaces were left between these timbers. Nevertheless, his tabulated scantlings suggest that the sum of the sidings of the floors and the first futtocks (measured at the heads of the floors) was nearly twenty inches, when the available space for this wood was only the 213 inch room and space. The bottom thus was almost solid, except inboard of the heels of the first futtocks near the keel)[44].

The frame had more air-space higher up, since the sidings of the futtocks and top timbers reduced slightly with increasing height above the keel (the top timber was sided only 8.6 inches at its head)[45] while the space available for them did not change. Above the lower deck, the frame was even lighter than this slight taper would suggest. First, the timbers were strongly tapered in their moulded dimension, from fourteen inches at the keel to only 2.4 inches at the rail. Second, above the heads of the third futtocks there was only the single tier of top timbers, if the complications around the ports are ignored. Thus, the uppermost part of the sides had only a fraction of the weight of framing timber used below (say 2.4 by 8.6 inches of top timber head in every 215 inches of room and space, in contrast to twice six by nine inches in the same space at gun deck level and twice nine by fourteen inches near the keel, reductions of some eighty and ninety percent, respectively. Since strength in the topsides was essential in a warship or armed merchantman to resist the forces of recoil of the guns and their weight when rolling in a heavy sea (as well as to withstand enemy gunfire), these single top timbers would seem a major handicap.[46]

Structure of the Bow

All these futtocks and top timbers served to frame only the ship's middle, probably the part between the deadwoods. Next came the "long Timbers." Sutherland did not explain what these were but it is clear that some were well forward, in the part of the ship where there were half-timbers rather than floors. It therefore appears that the long timbers in some way substituted in the forward part of the ship for some of the futtocks. The supplementary sources supply no useful guidance. The St. Lo print illustrates for each half-timber a set of futtocks and top timbers identical, except in curvature to those associated with each end of every floor. This seems to represent a different structural arrangement from Sutherland's. The faint scores on the frame model that might indicate the butts at the heads of the half-timbers are not visible in the published photographs. The ***Yarmouth*** contract does not mention long timbers. Thus, a comparison with later practice, hazardous though that may be, seems unavoidable.

Seventy years after Sutherland wrote, Marmaduke Stalkartt defined half-timbers as "timbers in the cant-bodies, which are answerable to the lower futtocks in the square-body" and long timbers as "timbers in the cant-bodies which reach from the deadwood to the second futtock-head".[47] The half-timbers, in other words, served as half floors but had the length of first futtocks. The long timbers then had to fill the spaces occupied amidships by both a second futtock and half of a floor; they were "long" indeed. This arrangement of the 1780s (see Figure 6) may have been the one that Sutherland knew.

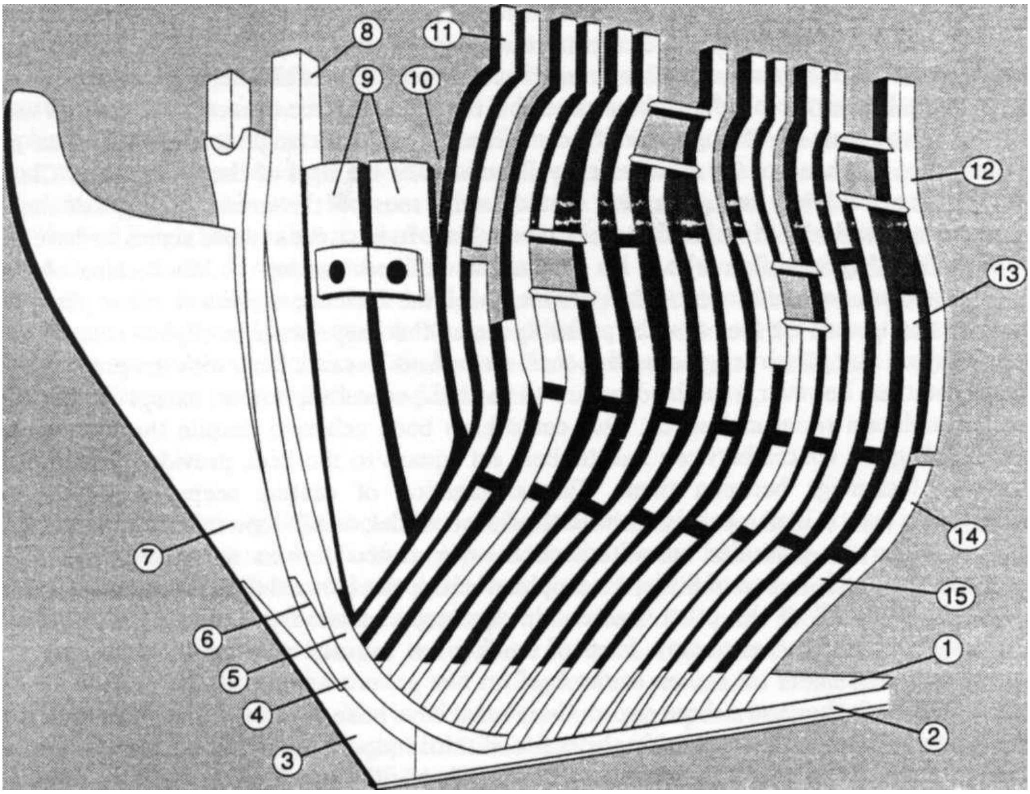

Figure 6: Perspective view of the structure of the port bow of Sutherland's ship. 1: deadwood (the arrangement of the various components is not indicated); 2: keel; 3: gripe; 4: stem; 5: apron; 6: scarph; 7: knee of the head; 8: knighthead; 9: hawse pieces; 10: gap between hawse piece and timber; 11: timber bearing the port end of the beakhead bulkhead; 12: top timber; 13: futtock; 14: long timber; 15: half-timber.

Sources: See Figure 3.

Sutherland also advised shipwrights to "Let your Long timbers be order'd forward after such a manner, that they may rake forward one after another, and take up as much Room and Space at the Head as at the Foot. Also turn or cant them forward, as much as possible, to save the bevelling of the Timber, and that the Hawse-pieces may have room to have sufficient Scarph downwards."[48] This is unclear. Even with the relatively straight edge of the deck in way of the forward half-timbers, there must still have been more space to be filled by the heads of the long timbers than by their heels, making it necessary to rake them ***aft*** a little (placing their heads somewhat abaft a vertical plane drawn through their heels) if room and space were to be maintained. A forward rake would certainly be counter-productive. Perhaps Sutherland's idea of "forward" rake was to have the heels of the timbers forward of their heads, the reverse of the modern meaning. At any rate, if the half-timbers were square to the keel and the long timbers were wide enough to occupy most of the space between them, there was little opportunity for raking the long timbers anyway. They certainly do not appear raked by any measurable amount in the frame model.

Sutherland was at least clear that the long timbers should be canted for the same reason that cant frames were used later: so that the outer face of the timbers could be shaped to the same line as the planks without excessive bevelling and the consequent waste of wood. Later this was done by setting an entire cant frame at an acute angle to the keel when seen in plan view, the head of the top timber well forward of the heel of the half-timber. Clearly, long timbers could only be significantly canted, in this sense, if the corresponding half-timbers were treated similarly, of which there is no indication. Indeed, Sutherland seems to have used the term "cant" quite differently: in his glossary, he defined "canting" as "the turning of Plank or Timber from one side to another, in order to see the Defects, or for any other purpose."[49] His direction to cant the long timbers probably means that they should be slightly rotated about an axis drawn along their lengths, so that their outer faces became flush with the planking. The axis of rotation, however, remained square to the keel seen from above, except for the slight rake to maintain room and space. This could have been achieved despite the long timbers almost filling the spaces between half-timbers set square to the keel provided there was no need for fastenings between them. This explanation of canting seems consistent with Sutherland's text. It is also consistent with the frame model, which shows these timbers square to the keel on the port side but with modern-style canted timbers to starboard. The only contrary evidence is in one of Sutherland's plates where the forward timbers follow prominent "S" bends, while all of the other frames are square to a view from abeam* This may be intended to illustrate the modern form of canting but it could also be a crude attempt to portray twisted timbers set square to the keel.

While Sutherland did not say so, there must have been top timbers associated with the long timbers and there was probably also a tier of third futtocks with their heels on or near the heads of the half-timbers. The frame model certainly has timbers reaching to the appropriate heights, although which are continuous with the long timbers and which are separate pieces cannot be determined from photographs.

The long timbers did not frame the bow itself. Because the headrails and other decorative work obscured the underlying hull form of sailing warships, that form is not obvious from casual inspection of paintings or models. Closer examination shows that the topsides of typical seventeenth and eighteenth-century ships ran more or less straight from amidships to the beakhead bulkhead at the forward edge of the forecastle. Only their lower part and the underwater body extended to meet the stem. Forward of the bulkhead the ship curved rapidly, following the typical bluff bow of the era. The half-timbers, long timbers and associated parts framed the ship only as far as the beakhead bulkhead. Forward of that, the bows were framed by the hawse pieces (so-called because the hawse holes for the anchor cables passed through them). In later ships these were futtock-like in form, except that they lay roughly parallel with rather than perpendicular to the keel in plan view. In Sutherland's day, however, hawse pieces evidently still retained an older form; the "great flitches of compass timber" as they had been described nearly a century earlier.[31] Each was a slab of oak at least as thick as the other timbers (and much thicker still in way of the hawse holes) and long enough to reach from the deck almost to the stem/keel scarph while curving to match the shape of the bow. At their lower ends, they tapered and were fayed onto the side of the stem and the foremost half-timber, well below the waterline. This is the arrangement shown on the port side of the frame model.[32]

Between the foremost hawse piece on either side and the stem, there may have been an additional timber, the knighthead, which rose above the stemhead to provide lateral support for the bowsprit. While Sutherland did not mention such a timber, one of his plates hints at its presence and one is fitted on the port side of the frame model. It would have been a relatively new feature in 1710; a generation earlier bowsprits had lain alongside, rather than on top of, the stemheads of English ships and there was no place for a knighthead of this kind.[53]

Sutherland noted in his table of scantlings that there should be four hawse pieces (presumably two per side), each twenty-two inches in "breadth."[54] In a 500-ton ship, the length of planking to be framed between the centreline and the beakhead bulkhead at deck level was about eight feet. Even leaving a few inches for air gaps between the various parts, allowing for the stem to occupy about a foot on either side of the centreline and an extra foot for a hypothetical knighthead, two twenty-two inch hawse pieces seem insufficient to frame each bow. In the frame model, however, no additional timbers are shown. Rather a triangular gap has been left in the framing near deck level, immediately abaft the after hawse piece. Curious though this structure appears, with its juxtaposition of enormously strong hawse pieces (requiring extravagant quantities of timber) and a point of extreme weakness, it does appear to be the arrangement that Sutherland intended.

Stern Frame

Sutherland said relatively little about the framing abaft the last floor. It is at least clear that the sternpost carried transoms and fashion pieces, while there were half-timbers in way of the after deadwood (Figure 3). These presumably had associated long timbers, futtocks and top timbers. The frame model has this basic arrangement, while the St. Lo print shows one futtock from each tier for each half floor aft, just as for those forward. These timbers were apparently set square to the keel, without the canting and raking forward, as indeed might be expected from the limited curvature of the topsides in the after part of contemporary ships. The transoms were attached to these timbers by a large, horizontal knee at either end, with the knees of the wing transom being twelve and one-half feet long and thus fastened to about fourteen separate timbers.[55] The knees of the lower transoms were probably shorter but still very large.

Below the lower transom, Sutherland's ship was probably framed by short, vertical timbers (later called "filling pieces"), although he nowhere said so. Such pieces were used in the frame model and it is difficult to see how a stern with a round tuck could be arranged without them. (They were usually not needed with a square tuck, since the aftermost half-timber or long timber could be placed close to the fashion piece throughout its length.) In side view, these filling pieces resemble short futtocks and the mix of horizontal and vertical pieces in this part of the ship appears unnecessarily complex. In three-quarter view, however, it can be seen that there was a small void between the stern post structure, the lowest transom, the aftermost long timber and the outer planking. The planks could not cross this void unsupported, yet there was insufficient space to fasten strong structural elements there. Thus, the void was filled almost solidly with filling pieces, which could be tapered to nothing at their lower ends since they did not need to carry a load onto the stern post. The planking fastenings probably passed through this filling into the stern post, thus holding the whole structure together. The vertical orientation of the filling pieces placed them perpendicular to the overlying planks so that they could best hold the strakes together.

Sutherland was almost silent on the structure of the topsides abaft the aftermost half-timber and above the fashion pieces. The frame model shows a timber extending the line of the fashion piece above the wing transom, thus defining the angle between the topside and the face of the stern. Above and ahead of this, there is a scatter of pieces resembling top timbers arranged around the ports and the doorways leading to the quarter galleries. The St. Lo print has little to add. Strangely, it shows a short fashion piece more suited to a square than a round tuck. For the area above the wing transom, it shows a single example of a "stern timber" which was probably the same as the timber above the model's wing transom, although it might be intended as one of several framing the face of the upper stern.[36]

Above the wing transom, the face of the stern of Sutherland's ship was composed of a counter (a concave-downward, aft-reaching extension), an aft-bowed, upward-tapering face of glass "lights" and associated woodwork, a gallery, and a mass of carved decoration. In the frame model, the border between the counter and the face of the stern is formed of a large, slightly arched, beam which is probably what Sutherland meant by the entry for a "counter rail," ten inches deep and 7.5 inches fore-and-aft, in his list of scantlings. Midway between that piece and the wing transom, the model has a second beam which Sutherland did not mention. The ***Yarmouth*** contract, however, calls for a transom "at the upper edge of the ports under the helm port to take hold of the sternpost," in addition to the regular transoms from the wing transom downwards. Inspection of a number of contemporary models suggests that this piece, sometimes referred as the "helm port transom," was essential to support the lids of the ports in the counter. Between these two near-horizontal elements, the counter was probably framed, as it is in the frame model, by a series of near-vertical pieces rising from the wing transom. Above the counter rail, Sutherland's list of scantlings included a "Stern Tire of Brackets next above the Counter," with the single dimension of 12.4 inches. These presumably served as a framework for the tier of "lights" at the upper deck level although their form is unclear. Likewise, his dimension of 8.7 inches for the "Galery Brackets sided at the lower Lights" probably refers to pieces that arose from the framework between those lights and swept aft to support an open gallery at quarterdeck level.[57] Otherwise Sutherland provided no information on this structure.

