“A VERY GOOD SAILER”
MERCHANT SHIP TECHNOLOGY
AND THE
DEVELOPMENT OF THE BRITISH ATLANTIC EMPIRE
1600—1800

by

© Phillip Frank Reid

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ABSTRACT

To understand the technology that helped create the British Atlantic in the early 1600s and expand it to the end of the next century, this study investigates Atlantic World history, maritime economic history, nautical archaeology, material culture studies, the history of technology, and the technical history of the ship. In addition to archival research in merchants' and shipbuilders' papers, the study relies on the technical analysis and modeling of extant vessel remains by ship archaeologists, and incorporates the study of replica vessels and the experiences of those who operate them, with an experimental-archaeology approach. The insights gained make it difficult to remain comfortable with inherited assumptions without further investigation, while making it easier to understand how a technology traditionally considered static served a new and rapidly expanding colonial-imperial enterprise so well. Experiments suggested by the processing and analysis of the source material present opportunities for the study of the period merchant ship to make a more significant contribution to Atlantic, maritime, and technological history.

The approach presented here can help free Atlantic World historians with no technical background from having to take the received wisdom of ship history at face value, and offer new avenues of inquiry into problems in maritime economic history going back to Ralph Davis's work in the 1960s. It demonstrates that strong elements of continuity and important changes were both responses to the evolving needs and high risks of the British Atlantic. Understanding those needs and risks is the goal; asking questions about ships is asking questions about people, and how they were similar to and

different from us, and in what ways, and why, so that we can better understand ourselves and our own world.

ACKNOWLEDGEMENTS

It is cliché to say something to the effect that no project like this would have been possible without the assistance of a rather large number of people. Now I know why: because it is literally true. It is especially true for this project. As the person whose name is on it, I take responsibility for the interpretations and conclusions contained herein—with no small amount of pride and satisfaction, despite my assumption that those interpretations and conclusions need further investigation, and may well be superseded by my own or others' work. (In fact, I hope that happens, at least to some extent.) It will be clear to the reader, though, how much this study owes to the experts who volunteered their contributions to it. For much of the time I spent researching this, I felt like a curator, following a collection strategy to acquire information, rather than objects, out of which I could assemble as comprehensive an interpretive effort as possible, with the solemn responsibility to treat that information with the greatest care.

So I have much sincere thanks to offer many people here. I will start with my adviser, Neil Kennedy, not so much because of his position but because he has been a true friend in every way for the past five years, and even before that he was encouraging to me as I began taking tentative steps toward such a prodigious undertaking. That is not to discount his capacity as adviser, to which he has been committed without lapse since he agreed to serve in it and began recommending good books. He has always taken an interest in the project, and in me, beyond what was obligatory. Long may we continue to share thoughts, drink recipes, and inappropriate remarks on appropriate subjects.

Among my host of debts to him is his selection of scholars to approach for a committee; we were fortunate that both of them accepted. I first heard of “Skip” Fischer about 16 years before I ever met him. His long friendship with Carl Swanson was instrumental in my winding up at MUN, and while I was a bit intimidated to approach him at first, I needn’t have been. I would do well to offer anyone who ever asks it of me the kindness and counsel he has offered me over the past four years. I know (because he told me so) that I can count on that indefinitely.

Knowing we had a project in mind that would dance back and forth over whatever the line is between history and related disciplines—especially those concerned with objects in historical and cultural contexts—Neil asked Jerry Pocius to bring his expertise in such matters to bear; the body of literature Jerry provided for me, and the conversations we had about that, gave me something much bigger than a contribution to this project (though they certainly gave me that too). The reader will discover how important the material-culture perspective is to a study such as this. Like Skip, Jerry is a busy man, but also like Skip, he never gave me the feeling that he didn’t quite have time for me. I appreciate that.

I thank the Department of History for more than just being there and doing what it is supposed to do. Even when I’m in a bad mood, I can’t think of a way in which the Department as a whole (and as individuals) could have been more supportive of me. I particularly want to thank former Graduate Coordinators John Sandlos, Jeff Webb, and Dominique Brégent-Heald. Thanks also to former Department Head Sean Cadigan for good conversation, and to Fran Warren, Renee Clowe, Colleen Banfield, and current

Head Terry Bishop Stirling for making necessary things happen. The Department has consistently provided me with the most financial support it could, including a research travel grant for the summer of 2015 that helped make my archival research possible, and has awarded me a Teaching Assistantship whose benefits, I am lucky to say, have been most rewarding intellectually and pedagogically.

I must also express gratitude for the Department's immediate and complete support when I suddenly had to defer my enrollment for a year for family medical reasons. Everything was taken care of and I was able to spend that year doing good work with good advice.

The School of Graduate Studies has provided me with a Graduate Fellowship for four years, making this entire enterprise possible; and this year also awarded me an A.G. Hatcher Memorial Scholarship, an honor and a substantial validation of my work.

I am grateful to Anne Thareau, Head of French and Spanish, for noticing the presence of a doctoral student from the History Department on her corridor, and connecting me with Scott Jamieson, with whom I had twice-weekly one-on-one French translation sessions for an entire semester, which I consider outrageous fortune. We produced translations of two subject-relevant journal articles together, which I will always treasure—as I will his kindness and deep insight into language and culture. I wish Professor Jamieson the happiest of retirements.

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Before I leave St. John's here, I have finally to thank Professor Dan Walker of the Department of Ocean and Naval Architectural Engineering for serving as a technical adviser to this project. Discussing technical matters with a naval architect who understands sailing craft contributed much to the analysis in Chapter Five, and thus for the final interpretations, conclusions, and direction of further work.

The other major research approach that took us outside the library and the archives was the attempt to gather and analyze the insights of people who actually sail these things (or, to be precise, reproductions of these things) rather than just read books and talk about them. Without the cooperation of the remarkable people who design and sail replica ships, this study would be up a creek. Jim Graczyk, former crew member of HM Armed Sloop *Welcome* on the Great Lakes, shared so much information and experience with me to start that phase of research. His former crewmate Theresa O'Byrne shared videos and experience too. William T. "Chip" Reynolds, master of the replica *Half Moon* in New York, sat down for a lengthy telephone interview about his experiences, as did masters Sharon Dounce of the *Kalmar Nyckel* in Wilmington, Delaware, Drew McMullen of the *Sultana* Education Foundation in Maryland, Walter Rybka of the U.S. Brig *Niagara* in Pennsylvania, and Eric Speth of the Jamestown ships *Susan Constant*, *Godspeed*, and *Discovery*. Joakim Severinson, Master Shipwright of the Swedish Ship *Götheborg*, answered my questionnaire in writing, and David Thorpe, crew member on *Mayflower II*'s 1957 transatlantic, helped me get my hands on articles he had published over the years in *Mayflower Quarterly*—as did Walt Powell, Executive Director of the Mayflower Society, who was so kind as to box up a collection of his own materials, including an original 1957 *National Geographic* featuring the cover story on the transatlantic, and a chip from a shipwright's adze from the hull of the *Mayflower II* herself. When a lonely scholar gets something like that in the mail, it lifts the spirits.

The third major research approach for this project was a more traditional archival one, and involved two months of travel—which is expensive. In addition to Departmental support, I received a short-term fellowship from the wonderful Phillips Library of the Peabody Essex Museum in Massachusetts, where I spent two weeks in June and July. Thanks to Head Librarian Kathy Flynn and librarians Catherine Robertson and Anne Deschaine for providing me with all those letters and documents from their collection. Thanks to Catherine also for posting a piece I wrote about my work there on the Library's blog.

I left Massachusetts with more shipbuilding agreements than I would have otherwise—and more context for them—thanks to Steve Klomps of the Peabody Essex Museum. Thanks to Steve and to maritime curator Dan Finamore for connecting us.

Malia Ebel, archivist at the New Hampshire Historical Society, is one of the friendliest people I've ever met. She also pulled all the material from their collection I requested far in advance of my July visit, knowing that impending building renovations would cut off access to them otherwise. The maritime material there is extensive and important and had I not been able to use it, the archival research would have suffered.

I was not so fortunate with my plan to visit the Newport Historical Society in Rhode Island, where renovations did indeed preclude access to their archives this past summer. Then, Kim Nusco at the John Carter Brown Library in Providence stepped in and welcomed me for a week at one of the most important repositories for study of early America in the world. Kim was far more proactively helpful than she had to be. She was also friendly and very knowledgeable; I thoroughly enjoyed my impromptu conversations with her when I should have been working. The reader will see how heavily I relied on the Brown papers in Chapters Three and Four.

My introduction (not quite a trial by fire, but close) to serious archival research happened at the Historical Society of Pennsylvania in Philadelphia. I thank the staff there for their assistance, and the staff of sister institution the Library Company of Philadelphia.

The final stop on our summer tour was Jamestown Settlement in Virginia, run by the Commonwealth of Virginia and the Jamestown-Yorktown Foundation. Jamestown is home to not one but three of the latest and most carefully-researched early 17th-century replica ships in the world—and home to people who know how to care for, operate, and interpret them. Their private library also houses one of three copies of Peter Wrike's extensive research report with supplementary materials, prepared as background for the design of the 2006 *Godspeed* and *Discovery*. Librarian Nancy Egloff came in the day after flying back from vacation in Ireland just to let me in to read that. She was as nice as she could be to a very homesick researcher. JoLynda Lawecki, who had answered all my initial queries to JYF, took me through the off-limits areas of the complex where I met interpreters Don Hulick and Hank Moseley and ships' officer Todd Egnor.

It was a great privilege to have access to scholars whose work so heavily informed the study. Thomas Truxes, Christopher French, Joseph Goldenberg, Ab Hoving,

and John McCusker all answered e-mails or (in Goldenberg's case) talked with me by telephone. Their advice and encouragement helped both specifically and generally. Special thanks go to archaeologists Nick Burningham and Fred Hocker. Burningham, central to the *Duyfken* project from construction to voyaging to published interpretation, reviewed a draft of a paper that would ultimately evolve into Chapter Six, going back and forth with me on important issues and problems. His criticism and suggestions added much to what I learned from his published work. Sharon Dounce connected me to Fred Hocker, Director of Research at the *Vasa* Museum in Stockholm and veteran ship archaeologist, who also reviewed a draft of that paper, and gave me what turned out to be about two months of work to do. The reader can imagine how much richer and more worthwhile this thesis is as a result of that. I started this project saying that only an effective combination of history and archaeology could accomplish it. Thanks to Burningham and Hocker, I had to put my money where my mouth was. That the paper they reviewed won the Student Paper Prize at NASOH 2015, I am sure, has much to do with their contributions.

The discussion of theory and methodology in Chapter Two benefited substantially from correspondence and discussion with my friend Steve Kinsey, biologist at the University of North Carolina Wilmington. For that part, I needed a scientist, and he was happy to make himself available.

It's funny how much we rely on people we've never met to help us with something like this. For answering queries and/or sending ships' plans to Dan Walker, I am happy to thank Peter Boyne and Loetta Vann of The Smithsonian; Amelia Fay of The

Manitoba Museum; Anna Shumilak of the Archives of Manitoba; Genevieve Jones-Edman of the National Library of Jamaica; Nigel Blanchford of the Society for Nautical Research; Jay Moore of The Mariners Museum Library; and Martin Salmons of Royal Museums Greenwich.

As for my own university library, I am much more in debt to the staff at Queen Elizabeth II Library at MUN than most graduate students, as I was 1,700 miles away for three of my four years. QEII librarians sent a whole bunch of their books to me through international mail, as well as promptly fulfilling requests for photocopies of articles not available online. They are consistently reliable and that is no small thing in this world.

For interlibrary loan, I became dependent on our local New Hanover County Public Library; Marsha Hayes at the reference desk procured materials for me I would not have gotten otherwise, especially masters' theses from Joyner Library at my last alma mater, East Carolina University. Reference staff at Randall Library at the University of North Carolina Wilmington also helped me find and borrow important secondary sources in the early phase of the project.

This was not my first graduate foray into maritime history. I got to reconnect with people I had known in my former graduate life through conferences of the North American Society for Oceanic History. Members of NASOH materially assisted me in pursuing this project; I thank Paul Fontenoy (a fellow ECU maritime alumnus), of the North Carolina Maritime Museum for his advice (and for connecting me to Ab Hoving); the eminent naval historian John Hattendorf of the U.S. Naval War College for giving me a list of useful names; my former classmate Sal Mercogliano of Campbell University for furthering the cause of my paper at the 2015 conference in May; Vic Mastone of the Commonwealth of Massachusetts for accepting my paper and to him and his wife Sharon for sharing an excellent lobster-and-rum dinner with us on his home turf this summer; Mark Bailey of the Australian Government for introducing himself and trying to get me in touch with replica people in his home country; Tim Runyan of ECU, a former professor of mine, for good conversation and buying our drinks; and Warren Riess of the University of Maine, outgoing NASOH President, author, archaeologist, supportive correspondent, and—now—thesis examiner.

Some say historians should write in chronological order, and I generally subscribe to that opinion. Nevertheless I have saved the earliest acknowledgements for last. Brad Rodgers and Gordon Watts, who taught me at ECU as a master's student in the late 90s, had encouraging words in the early days, and Gordon wrote a letter for me. Carl Swanson, who has inspired me pedagogically more than anyone since college, wrote letters too—one of which, according to Skip Fischer, was quite sufficient for him to fully-endorse my acceptance at MUN. Carl and Jan have always been hospitable to us and we count them friends. I wish Carl, too, the best of retirements. The ECU maritime program and history department have lost a big one.

Before I started at MUN, I undertook to learn French from scratch. Victoria Wheeler at Cape Fear Community College where I was teaching made that possible; she also inspired me pedagogically and I now count her a friend. Professors Theresa Hernandez and Pierre Lapaire at UNCW took my French to the next level and made it possible for me to do what I did at MUN, and they were kind and encouraging.

I undertook doctoral study only after—and because of—ten years of teaching history at Cape Fear Community College here in Wilmington. Robert Puckett and Donna Rowland ran our department, and there is no way they could have been better at what they did or more supportive in doing it. They provided an environment for me to develop as a person so drastically that it is difficult for me to remember who I was before, and I am literally afraid to think who I might have become otherwise. To add another cliché to what has grown into quite an impressive collection of them: All those students taught me far more than I ever taught them.

Standing over there by himself in all this is David Cecelski, scholar and author, whose book *The Waterman's Song* inspired me so much that I worked up the nerve to contact him out of the blue before I had even gotten so far as to apply to MUN. David not only responded; we had a telephone conversation I distinctly remember in which he expressed some of his opinions and confirmed some tentative ones of mine. The upshot was that I felt comfortable deciding that MUN was the right move largely thanks to David, and he already knows how grateful I am to him, but I do not mind reminding him.

Shortly before that, I watched my dear old friend Amy get her doctorate, and I thought, if she can do that with a full-time job and two kids, I can certainly do it with none of those things. She is one of two people who directly precipitated a serious soul-searching in the spring of 2009 that led me down this path, and she has been an unflagging cheerleader all the way to this point.

The other is my dear but not-quite-so-old friend Tift, who showed me what it looks like up-close when someone has the guts to take their talent and do their best with it, working without a net, just as afraid as anyone of falling but never looking down. She taught me that you don’t need a prefabricated structure for your life; you can make you own way. You can do something original. I don’t think I would have done this without her.

I think my parents have hoped I would do this all my life, though I cannot prove that. I do know that they have sat in the middle of the front row of supporters all along. I have often thought they cared about the enterprise more than I did, and we all need people like that in our lives.

I would never have considered, much less pursued, doctoral study had it not been for the humane treatment I have received at the hands of my wife Andie for the past 27 years of not deserving it. Her love and income make all things possible.

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Introduction

The sailing ship allowed Europeans to move themselves and what they needed to sustain themselves across oceans. It allowed European states and companies to supply weak new colonies, vulnerable to established indigenous power, with more people and supplies from home, some of which the settlers needed to establish commercial intercourse with indigenous peoples. It carried away whatever the settlers and natives produced and hoped to sell or trade beyond the sea. In a best-case scenario, for the settlers, at least, the services of sailing ships allowed settlements to become self-sustaining and then to expand—sometimes dramatically and with world-altering consequences. For some native peoples, the ships facilitated new economic opportunities, though of course those could not offset devastating losses to foreign disease and incursion, which the sailing ship also brought.