Wales and Outer Planking

With the ship's frame complete, Sutherland may have strengthened it by adding some of the internal structure, particularly the gundeck clamps (see below). Before doing much work inside, however, he planked most of the exterior surface, beginning with the wales (see Figure 7). These were thick strakes that ran the length of the ship and contributed significantly to its longitudinal strength. The lower wales, comprised of two strakes fourteen by 8.5 inches in section separated by a thinner one of similar width, were the largest. (Confusingly, Sutherland also referred to the two thicker strakes as the "upper" and "lower main wales," respectively.) In earlier ships, these wales followed the breadth sirmarks, which marked the point of maximum breadth of each frame-timber, but Sutherland called for them to be placed so that most of the gundeck knees could be bolted through them. Since in his published design most frame-timbers had a flat area at their maximum breadth, both criteria could probably have been fulfilled simultaneously, especially since the combined width of the lower wales was over three feet. The after ends of these lower wales came to the wing transom and were probably bolted to the large knees which that timber carried. Near the bows, where the required curvature was too tight to bend such thick timber, the wales were made of naturally curved or fire-bent pieces called "harpings."[58]

The various pieces that comprised each strake of the wales were scarphed end-to-end to prevent a loss of strength. In the frame model, these scarphs are cut horizontally and are worked only in the two thick strakes, the thinner strake between having butt joints (or perhaps vertically cut scarphs, which would be indistinguishable from butts in an external view of the finished hull). The horizontal orientation suggests that the builder expected the wales to resist primarily lateral, rather than vertical, stresses; that is, his concern appears to have been with the sides of the ship bulging outwards (perhaps when rolling) rather than with the bow and stern drooping or "hogging." This is rather surprising, given the obsession that most shipwrights had with the latter problem. Perhaps the scarphs in the gundeck clamps were cut vertically and those in the wales horizontally, so that the two joints could compliment each other (as those in the keel and keelson probably did). Sutherland did note that the scarphs in these two items should be set clear of one another to prevent local weakness. The wales were not quite rectangular in section but were shaped so that their parts that projected beyond the thinner planking had horizontal upper and lower surfaces while the inner parts were square to the surface of the underlying timbers. This squareness was essential if the seams were to be caulked.[59]

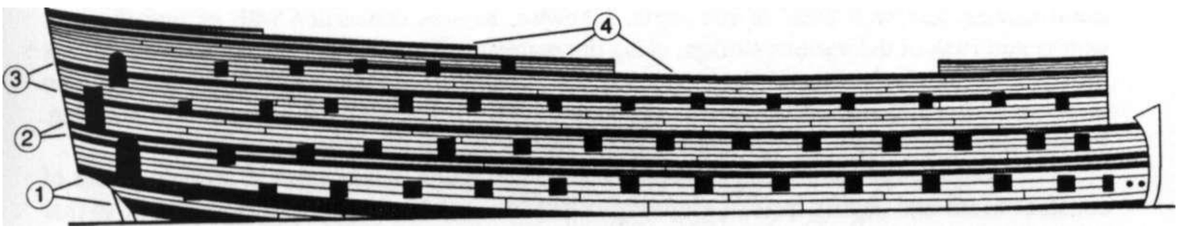

Figure 7: Planking of a three-decked ship-of-the-line. 1: main or lower wales; 2: channel wales; 3: wales; 4: rails. [Figure has been modified from original by completion of shape of counter, deletion of some possible indications of internal bulkheads and the smoothing of the strake edges. The irregularities in the latter may have been intended to indicate top and butt planking but appear rather to be a result of crude engraving. The indications of the planking butts shown here are as in the original but are incomplete and do not follow Sutherland's own rules for the shifting of butts.]

Source: Re-drawn from Sutherland's Plate 49.

In some ships, upper wales were then added, some distance above the lower ones. These were similar to the lower wales but lighter (each thick strake 11.45 by eight inches). Higher still were the lower and upper chain-wales, each a single strake little more than eight by four inches in section. These last were sometimes called "channels," although that term was more properly applied to the wide timbers (up to twenty-six inches wide by three to five inches deep) mounted on the upper chain wales that spread the chains of the lower rigging. (The lower chain wale received the bolts at the ends of these chains.) Thus, Sutherland sometimes called the chain-wales "channel wales."[60] At this point, the shipwrights may have added the sheerstrake ("sheering rail" to Sutherland) and the other rails that marked the tops of the hull sides. There had to be more than one such rail since some top timbers projected only a little above the waist while others extended to frame the forecastle, quarterdeck bulwarks and so on. Each rail was run as far fore-and-aft as there were timbers to carry it and thus was not always at the top of the side.[61]

With all these preliminaries completed, the normal-thickness planks were added. The planks of the bottom were 3.35 inches thick, increasing to five inches near the lower wales, then decreasing again to only two inches at the top timber heads, the changes in thickness being gradual and spread over three or four strakes (whether as a series of steps or faired to a smooth surface, Sutherland did not say). In the ***Yarmouth,*** all this planking was to be oak, except for the first ten feet above the keel, which could be made from elm or beech, and above the quarterdeck, where "Prutia deals" (softwood boards from what was then Prussia) were permitted. Similarly, Sutherland stated that the "Quick-work," the internal and external planking above the channel wales and decks, was commonly made of fir deals (a generic term that included various softwoods besides the modern botanist's "fir"), which were quicker to work and required less fastening than hardwood planks.[62]

All this planking was fastened to the timbers with 1.75 inch diameter treenails, there being no mention of metal fastenings. Sutherland gave many pointers to arranging the planking so that the butt joints did not cause excessive weakness. These included keeping them away from the keel scarphs and the pumps (pump suction tended to pull out the caulking), at least six feet apart lengthwise or with at least three whole strakes between the two with butts on the same timber, and ***well clear of the ports. Likewise, he was concerned with getting the best*** widths and runs of the various strakes, using the material efficiently, employing knot-free plank around the complex curves of the stern, and similar matters. On the other hand, he made no mention of the ribbands at this point, although they were directly in the way of the planking. Presumably they were removed and discarded as the planking reached them.[63]

Near the bow and stern, it was difficult to use actual planks (that is, straight pieces of constant width and depth); instead, shipwrights had to shape "snying" from large timbers, so that each piece curved across its width. These could then be fire-bent across their depth dimensions to fit the framing. Sutherland was properly critical of snying as wasteful of expensive compass timber and recommended that it be avoided by appropriate tapering of the strakes. He did not, however, mention the use of stealers, strakes which begin or end clear of the stem and sternpost and which have long been used to save much wasteful tapering of plank. With these few complications, the outer planking was completed to the uppermost parts of the ship, although it was still necessary to caulk the seams and add the wood sheathing (coppering was still some decades in the future).[64]

Internal Structure Below the Gundeck

With the outer planking complete, the shipwright could turn his attention to the internal structure of the hull. Even aside from the decks, this was far more complex than either the simple outer planking or the plain ceiling with which a nineteenth-century wooden merchantman was lined. Indeed, it is clear that Sutherland did not conceive of this internal structure as a single entity but as several, almost unrelated parts, some of which were primarily for strength while others did little more than cover the frame. For clarity, this complex is described here in sequence: structures below the gundeck (working inwards from the frame to the centreline, but excluding the orlop), the gundeck, the orlop and finally the structures above the gundeck.

Apart from the keelson, the principal longitudinal members of the internal structure were the clamps (heavy strakes run the length of the ship immediately beneath each deck and in contact with the inner faces of the timbers) and the thick strakes or "sleepers," which ran from stem to stern across the heads of the floors (see Figure 8). While Sutherland did not discuss the purposes of these items, it seems clear that the clamps both supported the weight of their deck and contributed important fore-and-aft strength. The gundeck lay close to the height of maximum breadth of each section and was not far from either the main wales or, amidships, the waterline. Thus, the gundeck clamps not only supported the weight of the heaviest deck on the ship but also formed a major part of the fore-and-aft structure in this critical part of the hull. Appropriately, in Sutherland's 500-ton ship they were made of two strakes (one above the other), each 15.5 inches deep and six inches thick.

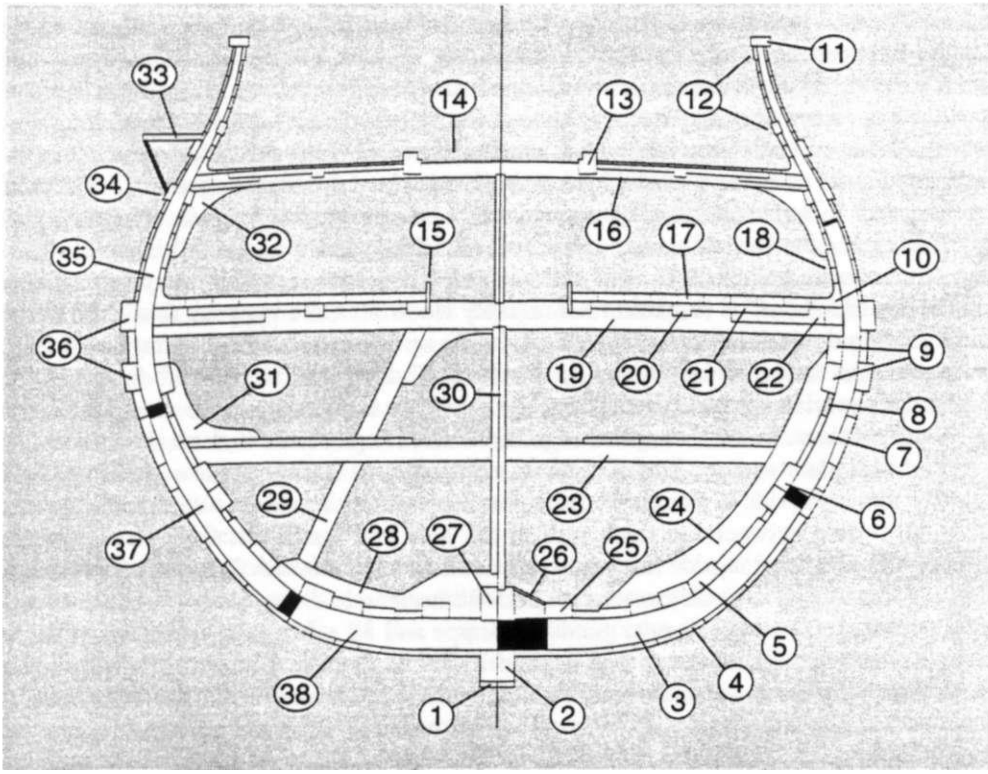

Figure **8:** Sections of hull amidships showing the internal structure, with the port side shown in way of a floor rider and the starboard side in way of a futtock rider. Both are shown clear of any ports. 1: false keel; 2: keel; 3: first futtock; 4: planking; 5: thick strakes; 6: middle bands; 7: third futtock; 8: air strake; 9: clamp; 10: waterway, 11: gunwale; 12: strings; 13: long coaming carling (seen in section); 14: main hatch; 15: coaming of main hatch (speculative feature); 16: upper deck beam; 17: planking of gundeck; 18: spirkit rising; 19: gundeck beam (hanging knees omitted for clarity); 20: carling; 21: ledge (seen in section); 22: lodging knee (seen in end view); 23: orlop beam (lodging knees omitted for clarity); 24: futtock rider; 25: thick stuff of the hold; 26: limber board; 27: keelson; 28: floor rider (only the half on the port side is shown); 29: cross pillar (here shown as bolted to the side of the floor rider away from the viewpoint, and kneed and bolted to the side of the gundeck beam away from the viewpoint; these details are speculative); 30: pillar (stepped into keelson or floor rider); 31: standard (omitted on starboard side for clarity, standards may not have been fitted in way of the futtock riders); 32: hanging knee; 33: channel (with chain to lower channel wale); 34: lower channel wale; 35: top timber; 36: main wale; 37: second futtock; 38: floor (only the half on the port side is shown; the limber holes are not shown). The spaces between the timbers are shaded black, except for the space above the third futtock on the starboard side.

Source: Arrangement and scantlings follow accompanying text and Sutherland. The gaps between the heads and heels of the timbers are speculative.]

The thick strakes comprised six strakes on either side of the ship, each 13.9 inches in width. The middle pair were 6.5 inches thick, the outer pair five inches, and the intervening ones something in between. They performed a particularly important function in covering the scarphs of the first futtocks with both the floors and second futtocks and providing much of the continuity between those pieces. This was obviously an area of weakness that was of special concern if the ship took the ground. The thick strakes would then have stopped the heels of the second futtocks from breaking into the hold as the weight of the topsides pressed their heads outwards. Between the clamps and thick strakes were lesser strakes, the middle bands that presumably served a similar function by crossing the heels of the third futtocks. They comprised two strakes, 5.7 inches thick. Finally, covering the heels of the first futtocks (and thus parallel to the keelson but a little distance away from it) there was a single 5.7-inch thick strake. Neither Sutherland nor the author of the ***Yarmouth*** contract named it but other authorities termed it the "thickstuff of the hold." Presumably it too served a purpose similar to the thick strakes, holding down the heels of the first futtocks and helping to bind them to the floors.

All this "inboard work" was to be "well hooked and scarphed," though whether Sutherland meant that the pieces in each strake should be hook scarphed to one another or that the adjacent strakes should be hooked together while the pieces in each strake were fastened end-to-end with plain scarphs is unclear. It was necessary to arrange these scarphs so that they did not he directly inside a planking butt, since that would have been a source of weakness.[65]

Any space between the thick stuff of the hold and the lowest thick strake (assuming that these did not he alongside each other) was filled with 43-inch thick, thirteen-inch wide strakes of "footwaling," a generic term that both Sutherland and the ***Yarmouth*** contract used to include the sleepers, middle bands, gundeck clamps and all other inner planking in the hold. The spaces between the sleepers and middle bands, and those between the latter and the gundeck clamps, were likewise covered with footwaling, apart from a small gap for ventilation immediately under the clamps (six inches wide in the ***Yarmouth)*** and perhaps another under the middle bands. In this lighter footwaling, the various pieces of each strake met in flat scarphs, since these needed only two treenails per timber rather than the four required by the simple butt joints used in the outer planking. It was, of course, still necessary to keep these scarphs away from those butts.[66]

Between the lowest strake of the footwaling and the keelson were the limber boards. Sutherland did not describe them but they were presumably the same removable boards as were fitted in later.[67] The addition of these boards completed the internal covering of the framing timbers below the gundeck clamps, which were then only visible through the air strakes.

Over much of the length of the ship, an additional set of transverse timbers, the riders, were fitted to the inner face of the footwaling to reinforce the floors and futtocks. The floor riders were of similar section to the floors (sided 13.4 inches, moulded 9.9 inches over the keelson) and were nearly as long, but less numerous. Sutherland allowed for only four in his table of scantlings and the ***Yarmouth*** had only five. They were bolted to the underlying structure at twenty-inch intervals with 1.18-inch diameter bolts. Between these riders and reaching above them (just as futtocks lay between but reached above the floors) were a set of "foot-hook riders" (now "futtock riders" and thirteen by 9.9 inches in section). There was a six and one-half foot overlap between the floor and futtock riders.[68]

Ahead of the forefoot, the additional reinforcement offered by the riders was provided instead by the breast hooks: large knees that spanned the inner face of the apron and tied the two sides of the bows together. This was particularly important, since there was no other transverse framing in this area while both the planking and footwaling ended at the stem. One breasthook was fitted under each deck, another under the hawse holes (above the gundeck), and four more between the foremast step and the gundeck clamps. Each was 10.9 inches thick, ten feet nine inches long and bolted every twenty inches.[69] The breasthooks under the decks were bolted to the corresponding clamps and thus provided some structural continuity across the stem between these major longitudinal elements. The footwaling could not all have been carried right to the stem, since the space available necessarily narrowed near the end of the ship, but if construction followed the sequence of Sutherland's implicit priority, the thick strakes would have run all the way. Thus, they also would have been tied together by breasthooks.

Franklin noted that the builder of the frame model had carefully shaped the breasthook that he fitted to the gundeck clamps so that its port half (representing the structure similar to Sutherland's) was stepped down relative to its more modern starboard half.[70] This feature has yet to be explained. I suggest that until Sutherland's time these breasthooks were intended to attach the clamps across the stem. It would therefore have been logical to place their upper surfaces flush with the upper faces of those clamps, as on the port side of the model. The deck beams, however, sat proud of the clamps (see below) and hence the deck planking followed a plane slightly above that of the clamps. Right forward, there would then have been no structural piece to which the ends of the deck planks could be fastened and the shipwrights must have interposed some sort of fillers; hardly a desirable arrangement and one that posed great difficulties when caulking the seam at the ends of the planks. The apparent solution was to fit the breasthook a little higher where it could carry the end of the deck, and hence become the "deck hook" of later terminology.[71]

Between the aftermost floor rider and the sternpost, transverse reinforcement similar to the breasthooks was provided by two rather similar pieces called "crutches", each nearly ten feet long. These tied the sides of the ship together across the deadwood, there being no continuous floors across the keel so far aft and hence a weakness similar to that in the bows.[72]

The riders, breasthooks and crutches completed the structure below the gundeck that followed the shape of the hull, but there were still more structural elements within the hold. Most prominently, pairs of large cross-pillars, each 7.9S inches square in section, had their heels bolted to the heads of the floor riders, while their heads met on the centreline at the level of the gundeck and there were fastened to a deck beam with knees in the ***Yarmouth.*** These pillars helped resist the strains of rolling and, particularly, of taking the ground. The ***Yarmouth*** was to have five pairs of cross-pillars, the same as the number of her floor riders. This may have been a general rule, but Sutherland offered no confirmation. Between the cross-pillars, a row of vertical pillars, 5.95 inches square in section, ran down the centreline to take the weight of the gundeck beams. There was one under each beam, stepped on the keelson or on a floor rider. A11 these pillars were decoratively turned above the level of the orlop.[73]

Surrounding the pillars and spanning the width of the hold was the orlop, the lowest deck in the ship, if a deck it was. Structurally, all the true decks were essentially variants of the gundeck, each being more lightly built but having the same basic features as the deck below. The orlop, however, was different and appears rather an afterthought, which in evolutionary terms it probably was.[74] Despite this uniqueness, it can most easily be understood structurally as a simplification of the gundeck and, for clarity, it is best left until after that greater deck has been considered.

Besides all these various features, the hold also contained the mast steps-large blocks set across the keelson (the ***Yarmouth*** contract called the mainmast step a "saddle," which may better indicate its form). While Sutherland gave no dimensions, the ***Yarmouth's*** were to be two feet seven inches fore-and-aft in the case of the mainmast, and two feet four inches athwartships in the case of the foremast. The latter was also to be fastened with eight bolts, presumably to the stem, apron and neighbouring pieces. Also in the hold were a well for the pumps, the lower parts of the bitts, and much more. Apart perhaps from the mast steps (which may have been big enough to contribute to the transverse strength of the hull), all can be considered fittings rather than structure and hence beyond the scope of this paper.

Structure of the Gundeck and Orlop

While each of the decks was essentially similar in structure, the gundeck, which bore the ship's main battery and provided transverse structural strength at the widest part of the hull, was the most heavily-built and had some features that were developed less prominently on the others. Thus, it is convenient first to explore the structure of this most complex deck, and then to describe the others in terms of their deviations from it.

The foundations of the gundeck's structure (see Figures 8-10) were the beams, thirteen inches fore and aft, 11.7 inches deep and curved to suit the intended camber of the deck (4.8 inches amidships). Each was made from a single piece of timber or from two or more scarphed together, if required. Ideally, there was a beam under or close to each port to take the weight of the gun and the force of its recoil and another half-way between adjacent ports, where it would be directly below a beam of the deck above (and thus well placed to receive a pillar). Clearly, there must also have been a beam over each floor rider so that the cross-pillars could be fitted in the hold, but that was probably achieved by adjusting the positions of the riders to suit the needs of the deck. Since the beams had to lie clear of the hatches and masts, however, there were none in way of the mainmast or the main hatch in Sutherland's design. His plate shows twenty-six beams for a gundeck with fourteen ports on each side, but his list of scantlings for a 500-ton ship calls for only eleven ports on the gundeck and hence there were probably only twenty or twenty-one beams.[75]

The ends of each beam were dovetailed into the gundeck clamps by about two inches, but their primary attachment to the sides was by means of two huge knees at each end (Figures 9-10). Forward of amidships, a hanging knee was bolted to the forward face of the beam and to the footwaling and timbers below, while a lodging knee was similarly bolted to the after face of the beam and to the timbers abaft the beam and above the clamps. These were not the puny knees familiar from more recent construction but were more vast: 85 inches thick with arms up to four feet long, bolted at sixteen to eighteen-inch centres with 1.6 inch diameter bolts. Indeed, the lodging knees were so large that the end of the fore-and-aft arm of each contacted the forward face of the hanging knee on the next beam aft. Thus, above the clamps, there was a continuous band of wood along the ship composed of lodging and hanging knees and the butts of the beams (which latter, because of the dovetailing, projected about a knee's-thickness above the clamps). The beams abaft amidships had an identical arrangement, except that their hanging knees lay abaft them and their lodging knees on their forward faces. This reversal meant that the lodging knees always lay in obtuse, rather than acute, angles between the beams and the ship's side, thus saving expense since acute-angled knees were particularly scarce. It also meant that somewhere near midships the ends of two lodging knees would meet without a beam between. This space was utilized for the main hatch.[76] No such economy was available with the hanging knees, since none occupied obtuse angles (although some were right-angled). While Sutherland accepted no substitute for the expensive acute knees, the ***Yarmouth*** contract was more practical permitting the substitution of futtock riders bolted to the beams "if so many knees cannot be had," but only for those beams that did not he under a gundeck port.

Old ships were further strengthened by the addition of standards, knees that arose from each beam end and attached it to the frames above, as hanging knees attached it to the frames below. Sutherland illustrated one per beam end but also implied that these were not used in new construction; his scantlings list called for only four "standers" per side (11.6 inches thick; substantially heavier than the hanging knees). Perhaps that number were fitted in new ships, with extras used to strengthen old hulls. Even then, they clearly cannot have been fitted where a beam lay under a port. They presumably lay on top of the deck planking, rather than in direct contact with the beam, since the latter arrangement would require that the planks bearing the guns be cut into short lengths between the standards with serious effects on their strength.[77]

Into the upper surfaces of the deck beams were set fore-and-aft timbers called carlings, 7.3 inches deep and 10.6 inches wide, each spanning from one beam to the next. Sutherland's list of scantlings required two rows down either side of the ship (except near the ends, where the narrowing deck required only one). His plate (Figure 9), on the other hand, shows three rows. The centremost bordered the hatches and may have been of larger dimensions, as were the "long coming carlings" of the upper deck (see below), and thus not included in the list. Alternatively, the greater number in the plate may simply have reflected the requirements of a ship substantially larger than 500 tons.

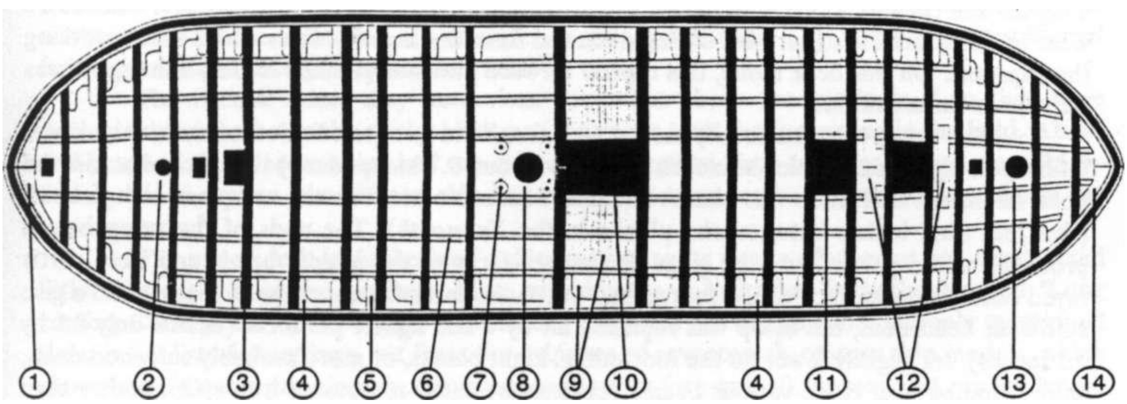

Figure 9: Plan of the structure of the gundeck of a large ship. 1: deck transom; 2: mizzen mast; 3: beam; 4: lodging knee (note reversal of orientation amidships); 5: hanging knee (seen from above); 6: carling; 7: pumps; 8: main mast; 9: ledges (shown only between the two beams amidships but fitted over the whole length of the deck); 10: main hatch; 11: hatch; 12: bitts (for anchor cables); 13: foremast; 14: deck hook. [Sutherland showed the deck transom as being almost symmetrical with the deck hook. It should probably be broader and less angled, with large knees at each end.]

Source: Re-drawn from Sutherland's Plate 42.