That is, of course, how and why those of European origin came to assert themselves in what they called the Americas, where we still live today in societies whose economies have generated a historically unprecedented amount of wealth over the past four hundred years or so. It is also how and why these same societies have such large populations of African descent. The ships carried the white people and their goods, including the black people. One sort of ship brought the explorer and then the conquistador, and a later one carried tobacco from the Chesapeake or codfish from Newfoundland while another brought stacked and chained West African prisoners of war and other slaves to the Chesapeake. Later still, another type of ship brought, manufactures and passengers from London to New York and returned with valuable colonial produce and colonial passengers in a complex transaction that usually worked out to London's advantage.

These ships turned oceans from dangerous chasms to dangerous highways, allowing their owners and passengers, clients and human cargoes to create empires. Their cousins—the warships—chased them—and each other—around the Atlantic basin in war after war as their imperial masters transferred their age-old rivalries to the new frontier.

Whether merchant or military or both, the ship was the most complex and expensive machine of the age. It demanded hard labor, financial outlay, and assumption of risk on a scale too great for individuals. Only some form of corporate enterprise could build and operate one. It is more than symbolic to say that the networks of interests that made up the Atlantic World intersected in the seemingly byzantine maze of the ship's rigging. Neither, however, is inscrutable. By making sense of the miles of rope running hither and thither above the deck of the ship, we can make more sense of the less-tangible but just as real networks of people and money and power running the world of that ship.

This project starts from the assumption that understanding a society's apex technology is a useful way to understand that society better. In order to understand that technology, we need to acquire first as much of an understanding of the society that used it as possible, in order to recognize, as we come across them, places in which the technology connects to its context. We historians teach our students that every individual, no matter how unusual or intelligent or visionary, is an inextricable part of her own time and place, and that there is no understanding that person without understanding that time and place. The same is true of any machine. A contextualized study of a technology allows us to avoid the traps of facile determinism, teleology, unwitting anachronism, and plain befuddlement. The sailing ship as an icon is as familiar to our Eurocentric world as the face of Lincoln or Elizabeth II. Despite the fact that we still have wind and water, so the thing still works and we still have some, the sailing ship as a machine is however quite alien to our world. It is a machine from another time, built and used by people with starkly different experiences and expectations from ours. We employ it for recreation and education. They employed it for their very livelihood and as their ultimate weapon. To understand it, we need to understand when, where, how and why they built it and used it the way they did.

Given that a machine is a product of its time and place and particular group of people, some specific chronological, geographic, and demographic parameters are required to make the proposed task manageable. This thesis examines the ocean-going merchant ship of the British Atlantic from the early years of American settlement through the crisis years, when the empire partially collapsed under the weight of its own success—a weight whose gravity kept the disputants in a tenuous and uncomfortable orbit around each other even after formal separation. This empire grew up intermingled with those of its chief rivals from Spain, France, and the Netherlands. Ship technology diffused easily across the political boundaries imposed by imperial authorities along with the people who did the same. Exploring that diffusion means exploring those inter-imperial relationships.

A specific temporal and spatial context provides the key to the code of a particular technology. It is not a limitation. Studying a particular technology teaches us how people use technology and why. If we find different technology in a different time and place, we can ask what it is about those people in that time and place that makes their technology different. We can ask better questions about other peoples' ships, and be better prepared to recognize the answers.

The history of technology tends to sit on the shelf alongside economic history. The two are closely related, but the questions economic historians ask and the methods they use to go about answering them do not provide a comprehensive understanding of technology. Taken alone, they can lead to an overly economically deterministic assessment of a technology, or to puzzlement as to why we find the technology where we do, doing what it was doing. We have to add the perspectives of political, cultural, and social history to end up with a robust technological history. Even then, we do not have enough—at least in the case of the sailing ship. Academic history has not yet digested enough evidence from outside our own discipline to give us the understanding we could hope for. Archaeology and material culture studies—a field drawing on archaeology, anthropology, and folklore—ask questions and suggest approaches we need if we are to understand any tangible object in its fullest historical context. As for the technical historiography of the ship, meticulously and expertly researched: it was mostly written by curators, antiquarians, and naval architects.

None of these approaches and efforts from outside the academic discipline of history will suffice on their own. They do not ask the same question we do, so we cannot look to them for the answers. Nevertheless, by combining their insights with our own questions and the insights our discipline has provided, we can advance our understanding of the technology in question well beyond where it stands now.

That advance will require some original work. Questions remain even after we consider what all the extant literature from across disciplines has to tell us. It may not require original techniques, but it may well require somewhat novel modifications of existing ones.

Economic, business, and social historians have drawn much from the papers of merchants and officials involved in the shipping business in this period. Reading the literature they have based on those sources left the strong suspicion that, while those historians omit mention of it because they are interested in other things, some of these original materials must contain commentary on technological matters. Owners and masters and builders had opinions about what specific technology to risk their money on, and had to make decisions based on those opinions. Much was at stake based on those decisions. Officials charged with policing maritime commerce expressed opinions on specific types of vessels operating in specific trades—especially if they felt those vessels posed a challenge to the state's right to collect revenue.[1] This study requires examining old sources with new questions.

Most historians writing maritime economic history do not have the technical understanding of the machine in question to ask technological questions of their sources, much less answer them. An important mandate for a study such as this is to translate what

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[1] British officials banned certain vessel types and rigs in home waters in the "Smuggling Act" of 1795, primarily to help ensure that their own interceptors held the performance advantage over would-be smugglers. The colonial-built merchant schooner *Sultana* was deemed worthy to serve as one of those interceptors in American waters just before the American Revolution-see Chapter Six.

technical sources have to say into terms accessible to the non-technical maritime historian.

That is something that the technical historians of the ship have not done, on the whole. Most well-researched, authoritative histories of ships as machines were written by specialists and enthusiasts for their fellows. Some of these leave behind even those of us with solid technical backgrounds, particularly those written by naval architects and relying on that level of expertise to make important points. A project like this would be seriously hampered without access to the technical advice of a naval architect, so that was procured.[2] Today's best ship archaeologists have technical expertise akin to that of the naval architect, and the study has drawn on substantial input from that quarter as well.

Today's naval architects and marine engineers have tools at their disposal that those working in the 1960s, when Howard Chapelle was writing his well-respected technical histories, would have envied. Taking our cues from the type of analysis Chapelle pioneered, we can use those new tools to augment his methods and apply them to vessels Chapelle was not particularly interested in—typical merchantmen. That is currently being done, and needs to be done more.

Analyzing plans in a computer, though, is not the same as sailing an actual vessel in wind and water. No intact merchant ship of this time and place still exists, but a few replicas do. Once we establish to what extent a given replica was built and is operated as it would have been at the time, we can learn much about the originals by processing and

[2] Prof. Dan Walker, Department of Ocean and Naval Architectural Engineering, Faculty of Engineering and Applied Science, Memorial University of Newfoundland. Dr. Walker answered technical questions during the research phase of this study.

analyzing the experiences of the experts involved with these vessels, taking our cue from the established methodology of experimental archaeology.

The insights we gather from this analysis will supplement the existing written and archaeological record—a record that needs supplementing. Both contemporary and modern commentators have shown much more interest in particularly fast vessels and in warships than they have in the ordinary merchantmen carrying the bulk of the people and goods that made the British Atlantic, and much of the Atlantic archaeological record is in the condition we would expect of wood decaying under warm water for centuries. It will take all of the evidence from all of these sources to give us a satisfactory understanding of the vessels most people took for granted at the time and have not paid much attention to since.

This introduction has posed no specific questions. Those questions belong in the context of the review of the literature that produced those questions, to which we now turn.

Chapter One: The Historical and Extra-Historical Literature: What We Think We Know

This literature review will explain why a comprehensive study of this subject requires more than passing familiarity with Atlantic World history, maritime economic history, the history of technology, the technical history of the ship, nautical archaeology, and material culture. These are the fields in which the ordinary British Atlantic merchant ship is situated. The objective of this review is to show that none of these fields alone can provide a full understanding of this subject, and that we can study the ordinary merchant ship as an intersection of all six areas of inquiry.

Part One: Atlantic World history

What we now call Atlantic World history grew out of colonial American and British imperial history of the early 20th century, and more specifically, from those works that emphasized the connections between the two.[1] Connections, webs, networks, the porosity of boundaries, cosmopolitanism, the confluence and conflict of disparate groups of people colliding to form new civilizations whether they wanted to or not—these are the emphases of the approach. Perhaps the first great accomplishment of the field, even before it acquired its current moniker—was to call attention to the inadequacy and anachronism of histories that were nationalist, whether intentionally so or not. Such histories divided people and lands with different lines than those conceived by the people

[1] For a review of the field's origins, see Nicholas Canny, "Writing Atlantic History; or, Reconfiguring the History of Colonial British America," in *The Journal of American History*, 86:3, *The Nation and Beyond: Transnational Perspectives on United States History: A Special Issue* (December 1999): 1093-1114.

occupying those lands at the time.[2] For maritime historians, the Atlantic World perspective is naturally attractive, as it has mapped the European American empires as lands at the periphery of an ocean basin, with the ocean serving as a means of connection. That geographic point of view serves as an especially important corrective to the long-standing U.S. westward-looking continental perspective.

History rarely serves us better than when it shifts our perspective from our own to that of a past people, so that we can understand their world in a way otherwise impossible. Ian Steele's *The English Atlantic: An Exploration of Communication and Community* did that in 1986.[3] Steele pointed out that, while to us in the jet age, the transportation of people, goods, and information across the Atlantic Basin in sailing ships seems inconceivably slow, miserable, risky, and unpredictable, it did not necessarily seem that way to people in the British Atlantic at the time. They had developed a sophisticated and dependable system of maritime communication that sustained the far-flung imperial community and knit it more closely together. Since their expectations of speed, risk, and comfort were vastly different from ours, we cannot appreciate what they were doing from their perspective unless we step out of our own.

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[2] For as convincing an example as one is likely to find on how contemporary prejudices can carry over into the modern thinking person's subconscious, see John Elliott's accessible but eloquent comparative history of the British and Spanish American empires in *Empires of the Atlantic World: Britain and Spain in America, 1492-1830* (New Haven, CT: Yale University Press, 2007). That our assumptions about Britain and Spain are still colored by the Black Legend is not the sort of anachronism we generally guard against.

[3] Ian K. Steele, *The English Atlantic, 1675-1740: An Exploration of Communication and Community* (Oxford: Oxford University Press, 1986). A 2007 *festschrift* to Steele provides a recent sampling of work inspired by him and a summation of his influence. Nancy Rhoden, ed., *English Atlantics Revisited* (Kingston ON: McGill-Queen's University Press, 2007).

Because Steele focused his book on what ships were used for, if not on ships themselves, *The English Atlantic* remains as directly relevant to this project, if not more so, than any book in the field. Other historians focused on the Eastern Seaboard colonies, French and Dutch colonies, slavery and the slave trade, the social history of sailors, the West Indian plantation, smuggling, piracy, and even naval operations wrote much of the context we need to understand ship technology. Studies like David Hancock's, of specific trades, flesh out the reality of what merchant ships were for,[4] and draw detailed insets on Steele's small-scale chart of the Atlantic.

When it comes to ship technology, though, Atlantic World history tends to cite either earlier maritime economic history[5] or, in a few cases, the technical ship histories. At some point in reading this literature, one begins to pick up on some amount of circularity in the treatment of the topic. Atlantic World historians depend on others with technical expertise to explain ships to them, though they are quite adept at explaining to us how those ships were employed.[6] The problem with this state of affairs is that Atlantic World historians have to take what technical historians have to say at face value, and we can do better than that.

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[4] David Hancock, *Oceans of Wine: Madeira and the Emergence of American Trade and Taste* (New Haven, CT: Yale University Press, 2009); and *Citizens of the World: London Merchants and the Integration of the British Atlantic Community* (Cambridge: Cambridge University Press, 1997).

[5] Most commonly, Ralph Davis (see note 7), though also close to ubiquitous in the footnotes is James F. Shepherd and Gary M. Walton, *Shipping, Maritime Trade, and the Economic Development of Colonial North America* (Cambridge: Cambridge University Press, 1972).

[6] For example, Steele cites ship historians John Harland and Alan McGowan for his brief discussion of the steering wheel (as he should). Steele, The *English Atlantic*, 50, note 39.

What is the significance of technological continuity and change in sea-going ships to the developments that preoccupy land-focused Atlantic World history? Does it matter that the ships moving everyone and everything around this world were so different from each other and changed over time? If so, how? Why? Does it matter that they did not change in the ways that they did not? How? Why?

What follows will demonstrate that yes, these questions do matter, if we want the fullest possible understanding of how this world worked, and why maritime interests made the decisions and investments they did, when they did. By exploring the priorities and realities of merchants, shipwrights, and the sailors whose skills and labor animated vessels powered by both wind and muscle, subsequent chapters will identify specific continuities and changes in hull design, rig, and the employment and operating environment of merchant ships, raising questions that, though further work will be necessary to answer, make a strong case that doing such work will ultimately yield insights useful to both maritime economic and technological historians. This project will make a contribution to Atlantic World history by accepting the general approach and objective of the field as its own, and by arguing for the importance, to others who are also sympathetic to the approach, of what the Atlantic World's ship technology can teach us about that world. With the goal of accessibility to the Atlantic World academic community, it will avoid technical terms wherever possible, and where impossible, explain them as clearly as possible. It will illustrate technical concepts simply and clearly and avoid digressions into technical matters that stray too far from their context.

Part Two: Maritime economic history

In the existing Atlantic World-related literature, we find the most discussion of merchant ships as we approach where the field meets maritime economic history. The most prominent marker of that place is Ralph Davis's *The Rise of the English Shipping Industry in the Seventeenth and Eighteenth Centuries*, first published in 1962.[7] Atlantic World and maritime economic historians rely on him for his unprecedented and unduplicated analysis of shipping data, and for his unusual attention to ships themselves in his sweeping treatment of the industry that made the British Empire. Davis called clearly for attention to ship technology by maritime economic historians. He suspected that the state of our understanding of ordinary merchant ships impeded our understanding of his subject, and he asked those with more technical comprehension than his own to address that. The most important attempts to do so are only now happening. What did happen in maritime economic history after Davis, and the discussion and debate about the role of merchant ship technology in this period, make up one of the key springboards for this study.

Davis was actually making two claims that were easy to confuse as one, and to dismiss as one. The first claim was that we could learn more about what Davis was working on by studying the technology of the ordinary merchant ship. The second was

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[7] Ralph Davis, *The Rise of the English Shipping Industry in the Seventeenth and Eighteenth Centuries* (London: Macmillan, 1962). The book was reprinted in 1972 with a new introduction by the author. After that it went out of print. The International Maritime Economic History Association reprinted it in 2012 as No. 48 in its *Research in Maritime History* series, with an introduction by Lewis R. Fischer and David M. Williams, in which they refer to the book as "one of the most significant books in maritime history published in the twentieth century" (iii). Unless otherwise noted, citations from Davis here will be from the 1972 edition.

that technological change in the merchant ship was significant, though we did not as yet know how, and played a significant role in the growth of productivity in the English shipping industry in the period. Most maritime economic historians, both at the time and since, have muddled those together, and in rejecting the second claim, felt comfortable ignoring the first.

Even ship historian Alan McGowan, though, with his technical understanding far surpassing that of almost any maritime economic historian,[8] dismisses any suggestion that some still-unknown change in basic ship design played a role in increased merchant ship productivity in the period, writing that it was "inconceivable that any such development could have occurred without its having left a single trace. Hull design per se is not a factor in this evidence of greater economic efficiency, although hull size is contributory." He adds that the only technical innovations that could have contributed to an increase in ton-per-man ratios in this period were the adoption of wheel steering and an increasing emphasis on using fore-and-aft sails on larger ships.[9] These last are the two technical innovations Steele accepted in *The English Atlantic.* We will investigate them rather than accept them as given.

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[8] Lack of technical knowledge is a common impediment in maritime history. Willem F.J. Mörzer Bruyns makes this point about the history of navigation in "Research in the History of Navigation: Its Role in Maritime History," *International Journal of Maritime History* 21:2 (December 2009): 285. We need more academically qualified maritime historians who know as much about ships, navigation, and oceanography as they do about economic theory and statistics.