Lighter timbers, the ledges (3.8 by 4.5 inches), were then let into adjacent carlings so that they lay eight inches apart, parallel to the beams. Identical ledges were fitted outboard of the outermost row of carlings with their outboard ends let into the lodging knees. The whole structure of beams, carlings (other than, possibly, the centre pair), ledges and (probably) lodging knees was arranged so that its upper surface was flush to receive the planking. The latter was therefore directly supported by anything from 3.8 to 11.7 inches of oak over most of its surface and nowhere had to make an unsupported span of more than eight inches.[78]

This planking must have begun with a waterway along each side of the ship from bow to stern, although Sutherland only mentioned this in his glossary. It was made of large timbers, channelled into an "L"-section to guide any water on the deck to the scuppers while keeping it away from the spaces between the timbers (Figure 8). On the ***Yarmouth,*** the waterways were "six inches in the chine in thickness, and fourteen inches broad," which I take to mean that they extended fourteen inches across the beams from the timbers and were six inches thick in the curve of their channels. At their inboard edges, they must have been only as thick as regular deck planking. Their upper parts must have extended substantially more than six inches above the lodging knees and thus may have served to cover a foot or so of the inside of the timbers. In the ***Yarmouth,*** both the waterways and all the deck planking outboard of the hatches were of oak, the latter being four inches thick. The planks were fastened to every beam they crossed with two spikes and to every ledge with two treenails. Sutherland's structure was probably similar; although he provided few details, he did call for oak planking, 2.9 inches thick.[79]

The central part of most decks between the centremost carlings (wherever that space was not occupied by hatches, mast partners or other fittings) received less wear than its outer parts and could not provide useful longitudinal strength (since the hatches broke the continuity). The ***Yarmouth*** contract therefore permitted the builder to use "Prutia deals" in those areas as a lighter and cheaper alternative to oak. On the gundeck, however, there would have been some wear in this central area forward of the mainmast from the anchor cables and the men working the capstans. On this deck alone, this central forward part was planked in oak, although it was only three inches thick.

The orlop was structurally similar to a simplified gundeck. In Sutherland's ship, it was built upon eight beams (eleven inches fore-and-aft and 9.7 inches deep) that arched across the hold, so placed that there was almost standing headroom between the orlop and the gundeck (five feet nine inches between the planks in the ***Yarmouth).*** The ends of the orlop beams probably rested partially on the projecting upper faces of the middle bands and were partly fayed onto the inner face of the footwaling, but Sutherland did not make that certain. To give sufficient headroom, the orlop was replaced aft by a still lighter platform (beams only 8.5 by 7.2 inches), set slightly lower on the footwaling. Light planks, or more probably softwood deals, were fastened over these various beams (perhaps by easily-removable iron spikes rather than treenails) to provide platforms for various cabins and storerooms. This planking may not have been continuous along the length of the ship. Thus, Sutherland wrote of "Orlopes and Platforms of suitable lengths and breadths"[80] while the ***Yarmouth*** contract called for "platforms upon the orlop beams for stowing cables and other stores," the first plurals of which descriptions may be significant. This planking may have been neither caulked nor sealed to the footwaling, since there was no expectation that large amounts of water would reach this level and no way to remove it if it did, except by allowing it to flow down to the pumps.[81]

Sutherland made no mention of any reinforcement of the orlop beam/footwaling joints (although he did show standard knees in one of his plates) but the ***Yarmouth*** contract appears to require a knee and rider (or two knees) at the end of every beam. If this is correct (and the document is not perfectly clear), it seems that the orlop beams were mostly fayed and bolted to the futtock riders (two bolts each), while a large lodging knee (three feet long in each arm and ten inches thick) was bolted to both the beam and the ship's side. Before and abaft the part of the ship that had riders, knees would have been substituted. These may have been the hanging knees used on the higher decks, but Sutherland's illustration of standards may be significant. That low in the hull and so near the ends, hanging knees would necessarily have had to fit into tight acute angles and would have been correspondingly expensive. Since there were no guns to be accommodated on the orlop, standards would have not been as disadvantageous there as higher up and might have been preferred in the interests of economy. The orlop had no pillars of its own but was worked around those of the gundeck.

Internal Structure above the Gundeck

Between the decks there were only three structural features: the inner covering of the timbers, riders and pillars. The latter carried the weight of the upper deck beams down to the gundeck. Unlike those later ships which had two rows of pillars above the gundeck (one at either side of the hatches), Sutherland's had only a single row down the centreline.[82] He gave no dimensions for them, although presumably they were thinner than those in the hold.

Between the upper surface of the gundeck waterways and the lower sills of the ports, a distance of perhaps fifteen or eighteen inches (the port sills were twenty-five inches above the deck planks), the inner faces of the timbers were covered by four-inch thick spirkit-risings. The ports were thirty-two inches wide and twenty-seven inches high. Between them, extending from the height of their lower sills to their upper ones, was a three-inch thick lining covering the timbers. The upper deck clamps (4.15 inches thick) ran around the ship somewhat above the gundeck ports, just as the gundeck clamps did lower down. Sutherland did not give a width for them, but if there were to be the seven feet three inches headroom between planks that the ***Yarmouth's*** contract required, there was nearly thirty inches available between the upper sills of the ports and the underside of the upper deck lodging knees. This was probably sufficient for two strakes of clamps and an air strake.[83]

The futtock riders may have risen somewhat above the gundeck; if so they were presumably worked over the spirkit risings as they were over the footwaling in the hold. Above and between them, some ships had top-riders to strengthen their topsides. These were 9.1 by 8.85 inches in section in a 500-ton ship and must have been worked between the ports of the various decks.[84]

The upper deck of Sutherland's ship, resting on its strake of clamps, was constructed b'ttle differently from the gundeck. Most prominently, it had what Sutherland called "Long coming **Carlings** for the Gratings," 10.1 inches deep and 8.7 inches wide. He only mentioned them in his list of scantlings, but from the evidence of seventeenth-century ship models, which show these features prominently, they were continuous fore-and-aft timbers that ran the length of the deck on either side of the hatches in the place of regular carlings and received the ends of the ledges in the usual way.[45] By joining the bow to the stern with continuous timber (unlike normal carlings which ran from beam to beam), they probably helped to resist hogging. They were scored into the beams but still stood proud of them and the deck planking.

Unlike the gundeck, the hanging knees of which projected into the hold, if Sutherland's directions for the placement of the beams (see above) were to be followed exactly, half of the upper deck beams would lie directly above a gundeck port, leaving insufficient space for a normal hanging knee. One solution was to use dagger knees (which projected obliquely downwards and either forward or aft) or curved knees, either of which could lie clear of the port below. Sutherland, however, advised that care be taken to place the beams clear of the ports to avoid the need for such unsatisfactory arrangements. Presumably, he intended that the beams be set rather to the edge of the ports above them such that the hanging knees (which lay beside, rather than under, the beams) would lie at the side of the ports on the deck below.

The upper deck was much more lightly-constructed than the gundeck (beams, 9.4 by 83 inches; carlings, 6.15 by 5.05; ledges 3.7 by three inches; knees 5.9 inches thick; bolts 0.77 inches in diameter; planking 23 inches thick of either true planks or "deals," the latter presumably softwood). The ***Yarmouth*** had an upper deck of oak in way of the guns, with "Prutia deals" being confined to the area between the long coaming carlings. Well aft, the upper deck's regular arrangement of beams, knees, carlings and ledges may have been replaced by light beams alone. One of Sutherland's plates appears to show such an arrangement in the cabin, abaft the aftermost port, where this deck would not have had to carry any guns.[86] Finally, the upper deck beams may not have been dovetailed into the clamps.The ***Yarmouth's*** upper deck had "coamings, head ledges and grating hatches" (small hatchways covered by gratings) between the guns, presumably to release the smoke from the main battery below. This feature seems to have been abandoned about 1700 and it is not surprising that Sutherland did not mention it.

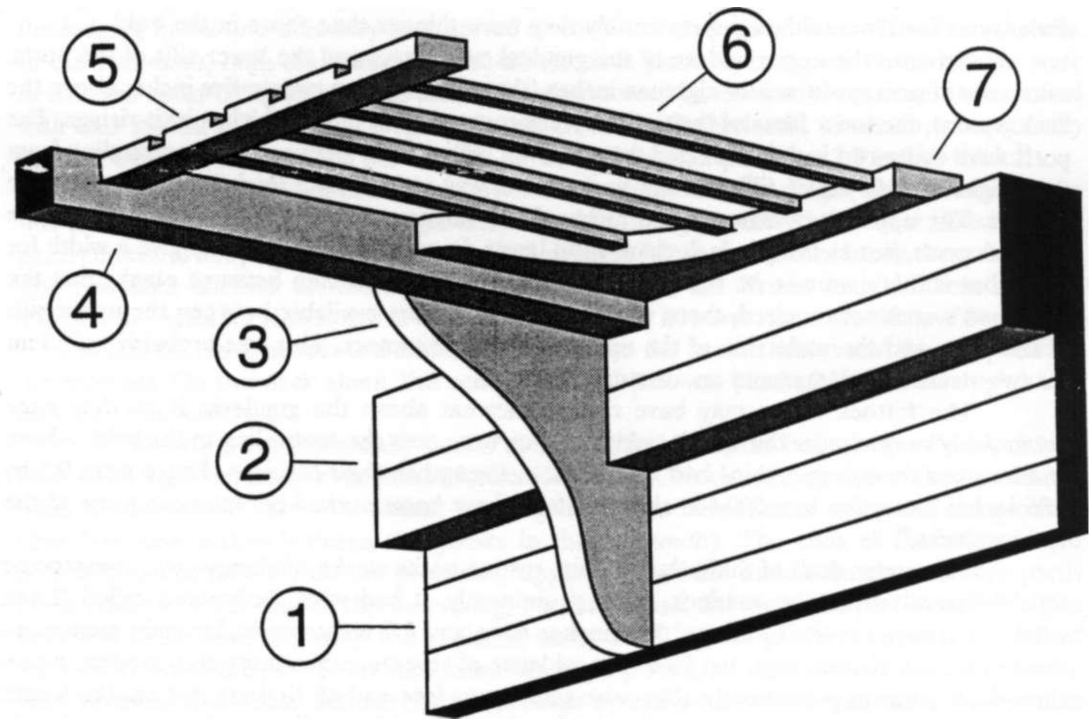

Figure 10: Diagram of the basic structure of the gundeck, seen from below in three-quarter view. 1: footwaling; 2: clamp; 3: hanging knee; 4: beam; 5: carling; 6: ledge; 7: lodging knee. Cut surfaces are shaded black. The nearer end of the carling would be supported by the next beam. A further set of ledges would extend from the scores in the carling shown to the next carling inboard. The deck planking would he over the beams, lodging knees, carlings and ledges.

Above the waterways of the upper deck was a further band of spirkit risings (three inches thick in Sutherland's 500-ton ship) and the upper deck ports. Above and below these ports were some rather enigmatic timbers called "strings" (equivalent to the modern "stringers"), the lower was 45 inches thick (of which only 1.2 inches was "left without the Spirkit-rising") and was "prick'd home to the out board Plank." The one above the ports was 2.9 inches thick but was still scored (by 0.75 inch) to fit around the timbers. The ***Yarmouth*** contract also called for a similar string of English oak (but no less than six inches deep and ten thick) in the vicinity of the upper deck ports, which was also to be "pricked home to the outside plank." Unfortunately, this similarity of wording is not matched by a clarity of meaning. Sutherland's glossary is not very helpful, defining "strings" as "parts used to strengthen; and what are called Clamps in the lower parts, are termed Strings upwards." (The latter meaning, which does not apply to the present timbers, is discussed below.) Much later, Stalkartt defined the same term as "the strake under the gunwale within-side, generally worked the same thickness as the sheer-strake, and scarphed in the same manner; the string and sheer-strake are bolted through the ship's side, between the main and fore-drifts, as that part of the ship requires all the security that is possible to assist the sheer of the ship." It appears that the use of these strings arose from a concern that the upper deck ports in the waist (the area between the forecastle and the quarterdeck) seriously weakened resistance to hogging. In the ***Yarmouth,*** the solution appears to have been to fit a strake between the ports and the rail that when scored around the top timbers (moulded 45 inches at this height) would have occupied all the space between them and would still have projected 55 inches inboard (in comparison to the four inches of the upper deck spirkit risings, thus 15 inches of the string were "left without" the spirkit risings). That string was then through-bolted (if "pricked" can be so interpreted, though it may have meant no more than "spiked") to the uppermost outer plank (the sheerstrake), as Stalkartt later described. The result, when combined with the gunwale, was a solid mass of timber that bound the heads of the top timbers and hence minimized their spreading, just as the long coaming carlings minimized spreading of the deck beams. Whether this structure of string and sheerstrake was continuous from bow to stern or was confined to the waist is uncertain, although the latter seems likely. If that was indeed the form of the strings in the ***Yarmouth,*** it was not quite what Sutherland had in mind. His string above the ports was relatively thin and only lightly scored around the top timbers, while he placed most of the strength and the "pricking" with the additional string below the ports, which was hardly scored at all. This may have been a personal idiosyncrasy of the author; certainly Stalkartt's explanation of the arrangement about 1780 seems to resemble more closely the ***Yarmouth's*** structure than Sutherland's, despite the latter's intermediate date.*[7] (Between the ports there was presumably the same lining as between the gundeck ports, although Sutherland did not say so.)

Still higher in the ship, the forecastle rested on its clamp, which was 33 inches thick but of variable depth, depending on the space available between the upper deck ports and the forecastle beams (suggesting both that the strings did not run forward of the break of the forecastle and that there was no lining above the ports in that area). By contrast, the quarter-deck rested on elm "strings," at least where it formed the deckhead of the Great Cabin. (These timbers were specifically confined to that cabin in the ***Yarmouth,*** where they were called "risings.") These strings, 8.7 inches deep and 63 inches thick, were substantially larger than those in the waist of Sutherland's ship and were even heavier than the upper deck clamps. Oddly, the quarterdeck beams were dovetailed into, and bolted to, these strings. It is unclear why such heavy construction was required so high in the ship, but it may be that this approach substituted for hanging knees, thus saving the captain the inconvenience of such obstructions in his cabin. Sutherland makes no mention of knees at this level, which is at least consistent with such an explanation. The ***Yarmouth*** contract did call for hanging knees on either end of the forecastle and quarterdeck beams, although only on alternate ones and perhaps not on those in the vicinity of the Great Cabin. It made no mention of any lodging knees for these decks.