[9] Alan McGowan, *The Century Before Steam: The Development of the Sailing Ship 1700-1820* (London: HMSO, 1980), 31. Davis hoped that nautical archaeology—a specialty just taking off when he was writing—would step up and show us what history could not on this question. We will return to nautical archaeology, whose contributions are key. While it is fair to say that what Davis hoped for has not quite materialized, this study will make it clear that we are probably close.

A bulky literature wrestles with how to measure productivity in the economy of the early British Atlantic, what the trends in productivity were, and what factors contributed what to it. The consensus is that productivity increased through the period—that in spite of the wars and their disruptions, the overall trend was for growth in the British Atlantic economy. The debate is more about what weight to assign each of the contributing factors. Another consensus within that debate is that technological change in merchant ships—changes in their design and construction—was not a primary factor. That leaves the question: Was it a factor at all? On that one, there is no consensus, but general scholarly opinion falls within a fairly narrow range, with perhaps Steele's "[t]echnology helped a little" in the middle.[10]

The seminal economic history on the productivity of early modern British merchant shipping started with Nobel laureate Douglass North and continued with his students Gary Walton and James Shepherd, in the heyday of econometric history.[11] While North comes across as more broad-minded on the subject than Walton and Shepherd, the thrust of all their work is that the security of the seas and more efficient business organization predominate as the factors bringing about productivity growth in shipping, and that technical change in merchant ship design and construction was somewhere between insignificant and a non-factor. Some heavyweights in the field, however, let no time pass before raising objections. John McCusker, Russell Menard, and the late

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[10] Steele, *The English Atlantic*, 50.

[11] Douglass C. North, "Sources of Productivity Change in Ocean Shipping, 1600-1850," *Journal of Political Economy* 76:5 (September-October 1968): 953-970; Gary M. Walton, "Obstacles to technical diffusion in ocean shipping, 1675-1775," *Explorations in Economic History* 8:2 (Winter 1970): 123-140; Shepherd and Walton, *Shipping, Maritime Trade, and the Economic Development of Colonial North America,* already cited.

Frederic Lane criticized the methodology of data analysis from more than one angle,[12] and while none of them came close to rejecting outright the work of the North school, none was willing to go along with characterizing the role of ship technology as obviously insignificant. Neither was Richard Unger, but to mention him is to flag another potential muddle. We read much more consensus about the importance of technical improvements in ships to productivity growth in the two centuries preceding the period of this study. Unger's work centers on the late Middle Ages and the Age of Discovery, as does Lane's. Their comments on this issue take a much broader chronological and geographic perspective than those of McCusker and Shepherd and Walton who specialize in British America. So, when Unger writes "[t]echnology mattered,"[13] we cannot take that as a refutation of what the North school was arguing.

In fact, the literature provides no such refutation. The most we can say is that it leaves the door ajar for exploring what role merchant ship technology *may* have played in the dynamic expansion and rapid development of the British Atlantic Empire in the Americas—a door Shepherd and Walton seemed too eager to close. We are left somewhere between those two scholars and Ralph Davis. That, though, is enough space to work in, and we should set out a distillation of this discussion to be clear about what space we are talking about.

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[12] Kenneth Morgan juxtaposes North, Walton, and Shepherd on the one hand with McCusker, Menard, and Nathan Rosenberg on the other. Rosenberg is much more concerned with the history of technology than the other two, so he will be discussed in that context. Kenneth Morgan, *Bristol & the Atlantic Trade in the Eighteenth Century* (Cambridge: Cambridge University Press, 1993), 46.

[13] Richard W. Unger, "Ship Design and Energy Use, 1350-1875," in Richard W. Unger, ed., *Shipping and Economic Growth 1350-1850* (Leiden: Brill, 2011), 267.

Economists measure productivity in terms of input and output. The more output per unit of input, the greater the productivity. This is a straightforward concept with a steam engine. If one engine produces 20 horsepower per pound of fuel burned and the other only 15, the first engine is more efficient—more productive—by an exact amount. It is of course vastly more complicated when scholars are attempting to measure overall productivity in a complex economy over a period of decades or centuries. As a recent collection of conference papers edited by Richard Unger makes clear, while economic historians are still working on shipping productivity, they largely agree on how to measure that productivity, and they agree that there was slow but steady growth in overall shipping productivity before, during, and after our period. They also agree that technical change was much more incremental in our period than it had been in the preceding one or would be in the succeeding one. They do not, however, write off those incremental changes as irrelevant to productivity growth in the period.[14]

The productivity measure most central to our purpose here is the ton-per-man ratio. Economic historians have scrutinized the idea closely, and debated how best to employ and interpret it, but it remains their favorite index. The basic idea is that the fewer humans it took to move a ship of a given capacity, the more efficient a cargo-moving machine it was, since wages, the cost of feeding and watering the crew, and the space taken up by the stores needed to do so all militated against the profit of the shippers—and those shippers saw this significant cost as one over which they had more control than they did over others. Davis was the first to argue convincingly that ton-per-man ratios in

[14] Unger in Unger, ed., *Shipping and Economic Growth,* 252.

our period increased over time, a trend interrupted, but never reversed, by war. Subsequent scholarship has reinforced his conclusion, but why did this happen?

To some extent, the size of the crew was dictated by the defensive capability of the ship. The more guns she carried, the more men she needed to man them in action, should that be called for. The installation of cannon penalized the ship as a profit-making commercial tool in several ways. The ship was more expensive to build if she were stoutly constructed enough to carry the weight of cannon and absorb the violence of their recoil. She was also heavier as a result of that stout construction, and thus either slower or in need of a more powerful, and thus more expensive and more labor-intensive, rig to move her as fast as a lighter ship of the same size, especially in light air. The guns took up cargo space, as did their heavy and bulky ammunition and gunpowder.

Owners, however, had good reason not to trust cargoes to unarmed vessels in the Atlantic World during much of our period. In the 17th century, European naval power in the western Atlantic and Caribbean was weak. Navies had not developed the bureaucratic structures or the physical infrastructure to maintain warships and their crews so far from home in good enough condition to police American waters,[15] so merchant ships were

[15] N.A.M. Rodger and Richard Harding trace these developments in the 18th century and credit them for much of the later fighting and commerce-policing effectiveness of the Royal Navy. See Rodger, *The Wooden World: An Anatomy of the Georgian Navy* (Glasgow: Collins, 1986); and *The Command of the Ocean* (London: Penguin Books, 2004); Harding, *Seapower and Naval Warfare, 1650-1830* (London: UCL Press, 1999); and *The Emergence of Britain's Global Naval Supremacy: The War of 1739-1748* (Woodbridge UK: Boydell, 2010). As Olaf Janzen pointed out to me, though, the argument for the importance of naval limitations in the period was made earlier by Gerald S. Graham. See *Empire of the North Atlantic: The Maritime Struggle for North America* (Toronto: University of Toronto Press, 1950); "Britain's Defence of Newfoundland," *Canadian Historical Review* 23:3 (September 1942): 260-279; "Newfoundland in British Strategy from Cabot to Napoleon," in R.A. MacKay, ed., *Newfoundland: Economic, Diplomatic, and Strategic Studies* (Toronto: Oxford University Press,1946), 245-264; and "Fisheries and Sea Power," Canadian Historical Association *Report of the Annual Meeting*, 20:1 (1941): 24-31.

vulnerable to pirates and privateers. The nascent marine insurance industry was inadequate and expensive. Risks being what they were, shippers felt compelled to bear the costs of armed freighters, just as those sending ships into the Mediterranean had done for a long time, since North African state-sponsored commerce raiding was endemic and effective there. So the merchant ships plying the Atlantic trade routes were a pragmatic compromise between cargo capacity and the ability to defend that cargo—galleons, or their direct descendents. The galleon was the stout, seaworthy, high-payload hybrid that carried the plunder of the New World back to Spain and—in the hands of her enemies—challenged her Armada in the English Channel.[16] Writing about the wreck of a famous English galleon at Bermuda—the *Sea Venture*—archaeologist Jonathan Adams summed up the type: "...[W]hile not ideal for any one task, [they] were brilliant general purpose ships."[17] They were certainly suited to a time and place where markets and colonial populations were still small, seas risky, navies short of specialized warships, and Spain still convinced it should and could keep its rivals out of the Americas altogether. The galleon was not a specialized ship, and it served a world that did not have the luxury of building and operating specialized ships.

In the Baltic, the Dutch had that luxury. Non-technical maritime economic history pays unusual attention to the *fluit* or *fluyt*, both as a specific type of specialized cargo

[16] For a succinct treatment of the type by one of the foremost historians of the Spanish American empire working in English, see Carla Rahn Phillips, "The Caravel and the Galleon," in Robert Gardiner, ed., *Cogs, Caravels, and Galleons: The Sailing Ship 1000-1650* in the Conway's History of the Ship series (Annapolis, MD: Naval Institute Press, 1994), 91-114.

[17] Jonathan Adams, "*Sea Venture*: A second interim report—part 1," *The International Journal of Nautical Archaeology and Underwater Exploration* 14:4 (1985); 297.

vessel and as an archetype for the economical pure cargo vessel in general.[18] Like any other ship, the *fluit* was the product of a specific and temporary set of conditions, but as an archetype, it does provide an illustrative counterpoint to the galleon. Capacious, lightly and thus cheaply built, simply rigged for ease of handling, and produced by a shipbuilding industry already experimenting with semi-standardized components and construction techniques, the type maximized efficiency for owners and shippers working in the secure Baltic bulk commodity trades. Economic historians consider the Atlantic's inhospitable conditions for such a vessel a primary barrier to the growth of Atlantic shipping productivity before about 1750.

Splitting a hybrid into its component specialties, though, cuts two ways. There would be no *fluit*-type pure cargo ships on Atlantic trade routes without the corresponding specialized warships to protect them. While the lumping-together of the "decline in piracy and privateering" we find in Shepherd and Walton is confusing, Christopher French attempts to clarify it for us—piracy ceased to be the threat it had been to Atlantic Basin commerce after the 1720s, as the bulk of recent work on the topic has shown, he argues, but privateering was a major component of naval warfare throughout the period. The difference, to French, is the increased effectiveness of wartime convoys

[18] The *fluyt* as an actual, specific type of ship did not last much past 1700. The term is used by economic historians like Walton as a term of convenience or archetype for the concept of a cheaply built, cheaply run, unarmed or lightly defended pure cargo carrier. For a summary treatment of the actual vessel, see AJ Hoving, "Seagoing Ships of the Netherlands," in Robert Gardiner, ed., *The Heyday of Sail: The Merchant Sailing Ship, 1650-1830* in the Conway's History of the Ship series (Edison, NJ: Chartwell Books, 2002), 47-51.

after the middle of the 18th century.[19] Convoys were the bane of the merchant shipper when they were first tried, but by the Seven Years War, the Royal Navy had the system worked out, with adequate numbers and types of naval vessels to provide proper escort and move shipping reasonably efficiently. This meant that more merchantmen, if they so chose, could sail unarmed or lightly armed, and thus approach the efficiency advantages of the *fluit* even in an otherwise-dangerous operating environment. Of course, in peacetime, with predation considered less of a threat, pure cargo ships were freer to sail with only nature and navigational mishap to worry about. North, Shepherd and Walton attribute the bulk of the increase in Atlantic shipping productivity to the increased security of the seas, and the concomitant decrease in merchant ship armament and accompanying increase in ton-per-man ratio. The lion's share of the rest of the credit goes, in their view, to the increased organizational and logistical efficiency of Atlantic business networks. In this sense, they certainly take an Atlantic World perspective, and it is one that subsequent Atlantic World scholarship has reinforced time and again. With established commercial relationships, well-traveled shipping routes, better cargo-loading logistics and shorter turn-around times, cargoes were loaded and shipped faster, even if the ships carrying those cargoes did not change at all—except to lose those guns and extra men and stores.

[19] This is the point at which growth in the British Atlantic accelerates sharply (see Davis). French's argument suggests more effective convoys may have had a role in that. See Christopher J. French, "Productivity in the Atlantic shipping industry: a quantitative study," *Journal of Interdisciplinary History* 17:3 (Winter 1987): 613-638.

Guy Chet argues in a much more recent book, though, that we have put too much stock in this interpretation. Privateers did not always adhere to the terms of their letters of marque, and in a world where illicit trade was widely practiced and widely accepted, the gains of their ventures were likely to find markets. The distinction between "pirate" and "privateer" is clear to us, but Chet argues that the distinction is anachronistic if we project it back into the early modern Atlantic World, that our understanding of the distinction relies too much on official imperial sources (and wishful official thinking); and that Atlantic piracy, as distinct from sanctioned privateering, was not as completely suppressed after 1726 as the current historical consensus assumes. Regardless of the extent to which outright piracy as we think of it survived to a significant extent in the Atlantic World after the 1720s, his argument only adds to the skepticism toward any view that maritime predation—whatever they called it or we want to call it—continued to be a serious threat to shipping. So, if merchant ships were less frequently armed after the 1720s, is that due to the increased availability and effectiveness of convoys and the increased availability and affordability of marine insurance? Chet takes a less sanguine view of 18th-century convoying than French, and a main thrust of his argument is that merchants increasingly used insurance policies rather than defensive measures to protect their interests. His critics, however, question his interpretation of the marine insurance business. He does present both anecdotal and legal evidence for the continuation of outright piracy in the British Atlantic into the mid-19th century, but provides no sense of the scale of that. Still, he makes a convincing case for skepticism toward any argument on the subject that resembles Shepherd and Walton's.[20] We are still tasked with studying the arming of merchant ships in this period, and the ramifications of that.

We are also tasked with understanding the technology of speed. Shepherd and Walton were convinced that ship speed did not increase at all over the period. They attributed all the observed decrease in voyage times to faster turn-around in port. While other scholars concur that passage times did not fall dramatically during our period on most routes, Shepherd and Walton use a small set of data to make such a claim—voyages from New York and New England to Jamaica and Barbados, 1686-1765.[21] What they do not mention is that, all other things being equal, bigger ships are faster ships—that is a principle of physics.[22] We know from Davis that Atlantic merchant ships were getting bigger, so if that was the case, how could they not have also gotten faster? That will not prove to be a simple question, but it will be another driving question of the study. Speed is probably the most productive concept with which to begin an attempt to understand ships, for a host of reasons to be introduced at the end of the chapter.

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[20] Guy Chet, *The Ocean is a Wilderness: Atlantic Piracy and the Limits of State Authority, 1688-1856* (Amherst: University of Massachusetts Press, 2014). For criticism of Chet, see Adrian Leonard's review in the *International Journal of Maritime History* 27:3 (August 2015): 583-584; Christopher Kingston's in the *Journal of Economic History* 75:3 (2015): 933-936; and Christopher P. Magra's in the *American Historical Review* 120:3 (June 2015): 969.

[21] Shepherd and Walton, 197, table 17. Speed data are fraught with problems, as Howard Chapelle (in a book published prior to Shepherd and Walton's but not cited by them) discusses at some length in *The Search for Speed Under Sail, 1700-1855* (New York: Norton, 1984), originally published in 1967.

[22] At least some prominent economic historians are aware of this; Nathan Rosenberg and L.E. Birdzell mention it in *How the West Grew Rich: the Economic Transformation of the Industrial World* (New York: Basic Books, 1986), 83. The theoretical hull speed of a vessel is a function of the square root of its waterline length. Recall that McGowan acknowledged hull size, if not design, as a contributing factor to increased efficiency, as measured by ton-per-man ratios, in the passage quoted earlier in which he disagrees with Davis.

Russell Menard comes down in a quite different place in his weighing of safer seas versus better ships—at least for a forty-year period in the 18th century (1725-1765) in the Atlantic tobacco trade, for which he argues we have better data to work with than for other trades in much of the rest of our period. He is confident enough in his methodology to attribute 40% of productivity growth to safer seas and 60% to better ships.[23] That is a far cry from North or Shepherd and Walton. Discussing specifically the tobacco trade, Menard says Walton is "too quick to dismiss technical changes in ship design and navigation. The difficulty stems from a reliance on evidence that does not measure directly the performance of ships in the Chesapeake tobacco trade." Menard says that Walton did not restrict his data set exclusively to ships making the London-Chesapeake run, so he included coastal and inter-island vessels which were quite different in terms of ton-per-man ratios, operating costs, and transit times. He also says that Walton overestimates the decline in port times, which thus exaggerates the contribution of that factor at the expense of others, and that he "missed a decline in running time by relying on evidence from American coastal voyages. [24] Christopher French throws more cold water on the idea of a general decline in port turn-around times and further complicates the matter by claiming that there was no general decline in time spent in colonial ports in the first three-quarters of the 18th century, at least for ships

[23] Russell R. Menard, “Transport Costs and Long-Range Trade, 1300-1800: Was there a European ‘transport Revolution’ in the Early Modern Era?” in James D. Tracy, ed., *The Political Economy of Merchant Empires* (Cambridge: Cambridge University Press, 1991), 262.

[24] Menard in Tracy, ed., 258. Menard is discussing two specific works here: Shepherd and Walton’s *Shipping, Maritime Trade, and the Economic Development of Colonial North America*; and Walton’s "A Measure of Productivity Change in American Colonial Shipping," *Economic History Review*, 2nd series, 21 (1968): 268-282.

trading from London to New York, Jamaica, and Virginia, and that Walton's demonstration of a decline in port times in the Chesapeake hinges on data from the Scottish trade which grew to be more efficient than the London-based trade.[25] Menard continues: "It was not that ships improved their speed under constant conditions but rather that they shifted their routes and thus encountered different conditions."[26] This was made possible, he believes, by the introduction of more weatherly and maneuverable ships, largely thanks to the adoption of jib sails and the steering wheel—here he relies on Steele's *English Atlantic*, which reinforces the impression that to some extent this literature is caught in a self-referential loop—and this allowed masters to tighten the circle of sailing. He then faults Walton's evidence for being "particularly misleading on the characteristics of ships, the key to his argument that technical improvements were not important in the tobacco trade." Menard is not arguing that Walton is totally wrong, just that he has overly downgraded the ship-technology factor.[27]

Menard, though, does accept Walton's conclusion that ships did not get inherently faster—"[it] was not that ships improved their speed under constant conditions…"—though we will not be leaving it at that, because if it is true, we need to know why, and a fresh examination may bring us closer to knowing how true it really is.

[25] French, "Productivity," 623-624.

[26] Menard in Tracy, ed., 259.

[27] Menard in Tracy, ed., 260-261.

John McCusker, Menard's co-author on the landmark *The Economy of British North America, 1607-1789*,[28] the best compendium of work on the subject up to 1985, entered this debate as early as his 1968 doctoral dissertation, by objecting to Walton's claim that ships did not grow in the century prior to the American Revolution. McCusker has spent the last half-century doing work most historians would avoid but for which we are greatly in his debt, and a major outcome of that is clarity on the issue of tonnage. Since some sort of tonnage figure is frequently all the description of a particular vessel we can find in the official records besides her name, it is more than important to know what the term meant—and it meant several different things at the same time, and those meanings changed over time. They are anything but interchangeable.[29] McCusker faults Walton for assuming that registered tonnage and actual tonnage were the same and for basing his conclusions on that, when in fact, McCusker says, those two measurements were quite different, and ships did indeed grow during this period.[30]

What are we to make of this discussion, standing on the sidelines of quantitative economic history and trying to figure out what it has to tell us about ships? The first caution flag to throw up reminds us to make apples-to-apples comparisons. The apparent contradictions here arise from the fact that different authors treat different trades at

[28] John J. McCusker and Russell R. Menard, *The Economy of British America, 1607-1789* (Chapel Hill: University of North Carolina Press, 1991).

[29] McCusker explains the ins and outs of tonnage in a surprisingly accessible article, "The Tonnage of Ships Engaged in British Colonial Trade During the Eighteenth Century," originally published in *Research in Economic History* 6 (1981): 73–105, and re-published in the collection *Essays in the Economic History of the Atlantic World* (London: Routledge, 1997), 26-45. We will go over this in detail in Chapter Five.

[30] John J. McCusker, *Rum and the American Revolution: The Rum Trade and the Balance of Payments of the Thirteen Continental Colonies* (London: Routledge, 1997), 836-838, note 27. This is a published version, with minor revisions, of McCusker's University of Pittsburgh dissertation.

different times, constrained by the surviving records and the large gaps in those. To treat the entire period under consideration here means to avoid extrapolating scholars' claims outside their more-specific contexts. For example, Steele writes: "Innovations in ship design were minimal between 1675 and 1740 and had little effect on the speed, frequency, or safety of Atlantic crossings."[31] We have two tasks, not one, in evaluating this claim—to decide if Steele was right for the period he specifies, and to decide if his statement applies to the periods before and after without presupposing that it does or does not.

Pointing out that different trades had different productivities at different times is valuable insurance against over-generalization, but it does not upset the general consensus that Atlantic shipping productivity in the period generally improved over time, even as demands on that shipping—from expanding populations, trade volumes, and rising costs—increased. In that sense, what Davis concluded fifty years ago stands.

The debate also leaves room for an investigation of ship technology and an attempt to assess where it fits in this discussion—how it might have been affected by the other productivity factors, and how it might have affected them. There is much more to understanding a technology than those aspects encompassed by a discussion of productivity. We cannot grasp all the reasons people make and use a technology the way they do by limiting ourselves to the questions that frame this discussion and leave no room for those from a cultural, technical, or political perspective. To move beyond that,

[31] Steele, *The English Atlantic*, 17.

we need to look on the shelf where maritime economic history sits next to the history of technology.

Part Three: History of Technology

Frederic C. Lane and Nathan Rosenberg, already mentioned, both weigh in on the productivity discussion, with a focus on technological innovation—what it means, to whom, and when. Lane faults what he considers the traditional definition of technological innovation—which he attributes to Shepherd and Walton, specifically. For Lane, Shepherd and Walton's definition—"an advance in knowledge that allows fewer inputs to produce a given output"—does not take into account a technique already known but not previously utilized, then employed as conditions change in such a way that its employment becomes practical or desirable. So, the adoption of the *fluit*-like economical pure cargo carrier in the Atlantic would not be a technological innovation or change by the Shepherd and Walton definition, but would be to Lane.[32]

Lane criticizes North and Walton for failing to give adequate credit to innovation in their assessments of shipping productivity. After presenting examples of technological discoveries that could not, at the time of their discovery, overcome political or economic barriers to their employment, he suggests that historians should reverse what North and Shepherd and Walton did, by looking first for the technological innovation, and *then* examining the factors hostile to it—insecure seas, high costs—to explain its absence in a

[32] Frederic C. Lane, «Progrès technologique et productivité dans les transports maritimes de la fin du Moyen Age au début des Temps Modernes», *Revue Historique* 251 (1974): 284.

given subsequent time and place—a methodology that goes hand-in-hand with his call for including the adoption of previously known technology in the definition of innovation.[33]

Another way to express Lane's objection to the North-Walton approach is as a failure to distinguish between the discovery of a technology and its diffusion.[34] Technologies are just footnotes of curiosities if they are not adopted, so the study of diffusion is just as central to the history of technology as that of invention. Nathan Rosenberg examines diffusion as much more than the adoption of a technology, though. He argues that what we tend to consider diffusion—the dissemination of an innovation—is actually a process of "'secondary inventions'" in which the original technology is modified, improved, and adapted to better suit those employing it—especially those employing it outside the time and place of its original setting.[35] To Rosenberg, understanding this process is just as important to understanding major inventions—whose importance, he says, is by no means immediately apparent but requires time to realize, as costs come down, technical obstacles to commercial feasibility are overcome, and enough people adopt the invention. So even "Eureka!" moments are more processes than moments, at least in terms of real social benefit.[36]

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[33] Lane, 286-287.

[34] Lane, 284-285. To return to the consensus, though: Lane may have objected to North's and Walton's methods, and to Shepherd and Walton's definition, but in the end he winds up right where Shepherd and Walton did, concluding that the technological potential went unrealized due to the conjuncture of political and economic barriers (Lane, 302).

[35] Nathan Rosenberg, "Factors Affecting the Diffusion of Technology," *Explorations in Economic History* 10:1 (Fall 1972): 7.

[36] Rosenberg, 8.

Rosenberg, too, objects to North's assessment of the role of technological change in shipping productivity. While lauding him for, and agreeing with him on, his argument for the overwhelming importance of organizational and marketing improvements, Rosenberg finds North's "attempt to downgrade the contribution of technological change to the growth in productivity of ocean shipping …more questionable."[37] His specific objection is very close to Lane's. To Rosenberg, the existence of a successful pure cargo ship type by 1600 (the *fluit*) means that, security-related obstacles to its employment in the Atlantic aside, the fact that it was eventually adopted constitutes technological change. He gives North the benefit of the doubt by saying that North's impression of technological change as "scarcely of any significance whatever" was "doubtless unintentional," but that it ultimately serves to obscure the process of diffusion of that technology in the Atlantic.[38]

Adding to our understanding of the productivity debate is secondary to the purpose of discussing this transitional material—transitional from economic to technological history. The primary purpose here is to begin considering the questions technological historians—and their counterparts in related disciplines—ask and how they go about asking them. Lane and Rosenberg show that we can only do that if we engage the economic history, while some of the economic historians, on the other hand, do attempt to accomplish their goals without seriously engaging technological issues. As we

[37] Rosenberg, 30.

[38] Rosenberg, 29-33. The specific work of North's Rosenberg refers to is "Sources of Productivity Change in Ocean Shipping, 1600-1850." Rosenberg separates North from Walton by citing the latter's "Obstacles to Technical Diffusion in Ocean Shipping," which given its title alone is immune from the charge of ignoring diffusion (Rosenberg, 31).

move across the technological history shelf, we move farther from econometrics at one end and closer to technical ship history on the other—but the history of technology section has important questions to grapple with before we get to the narrow focus on the other side.

History, anthropology, archaeology, sociology, and economics all offer access points to the history of technology. Technology itself is an inclusive concept, encompassing tangible objects and complex machines, and everything we now refer to as 'intellectual property'—ideas, plans, processes. The great material-culture scholar Henry Glassie defines it with his usual elegance: "Technology is the means by which the natural literally becomes the cultural, by which the substances won from nature become useful to man."[39] Studying ships fits perfectly well within the parameters of the history of technology. Studying ships of this period takes departure, though, from much of the literature of that specialty, which concerns itself with the technology of the 'industrial' world, with its corporations, its factories, its mass distribution outlets, and its detailed records. The British Atlantic from 1600 to 1800 was not that world. The differences matter. Nor was it, though, the ancient world. The tools and techniques of prehistoric archaeology can and should be, to a large extent, adapted for use in our period, as the historical record—especially that related to technology—is so much more sparse than that of the last two centuries. There *is* a historical record, though, and it is much more complete and accessible than those of the ancient and medieval worlds. So a useful

[39] Glassie, *Folk Housing in Middle Virginia: A Structural Analysis of Historic Artifacts* (Knoxville: University of Tennessee Press, 1975), 122.

history-of-technology approach to this topic can take something from the current sociological and anthropological approaches, but must also rely heavily on the archaeological contribution, and whatever results from all of that must have something to say to economic historians of technology.

Two closely related surveys by Joel Mokyr served as the principal overview of the history of technology for this project.[40] Both introduce and explore central themes of the history of technology from the ancient world to our own. Particularly germane here is Mokyr's observation that "[s]ome technological systems, such as ships, mines, and farms, are complex and interrelated. Dramatic sudden changes are not impossible in such systems, but are less likely because of the need to preserve compatibility with other components."[41] Mokyr contrasts "macroinventions," which are revolutionary, to "microinventions," which are evolutionary.[42] The complex system which is also itself part of a larger complex system—such as the ship—tends to improve over time by microinvention, while remaining compatible with components of the larger surrounding system. Using different terminology, Mokyr is describing the same process Rosenberg

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[40] Joel Mokyr, *Twenty-Five Centuries of Technological Change: An Historical Survey* (London: Taylor & Francis, 2007); and *The Lever of Riches: Technological Creativity and Economic Progress* (Oxford: Oxford University Press, 1990), Kindle Edition.

[41] Mokyr, *The Lever of Riches*, location 4826. Two of the most important of the ancillary complex systems when it comes to ships are the science of navigation and the development of ports and their facilities for servicing ships. We will briefly address both.

[42] Mokyr, *The Lever of Riches*, location 299. "The archgradualist Gilfillan chose as his case study the development of the ship, in which macroinventions were rare. The eighteenth-century ship was significantly different from the early fifteenth-century ship, yet with few exceptions these changes were the result of cumulative microinventions," location 4808. Mokyr is citing S. C. Gilfillan's *Inventing the Ship: A Study of the Inventions Made in Her History Between Floating Log and Rotorship; A Self-Contained but Companion Volume to the Author's "Sociology of invention"* (Chicago: Follett, 1935; reprint MIT Press, 1970). Gilfillan was a curator of ships at Chicago's Museum of Science and Industry. We will turn to his work in the next chapter.

did. Whether we call it diffusion broadly defined, secondary invention, or microinvention, this is where the topic of this study fits into the history of technology.

Naturally enough, the social sciences focus on social groups as creators and users of technology. The introduction and growth of the SCOT (social construction of technology) approach from the 1980s into the present took technology studies away from the technological determinism of the 1930s Chicago school of sociologists and even further away from the Victorian 'heroic inventor' tradition that Gilfillan and the other Chicago scholars were reacting against when they resurrected, according to Christine MacLeod, an 18th-century form of determinism.[43] SCOT is not necessarily squeamish about famous inventors—co-founder Thomas P. Hughes wrote a book about Thomas Edison[44]—but sets out to show how the Edisons of the world, and their inventions, are not theirs alone but that their fame and the credit they are given in popular history stem from their success—both deliberate and fortuitous—in persuading their societies to adopt their versions of technology and not those of their rivals.

We have no Thomas Edisons to consider here. We are in no danger of paying too much attention to inventors, and are not tasked with properly contextualizing their stories, as Hughes was, because we are in no position to know who invented what and when. The social-group emphasis in current technological studies is a natural fit for us. That still

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[43] Wiebe Bijker, Thomas P. Hughes, and Trevor Pinch, eds., *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, Anniversary Edition, (Cambridge, MA: MIT Press, 2012), Kindle Edition; Christine MacLeod, "Concepts of Invention and the Patent Controversy in Victorian Britain," in Robert Fox, ed., *Technological Change: Methods and Themes in the History of Technology* (Amsterdam: Harwood, 1996), 137-153.

[44] See Thomas P. Hughes, "The Evolution of Large Technological Systems," in Bijker et al., eds., *The Social Construction of Technology*, 45-76.

leaves us potentially vulnerable to technological determinism, and does not excuse us from considering agency, or the role of conscious human choice, whether individual or group, in technological decisions. Those concerns will serve as a frame upon which to hang an argument for the theoretical and methodological approaches of this study.

For now, we can turn around and give the economic historians their due. Mokyr's "complex and interrelated system" includes the business organization, marketing techniques, infrastructure, naval developments, and maritime security concerns that North, Walton et al. brought to the fore, and the technology-in-culture context offered by those advocating—or arguing with—a SCOT perspective, without which our consideration of technology would be stripped of its context. Without that context, we would be left with a technical analysis unable to contribute to any of the discussions in our discipline. So when we are examining specific technological developments—whether they seem rather static or more dynamic—we are looking for how those developments mesh with their context—with the "complex and interrelated system" of which they are components. To do that, we will go back to economic history, consider insights from the history of ports and the history of navigation, and add insights from archaeology and material culture to make sense of why we find a change in rig or stasis in size when and where we do.

Part Four: Technical Ship History

Exploring those specific technological developments brings us to the technical history of the ship, and that requires leaving the academic history department. Museum curators, archaeologists, self-taught enthusiasts, and naval architects dominate this literature. The volume of research they have done, on paintings, drawings, models, and plans, is prodigious and has much to offer the academic historian who possesses enough technical understanding to access it.

The most accessible ship histories are those that provide at least some historical context for the subject. Among those, probably the most accessible are Alan McGowan's short illustrated surveys *Tiller and Whipstaff: The Development of the Sailing Ship, 1400-1700* and *The Century Before Steam: The Development of the Sailing Ship 1700-1820*.[45] McGowan was a curator at the National Maritime Museum, Greenwich, and he distills a vast knowledge of the subject into volumes no larger than a child's storybook, providing the reader with an authoritative overview, no technical expertise required.