In Sutherland's ship, both the forecastle and the quarterdeck beams were 7.2 inches fore-and-aft and 4.8 inches deep, set on twenty-four to twenty-eight inch centres. Being so close together, they do not appear to have carried any carlings or ledges. They were covered with two-inch plank. The ***Yarmouth*** was essentially identical, except for its heavier scantlings, and was planked in oak in way of the guns, with the option of "Prutia deals" elsewhere.

Since the forecastle and quarterdeck did not extend the full length of the ship, bulkheads were needed to close off their open ends. These contributed little strength to the hull and Sutherland provided only an enigmatic note in his list of scantlings that the "Bulk-head Brackets" should be 7.5 inches thick. The ***Yarmouth*** contract is a bit more helpful, calling for standards nine inches thick with arms at least forty-two inches long to be bolted to the upper deck at the ends of each bulkhead and for an oak plank ten inches broad and four inches thick to be fayed to the deck planks to receive the bulkhead stanchions; the joint was sealed with tar and hair. Presumably light boards, panelling and other work were fastened to the stanchions to complete the bulkheads.

The forecastle was the highest structure forward. Aft, above the quarterdeck, there were more spirkit risings (2.9 inches thick), presumably more lining between the ports and a clamp in way of the poop. That deck was then built on 5.1 by 335 inch beams at 17.4 inch centres.[88] It presumably resembled the quarterdeck in other respects. With its completion, the fundamental structure of the ship was finished.

There was, of course, still a great deal of other work to be done before it was ready for sea: completing the cabins and store rooms, for example, along with fitting the capstans, bitts, rudder and steering gear and much else, then ballasting, masting, rigging and storing, not to mention manning. While Sutherland's book contains useful information on most of these topics, they are beyond the scope of this essay.

Some Comparisons

Given Sutherland's credentials and the close correspondence between his account and the other contemporary sources used here, there is little doubt that his description of ship structure is authoritative, although my interpretation of it may not always be so. It is less sure to what exact period this description applies. Sutherland's book was published in 1711, after the author had spent more than fifteen years in the Royal dockyards. In almost everything he wrote, he seems to have been explaining what was done rather than advocating new developments. Thus, the book might be expected to contain a description of a ship of about 1700-1710. The inclusion of the heavy long coaming carlings suggests the earlier date; at least the surviving model evidence indicates that these went out of fashion on major warships very early in the eighteenth century.[89] It would, however, be rash to date such a feature with great precision on the basis of models alone. Likewise, Sutherland made no mention of a wheel. English ships were probably first fitted with them in the 1690s, although they were not common even on major warships until some years later; the whipstaff, which they replaced, may have remained in mercantile use until the 1750s'[90] Thus, while the lack of a wheel represented something less than the latest technology, it would certainly not have been anachronistic on a merchantman in 1710. Conversely, Sutherland's description is of a ship with an enclosed rudder head, a feature introduced on English warships between 1690 and 1700-[91] and without the small upper deck hatches between the guns that the ***Yarmouth*** (launched in 1695) had.

If it were intended to represent a warship, therefore, Sutherland's account was of one with features that were typical in 1700-1705, though not impossible a few years earlier or later. It is entirely likely, however, that he intended to describe a large armed merchantman or perhaps a generic ship suited to either role. If so, and assuming that the private yards lagged a little behind the practices of the Royal dockyards, his account could well apply to ships building in 1710. The hull structure that he described soon became outmoded, however; for warships at least. Indeed, if the conventional date of the ***circa*** 1715 frame model is correct, then within five years of Sutherland's book being published the Navy Board was considering some of the more significant changes in English ship structure introduced between the early Tudor revolutionary developments and the adoption of diagonal framing around 1815. The description developed in this essay may, therefore, have more relevance to warships built thirty years before Sutherland wrote than it does to those laid down a decade after.

It should be stressed, however, that these structures were not invariant even at a single point in time. Given the paucity of other sources, it would be easy, but mistaken, to suppose that Sutherland's account explained the structure of ***all*** English ships constructed around 1710. While the Navy Board and some private owners may have exerted a standardizing influence, it is likely that master shipwrights built in whatever way they perceived best. Since each shipwright had learned slightly different methods as an apprentice and during his subsequent career, each would have had his own preferences for certain details. If we had sufficient data, every ship would be seen to be slightly different from every other, although those built by the same man, in the same yard or in the same town would probably be identifiable by certain idiosyncrasies—not because of geographic specialization alone but because in an era of limited travel and restricted communications, shipwrights would have had more ideas in common with their neighbours than with men living at some distance. In the extreme, of course, English shipwrights had quite different practices from those of other countries. In parts of the Netherlands, for example, the shipwrights of Sutherland's time were still planking the bottom of their hulls before adding any floor timbers,[92] while in the French Royal yards the futtocks were already being arranged into modern articulated frames and bolted together, a stage of development that Anglo-American builders did not reach until the nineteenth century and which never became universal in England itself. Thus, the description of ship structure developed in this paper may be taken as representative of the way in which some English ships were built in Sutherland's time but not as a definitive statement of the way that they were all constructed.[93]

Indeed, a significant result of examining ship structures in the degree of detail followed here is that it reveals the wide potential for individual variations in building practices. The oft-repeated preferences of the Navy Board or the members of Lloyd's for "River-built" ships (the products of yards on the Thames) and the generally low opinions of colonial or "plantation-built" hulls may not be the crude prejudices they sometimes appear. Rather, by employing more developed structures (strings deeply scored about the top timbers, for example), more appropriate scantlings, and more care in making close-fitting joints of the most appropriate types, and by developing the skill to shape awkward features (such as a round tuck), the shipwrights and yards that stressed quality over price had ample technical scope to produce significantly better shaped, stronger and longer-lasting hulls.

It would be instructive to compare the account of ship structure in this essay, based as it is on a variety of historical sources, with information derived from direct examination of the remains of English ships dating from about 1700. Unfortunately, little such information is available. Seven warships of approximately Sutherland's date have been listed under the British Protection of Wrecks Act and are thus reserved for archaeological study, while an eighth, the ***Sapphire,*** has been partially excavated in Bay Bulls, Newfoundland. Moreover, six merchantmen which may or do date from around 1700 have been reported, all from the United States and its waters (Appendix 1). Yet of these fourteen vessels, only for the oldest, the ***Dartmouth,*** have sufficient structural details been published for any worthwhile comparison to be made.

The ***Dartmouth*** (thirty-six guns and 266 tons) was built in 1655 on the lines of a Dunkirk frigate. She had a major refit in 1678, which might have involved some structural changes, before being lost on the Scottish coast in 1690.[94] All that remained of her hull when she was excavated in the 1970s was an area of the starboard half of the bottom, roughly thirty-five feet long and ten wide, which was still attached to eighteen feet of her keel in the vicinity of the after deadwood. This fragment included timbers and outer planking, along with a small amount of foot waling. The keel remnant included a scarph and still bore part of the deadwood. Colin Martin's report on this small piece of wreckage remains one of the most detailed, and almost certainly the most thoughtful studies yet published on the structure of a post-Medieval

English ship; more than a decade after it appeared it is still a model of how such a topic should be addressed. Yet the author compared this hull of 1655 with a modern, semi-popular account of late eighteenth-century ship structure, itself largely based on Steel's text of 1805. By doing so, he concluded that the ***Dartmouth*** had several unexpected structural features and proceeded to account for these with some highly-imaginative hypotheses. This not only led to an erroneous interpretation of his own site but has also caused no little confusion to subsequent students, including the current writer.[95] In fact, what remains of the ***Dartmouth's*** structure conforms closely to Sutherland's description, although it also adds additional details.

The ***Dartmouth's*** keel was of elm and was probably square in section (sided and moulded thirteen inches), with an additional false keel below (moulded eight inches), just as Sutherland described. The surviving keel scarph (fifty-two inches long and probably one of two in the ship) is illustrated in Figure 1, where it has already served to supplement the historical information. The keel bore one bolt (one-inch diameter) per floor, as expected. Martin found that these were somewhat staggered across the width of the keel, presumably to avoid a weakness along the grain. The garboard rabbets were caulked with oakum, tar and resin and the stopwater covering the keel scarph had been nailed into place over a layer of tar and hair, while some of the faying surfaces of the timbers still retained white paying stuff (apparently a mixture of white lead and oil). Interestingly, the bearding line of the rabbet (its upper edge) was set a little below the top of the keel. Since neither the remains of the ***Dartmouth*** nor anything in Sutherland's account suggest that the floors were scored to receive the keel, they must have lain flush with its upper surface. Near the rabbet, therefore, there must have been gaps between the floors and the garboards. These gaps, which resulted more from the designed shape of the hull than from deliberate structural features, probably served as limber holes. None of these observations conflict with Sutherland's text.

Lying on the upper face of the keel, however, Martin found a large piece of elm that he thought inconsistent with historical expectations and which he chose to call a "rising deadwood." This massive piece seems originally to have been up to forty-eight inches wide on its upper surface and at least a foot deep. From the length of the surviving keel scarph and the documented lengths of keel timbers used in the 1678 refit, Martin concluded that the piece of the keel abaft the scarph and extending to the sternpost tenon was twenty-nine and one-half feet long. If he were correct, the "rising deadwood" must have been originally at least thirty-five feet long (perhaps composed of more than one piece of wood, although the surviving fourteen feet was shaped from a single log). It thus extended for nearly half the length of the ***Dartmouth's*** eighty-foot keel. This "rising deadwood" was trapezoidal in section, its lower surface matching the upper face of the keel, to which it was bolted, while its sides flared out following the shape of the inner surface of the planking from the garboards upwards (see Figure 11). The aftermost surviving timbers butted against the upper corners of this trapezoid where it was bevelled to receive their heels, making the "rising deadwood" hexagonal. The next five timbers per side forward had tapered heels which lay between the "rising deadwood" and the planking. Martin provided an ingenious explanation for this massive structure but it was not required. His "rising deadwood" was simply the ***Dartmouth's*** after deadwood. It did not conform to his expectations for a "wall-like" nineteenth-century deadwood, but it only differs in one essential from my interpretation of Sutherland's account. That difference lies in its length: Sutherland's book suggests that the deadwoods should be around one-quarter the length of the keel whereas the ***Dartmouth's*** appeared to stretch some forty-five percent or more forward from the heel (allowing for the thickness of the sternpost beyond the deadwood's after end).[96] Yet the ***Dartmouth*** had specifically been built on the lines of a Dunkirk frigate. Exactly what such lines were is unclear, although it is certain that the Dunkirkers were faster than English Great Ships of the 1650s and it is likely they had relatively fine lines.[97] A deadwood was used where the fine sections near ***the keel made floor timbers impractical. Thus, one might expect that the Dartmouth*** would have had a longer deadwood than more conventional English ships, although perhaps not one quite as long as Martin estimated that she had.

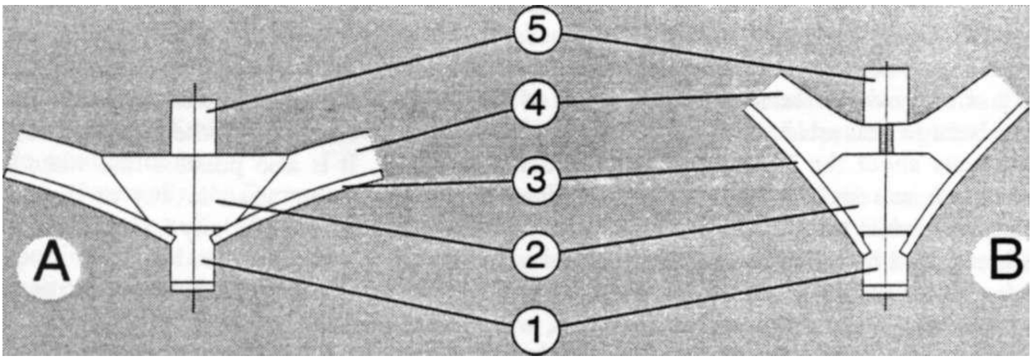

Figure 11: Sections showing the hypothetical reconstruction of the deadwood and half-timbers in the ***Dartmouth,*** as explained in the accompanying text. A: Section near the forward end of the deadwood. B: Section near the aftermost surviving end of the deadwood. 1: keel; 2: deadwood; 3: planking; 4: half-timber or long timber; 5: keelson.

Source: Modified from Martin, Figure 17.

Martin did not explain the two types of junction that he observed between the deadwood and the timbers. None was evident until an hypothesis was required while preparing the accompanying figures. As shown in Figure 2, the underside of the keelson (strictly the tops of the scores in that piece) must have followed a smooth curve, known to later shipwrights as the "cutting down line." This followed the shape of the hull so that, unless particular floors or half-timbers were unusually deep or were cut away, their upper surfaces (for the half-timbers, the projection of those surfaces) crossed the centreline at the level of the cutting down line. If the upper surface of the deadwood were curved, as was later practice, that surface could readily follow the cutting down line too. In Sutherland's day, however, the profile of the deadwood followed a series of straight lines and steps. There must therefore have been a gap of variable depth between the deadwood and the keelson (Figure 2). The surviving remnant of the ***Dartmouth*** included the foremost end of the deadwood, where this gap would have been small and the timbers could not lap onto the deadwood's upper surface (Figure 11A). Further aft, the gap was larger and the timbers, maintaining their position relative to the cutting down line, lay higher relative to the deadwood (Figure 11B). Yet further aft, the deadwood probably rose a step, lifting its upper surface to the cutting down line once again (Figure 2).

The ***Dartmouth's*** surviving framing timbers were all oak. Their dimensions were somewhat variable (sided ten inches and moulded eight, on average) but in all cases a wide timber was placed adjacent to a narrow one so that alternate timbers were arranged on twenty-four inch centres. Presumably, the floors and half-timbers were placed according to a designed twenty-four inch room-and-space, but were individually thicker or thinner than the intended average, depending on what suitable timbers were available in the dockyard when the ship was built. The lower futtocks and the long timbers would then have been chosen to fit between the floors and half-timbers, the available space being one criterion in selecting a particular timber for any location.[98]

Although the ***Dartmouth's*** lower futtocks almost filled their rooms (on average, there was twenty inches of timber in each twenty-four inch room-and-space), adjacent futtocks and floors were not in direct contact and Martin found no evidence of fore-and-aft fastenings. The latter observation agrees with Sutherland's account, although the lack of contact between any timbers (assuming that it was not simply the result of erosion of the wreckage) is rather surprising. One might have expected that every third or fourth pair of timbers (the fifth and sixth of every six or the seventh and eighth of every eight, forming the frame-timbers) would have been in contact. Martin's observations do accord, however, with Sutherland's confusing comments about the "spacing" of timbers during planking. It is also possible that when the ***Dartmouth*** was built in 1655 ***articulated*** frame-timbers were not used in way of the after deadwood, while too little of her hull forward of that piece survived for any frame-timbers to be recognized by the archaeologists.

More surprisingly still, the heels of the futtocks of the ***Dartmouth*** extended all the way to the heads of the floors and half-timbers, where what might be termed "scarphing chocks" were fitted into the butts. This is by far the earliest evidence of which I am aware for such chocks. While at first sight they represent a notable difference from the structure described by Sutherland, it seems that their origin and initial purpose have been misunderstood. According to a 1737 account, such chocks were then employed in the English Royal dockyards because they allowed the use of relatively gently-curved (and hence relatively cheap) pieces of wood where the shape of the hull called for tighter-curving timbers.[99] The required outer shape of the timber was cut from the main piece, crossing the grain where necessary, while any deficiency on the inner face was made up with a chock, which also scarphed the butt between adjacent futtocks. It is likely that economy rather than strength was the objective behind the chocks seen in the ***Dartmouth*** and also that Sutherland employed such chocks in his ships when necessary; his text generally avoided this level of complexity, adopting a somewhat stylized account suited to a textbook.

In those timbers that butted onto the ***Dartmouth's*** deadwood, there was no sign of the heels of the half-timbers projecting further down than those of the long timbers in the sort of regular alternation seen in so many "Navy Board" models and reproduced in Figure 3. On the evidence of this one wreck, this would appear to be no more than an attractive modelling convention. The heads of these timbers did extend to different heights, although much less regularly than Figure 3 suggests. Unfortunately, it is unclear from Martin's report (and may not have been from the surviving fragment of the wreck), whether the shorter pieces were of about half the length of a floor (as the St. Lo print shows) or were of similar length to a first futtock (as suggested above).

The surviving outer planking on the ***Dartmouth*** was elm (2.5 to three inches thick) and fastened with oak treenails (15 inches in diameter). These treenails were tightened by driving oakum into two or three slots in their heads. There were also a few one-inch diameter iron bolts driven through the planking, with their heads formed over roves. Their positions did not follow any evident pattern. Indeed, the most interesting feature of all these fastenings was their irregularity. The aim seems to have been to drive one treenail inward and one outward at each plank/timber cross, the treenails being staggered across the width of each piece. Some treenails required by this rule were missing, however, while there were many additional ones scattered about. Martin suggested plausibly that the latter were additions designed to strengthen the ageing hull. Some were driven down the side of an existing treenail, thus tightening it, while others fell on the seam between two planks and yet others were clustered into small groups.

The overall impression is of an almost random scatter of treenails, quite unlike the neat arrangement of diagonally-offset pairs so often seen in models. Presumably the shipwrights were initially anxious to avoid setting up lines of weakness along the grain of the planks or the timbers. Thereafter, assorted repairs could only add to the randomness. Indeed, the wreckage included one stealer, a feature that Sutherland did not mention. Martin suggested that it might have been part of a repair.

Outside the planking, the ***Dartmouth*** had been sheathed with half-inch "fir" deals, overlying a layer of hair and tar. The deals had been arranged to he over the seams in the planking and were fastened with flat-headed iron nails. The keel seems to have received the same treatment. Sutherland probably intended similar sheathing for his ship, although he made little mention of it.

Internally, ***the Dartmouth*** had elm footwaling (2.5 inches thick) and the remnant of one piece of thick stuff (of elm 4.5 inches thick); these were termed "ceiling" and "stringer," respectively, by Martin. One strake of footwaling included a scarph, in this case a simple plain scarph cut so that its diagonal face passed from inside the hold out to the timbers, rather than from side to side of the strake.

In conclusion, apart from the supposed length of the deadwood, the lack of any apparent contact between the frame-timbers, the presence of chocks in the butts between the timbers and the one stealer, what has survived of the ***Dartmouth*** conforms closely to Sutherland's description. The unexpected features can potentially be explained by the hypotheses developed above and thus there need be no conflict between the historical and archaeological sources. The archaeological evidence does, however, provide some important details missing from Sutherland's account, notably the form of the keel scarph and the details of the caulking, paying, sheathing and limber holes. Most important, the fragment of the ***Dartmouth*** is a valuable reminder that real ships were much less tidy than textbooks and models suggest. Those sources usually present idealized versions of how some archetypal ship ***should*** have looked, while actual ships were more complex and less regular. Besides the structural complications from local damage and subsequent repair (such as the ***Dartmouth's*** stealer), there were the staggering of fastenings and the tool marks left by workmanship that rarely attempted a cabinetmaker's standards of finish. Moreover, there were much more fundamental irregularities. Shipbuilding lumber did not come in standard sizes, as steel plates do. Shipwrights seem to have been reluctant to trim large, and disproportionately expensive, pieces to required sizes and shapes. Rather they sought to match the sizes and curvatures of the pieces on hand with the spaces to be filled. Thus, if one floor was wider than required, it could be paired with undersized first futtocks; if another was long on one side of the centreline and short on the other, it could still be used if one short second futtock and another long one were available, and so on. When economy was more pressing than durability, the maritime glossaries list a selection of "ekeing pieces," "chocks," "firs" and the like, all intended to make up for deficiencies in the principle pieces used in a ship's structure.[100] The ***Dartmouth's*** builders seem to have taken full advantage of these opportunities. Some archaeological reports suggest that other ships were not quite so irregular, but none can have been as tidily finished as a fine-quality model.

Had more of the ***Dartmouth*** survived, she would presumably have exhibited greater differences from Sutherland's account, in keeping with her construction half a century before he wrote. Nevertheless, it is clear that her builder adopted essentially the same structural concepts as did the later author. With this archaeological support, Sutherland's description of a ship structure of about 1710 can serve as a firm foundation for explorations of other English wooden ships.

Appendix 1 : Some Nautical Archaeological Sites of Ages Comparable to Sutherland's *Ship-builder's Assistant*

Warships

1. The ***Dartmouth*** (thirty-six guns and 266 tons) was built in 1655 on the lines of a Dunkirk frigate. Her surviving structure is discussed in this essay.
2. The ***Hazardous*** (a Fourth Rate of fifty-four guns), wrecked on the south coast of England in 1706, was built in 1698 and was of similar size to the 500-ton ship described in Sutherland's book. However, it was a prize captured from the French and had a French-style structure.[101]
3 and 4. The "Goodwin Sands" wrecks (one of which is believed to be the ***Stirling Castle,*** a seventy-gun Third Rate launched in 1699, while another may be the seventy-gun ***Restoration*** of 1702) were lost on a sandbank in the English Channel during the Great Storm of 1703.[102] They will be of great importance to the present topic when their details are published, provided that those include the hull structure. No appropriate survey seems yet to have been attempted.
5. The ***Anne,*** another seventy-gun Third Rate (launched in 1678 and lost in 1690 on a beach to the east of Hastings, England following damage in the Battle of Beachy Head), might also yield evidence relevant to Sutherland's era and certainly would to a slightly earlier period, if she is ever excavated and surveyed.[103]
6. The ***Sapphire,*** a thirty-two-gun Fifth Rate built in 1675 and sunk in action during 1696 in Bay Bulls, Newfoundland, could be of similar value, since a substantial part of the hull is intact, but the surveys carried out in the 1970s by both the Newfoundland Marine Archaeology Society and the underwater archaeology unit of what is now the Canadian Parks Service did not extend to complete excavation. Whatever limited structural data was obtained has yet to be published.[104]
7 and 8. The ***Royal James,*** a First Rate built in 1671 and lost during the Battle of Sole Bay the following year, and the ***Coronation,*** a ninety-gun Second Rate built in 1685 and lost off Plymouth, England in 1691, have each been given protected status under British law but nothing of substance has yet been published on either site.

Merchantmen

1 and 2. The Brown's Ferry vessel (South Carolina) and the Hart's Cove wreck (New Hampshire) are the remains of small and lightly-built hulls for inland or coastal use. The former has been dated to ***circa*** 1740 while the latter was probably lost in the 1690s. Given their size and light construction, neither can be directly compared to Sutherland's account.[105]
3 and 4. The Rose Hill and Otter Creek wrecks (both in North Carolina) are the remains of rather larger craft, possibly a sloop of around 130 tons and a schooner of about sixty-five tons, respectively, and both probably date from the eighteenth century.[106] Each has ship-type construction rather similar to that described by Sutherland. Unfortunately, neither was found with associated dateable artifacts and their tentative dates are based on their hull structures alone. Despite the admirable detail in which they have been recorded, their use in the present discussion would involve a circularity of logic that would only further confuse an already complex topic.
5. The Ronson Ship, an abandoned hull found under Manhattan where it was incorporated into landfill between 1745 and 1755, is thought to have been a Virginia-built tobacco carrier.[107] Since she was evidently old when buried, she may have been built during or soon after Sutherland's time. Publication of the details of her structure is still awaited.

6. The ***Whidah*** was a British merchantman captured by pirates in 1717 and subsequently used as their flagship. She was lost on Cape Cod and since 1984 has been the subject of a commercial excavation with limited archaeological control. No substantial hull fragments have survived on the site.[108]

NOTES

* Trevor Kenchington is an amateur nautical archaeologist with particular interests in post-Medieval wooden ships. He lives in Musquodoboit Harbour, Nova Scotia.

1. This essay has benefitted greatly from the advice and assistance of David H. Roberts of Jean Boudriot Publications, who provided many helpful comments on an earlier draft and kindly furnished me with a copy of his pre-publication translation of the Ollivier manuscript. I am also indebted to Lewis R. Fischer, without whose encouragement and editorial advice this work would never have reached its present form. Clayton A. Feldman of Seaways Publishing and Richard W. Lawrence of the Division of Archives and History, North Carolina, have also provided information in advance of publication and helped hone my ideas on ship construction. John Graves of the Ship Model Section, National Maritime Museum, kindly answered my queries concerning the 1715 frame model. I thank them all for their help. Any remaining errors are my own.

2. J.R Steffy, "The Reconstruction of the 11th Century Serçe Liman Vessel: A Preliminary Report," ***International Journal of Nautical Archaeology,*** XI (198 ;),

3. The distinction between ***skin*** and ***skeleton-based*** construction methods is discussed by B. Greenhill, ***Archaeology of the Boat: A New Introductory Study*** (London, 1976), a useful summary of post-Medieval developments in England. But it should not be relied on as anything more than a convenient way of classifying some hull structures. Quite large ships with heavy frames can be built by lapstrake methods.

4. See, for example, W. Salisbury and RC Anderson (eds.), ***A Treatise on Shipbuilding and a Treatise on Rigging Written about 1620-1625*** (London, 1958); B. Lavery (ed.), ***Deane's Doctrine of Naval Architecture, 1670*** (London, 1981). See also unpublished manuscripts attributed to Mathew Baker ("Fragments of Ancient English Shipwrightry" [Pepsyian Library, Magdalene College, Cambridge]), Thomas Harriott (British Library) and, more speculatively, either George Weymouth or Phineas Pett (Scott Library, Royal Institute of Naval Architects).

5. W. Sutherland, ***The Ship-builders Assistant: or, Some Essays Towards Compleating the Art of Marine Architecture etc.*** (London, 1711; reprint, Rotherfield, England, 1989).

6. Despite these efforts, this essay cannot explore terminological development in detail and my usage should not be taken as definitive for 1710 or any other time.

7. This print is dedicated to "George S*. Lo Esq'. Com', of her Maj*. Navy." St. Lo was Commissioner of Chatham Dockyard until a reorganization in 1712 led to his appointment as Commander-in-Chief of all ships in the Medway and at the Nore, a position he held until George I's accession to the throne in 1714. He had not previously served at sea since the 1690s (when it would not have been "Her" Majesty's navy) and was not employed by the Admiralty or the Navy Board after 1714. See J.K. Laughton, ***Dictionary of National Biography,*** L, 172. A copy of the print is in the collection of the National Maritime Museum, Greenwich and has been published in B. Lavery, ***The Ship of the Line: Volume II: Design, Construction and Fittings*** (London, 1984), 29.