Much more demanding, though still amply illustrated and attractively presented, are the twelve volumes in *Conway's History of the Ship*, re-published in the U.S. by the Naval Institute Press.[46] The series brought together an international team of top maritime historians and, produced in the 1990s, remains reasonably current. Prominent among the editors were scholars also affiliated with the National Maritime Museum and with the major museums of the Netherlands, though academic historians are represented—Christopher French, Carla Rahn Phillips, and Richard Unger among them. For its breadth and depth, the Conway series is an indispensable reference to historians of the ship, whether academic or not. It is, however, for readers already interested in ships. Non-

[45] Alan McGowan, *Tiller and Whipstaff: The Development of the Sailing Ship, 1400-1700* (London: HMSO, 1981); and *The Century Before Steam,* already cited.

[46] For this project, the essential volume is *The Heyday of Sail: The Merchant Sailing Ship, 1650-1830*, already cited.

maritime historians are not going to pick up one of these volumes and suddenly understand the importance of ships to their fields.

Digesting this literature leads to the conclusion that its most important general limitation is that it is descriptive rather than interpretive. It is about *what* and *when*, rather than *how* and *why*. The best example that comes to mind is from John Harland's *Seamanship in the Age of Sail*, a unique, masterful and comprehensive reference on the operation of the sailing warship. Harland begins his third chapter with a summary of the development of the typical square-rig sail plan from 1580 to 1900. He finishes it in two pages. A typical excerpt reads: "The sail plan has extended upwards, topgallants now being set on all three masts, with royals on fore and main above these. The topsails are proportionately larger, relative to the courses, than was the case earlier."[47] The quote does not leave out the explanation of why these changes occurred. There is none.

What Harland and his fellows have done for us is, of course, a great service. There is no reason to doubt that Harland's summary is accurate. Taking that as given, we have the outline we need to begin asking the *how* and *why* questions. Books like his, and Karl Heinz Marquardt's *Eighteenth Century Rigs and Rigging*, omit no detail of these complex machines, and treat the evolution of those details with overt attention to sources, source problems, debates, and lingering questions.[48] Leafing through these large heavy

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[47] John Harland, *Seamanship in the Age of Sail* (Annapolis, MD: Naval Institute Press, 1984), 36. Harland himself is a good example of the sort of person who wrote much of this literature. A medical doctor by profession, he is a multilingual amateur scholar and frequent contributor to the British journal *The Mariner's Mirror*, published by the Society for Nautical Research, the preeminent organization for research on the technical history of the ship in the English-speaking world.

[48] Karl Heinz Marquardt, *Eighteenth Century Rigs and Rigging*, (London: Conway Maritime Press via ANOVA, 1993).

books with their exacting diagrams and renderings brings home how fortunate we are to know as much as we do about ships that have not sailed the seas for two or three centuries. We know what these people did. We know some things—and not others—about how they built their ships and how those ships worked. We know the ships changed over time and we know what most of those changes were. We know what aspects of them remained largely the same for relatively long periods between more drastic changes. We even know what some of the major benefits and drawbacks of these changes and continuities were. What remains is to explain those in terms of the world to which they belonged. The primary purpose of this technical literature was to explain how ships work. The primary purpose of the kind of study undertaken here is to explain how a society worked by relating that to how its ships worked.

To focus such a study on typical merchant vessels is problematic, since most of the technical literature has found it more convenient and compelling to focus on warships and on merchant ships specifically designed for speed. The convenience is source-related. We have far more contemporary plans, descriptions, inventories, and art related to ships of particular interest to the state and to the public imagination. We still have two warships from the end of our period—*HMS Victory* and *USS Constitution*.

The fascination with warships likely belongs to the broader fascination with war. The fascination with fast ships, on the other hand, is worth some consideration here, as it touches on issues of theory and method. Two of the most authoritative and informative references in this literature—Howard Chapelle's *The Search for Speed Under Sail, 1700-1855* and David MacGregor's *Fast Sailing Ships: Their Design and Construction, 1775-*

1875[49]—are easy to read teleologically and deterministically, though it would be going too far to ascribe such thinking to their authors. They seek to uncover the origins of, and evolution toward, the 19th century "clipper" ships, the fastest wooden square-riggers ever built. They are also nationalist in scope if not intent. Chapelle is interested in American ships, MacGregor in British. The clippers sailed in a contest of maritime pride between the two powers, and these two ship historians start there, with MacGregor's purpose being to prove that British clippers developed independently of, and were not mere imitations of, American ships. He does not argue with Chapelle on this point—in fact, the two collaborated behind the scenes—but Chapelle was clearly interested to highlight American maritime technological know-how leading up to those 1850s speed records.[50]

The nature of such selective works leads their authors to pick and choose from amongst the available evidence to find those examples that suit their purposes. We should not assume that the result represents anything approaching a comprehensive description of the evolution of the sailing ship. It is not that Chapelle and MacGregor are wrong. They were both careful scholars who stuck close to their source material, made clear their awareness of the limitations of that source material, and made no claims they could not support. A "search for speed," though, is a narrow focus. It can lead us to view fast ships

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[49] David R. MacGregor, *Fast Sailing Ships: Their Design and Construction, 1775-1875* (Lymington UK: Nautical Publishing Co., 1973). To give MacGregor his due, he did publish a sequel of sorts to *Fast Sailing Ships* to address the not-so-fast sailing ships: *Merchant Sailing Ships 1775-1815: Their Design and Construction* (Watford UK: Argus Books, 1980). This is a much more modest volume in size, scope, and cost of production than its lavishly printed predecessor—which, given the preferences of both the majority of authors and their readers, seems appropriate.

[50] An agenda influenced by nationalist history clearly motivates Marquardt's *Global Schooner* as well; he takes as his task the disproving of the notion that the type was an American invention, as has been frequently claimed. The title itself is a strong hint. Karl Heinz Marquardt, *The Global Schooner: Origins, Development, Design and Construction, 1695-1845* (Annapolis, MD: Naval Institute Press, 2003).

as apex technology—as the best they could do. Fast, though, is usually *not* best, as far as commercial shipping is concerned. If we understand that, we understand far more about shipping than we ever will from reading any number of books about "fast" ships.

This is also a good place to point out the danger of using concepts like "apex technology" and value-laden terms like "best," "improvement" and "stagnation." As historians, we should be more interested in what contemporaries viewed as "best" or "improvements" than what seem to be so to us. The appearance of the phrase "apex technology" in the introduction to this thesis warrants explanation. There, it was applied to the sailing ship in general, but one cannot support the notion that any given type of sailing ship in the period deserves that appellation.

If the fastest ships are not the apex of the apex, why not? Because speed demands sacrifices of other desirable attributes that, for a cargo vessel, are usually too dear a price to pay for a benefit that may not be as innately desirable as we might at first assume. Fast merchant ships are niche technology. A ship is as much a balance of contradictory imperatives—a complex of compromises—as it is of wood, rope, air and water. Unpacking that complex will be a primary thrust of the study, and will afford us as much of our understanding of ships, their role in this world, and the way technology functions in the real world as anything. This technical history teaches us enough about the machine itself to do that, and the Atlantic World and maritime economic history imparts required contextual information, such as the seasons of certain markets for agricultural products and how those, combined with the distances of the trade routes for those products and the seasonal weather patterns on those routes, dictated the maximum useful speed, and capacity, of the vessels engaged in those trades. We need all of that, and we need to put it together.

Part Five: Archaeology

Historians of the ship study plans and documents. Nautical archaeologists[51] study those as well, but they also study ships—the wrecks of ships, the remains of ships' cargoes, reconstructions of ships, and the performance of replica ships. We need to know what they have learned by doing that, and add that to what the Chapelles and MacGregors have to tell us. Ralph Davis had high hopes for nautical archaeology in the 1960s.[52] The archaeology relevant to our purpose, though, like all historical archaeology, has worked at a couple of disadvantages relative to its venerable parent, prehistoric archaeology, and the historical archaeology of the early modern period has even more competition from the discipline of history than its classical branch.

Prehistoric archaeologists tend to be the sole authorities on their subjects, given the meaning of the word "prehistoric." Historical archaeology, a much younger discipline developed, as we know it, in the 1960s, has had to justify itself to the history departments all along, and this is certainly just as true of the archaeologists who get wet as those who get dusty. Given the need for artificial life support, the archaeology of sunken ships is more expensive, more logistically difficult, and thus so far has been less extensive than

[51] Archaeologists do not necessarily consider "nautical archaeology" and "maritime archaeology" synonymous, but the definitions of those terms vary somewhat by practitioner. The issue is one of scope. The archaeology of ships is a narrower focus than that of an archaeology of all cultural remains having to do with humans and the sea, and an archaeology broader even than that includes the study of social forces at work away from the coast that shaped what went on at the water's edge and beyond, as Jon Adams attempts. See Jonathan Adams, *A Maritime Archaeology of Ships: Innovation and Social Change in Medieval and Early Modern Europe* (Oxford: Oxbow, 2013), 2.

[52] Davis, 74.

terrestrial projects. Be that as it may, in over a half-century of effort, the enterprise has produced a large volume of work, its own journals, and its own graduate programs.

What nautical archaeology critically lacks—for our period in the Atlantic—is the volume of data enjoyed by economic and archive-based maritime historians. For example, in North America and the Caribbean, we find studies of less than twenty archaeological sites containing remains of American-built ships from our period—out of the thousands of vessels of all types that plied our waters in those two hundred years. So an effort to, say, discern an evolutionary pattern in framing techniques—something we could never do *without* archaeology—is seriously hampered by the dearth of evidence. A scattered sampling of random types of vessels built in different places at different times and under different imperatives does not a reliable data set make—as the work on this particular problem freely admits. While a tentative theory of 18th-century framing evolution was proposed by a group of archaeologists in 1995, a 2004 study of the subject concluded that the evidence could not support that theory. The only solution to this problem is more evidence.[53]

Nautical archaeology is also limited by what does not survive from a wooden shipwreck. In simplest layman's terms, all an archaeologist can hope to find—except in

[53] John W. Morris, Gordon P. Watts Jr., and Marianne Franklin, "The Comparative Analysis of 18th-Century Vessel Remains in the Archaeological Record: A Synthesized Theory of Framing Evolution," *Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference 1995,* Society for Historical Archaeology; and Kellie M. VanHorn, "Eighteenth Century Colonial American Merchant Ship Construction" (Master's thesis, Texas A&M University, 2004). VanHorn considered all of the extant North American (and Caribbean) sites and concluded that the evidence could not support a theory of framing evolution such as Morris et al. were claiming, at least for colonial American vessels. Morris et al. presented their findings as no more than preliminary and tentative.

very cold, anaerobic water such as the Baltic or Arctic—is the bottom of the ship.[54] Usually, anything above the turn of the bilge[55] is lost, from long-term exposure to current, storm, decomposition, and marine animals. Only what is buried in an anaerobic environment such as sand or mud will survive. If the entire bottom section—from stem (front) to stern (back) survives, that is exceptional and fortunate. Usually, even the vessel's length has to be estimated.

Archaeologists have to be clever at gleaning as much information as possible from what they have. The ship's rig is gone, but if enough of the bottom survives, they can tell how many masts she had because masts terminate in distinctive structures on top of the keel (backbone) called steps. If the turn of the bilge survives, they can infer much about the shape of the hull, and thus what sort of ship she might have been—fast interceptor or capacious cargo carrier. From framing and fastening patterns and techniques, they can tell how heavily built she was, which may indicate whether or not she was a warship. Fortunately, cannon and shot remain on a wreck site, perhaps obviating the need for that particular piece of guesswork, but that is complicated by the

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[54] Indeed, those cold waters have yielded stunningly intact vessels from our period—many more than the famous *Vasa* from Stockholm harbor. Baltic nautical archaeology is ideal in that sense. See Jonathan Adams and Johan Rönnby, eds., *Interpreting Shipwrecks: Maritime Archaeological Approaches* (Southampton UK: Highfield Press, 2013). Atlantic nautical archaeology can only wish for such material. We are fortunate, though, that the near-Arctic waters of Red Bay, Labrador, yielded the unusually intact remains of a late 16th century Basque whaler, identified as the *San Juan de Pasajes*. The Red Bay wreck has been extensively excavated, studied, and reconstructed since 1978, and four more have since been found. See Robert Grenier, "The basque whaling ship from Red Bay, Labrador: a treasure trove of data on Iberian Atlantic shipbuilding design and techniques in the mid-16th century," in Francisco J.S. Alves, ed., *Proceedings of the International Symposium on the Archaeology of medieval and modern ships of the Iberian-Atlantic Tradition*, Lisbon, 1998 (Lisbon, 2001), 269-293; and Robert Grenier, Mark-André Bernier, and Willis Stevens, *The underwater archaeology of Red Bay: Basque Shipbuilding and Whaling in the 16th century* (5 vols.; Ottawa: Parks Canada, 2007). Because of the volume and longevity of the North Atlantic fisheries, a large number of period wrecks have been, and may still be, found in the waters around Newfoundland and the Maritime Provinces, and most of these have yet to be fully investigated.

[55] The turn of the bilge is where the bottom begins curving into the sides.

fact that merchant ships were frequently armed in our period. Types of woods indicate possible place of origin, and carbon- and tree-ring dating place the vessel in time. Artifacts found on or around the wreck yield more clues about what, and who, were on board. Comparing the remains of an actual ship to what we read in shipbuilding treatises provides a real-world corrective to the notion we would otherwise have little hard evidence to question—that shipbuilding techniques were fairly uniform and standardized. As a supplement to archived plans and drawings, actual wreck remains reveal details of physical construction we would never otherwise see.

Some archaeology, like technical ship history, is much more descriptive than interpretive. The example of the framing-evolution problem explains why this is so, to a large extent—the evidence is so limited. Much archaeology, though, is done for the purpose of recording cultural resources, under a mandate from governments to identify and record such things before they are destroyed by construction projects or nature. This bread-and-butter of the field also contributes to a descriptive bent. We cannot answer important *how* and *why* questions about ships by reading a stack of archaeological site reports and theses any more than we can by reading a stack of *Mariner's Mirror* articles. Neither, though, can we ignore what they have to contribute. They are more evidence to be gathered and incorporated.

In Europe and the UK, theoretical and interpretive archaeology is more prominent, and the kind of study attempted here would more likely be done by an archaeologist than a historian over there. Scandinavians were pioneering practitioners, having excavated, reconstructed, and extensively tested vessels from the Viking age, and they are still well-represented in the literature. The faculty of the Centre for Maritime Archaeology at the University of Southampton in England, headed by Jon Adams, also pop up regularly in the latest theoretical and interpretive publications.[56] This scholarship insists on interpreting the design, construction, and use of ships in the context of broad social forces while bringing to bear the technical expertise few academic historians can approach. Much if not most of what needs to be done on this topic can and should be accomplished by exporting their theory and method.

Part Six: Material Culture

Ships are objects. While not all archaeologists study objects, archaeology—along with anthropology, folklore, sociology, art history, and history—does contribute to the field of material culture studies, an effort to understand objects from a humanistic and/or social-science perspective coalescing, like so many other new intellectual and cultural undertakings, in the restless 1960s. Their internal theoretical and methodological differences aside, pioneers of historical archaeology insisted that archaeologists move beyond description and take the interpretive step, refusing to leave that to their counterparts in the archives.[57] Anthropologists applied theory and method developed for studying ancient and non-literate cultures to modern, literate ones. Folklorists expanded

[56] See, in addition to the Adams volumes already cited: Lucy Blue, Fred Hocker and Anton Englert, eds., *Connected by the Sea: Proceedings of the Tenth International Symposium on Boat and Ship Archaeology, Roskilde 2003* (Oxford: Oxbow, 2006); Julian Whitewright, "The Potential Performance of Ancient Mediterranean Sailing Rigs," *International Journal of Nautical Archaeology* 40:1 (2011): 2-17; and "Technological Continuity and Change: The Lateen Sail in the Medieval Mediterranean," *Al-Masāq* 24:1 (April 2012): 1-19.