8. Catalogue number SLR0405. J. Franklin, ***Navy Board Ship Models 1650-1750***(London, 1989), 150-153, has published photographs, drawings and a discussion of this model. The 1715 date is imprecise and based on the model's dimensions (which correspond to those of a fifty-gun ship under the 1706 Establishment but not under that of 1719) and on the starboard main wales being composed of three strakes of equal thickness (rather than two strakes separated by a thinner one), a feature not otherwise known before 1717; John Graves, personal communication. The many points of correspondence between the port (but not the starboard) side of this model and Sutherland's account (which probably relates to warships of 1700-1705) certainly support a general date of 1705-1720 for the model.

9. Public Record Office (PRO), A D M 106/3071. This is also published in Lavery, ***Ship of the Line II,*** 165-167. In addition to the information extracted here, this document contains a detailed list of scantlings for a ship rather larger than Sutherland's.

10. C J . M . Martin, T h e *Dartmouth,* a British Frigate Wrecked off Mull, 1690. 5. The Ship," *International Journal of Nautical Archaeology,* VII (1978), 29-58.

11. Further information on the final wooden ship structures developed in the English Post-Medieval tradition can be found in many recent publications. For a particularly clear account, see B. Greenhill with S. Manning, *The Evolution of the Wooden Ship* (New York, 1988).

12. According to the *Yarmouth* contract, these scarphs were to be "tabled;" that is, a small part of each keel piece within the joint was left proud of the rest (a "table"), while a hollow was cut nearby to receive the table of the other keel piece. The *Dartmouth's* keel scarph (see Figure 1) was of this form. Sutherland may have intended similar scarphs for his ship.

13. Early eighteenth century bolts were not threaded as are modern ones ("screw bolts" as they were called when first introduced). Rather, they were wrought iron rods, driven through pre-drilled holes in the timber. One end was formed into a rounded head, sometimes over a rove. The other could lie in a blind hole or, when through-bolting, could be secured by being clenched over a rove or having a forelock wedge passed through it. T.R. Blanckley, *A Naval Expositor etc.* (London, 17S0; reprint, Rotherfield, England, 1988), 15-17, has provided a clear explanation of the types of bolts used by shipwrights a few decades after Sutherland.

14. In shipbuilding, the dimensions of the structural pieces are referred to as their "siding" and "moulding." In general, "siding" is measured across the width while "moulding" is its depth. For pieces that follow the curve of the hull, however, such that their orientations change along their lengths, and for those that are nearly vertical, the "moulding" is measured on an axis from inside the hull to the outside and siding is perpendicular to it.

15. That is, a triangular-sectioned groove (a "rebate," "rabbet" or, to Sutherland, a "rabbit") was cut along the keel to receive the edge of the lowest plank, the exact section being carefully shaped so that the lower corner of this plank, the garboard, would lie flush with the keel throughout its length, despite the garboard being twisted as it conformed to the curve of the hull.

16. Sutherland, *The Ship-builders Assistant,* 25, 62,69, 160, and plates 38 and 64. Because of the many errors that have crept into recently-published accounts of wooden ship structures, I here support my account with full references to Sutherland's text. Page number references are to both the original and the reprinted edition. The plates were not sequentially numbered in the original. Here they are referenced by the page that they face.

17. *Ibid.,* 25, 35, 69,110, plate 38. Sutherland did not state what type of wood should be used for the false stem, nor for many other parts of his ship. He probably intended the entire hull to be oak except where he specified otherwise. The *Yarmouth* was required to be English oak or elm throughout, except for some particular pieces.

18. The *Yarmouth,* however, was to be fitted with a separate skeg that was to be fastened with a stirrup; a piece that Blanckley *(A Naval Expositor,* 162) later defined as "an Iron Plate that turns up on each Side of a Ship's Keel, at her Fore-foot or Stern, where it is bolted."

19. Sutherland, *The Ship-builders Assistant,* 25, 35,69, 70, plate 27. Blanckley, *A Naval Expositor,* 161, noted the scoring of the transoms of his day. It is not, however, evident in the St. Lo print nor did Sutherland mention it.

20. Sutherland *The Ship-builders Assistant,* 25, 69, plate 27. While he only mentioned it in passing in the text, Sutherland illustrated one proposed variant of stern structure in plates 38 and 42. This involved the construction of a curved sternpost (very similar in shape and structure to the stem) with a large and almost triangular piece of timber abaft to take the rudder irons. This was a most unusual arrangement that Sutherland claimed was stronger than tenoning the post into the keel. If so, this advantage was not sufficient to persuade his contemporaries to adopt the method for general use and it is not certain that any eighteenth-century English ship was built this way.

21. This differs in important ways from the "transom" stern seen in some larger modem craft. Neither of these modern usages should be confused with the structural elements that bore the same name in eighteenth-century ships.

22. The deadwoods were not in fact placed on the keel until after all the principal floors were in place and well shored; Sutherland *The Ship-builders Assistant,* 26). This delay was of no consequence to the finished structure of the ship but it does emphasize the shipwright's conceptual distinction between the framing of the central part and of the ends. This distinction, recognizable in around 1700, will have considerable significance when interpreting descriptions of earlier ship structures.

23. *Ibid.,* 26, plates 27, 38, 42.

24. In Sutherland's day, as now, a shipbuilding "knee" resembled the angle bracket of a house carpenter (though much enlarged) and was designed to support an angular joint between timbers. Whenever possible it was made of a piece of wood with the grain following the angle desired for the joint (usually cut from the junction of a branch or a root with the main stem of a tree). Various arrangements for building up knees from smaller pieces, for reinforcing them with iron and ultimately for replacing them with iron brackets began to appear in Sutherland's time but did not become common in English shipbuilding until later.

25. Sutherland, ***The Ship-builders Assistant,*** plate 27. A similar knee was fitted in the ***Yarmouth,*** with arms six-feet long, bolted at twenty-two inch intervals.

26. ***Ibid.,*** 62-63, plate 64. Sutherland only allowed for two pieces of wood in this head structure, although large ships of his day may have had the knee of the head built up from several smaller pieces, as was the later practice. The head may not have been added until later in the construction sequence than its position in this essay implies, but Sutherland does not make this certain.

27. More confusion surrounds the ***ribs*** of post-Medieval ships than any other part. Thus, a theoretical note, in contrast to the descriptive approach otherwise followed in this essay, may aid the reader. All the ***ribs*** used in these ships, from the mid-sixteenth to the mid-twentieth centuries, can be arbitrarily divided into two groups that I prefer to call ***articulated*** and ***disarticulatedframes.*** (Intermediate forms were unusual, but not unknown.) For this purpose, a ***frame*** comprises one floor (or one long and one short floor, where such an arrangement was used) and one full set (per side) of futtocks, top timbers and any scarphing chocks or other incidental pieces. In an ***articulatedframe,*** these several pieces were either fastened together, placed in intimate contact with one another or both. The isolated frame-timber shown in Figure 5 is an example. A ***disarticulated frame,*** by contrast, has no direct fastening nor anything more than chance contact between its pieces, except for those where the heel of one butts or is scarphed onto the head of another. A ***disarticulated frame*** therefore resembles two parallel rows of pieces, one including the floor and (where they are used in the ***frame)*** second futtocks, while the other includes the first and (if used) third futtocks. From the mid-nineteenth century, most ships had all their ***ribs*** formed as ***articulated frames.*** Before 1800, however, it was normal for English ships to have a mixture of the two types. They have been known by a variety of names. Among eighteenth-century authors, ***articulated frames*** seem to have been "frame-timbers* to Sutherland, "frame Bends" to Blanckley ***(A Naval Expositor,*** 8), and "frames," "frames of timbers," "principal timbers" and "frame-timbers" to W. Falconer ***(An Universal Dictionary of the Marine etc.*** (2nd ed., London, 1780; reprint, New York, 1970), 257, 292-3), whose dictionary is frequently inconsistent in this way. Later shipwrights mostly referred to ***articulated frames*** simply as "frames." Some modern commentators, however, have rather misleadingly called them ***double frames*** or, taking a more functional approach, ***mould frames.*** The ***disarticulated frames*** of later eighteenth-century hulls were "fitting timbers" to Falconer ***(An Universal Dictionary,*** 293) and some modern authors have called them ***filling frames.*** Others, unfortunately, have called them ***single frames.*** I reject this highly-artificial term since it requires a matched pair of such "single" units to contain one full set of pieces (from floor to top timbers). Thus, they are at best ***half frames,*** although I do not recommend that term since it could equally be applied to the port or starboard half of an ***articulated frame.*** It is not certain that Sutherland thought in these terms at alt. He did recognize the sort of unit here termed an ***articulatedframe*** (his "frame-timber") but he used no word synonymously with ***frame*** and there is no evidence that he saw a particular ***disarticulated*** first futtock, for example, as more or less associated with the floor forward than with the one abaft. Thus, he may not have conceived of the various pieces in each ***disarticulated frame*** as being grouped into discrete ***frame*** units at all. (In the text of this essay, the unmodified term "frame" is used only with its older meaning of the entire "skeleton" of the hull.)

28. Sutherland ***The Ship-builders Assistant,*** 26, 70, plate 27.

29. ***Ibid.,*** 26.

30. ***Ibid.,*** plates 27, 38.

31. ***Ibid.,*** 26, 70.

32. ***Ibid.***

33. ***Ibid.,*** 42.

34. ***Ibid.,*** 165.

35. ***Ibid.,*** 26, 70, 79-80, plate 82.

36. ***Ibid.,*** plate 82.

37. It is, for example, seen in sixteenth-century Iberian ships; see T J. Oertling, "The Molasses Reef Wreck Hull Analysis: Final report," ***International Journal of Nautical Archaeology,*** XVIII (1989), 229-243.

38. Sutherland, ***The Ship-builders Assistant,*** 26.

39. ***Ibid.,*** 35.

40. *Ibid.,* 26.

41. The orientation of the frame-timbers probably reversed near the frame-timber that lay at the point of maximum breadth of the hull, rather than at the mid-point of the length. In his glossary, Sutherland *(Ibid.,* 162) described this frame-timber as "the Midship flat," while Blanckley *(A Naval Expositor,* 8) called it "the Midship-bend." It corresponds to the "dead flat" of modern naval architecture, although in many modern and some eighteenth-century designs the hull has no longitudinal curvature amidships and the dead flat extends over a significant part of the ship's length.

42. Sutherland, *The Ship-builders Assistant,* 39.

43. *Ibid.,* 35, 39.

44. *Ibid.,* 39. Thus, the *Yarmouth* contract required that its "Navel timbers" (first futtocks) "fill the rooms" or fully occupy the spaces between floors. While Sutherland stated that this practice had been abandoned by his day, Blaise Ollivier, Master Shipwright of the King of France, noted in a manuscript report on an apparent espionage mission in 1737 that English shipwrights at the Deptford dockyard (where Sutherland had worked some thirty years earlier) went so far as to caulk the seams between the adjacent floors and futtocks. The shipwrights at the dockyard at Woolwich, only a few miles downriver, not only did not caulk these seams but left considerable air gaps. Thus, the development of a less-solid bottom was much more complex than Sutherland suggests. D.H. Roberts (ed.), *18ih Century Shipbuilding: Remarks on the Navies of the English <& the Dutch by Blaise Ollivier (1737)* (Rotherfield, England, 1992), remarks 12 and 45.

45. Sutherland, *The Ship-builders Assistant,* 70.

46. Something of the inadequacy of the arrangement may have been evident to contemporary shipwrights: the *Yarmouth* was required to have oak chocks between her timbers "in the wake of the chain bolt".

47. M. Stalkartt, *Naval Architecture* (London, 1787; reprint, Rotherfield, England, 1991), 220 and 223. Neither Blanckley, nor Falconer mentioned long timbers in their dictionaries.

48. Sutherland, *The Ship-builders Assistant,* 35.

49. *Ibid.,* 159. Falconer, *An Universal Dictionary,* 74, wrote: "CANTING, as a sea-phrase, denotes the act of turning any thing about."

50. Sutherland, *The Ship-builders Assistant,* plate 38.

51. Salisbury and Anderson (eds.), *A Treatise,* 7.

52. Except that in the model the forward hawse piece curves aft at its lower end to fay against the foremost long timber, below the after hawse piece, while Sutherland's plate 38 shows the after one reaching downwards to the stem, below the forward one. These may be genuinely alternative arrangements, although the latter requires the after hawse piece to be extremely wide at its lower end. The model's arrangement seems more believable and is followed in Figure 6.

53. Sutherland, *The Ship-builders Assistant,* plate 38. The term "knighthead" was also used for the vertical timbers of the bitts. These had been in use since at least the early seventeenth century; Salisbury and Anderson (eds.), *A Treatise,* 7.

54. Sutherland, *The Ship-builders Assistant,* 70.

55. *Ibid.*

56. The contemporary nomenclature of the timbers that terminated the topsides above the wing transom is unclear. Some modem authors have used the term "stern timber" for a continuous element running from the wing transom to the top of the stem, framing the counter and flat face of the upper stem. I see no evidence that such a piece existed. Rather, this area seems to have been framed by a large number of short pieces worked around the galleries and lights. Indeed, the First Rate in the St. Lo print should have had open galleries with the lights set forward of the plane of the stem, eliminating any possibility of a continuous timber in that plane. Thus, I identify the print's "stem timber" with the piece that terminates the topside. Sutherland's list of scantlings included "quarter-pieces," eighteen inches fore-and-aft, which might be synonymous. His glossary defined the same term as "large carved pieces fixed to terminate the Quarter with the Stem," which is inconsistent with the listed scantling and seems rather to refer to decorative detail added outside the planking than to any structural element. It is, however, possible that the scantling refers to a timber that lay behind this carving. If so, it might be the one of present interest, but it seems more likely to have been one that delimited the outer, after comer of the quarter gallery (outboard of the "stem timber"). Falconer, *An Universal Dictionary,* 225, 279, plates VII, X, likewise used the term "quarter-piece" to refer to decorative elements, outboard of any hull structure. In one place (p. 279, plate X), he referred to the timber of present interest as though it were continuous with the fashion piece and he used that term to encompass the whole item, from keel to uppermost rail. Elsewhere, however, he wrote that "The Side Counter Timbers—terminate the ship abaft within the quarter-gallery" (p. 17), which appears to be a reference to the "stem timber" of the St. Lo print.

57. Sutherland, ***The Ship-builders Assistant,*** 75.

58. ***Ibid.,*** 41, 46, 74, plates 42, 49.

59. ***Ibid.,*** 41, 49. The arrangement of the frame model's scarphs notwithstanding, Sutherland was evidently conscious of the need to prevent hogging (p. 49).

60. ***Ibid.,*** 41, 46, 49, 74-5, plates 42, 49.

61. ***Ibid.,*** 75, plate 49.

62. ***Ibid.,*** 46, 74, 162.

63. ***Ibid.,*** 4649, 74.

64. ***Ibid.,*** 48, 54-55. One process used in fire-bending resulted in the concave face of the planks becoming charred, as has been observed in several archaeological studies. By 1737, the English Royal dockyards were "stoving" planks (a process that involved their being placed on hot, wet sand) and had just started the later technique of steaming (Roberts [ed.], ***18th Century Shipbuilding,*** remarks 33, 59 and 112). The difference between fire-bending and stoving, if any, are unknown to the present writer.

65. Sutherland, ***The Ship-builders Assistant,*** 44,49,70, plate 42. The ***Yarmouth*** evidently had essentially the same arrangement of internal strength members, although middle bands were not mentioned in the contract for her construction. A hook scarph is rather similar to a tabled scarph (the keel scarph in Figure 1) but has the protrusion and matching hollow carried the full width of the plank rather than confined to its centre. "Hooks" in general were described by Blanckley, ***A Naval Expositor,*** 78, as interlocking dentations in adjacent strakes of planking. When employed in the clamps, either technique would resist tension along the length of the strakes through wood-to-wood contact, whereas plain scarphs could only resist such tension through the shear strength of the bolts. These uncertainties in the details of the scarphs, as with the surrounding scarphs in the wales, could readily be resolved if a suitable wreck were examined.

66. Sutherland, ***The Ship-builders Assistant,*** 49, 70. Blanckley, ***A Naval Expositor, 57,*** explicitly defined "Foot waaling" ***[sic]*** as "all the Inboard Planking, from the Keelson upwards to the Orlop Clamps," thus excluding the strakes between the orlop and the gundeck clamps. This usage differs from Sutherland's apparent intent, although the latter did not provide a definition in his glossary.

67. Sutherland, ***The Ship-builders Assistant,*** 70.

68. ***Ibid.,*** 40, 42, 71, plate 42.

69. ***Ibid.,*** 40, 71, 158, plate 42. The ***Yarmouth*** had essentially the same arrangement.

70. Franklin, ***Navy Board Ship Models,*** 152.

71. Ollivier (Roberts [ed.], ***18th Century Shipbuilding,*** remarks 22 and 72) noted two arrangements used at different English dockyards in 1737. One had the deck hook flush with the under surface of the planking and a waterway laid over the deck hook against the hawse pieces. The hood ends of the deck planks then butted against this waterway. The second had tne deck hook higher still, so that it was flush with the upper surface of the deck planks, the hood ends of which lay in a rabbet cut into the upper, after edge of the deck hook. These seem to be variants of the later method, represented in the starboard side of the frame model. Sutherland's breast hooks probably lay lower than either.

72. Sutherland, ***The Ship-builders Assistant,*** 71, 159.

73. ***Ibid.,*** 36, 40, 44, 71, plate 42.

74. Falconer, ***An Universal Dictionary,*** 97, listed the decks of a ship but did not include the orlop among them. Stalkartt, ***Naval Architecture,*** 224, writing seventy years after Sutherland, defined it as "the lower, but ***temporary*** deck in large ships" (my emphasis). In various ships at different times, the planks were not permanently fastened to the orlop beams but were only laid where and when required.

75. Sutherland, ***The Ship-builders Assistant,*** 36, 39-40, 44,71-72, plate 42. He made no mention of the curved, half-length beams ("spurs," "spur beams" or "carling knees") that in some later structures (e.g., those of warships in 1737 [Roberts (ed.), ***18th Century Shipbuilding,*** remark 89]) partly filled the gaps abreast of the masts and hatchways. His plate (see Figure 9) is sufficiently detailed that it should have shown these features if he had used them, although he might have regarded them somewhat as practical expedients and thus ignored them, much as he did sheathing on the planking.

76. Sutherland, ***The Ship-builders Assistant,*** 36, 39-40, 71-72, plate 42.

77. ***Ibid.,*** 44, 72, plate 42. Later ships certainly had the standards on top of continuous deck planks; Roberts (ed.), ***18th Century Shipbuilding,*** remark 144.

78. Sutherland, ***The Ship-builders Assistant,*** 42-43, 72, plate 42.

79. *Ibid.,* 72, 165.

80. *Ibid.,* 36.

81. *Ibid.,* 71, plate 42. It is not impossible that the orlop beams extended to the timbers (as did those of the gundeck and higher decks) in Sutherland's ship and that the footwaling was worked over and around them. In the *Yarmouth,* however, where there seem to have been no distinct middle bands, it seems certain that the beams were simply fayed against the footwaling and fastened there.

82. *Ibid.,* plate 42.

83. *Ibid.,* 44, 72-73.

84. *Ibid.,* 71.

85. Franldin, *Navy Board Ship Models,* 20-22, refers to these pieces as "long carlings." They served in part as coamings for the hatches; Sutherland's "coming" is probably a variant of "coaming" rather than a derivative of the verb "to come."

86. Sutherland, *The Ship-builders Assistant,* 36, 39-40, 73, plate 42.

87. *Ibid.,* 73, 164; Stalkartt, *Naval Architecture,* 229-230. Blanckley, *A Naval Expositor,* 165, defined "string" as "that strake of Plank within Side of the Ship that is wrought over the upper Deck Ports in the Wast," thus confirming the location of the strings but not adding anything to an understanding of their form. Falconer, *An Universal Dictionary', was.* no more helpful, merely defining "string" as "the highest range of planks in a ship's ceiling; or that which lies between the gunnel, and the upper edge of the upper deck ports." His Plate VII seems to show this string extending between the top timbers to meet the sheerstrake but could also be interpreted in other ways.

88. Sutherland, *The Ship-builders Assistant,* 73-74.

89. Franklin, *Navy Board Ship Models,* 20-21.

90. D.H. Roberts, "The Origin of the Steering Wheel," *Mariner's Mirror,* LXXV (1989), 272-273; J. Franklin, "A Further Note on the Introduction of the Steering Wheel," *ibid.,* LXXVI (1990), 171-173. Blanckley, *A Naval Expositor,* 186, whose book was published in 1750, treated wheel steering and whipstaffs equally, suggesting a much later survival of the latter on merchant ships than warship developments might suggest. In his very extensive fitting out lists, Sutherland, *The Ship-builders Assistant,* 131, mentioned a tiller rope but no other piece of potential wheel-related equipment. Since that rope was only three fathoms long and had no associated blocks, it seems more likely to have been intended for a relieving tackle for a whipstaff than for wheel steering.

91. Franklin, *Navy Board Ship Models,* 43.

92. A J. Hoving, "A 17th-Century Dutch 134-foot *Pinas,* Part 1," *International Journal of Nautical Archaeology,* XVII (1988), 211-222.

93. Some variations in English practices have been mentioned in this paper. Ollivier described many others that he noted in 1737.

94. Martin, "The *Dartmouth."* George St. Lo, to whom the print of timbers cited above was later dedicated, was captain of this ship between 1682 and 1688; Laughton, *Dictionary of National Biography,* L, 172.

95. J. Carter and T J. Kenchington, "The Terence Bay Wreck: Survey and Excavation of a Mid-18th Century Fishing Schooner," *Society for Historical Archaeology, Special Publication, TV* (1985), 13-26, includes an interpretation of wreck structure which draws heavily, and erroneously, from Martin, The *Dartmouth."*

96. They depend on an assumption, for which there is no direct evidence, that the three keel pieces used in the 1678 refit were of equal lengths. If the aftermost was in fact shorter, then so would be the estimated length of the deadwood.

97. Lavery, *Ship of the Line II,* 18-19.

98. There is another partial explanation for this observed alternation of wide and narrow timbers: the wide ones may have been the remnants of floors and half-timbers while the narrow ones were futtocks and long timbers. Martin, "The *Dartmouth,"* did not address this possibility, nor did he provide sufficiently detailed data for it to be confirmed or refuted.

99. Roberts (ed.), *18th Century Shipbuilding,* remark 45. If the objective of these pieces were primarily to allow the use of less curved pieces, it may be inappropriate to call them "scarphing chocks" at all. Stalkartt, *Naval Architecture,* 214, writing at a time when these features would be expected in warship construction, would probably have called them simply "chocks," which he defined as "pieces fayed to the heads and heels of the timbers, to make good the deficiency thereof." Sutherland's definitions were less explicit.

100. Thus Sutherland, *The Ship-builders Assistant,* 159-160 defined "Chok; a small Piece of Timber fitted to a larger to make out the Substance required;* To Eek; to fit a Part for the fashioning put another more material...the Eeking is only applied to continue the

Shape and Fashion of the Part, and for little other Service;" and "Firs; smaller pieces than Choks, but to answer the same Design, in supplying the Wants that may happen in some parts of the Ship."

101. N.C Owen, "HMS *Hazardous* Wrecked 1706. Pre-Disturbance Survey Report 1987," *International Journal of Nautical Archaeology,* XVII (1988), 285-293; Owen, *"Hazardous* 1990-1991 Interim Report," *ibid.,* XX (1991), 325-334. Very recently, the *Hazardous* team has found another contemporary wreck nearby, which has been tentatively identified as the eighteen-gun *Eagle,* lost in 1703; see Owen, "A New Wreck in Bracidesham Bay, Sussex," *Nautical Archaeology Society Newsletter,* No. 1 (1992), 13.

102. DJ. Lyon, "The Goodwins Wreck," *International Journal of Nautical Archaeology,* IX (1980), 339-342; D.RJ. Perkins, "An Analysis of Lead Musket Shot from the Wreck of an Early 18th Century Man-of—War," *ibid.,* XII (1983), 339-342; Perkins, "A Note on the Ship's Kettles and Bells found on the Goodwin Sands Wrecks of 1703," *Nautical Archaeology Society Newsletter* (June 1984).

103. P. Marsden and DJ. Lyon, "A Wreck Believed to be the Warship *Anne,* Lost in 1690," *International Journal of Nautical Archaeology,* VI (1977), 9-20; P. Marsden, "The Wreck of the *Anne," Mariner's Mirror,* LXX (1984), 387-388.

104. G. Farmer and J. Carter, The Marine Dig for the *Sapphire* at Bay Bulls," *Canadian Geographic Journal,* XCVIII, No. 1 (1979), 62-67; J.M. Barber, "Marine Archaeology in Newfoundland—A Review," *Progressin Underwater Science,* V (1980), 71-83.

105. A.B. Albright and J.R. Steffy, The Brown's Ferry Vessel, South Carolina. Preliminary Report," *International Journal of Nautical Archaeology,* VIII (1979), 121-142; S. Smith and D. Switzer, "Hart's Cove 1986 Field Report," in A.B. Albright (ed.), *Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference 1987* (Pleasant Hill, CA, 1987), 107-108.

106. R.W. Lawrence, "Current Underwater Archaeological Research in North Carolina," in J.B. Arnold (ed.), *Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference 1989* (Pleasant Hill, CA, 1989), 55-59; R.W. Lawrence, personal communication.

107. W. Riess, The Ship Beneath Manhattan," in P. Throckmorton (ed.), *History from the Sea* (London, 1987), 185-187.

108. W. Riess, WA. Bayreuther and R. Cembrola, The *Widah* Investigation: Satisfying Both Archaeological and Salvage Interests," *Society for Historical Archaeology, Special Publication, TV* (1985), 96-97; M. Roberts, The Site Testing Program for the Pirate Ship *Whydah,"* in Albright (ed.), *Underwater Archaeology 1987,* 33-37; KA. Turner, The Historical Research of the British Archives for the *Whydah* Ship Project, Massachusetts," *ibid.,* 37-39; J.R. Reedy, "Field Procedures Developed on WLF-HA-1 the *Whydah* Site off Wellfieet, Cape Cod," *ibid.,* 4143; J.R. Reedy, "Field Procedures Developed for a Scattered, Deeply Buried Site in a High Energy Location: The *Whydah* (WLF-HA-1), Cape Cod, Massachusetts, USA," *International Journal of Nautical Archaeology,* XX (1991), 53-58; DA Muncher, The Conservation of WLF-HA-1: The *Whydah* Shipwreck Site," *ibid.,* XX (1991), 335-349.