[57] For examples, see Mark P. Leone and Parker Potter Jr., eds., *The Recovery of Meaning: Historical Archaeology in the Eastern United States* (Washington, DC: Smithsonian, 1988), particularly the essay by Stanley South; and James Deetz, *In Small Things Forgotten: An Archaeology of Early American Life, Rev. Ed.* (New York: Doubleday, 1996).

their interests from storytelling to other vernacular and artisanal forms of expression—including the making and using of objects for work, pleasure, artistic expression, or some combination of the three. Sociologists asked what mass consumption, materialism, and mass production could tell us about modern societies.[58]

All the colonial-period houses Henry Glassie studied in *Folk Housing in Middle Virginia* provided shelter from the weather, warmth in winter, and some sort of separation of space into more-public and more-private.[59] It was Glassie's take on *how* and *why* he found the similarities and differences in the way the houses performed those functions that made for an innovative, fascinating, and controversial study of how tangible culture reflects intangible culture over time. Glassie refuses to do archival research. Objects and landscapes and the things people show and tell him are his only sources. The archives could have helped him answer the questions he asked about the Virginia houses, and might well have altered his conclusions for the better. Instead of moving in that direction in his later work, he chose to move away from history and work

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[58] For introductions to the wide material-culture field, see: Tara Hamling and Catherine Richardson, eds., *Everyday Objects: Medieval and Early Modern Material Culture and its Meanings* (Farnham UK: Ashgate Press, 2010; Karen Harvey, ed., *History and Material Culture: A Student's Guide to Approaching Alternative Sources* (London: Routledge, 2009); Dan Hicks and Mary C. Beaudry, eds., *The Oxford Handbook of Material Culture Studies* (Oxford: Oxford University Press, 2010); Jack Larkin, *The Reshaping of Everyday Life, 1790-1840* (New York: Harper Collins, 1988); Ann Smart Martin and J. Ritchie Garrison, eds., *Material Culture: The Shape of the Field* (Knoxville: University of Tennessee Press, 1997); Daniel Miller, *Material Culture: Why Some Things Matter* (Chicago: University of Chicago Press, 1998); Gerald L. Pocius, ed., *Living in a Material World: Canadian and American Approaches to Material Culture,* Issue 19 of Social and Economic Papers (St. John's: Institute of Social and Economic Research, Memorial University of Newfoundland, 1991); Robert Blair St. George, ed., *Material Life in America, 1600-1860* (Boston: Northeastern University Press, 1988); Thomas J. Schlereth, *Material Culture Studies in America* (Nashville, TN: AASLH, 1982); Christopher Y. Tilley, *Handbook of Material Culture* (London: Sage Publications, 2006); and Ian Woodward, *Understanding Material Culture* (London: Sage Publications, 2007).

[59] Glassie, *Folk Housing in Middle Virginia,* already cited.

in the present and recent past, where his preferred sources could provide him with more of the evidence he wanted to look at. While he may stand well outside our discipline, his criticisms of what our discipline has typically ignored or downplayed in its devotion to pieces of paper demand our attention. The most important of those criticisms for this project has to do with continuity and change in history. In his collection of essays on *Material Culture*, he writes:

> Despite the revolutions, there is the humble, fulfilling continuity of daily life among family and friends. The great historian EP Thompson told me that here lay folklore's challenge to history, the basis of a powerful critique. History and its commitment to dramatic change, he said, had no graceful way to deal with the continuity that characterizes normal existence as people pass the time, working and eating, loving and fighting, and fading away. History incapable of describing most of life is no history at all.[60]

In *Folk Housing*:

> History's 'decisive question,' wrote Von Martin, 'is whether inertia or change predominates.' The answer that comes clearly from artifactual analysis is that little things change swiftly but big things do not. Continuity more than change is the human condition. If organized around the goal of isolating variable, datable details, rather than around the goal of comprehending patterns of stasis and change, a discipline is doomed to the study of trivia.[61]

Returning to the discussions of "productivity" and "technological change" in Parts Two and Three of this review, we can say that all of that literature agrees that ship technology in our period is not characterized by dramatic change. Rosenberg and Mokyr probably would agree that "little things change swiftly but big things do not," and explain why. Regardless of how significant we decide the changes were that did take place, too strong

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[60] Henry H. Glassie, *Material Culture* (South Bend: Indiana University Press, 1999), 34.

[61] Glassie, *Folk Housing*, 75.

an emphasis on change would distort the reality of history. In a study of a technology that changed only somewhat, and remained the same in important ways for a long time, an apprehension of the proper relationship between continuity and change is important.

Chapter Two: Theory and method: How to Study 17th- and 18th- Century Atlantic Merchant Ship Technology

To explore possible answers to the questions raised by the literature, we need to employ multiple research strategies in analyzing specified concepts while avoiding intellectual and methodological traps and errors waiting to beset any such endeavor, should the scholar be unprepared for them. Since it is generally good practice to consider the hazards of a voyage before undertaking it, we will first discuss those. In addressing potential problems, we will identify and pick up important theoretical and methodological insights and tools to use in the rest of the study. Then we will move to the development of a vessel analysis map and comments on a list of concepts central to the understanding of the subject.

Technological determinism

We have a tendency to see technological imperatives writ small—as in, the need for better windward performance driving a rig change, or the lack of that need driving rig continuity—as primary determinants of technology and its use, assigned disproportionate weight at the expense of broad socioeconomic, cultural, political and environmental influences. When one is focused on technology, it is easy to be overly focused on it, as with any other topic. So we should make sure we understand that issue so we can avoid it.

Don Leggett and Richard Dunn, in their introduction to *Re-inventing the Ship: Science, Technology and the Maritime World, 1800-1918,* tell us that technological determinism is “more pervasive” in maritime studies than the evolutionary model—it reduces technology to a “’factor’ determining the grand narratives of maritime expansion and naval supremacy"—as in steam technology determining the global expansion of Britain, for example. The model asserts "that technology, and its intrinsic characteristics, affect change in an inevitable way that necessitates action in the surrounding world, often reducing the complexities in a group's interaction with technology."[1] They claim that contemporary historians of technology offer this as one reason why their specialty has been marginalized—that it is too often perceived to be deterministic and thus unsophisticated and uninteresting.

We need to unpack this. First, we need to consider reductionism as something other than an absolute negative. Theories and models necessarily oversimplify reality. As Neil Kennedy deftly put it: "It is not the job of theory to reproduce the complexity of the world."[2] "[R]educing the complexities in a group's interaction with technology" is not necessarily a problem. The problem comes when we are wrong—especially, when we subscribe to false cause-and-effect relationships. When we assume that changes in typical Mediterranean merchant ship rigs in the early Middle Ages are best explained by successful experiments to increase windward performance, when a better case can be made that those changes were responses to economic pressures growing out of the collapse of the imperial Roman trading networks, we have fallen prey to the chief danger of technological determinism.[3] We have to explore outside the technology itself—get off

[1] Don Leggett and Richard Dunn, eds., *Re-inventing the Ship: Science, Technology and the Maritime World, 1800-1918* (Farnham UK: Ashgate, 2012), 6.

[2] Kennedy, personal communication, 27 September 2015.

[3] Such indeed seems to be the case. On the historical side, see Richard Unger, *The Ship in the Medieval Economy, 600-1600* (Montreal: McGill-Queen's University Press, 1980), 33-73; on the archaeological side,

the ship and take note of what is going on in her world—to understand why the technology is what it is. Back aboard, it is by experimentation—on the water and in the laboratory—that we can substantially augment what careful readings of surviving logbooks can tell us about how vessels actually perform. Should we discover no performance advantage of one vessel or rig type over another, that pushes us to look for other explanations for the differences.

Another way of expressing the issue is by casting it in terms of the old adage 'form follows function.' Material culture studies have plenty to say about that. Adrian Forty's *Objects of Desire* stands out here. Forty is highly skeptical of individual "agency" and emphasizes other forces at work to shape the technology that gets made and used. He is writing about consumption in our own world of industrial mass-production, but his thoughts apply more broadly. His emphasis is on design as an agent of ideology. He discounts functionalism and technological determinism, and is especially interested in the creation of demand. As for 'form follows function,' Forty expresses surprise that scholars should have given it the credence he thinks they have, which to him "can only be explained by its accordance with the widespread assumption that, despite all evidence to the contrary, individuals are the masters of their own will and destiny."[4]

'Form follows function' is a form of technological determinism, and whether or not we want to go as far as Forty in our assessment of the role of individual agency, we have to take into account the forces he is interested in to understand why technology

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see Whitewright, "Technological Continuity and Change: The Lateen Sail in the Medieval Mediterranean," 1-19 (particularly 14).

[4] Forty, *Objects of Desire: Design and Society since 1750* (London: Thames & Hudson, 1986), 242.

really gets created and used as it does. A different adage may well apply to merchant ships as much as it does to consumer products—form follows fashion, a theme to which we will return.[5]

The second danger here is of course the old nemesis, teleology. Any way of thinking in which the "intrinsic characteristics" of technology "affect change in an inevitable way" is teleological thinking. It is so easy to discern deliberate, logical, linear development, whether or not it is really there. What makes it more difficult to avoid is that there *is* such a thing as 'progress'—in that there is such a thing as increasing human knowledge based on cumulative experience. We know how lift works—how the slot effect works between adjacent sails to produce a Venturi effect in air pressure. They did not know that. We can make a strong case that that represents 'progress.' What we must not do is ascribe meaning, or historical influence, to the possession or lack thereof of such knowledge based on assumption, without solid evidence.

Julian Whitewright, writing about rig development, argues that traditional explanations of that technology assume technological determinism—specifically, that "observable change must have occurred for an explicable, logical reason—generally the 'need' for better windward performance." The logical, unilinear process conceived by the deterministic model "dictates that 'older, simpler' technologies must become redundant once 'newer, better' ones are developed." Whitewright, with other contemporary theoretical archaeologists and anthropologists, sets out to refute such a model.[6]

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[5] We will discuss the role of fashion in ship design and construction.

[6] Whitewright, "Technological Continuity and Change: The Lateen Sail in the Medieval Mediterranean," 1.

The historian of technology Thomas P. Hughes' influential *Networks of Power* (1983) "avoids technological determinism by showing how factors from all the areas of social or historical analysis have to coincide at the same time for a certain technology to develop in a certain way."[7] That is precisely how to understand the viability niche of a merchant ship, whether that niche lasts a decade or an age.

The foregoing, then, helps us know what not to think and what not to do. We still need a way of thinking and talking about contextualized technological continuity and change, though, so that we know what to think and what to do. Using concepts borrowed from evolution by natural selection is useful, but requires justification, as the practice has been, and still is, a matter of strong debate in archaeology and the history of technology.

Because natural evolution and technological developments work by different mechanisms—natural selection by random mutation in the former case and human conscious choice in the latter—Joel Mokyr, a proponent of evolutionary thinking in technological history, cautions that we must employ such thinking "with great care." We are, Mokyr says, "between…a world of pure independence and a 'necessity is the mother of invention' type of world.[8]

Through analogy, though, we can relate those distinct mechanisms of change. "For economic and technical evolution the mechanism analogous to genetic mutation is

[7] Hughes, "The Evolution of Large Technological Systems," in Bijker et al., locations 1486-2158.

[8] Mokyr in Fox, ed., *Technological Change*, 65-66. The latter "type of world" is a technologically deterministic world. We will deal with that elsewhere.

innovation."[9] Conscious choice, or "directed variation" as Mokyr calls it,[10] drives innovation. Even when accident and unintended consequences create pressure to innovate, it is conscious choice—constrained though it may be—that causes it to happen.

Because the mechanism for change is different, we cannot use the evolution analogy as an *explanation* for how change works in technological history. Conscious decision can prolong or end the "life" of a technology no matter how well- or ill-suited that technology is to current operating conditions, whereas in nature, conditions would select for its survival or extinction. Some contemporary historians of maritime technology object to evolutionary language because it "weaves technological change into the fabric of maritime history without reflexive consideration, by shrouding the agency of actors and the cultural specificity of technical decision making."[11] The objection is valid insofar as it serves as a caution as to how *not* to use the analogy. It is also worth acknowledging here that a debate over evolution as a model[12] for social and technological

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[9] Henk van den Belt and Arie Rip, "The Nelson-Winter-Dosi Model and Synthetic Dye Chemistry," in Bijker et al., 131. Mokyr distinguishes between "innovation" and "invention," following a "Schumpeterian distinction between invention and implementation-diffusion ('innovation')." In the history of technology, understanding that distinction is, in general, important; for one thing, it helps us to put invention in its place, prompting us to think beyond the inventor(s) to the conditions and processes that foster the acceptance or rejection of the invention, and the degree of either (Mokyr in Fox, ed., *Technological Change*, 73).

[10] Mokyr in Fox, ed., *Technological Change*, 65. "Directed variation" will never be as random as we believe natural mutation to be," says Mokyr, "because those manipulating technology are more likely to try innovations they think are most likely to prove useful."

[11] Leggett and Dunn, eds., *Re-inventing the Ship*, 4-6. The example they cite of the evolutionary model is Gilfillan's *Inventing the Ship*, after which they have taken the title for their own volume.

[12] There seems to be no clear distinction between "analogy" and "model" when it comes to the use of evolutionary concepts in thinking about the history of technology. "Analogy," though, is more specific, as "model" means different things in different fields, and it suggests something with explanatory power beyond analogy—something like Gilfillan's concept of it, already rejected.

change carries on in theoretical archaeology—a branch of that discipline more prominent in the United Kingdom and Europe than in the United States. A major objection to evolutionary archaeological models is that they do not properly account for *agency:* "…the frequent use of [evolutionary] terms both indicates and instigates thinking about developments of ship types as autonomous rather than being the function of human decisions regarding continuity or adaptations."[13] This is also the case for Leggett's and Dunn's objection for technological history. At least one prominent theoretical archaeologist, though, finds "agency" problematic too,[14] and a proponent of agency within archaeology, John Robb, qualifies his endorsement of the concept. Individuals do act with intention, yes, but "agency is not necessarily about individuals" and "quite often an individual's intentionality plays a minor part in social action and its consequences." Robb assigns individual intentionality to the "'agency of why,'" an agency from the "actor's point of view," and contrasts that to the "'agency of how,'" "the reproduction of social relations in fields of action." Because the "'agency of how'" guides and limits the "'agency of why,'' "we should resist the temptation to view intentional, motivated action as the spark that drives social life and social change."[15] Robb seems to be leaving room

[13] Thijs Maarleveld, "Type or technique. Some thoughts on boat and ship finds as indicative of cultural traditions," *International Journal of Nautical Archaeology* 24:1 (1995): 4. Maarleveld does not explicitly reject all evolutionary concepts as applied to ship archaeology. His purpose is to argue against improper use of types (see note 26).

[14] Kristian Kristiansen, "Genes versus agents. A discussion of the widening theoretical gap in archaeology," *Archaeological Dialogues* 11:2 (December 2004): 77–99.

[15] John Robb, "Agency: A Personal View," *Archaeological Dialogues* 11:2 (December 2004): 107.

for evolutionary concepts by acknowledging that conscious choice is not the primary directive force in "social life and social change."

We also should consider the real world in which "conscious choice" has to function. In their general rejection of "perfect rationality" in neoclassical economics, neo-Schumpeterian economists include technological change. An evolutionary analogy can emphasize the "limited powers of perception and choice of human decision-makers."[16] There is no need to deny what we tend to call "human agency" here, but we must acknowledge its limitations. A discussion of the law of unintended consequences will add to that presently.

British theoretical archaeologist Stephen Shennan refers to academic history as "a rather atheoretical discipline." This is not intended to be dismissive or to suggest that the agendas of historians and social scientists are incompatible. In fact, Trevor Pinch is right to pitch his "radical" social constructivist agenda, which as far as he is concerned requires historians and sociologists of technology to collaborate.[17] While Shennan is devoted to social science theory, he seems to leave room for an employment of evolutionary concepts as used here. We inherit cultural traditions. Multiple "processes act on existing and novel variation," and that affects what future generations inherit. "Some

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[16] Van den Belt and Rip, "The Nelson-Winter-Dosi Model and Synthetic Dye Chemistry," in Bijker et al., 130-132. The close use of "model" and "analogy" in this quote would seem to support this word choice—see note 12. Stressing the limitations of conscious choice in an evolutionary-analogy approach to the history of technology is not the same as the "constrained choice" or "soft determinism" ascribed by Bert Hall to Lynn White; Hall does not use evolutionary language to describe White's approach in *Medieval Technology and Social Change*. See Bert Hall, "Lynn White's *Medieval Technology and Social Change After Thirty Years*," in Fox, ed., *Technological Change*, 96.

[17] Stephen Shennan, "Culture, society and evolutionary theory," *Archaeological Dialogues* 11:2 (December 2004): 113; Trevor Pinch, "The Social Construction of Technology: A Review," in Fox, ed., *Technological Change*, 22, note 24.

may wish to see that as a metaphor," Shennan writes. "That is fine by me. The role of analogy and metaphor in scientific reasoning is well established….[18]

Even if we restrict our employment of evolution to analogy, that requires us to think of "operating conditions" broadly—which we should be doing anyway. A ship might be in many ways ill-suited for some of its operating conditions. We find expensive, heavily armed English merchantmen in the Atlantic service in the late 17th and early 18th centuries, as opposed to cheaper, more efficient single-purpose carriers built to the Dutch *fluit* concept. Why?

The evolutionary analogue to the *fluit* concept is *symmorphosis* in organisms, by which "systems are built to minimally meet functional needs, without excess that is expensive to maintain." The environment, though, may exert pressure for what, in normal circumstances, would seem to be overbuilt. Bones, for example, "are overbuilt for most circumstances," because at times they may be highly stressed and the consequences of failure are dire. "These safety factors are under strong selection, because the extremes of function are frequently life and death situations."[19]

Symmorphosis is indeed what we expect to find in the technological history of the merchant ship when we are coming at it from the perspective of economics—but the "environment" in this case includes much more than "economics"—it also encompasses the political, social, cultural, and natural environments in which the vessel operates, and

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[18] Shennan, 109.

[19] Steve Kinsey, personal e-mail, 2 Sept 2015. Steve—professor of biology and marine biology at the University of North Carolina Wilmington—volunteered stimulating and instructive advice on, and discussion of, "real" evolution by natural selection.

such operating conditions offer us explanations for why we do *not* find something analogous to symmorphosis in late 17^{th}- and early 18^{th}-century transatlantic British merchantmen. The protectionism of the Navigation Acts, the British government's subsidies of the defensible ships British builders were accustomed to building, and the presence of pirates and privateers in the Atlantic and Caribbean acted together to trump any pressure toward adopting the Dutch example in those waters at that time.[20]

Steve Kinsey's example of an exception to symmorphosis—the strength of bones—is just as apt to our subject as the concept of symmorphosis itself. We are accustomed by now to attribute what resistance to change there was in design and construction techniques in the early modern period to the prime reality that sending people to sea in ships was inherently dangerous, that the basic ingredients of safe ships had been worked out over a long period of time, and that with no way to predict all the possible outcomes of significant changes, such changes were assumed to carry significant—perhaps unacceptable—risks. Beyond that, we could consider what owners and builders were willing to spend to reach a certain comfort level with the projected strength and longevity of their vessels—are their ships "overbuilt systems"?

[20] Walton, "Obstacles to technical diffusion in ocean shipping, 1675-1775," 127. England's experience in the corsair-ridden waters of the Mediterranean largely accounts for the development of its defensible merchant ship of that period. Davis writes that the stifling of foreign competition effected by the Navigation Acts removed any motivation to experiment with cheaper *fluit*-like cargo carriers in the transatlantic trades—see p. 57 (2012 edition). However, the limitations of the Acts' effectiveness kept the door open for Britain's rivals, and thus to impetus for some effort to compete with those rivals. In other words, the Acts were not effective enough to allow British merchant ship technology to stand still. If they had been, some of the changes we will discuss in later chapters would be difficult to explain. Davis's claim, then, must not be taken too far.

We could base another objection to the evolution analogy on the law of unintended consequences. All individual and group human actions have unintended consequences. In nature, we can observe consequences of natural changes incidental to the condition or set of conditions that brought about those changes. Something analogous should apply to how the law of unintended consequences affects technology. If people make decisions to change or not to change a technology in response to a certain condition, and then realize that these decisions are having a negative effect on some other aspect of operation, then they will respond to that, either by making another change in response, or by continuing in the same direction, having decided that the benefits to that outweigh the costs, despite the unanticipated negative consequences. In a study of the history of residential stoves in the United States, Ruth Cowan examines the "social networks" in which her stove consumers were "embedded," and shows how social groups, "acting in what they perceive to be their own best interests, can, because they are embedded in a complex network, produce effects that may be quite different, perhaps even diametrically opposed, to what they intended."[21] While the mechanism that determines change is different in nature than in technology, the two processes are still analogous.

To that we should add that the umbrella term "people" ignores the reality of different interest groups acting on the technology with their own agendas, which may be more or less complementary. For our late 17th-century Atlantic merchantman, those would include the Crown, factions within Parliament, London merchants, American

[21] Cowan, "The Consumption Junction: A Proposal for Research Strategies in the Sociology of Technology," in Bijker et al., *The Social Construction of Technological Systems*, 271.

merchants, mariners, shipwrights, pirates, and foreign competitors, both commercial and political-military. That too is analogous to the myriad of forces acting upon the subject in nature—forces which, as in human affairs, rarely act in concert.

Conflicting selection happens in "systems that perform more than one function," when a change in one of those functions interferes with the function of the other. That does not necessarily happen, though. One "function may drive the overall selection of the system," but the other function may be altered in a way that benefits the system as well.[22]

If we consider the case in which one pressure is driving continuity and change more than any others, then we have an analogy for considering the ordering of priorities in the design and construction of merchant ships. Is capacity preeminent? Is it seaworthiness? Does one of those conveniently follow the other, as nutrient delivery follows oxygen delivery demand? Do both clash with speed in a conflicting selection scenario?

Since mutation is random, there can be no guarantee that a mutation will happen, regardless of the strength of the selective pressures. If a given mutation does not happen, the organism might die out. While conscious-choice innovations are more likely to be useful more times than they are not, though, how many times do conscious-choice changes in technology—or decisions *not* to change that technology—prove unfortunate? Here we can at least recognize a further analogy, between a mutation scenario in nature that does not enhance—or militates against—a subject organism's ability to survive in its environment, and a technology about which decisions are made that militate against the

[22] Kinsey, personal e-mail, 2 Sept 2015.

technology's success. This of course relates back to the key concept that conscious choice options are limited.

In both the natural and technological processes, the subject—the organism or the technology—either remains the same or changes in response to environmental conditions. In both processes, the subject does not change itself—it is changed by forces acting upon it. In both processes, we observe adaptability at work. In both processes, we observe vestigial traits.[23] If environmental conditions and/or mutation do not select strongly enough against the continuation of a trait, it may well exist for a long time past its usefulness—as is perhaps the case to some extent with 17th-century stern castles. In both processes, we observe the variety of possible successful responses to conditions, existing and competing at the same time. In both processes, we observe that changes can produce either viable or non-viable subjects in a given set of conditions. In nature, these are mutations or sudden drastic environmental impacts on the subject population. In technology, they are accidents and experiments leading to innovation.

We can add further richness to the analogy by considering "the independent evolution of the same trait," or *convergent evolution*—

> This is very common, especially when there is a strong selective pressure. For example bioluminescence has evolved independently dozens of times, and it is under strong selection in certain environments because of the advantages it provides….[24]

[23] Both of these similarities are mentioned by Gilfillan early in his discussion and attributed to H.H. Brindley, a "nautical authority." Gilfillan, *The Sociology of Invention*, 14, and note 7, 159.

[24] Kinsey, personal e-mail, 2 Sept 2015.

In the history of ship technology, convergent evolution is an elegant analogy to the development of the two-masted fore-and-aft rig, a prevalent version of which we call the schooner. Almost a century ago, Yale professor E.P. Morris wrote a tour-de-force of investigation into the possible origins of such vessels.[25] The study strongly suggested that such a satisfactory solution to the challenges of near-shore sailing at relatively low cost in money and manpower developed independently and simultaneously. Analogizing such development as convergent evolution also helps inoculate against jingoistic and culturally chauvinistic interpretations.[26]

Finally, the analogy reminds us that both organisms and technologies function in the same environment—they function in what we call "nature." Ships must function in a human-created economy, culture, and political arena, but they must also function at the volatile boundary layer of atmosphere and ocean. They exploit variations in air pressure for motive energy, or convert oxygen and organic matter for it. They are made of materials that must be extracted from nature and that are subject to the natural processes of physical stress, fungal invasion, corrosion, and UV degradation.

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[25] E.P. Morris, *The Fore-And-Aft Rig in America* (New Haven, CT: Yale University Press, 1927).

[26] Recall Marquardt's *The Global Schooner*, one of whose chief purposes was to debunk an old American claim to have "invented" the schooner and that the popular vessel was thus distinctly American. "Convergent evolution," as described and analogized here, is close to what Daniel Zwick calls "'evolutionary convergence'" in shipbuilding, "in which two unrelated conceptual lineages (two distinctive shipbuilding traditions)" begin "to display analogous features … due to extra-somatic pressures"; though his example, Henry V's ambitious warship *Grâce Dieu* of 1418, inspired by great Genoese mercenary carracks used by the French, is something different. It involved two distinct building techniques—Northern European clinker and Southern European carvel—being combined, in a "freak" example that never saw service and was never duplicated, to which Zwick thus refers as an "evolutionary *cul-de-sac*." See Daniel Zwick, "Conceptual Evolution in Ancient Shipbuilding: An Attempt to Reinvigorate a Shunned Theoretical Framework," in Jonathan Adams and Johann Rönnby, eds., *Interpreting Shipwrecks: Maritime Archaeological Approaches* (Southampton UK: Highfield Press, 2013), 51-52.

The evolutionary analogy has something more compelling to offer, which is that it can help us avoid teleological thinking. We are hard-wired to look for cause-and-effect relationships and to see patterns—whether or not they are actually there. A pertinent example is the "type fallacy" in the archaeological interpretation of shipbuilding, in which vessels are grouped into "types" that ultimately prove arbitrary, and obscure the discernment of true typologies.[27] The structure of our language makes it difficult to avoid speaking teleologically even if we wish to avoid it. The "temptation to think in terms of … 'standard type[s]'" of ships as representing technological equilibrium and of "imperfect approximations" of those types as "hybrid," or intermediate stages in a linear process is a Platonic sort of thinking also closely tied to our predilection for finding patterns and order. Zwick is right to point out that the "underlying conceptual problem is deeply embedded within the rationale of evolutionary theory—without being caused by it, as has been often unjustly implied."[28]

Careful use of that theory can help us avoid, rather than fall into, that underlying, almost sub-conscious assumption of linear "progress," of a "natural" process of cause-and-effect "improvements" by which Thing B is "better than" Thing A, its "primitive" precursor—the kind of subconscious assumption that could make us forget to question whether an 18th-century merchantman's rig is really "better" than that of its 17th-century counterpart—and thus that 18th-century people were better at solving their water-transport problems than 17th-century people, which is far more important. That very

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[27] See Zwick, in Adams and Rönnby, eds., *Interpreting Shipwrecks*, 60-61.

[28] Zwick, in Adams and Rönnby, eds., *Interpreting Shipwrecks*, 49.

question has been the subject of lively discussion with replica ship masters and nautical archaeologists in this study. It is by no means settled.

The key fallacy to avoid is the assumption—conscious or not—that evolution is linear. Or rather, that evolution is *solely* linear. Evolution *is* linear, and simultaneously looping and branching and networked. If we remember that evolution in nature is far more complex than anything we do as humans, and think about the ways in which that is so, then we cannot blame any simplistic thinking on an evolutionary analogy. This is not making things more complex for its own sake. That impedes the effective use of theory. Using evolution as an effective analogy, though, requires appreciating its complexity. We can satisfy Jon Adams, who rightly insists that we look for the socioeconomic, political, and environmental pressures acting on continuity and change in ship technology—"operating conditions."[29]

The analogy can also help us understand extinction. Mokyr points out the difference between biological and technological extinction. In the former, once DNA is lost, it is irrecoverable.[30] In technology, the knowledge of the technology can be preserved, in memory or books, for example, even if the technology falls out of use. "Yet," he adds, "when the knowledge is to a large extent tacit or deliberately kept secret, it may become impossible to re-create a technology."[31] This is what makes the extinction of early modern merchant sailing ships so challenging to us. So much of the how-to

[29] Adams, *A Maritime Archaeology of Ships*.

[30] It is possible, though, for the mutation to re-occur—and for inventions to be simultaneous.

[31] Mokyr in Fox, ed., *Technological Change*, 75, note 27.

information *was* tacit, given the nature of artisanal craft, and *was* kept secret, in the master-apprentice system, that when we attempt to replicate these machines, we are left to guess to some extent as to their design, construction and operation. We are left to pin our future hopes on experimental archaeology, learning through trial-and-error what no one alive can teach us, by operating best-guess replicas, and on the 'reverse naval architecture' of shipwreck archaeologists when we are lucky enough to find remains intact enough to permit the recapture of the original design method. We will explore all of that.

Toward an analysis of the original evidence: two analysis maps, with comments

Finally, as we turn from theoretical and methodological approaches to applying those approaches to the evidence, we will consider a generic analysis map inter-relating the broadest useful selection of contextual forces, and a narrower one restricted to the technological considerations whose relationships to each other we must understand, along with explanatory comments on each.

General vessel analysis map

This analysis map (following page) avoids linear thinking. The ingredients do not interrelate in a linear fashion but in a network spread out in all directions like one of David Hancock's Atlantic business networks.

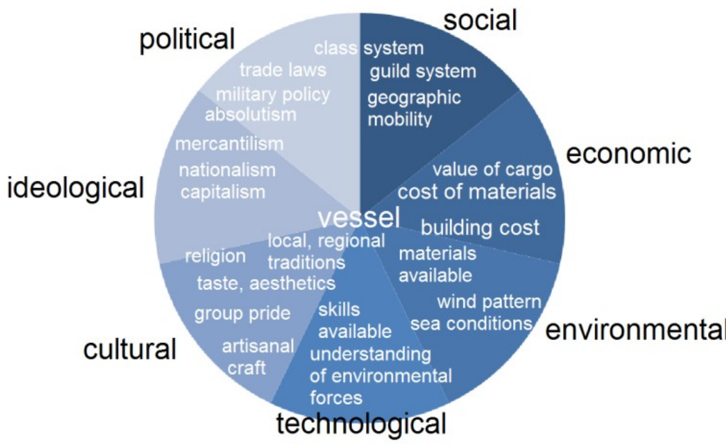

Figure 1 General vessel analysis map.[32]

The closer a label is to another wedge, the closer it is conceived to be related to what is in the adjacent wedge. Labels crossing lines are labels bridging categories. A circular scheme presents several choices as to where to start and end. Following are explicatory comments on selected ingredients in the analysis map.

Political and *Ideological*

trade laws—Trade laws attempt to dictate where and with whom subjects to those laws may trade, and what taxes and duties they will pay in doing so. Just as so many modern yachts have been designed as racing-rule beaters, taking advantage of loopholes in the design rules to gain an advantage, the way taxes and duties on ships were assessed

[32] This is a revised and expanded version of analysis map developed at an earlier stage of this project. The analysis map is now more in line with the conceptual frameworks of archaeology, and with current trends in our own discipline. It was Fred Hocker's suggestion to separate ideological and technological aspects out of culture, though as aspects of culture, they remain adjacent to it here.

at a given place at a given time could and did give a certain type of design a major advantage over another. The most famous example was the 'Sound' toll for northern European vessels passing between Denmark and Sweden. In the 17th century, this was assessed based on deck area, so the extreme tumblehome[33] that gave the *fluyt* great hull capacity relative to her deck space gave her a real advantage in this area. By 1700, when that toll structure changed, this advantage evaporated.[34] Thus it is imperative to look up what taxes and duties were imposed on any ship, because this might explain an advantage or disadvantage that technological factors—or other economic factors—will not.

Trade laws in this period emphasized protectionism rather than free trade, designed as they were to further an imperial agenda whose economic policy we generally call *mercantilism*. Protectionism alters market conditions such that what would otherwise be competitive or not might be the opposite. Protectionism also is directly related to smuggling too, so any vessels specially suited to illicit trades are to that extent the creatures of protectionism as well. Depending on the situation, then, a vessel could be more or less fast or capacious or defensible depending on the status of her trade within the mercantilist sphere. The conflict between the imperial bureaucracy and smuggling merchants is an aspect of the conflict between mercantilism and free-market *capitalism*. The latter part of our period is the age of Adam Smith.

military policy— We are looking at a period with more war than peace, and while we would expect to find more emphasis on defensive—or, in the case of a privateer,

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[33] Tumblehome is the re-curve of the sides inward as they rise, so that the ship is much narrower at deck level than at the waterline.

[34] See Hoving in Gardiner, ed., *The Heyday of Sail*, 47-51.

offensive—capability in periods of warfare and less during peacetime, it is worth keeping in mind that the supply of ships is not terribly short-term elastic, given the capital-, labor-, and time-intensive nature of shipbuilding.[35] Something worth investigating is what changes in armament and associated defensive capability we would expect to find on a given ship at a given time, given the state of warfare in which she was operating.[36]

War in our period also leads to the capture of prizes—usually, thousands of them. So the presence of a vessel in the hands of a certain owner, flying a certain flag, engaged in a certain trade, may well be a direct result of a prize action. Davis wrote that the English shipbuilding industry waited decades to build ships inspired by the Dutch way, simply because the English had captured so many Dutch merchantmen in the series of Anglo-Dutch Wars in the mid-17th century.[37]

Cultural

There is more than one means to an end, as previously noted. We see a constant interplay—and some tension—in ship design and construction between *traditions* and pressures to innovate, conservatism and dynamism, in the *artisanal craft* that was ship creation in the early modern period.[38] *Locales and regions* had their traditions and

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[35] See Jari Ojala, "Productivity and Technological Change in Eighteenth- and Nineteenth- Century Sea Transport: A Case Study of Sailing Ship Efficiency in Kokkola, Finland, 1721-1913," *International Journal of Maritime History* 9:1 (1996-1997), 93-123.

[36] The data compiled by Shepherd and Walton clearly indicate that merchantmen were, as a rule, more heavily armed during wartime—see pp. 76 and 196-197. French's research adds that, even so, the general trend was for reduced armament after the Seven Years War in both peacetime and wartime. See French, "Shipping Productivity," 631.

[37] Davis (2012 ed.), 47.

[38] On the dialectic of tradition and innovation in vernacular craft, see David A. Taylor, *Boat Building in Winterton, Trinity Bay, Newfoundland* (Ottawa: National Museums of Canada (Canadian Museum of

preferences, but individual designer-builders had plenty of latitude,[39] and no one political power could hope to maintain exclusive control over any maritime technology, given the access to transport of the men in the trade[40] and the nature of ships as technology that regularly showed up in foreign ports. Much ink has flowed in writing the history of the ship trying to trace the origin and progress of a certain technology from one group of people to another, such as whether the development of the fore-and-aft rig in Bermuda was due to direct Dutch influence. To make things more difficult, it is always quite plausible that the same technology developed in two or more different places at the same time independently of each other, such as French and Native American dugouts.[41]

We do see examples where a certain group does not adopt a certain technology even though it is effective technology, they know about it, and they are capable of executing it. Cultural factors—*group pride*, tradition, vested interests, *tastes and aesthetics***,** including fashion, or just lack of enthusiasm for the perceived benefits—can lie behind decisions that directly affect ship technology, just as much as the political and security factors emphasized by Lane.

Civilization, Mercury Series, Canadian Centre for Folk Culture Studies Paper No. 41)), 1982. Taylor's study is contemporary, but the basic character of his subject matter has not changed significantly over the centuries, even as tools and contextual factors have.

[39] As the archaeological record, limited though it is, strongly suggests.

[40] Davis includes a quote from the Thames shipbuilders' lobby connecting the increase in British American shipbuilding to the emigration of English shipwrights to America—see p. 64 (2012 edition). Ships' carpenters and land-based shipwrights possessed an overlapping skill set and the former were sometimes hired right out of the yards. See Robert Barker, *The Unfortunate Shipwright: Or Cruel Captain* (London, 1795), Google Books facsimile.

[41] Joseph T. Butler, ed., *The European Origins of the Small Watercraft of the United States and Canada* (Thibodeaux, LA: Center for Traditional Louisiana Boatbuilding and the Museum Small Craft Association, 1992).

Technological

skills available—The relationship between available skills and what technology those skills could produce is a promising area for investigation, because different methods could produce similar products. Sometimes the historical and archaeological record tells us more about the skills available to build a certain craft, and sometimes it tells us more about the result, and we have to investigate the design and construction to infer the skill set, as with 'reverse naval architecture,' which we will discuss at length.

understanding of environmental forces—Early modern sailors knew a great deal about how sails worked, even if they did not know why they worked as they did. Much of what we know about hydrodynamics, they knew as well, though of course they could neither demonstrate the principles nor describe them as we can. Understanding their understanding of the forces acting on the ship is at the core of what nautical archaeologists have been working on. If we can identify ways in which their ships worked in accord with these forces, and ways in which they did not, that should help us advance our understanding of what they did or did not understand, though we must take care to distinguish between what they did not understand, and what they discounted, or sacrificed to other priorities.

Environmental

materials available—Continuity is particularly strong here, at least in general. Variability in the specifics is an instructive subject in itself. Ships were made of wood lumber and pegs, iron bolts and nails, hemp rope, flax and cotton sails, and pine products for preserving and waterproofing. We should pay attention to what wood was available where and when, given environmental and political vagaries, and how builders and owners evaluated the relative properties of different woods, employing them in construction accordingly. Trade laws and trade patterns for materials used in ship construction figure prominently in economic policy.

wind pattern—In maritime history courses, we teach the basic wind patterns, and the currents they drive, of the Atlantic basin to undergraduates on the first day of class. Sailing ships can only proceed to windward at wide angles to the wind direction. Sailing upwind is slow, inefficient, and uncomfortable, as the ship heels (leans over) much more, and heads into oncoming seas, which she takes on her bow and over her foredeck, making for a rough, wet ride. The ability to maneuver to windward to avoid danger is important, but steady winds blowing more or less in the direction one wants to go are the keys to voyaging. The circuitous route by which ships navigated the Atlantic basin was dictated by that principle. The ability to take best advantage of winds from abaft the beam (aft of amidships) was as important as any consideration in sail plan for ocean-going ships. Coastwise vessels needed more maneuverability, were more likely to encounter headwinds close to dangerous shores, and did not sail long downwind legs without course alteration to the extent ocean-crossing ships did. Assuming that is why they tended to have fore-and-aft rigs in this period, though, is a potential trap. Those rigs require fewer hands to work, and coastal vessels were smaller. Labor and size considerations are important.

sea conditions—The North Atlantic in winter is brutal. A succession of violent storms kicks up waves sometimes as high as these ships were long, and drives freezing precipitation into the rigging and the faces of the crew. It would be incorrect to say that these ships were designed and built to survive Caribbean and Atlantic hurricanes, as that was not feasible given the technology available. These ships were not likely to survive envelopment by a hurricane, and tried to avoid them. That any of them did survive—and plenty did—is a testament to their seaworthiness. For Atlantic service, ships had to be designed, built, and maintained to a standard not at all necessary or even suitable for riverine or near-shore work, or even service in the Mediterranean. The *teredo navalis* shipworm (actually a mollusk) presented another constant threat to hulls spending time in the warmer southern Atlantic and Caribbean.

Economic

value of cargo—Generally, low-value cargoes are bulk cargoes. Since the cargo is not worth much per unit—whatever that unit is—merchants need to ship a lot of it to make a decent profit on the voyage. Depending on other factors, though—distance of voyage, difficulty of voyage, costs of voyage—we might find a very large ship full of high-value cargo—such as an East Indiaman. Passengers are usually the highest-value cargoes, and passengers want to make the fastest possible voyages while remaining relatively comfortable, so vessels designed especially for carrying passengers (e.g. packets) may be quite technologically distinct—and emphasize speed.[42] The same applies to advice vessels—those primarily employed in carrying express mail and/or important documents and messages. These, however, are frequently government or military vessels.

[42] The passenger service is where we see the first commercially viable steamships.

cost of materials—Cost of materials is important, but cost of shipping those materials is also important. So, while timber was certainly far cheaper in America than in Britain, it was too expensive to ship bulk timber across the Atlantic in quantities sufficient to build ships in English yards—it was low-value, high-stowage-factor cargo. So the ships were built in America—and they could then carry timber with them across the Atlantic. For vessels to be used locally or regionally, we expect to find local materials used in their construction.

building cost—Shipbuilding in New England competed with its Thames Estuary counterpart by 1700. That was entirely due to the difference in building cost. Despite the loud protests of British politicians, that competition remained and grew until the Revolution. Who was building what and where at what time has much to do with cost of skilled shipwrightry as well as materials.

Social

In merchant ship technology, an instructive issue arises when we consider the trade interests of artisanal shipwrights compared to those in the naval establishment who had political connections, and who were advocating for the new science of 'naval architecture' for all ships, as an improvement over the predominance of artisanal shipwrightry, which, like all *guild-system* crafts rooted in the Middle Ages, kept its trade secrets secret to the extent that it could, as the skills those artisans possessed were their livelihood.

geographic mobility—The moving-around of people and goods made this world. People left an old place for a new place. Sometimes they went back to the old place, and sometimes they made their new homes permanent. They brought skills and attitudes with them from the old place, attempted to preserve them in the new place, and were forced to adapt them if they were to make it in the new place. We should learn much from exploring how ships changed, or did not, as ship technology crossed the Atlantic and European traditions met each other and met the traditions of New World natives and of Africans. Here, though, we have to remember convergent evolution. A similar trait in a canoe in Senegal to one in France does not prove a connection. Those traits could well have evolved independently.

Next, we discuss a secondary analysis map specific to vessel technology:

Specific vessel technology analysis map

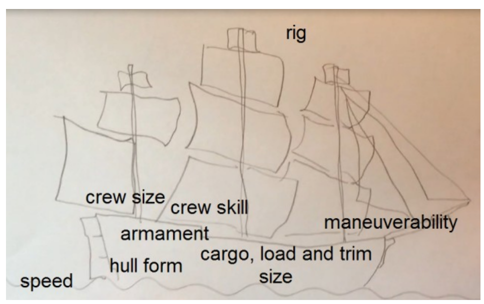

Figure 2 Specific vessel technology analysis map.

speed—Speed is ideal in an abstract sense, but for most applications, too costly. Speed costs capacity unless size increases, and size increase carries its own set of high costs. A fast vessel costs more to build and rig than an otherwise-comparable slower one. In our day, we get the speed that comes along with huge size as a bonus, but only because our population is so high—and thus our markets so large—that we can make and sell the enormous cargoes our large ships carry. Size back then was limited by the amount of cargo that could be obtained and/or sold, and also by the need to spread risk.[43] Except for niche situations, where the value of the cargo trumped the usual considerations, it was much more advantageous to maximize capacity, defensibility, tons-per-man, and simplicity of rig. To what extent differences in *hull form* influenced speed for a ship of given capacity will be explored, as will the relative effect of surface friction (largely due to fouling) on hull resistance.

maneuverability—To a certain extent, maneuverability goes hand-in-hand with speed, provided the speed is due to factors other than size. One can, though, increase maneuverability by modifying the rig, without necessarily modifying the *hull form*, assuming no such modification is necessary to accommodate the modification in rig. So in our period, maneuverability is closely tied to variations in rig. The general increase in the presence of fore-and-aft sails[44] on square-rigged vessels indicates the awareness that staysails and jibs and spankers made these vessels better sailers on (into) the wind, making them more versatile. Since these fore-and-aft sails were easier to handle than square sails,[45] there was no labor-related penalty. For vessels primarily rigged fore-and-

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[43] The English learned a hard lesson from the debacle of the *Trades Increase* of 1609 (see Davis, 261-262). The *Trades Increase* was a massive East Indiaman of 1609. James I was on board for her launching ceremonies. She sailed to the Indies with high hopes but she was wrecked, and the loss of so much cargo and such an expensive ship was a disaster not soon forgotten. No English ship surpassed her in size until 1787. Unger also discusses the relationship between ship size and risk assumption in Unger, ed., *Shipping and Economic Growth*, 250.

[44] Fore-and-aft sails are usually triangular, with the front edge secured to a mast or a taut line called a stay, like the sails on modern sailboats.

[45] Square sails are hung from horizontal spars called yards on which sailors have to stand to set or furl them, requiring the crew to climb high into the rigging, or lower those heavy yards and sails to the deck.

aft and used for coasting, windward ability[46] and ease of handling were great advantages, but these vessels almost always carried some amount of square canvas as well, since fore-and-aft sails are never as effective downwind as square sails, which are balanced over a vessel's center line as winged-out fore-and-aft sails can never be, secured as they are at their leading edges to structural members on the center line.[47] Square sails balanced over the center line reduce the tendency to roll by offering more-or-less equal sail area to the wind on either side of the ship. Roll is fatiguing—and sickening—to humans aboard, and hard on the rig. It also slows the ship down. Square sails also offer more sail area for the wind to push on than fore-and-aft sails, and their more complex rigging makes them easier to fix in place and prevent slatting, lifting, and collapsing.

rig—The rig of a vessel has to balance the hull. It must be powerful enough to move the loaded hull well, but not so powerful as to overwhelm it. It is also dictated by the crew factor. A large rig—or a complex one, which is not necessarily the same thing—takes more labor to handle, and since crew is usually the highest cost of operation, this may dictate a simpler, and slower, rig than the hull could perhaps handle. The wind is free, but harnessing it is not. The caveat to that is that "simpler" and "cheaper" do not automatically go hand-in-hand. Rig is also related closely to size. As ships grew larger, their rigs needed to be divided into more manageable sails. The labor factor kicked in.[48]

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[46] Windward ability is the ability to sail into the wind to some extent.

[47] The spinnaker, the balloon-like racing sail flown when sailing downwind, on a yacht is a modern analogue, though the absence of a yard to restrain the bottom edge makes this sail difficult to handle.

[48] We have seen a reversal of this process in modern yachts, due to changes in technology. As sail-handling equipment got more powerful and more automated, and materials got stronger and lighter, yachts could fly

A square-rigged vessel whose sail plan is divided up in a typical 18th-century fashion does not necessarily sail better than one with fewer sails as in the 17th century. In fact, her rig has more windage and thus drag, and it takes longer to operate her multiple sheets and braces and thus adjust her sail plan to conditions. The simpler square rigs of the 17th century, though, with their larger sails, may not have been viable for the larger 18th-century square-riggers, given size and labor considerations. Too-large individual sails were too powerful for men to handle without more mechanical advantage than was available at the time. To what extent all of this can be sorted, proven or disproven, and prioritized in explaining continuity and change in rig technology is one of the most important issues for us to explore.

The rig is also related to maneuverability. A vessel intended primarily for reaching and running in the open sea would carry a primarily square rig, while one intended for coasting or operating in more restricted waters would probably be primarily fore-and-aft rigged.

capacity—Capacity is inherently desirable for a merchant ship and obviously closely related to *hull form*. The more she can carry per voyage, while still operating safely and efficiently, the more money she can make, no matter the value of her cargo. That, though, is only true if she can obtain and then sell the cargo. Half-empty vessels are not usually profitable. Ballast[49] requires labor to load and unload but is usually worthless

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bigger sails on bigger spars, and reduce windage and drag by simplifying rigs, so we see fewer split sail plans now than we did 40 years ago.

[49] In the absence of suitably heavy cargo, weight placed low in the hull for stability—usually stone, sand, or gravel.

on the market—so it is a cost. In some niche, high-value trades, such as highly perishable and highly valuable cargo, such as fresh fish, or illegal cargo that must be smuggled past armed interceptors, it might be worthwhile to sacrifice capacity for speed and maneuverability, but not for most trades most of the time. Even for slaving, where the cargo is high-value, perishable, costly to maintain, and extremely dangerous, we do not generally see particularly fast, specialized vessels employed, until after 1807-1808 when the trade became illegal and slaving became smuggling.

Before our period, capacity in the northern European trades was achieved by the 'round ship' whose breadth was a much greater proportion of her length than what we are used to. That general design characteristic was still quite evident in the ships that showed up at the mouth of the Chesapeake in 1607. These vessels were seaworthy, and capacious for their size, but some were slow and ungainly. A manageable increase in size allowed builders to pursue the 'box form,' basically a rectangular cargo compartment fitted with some concessions to hydrodynamics.[50] Perhaps the most important single development in the merchant ship throughout our period was this increase in the beam-to-length ratio which, while demanding a cost in terms of increased size, paid off in increased capacity, greater ton-per-man ratios as rigs were adapted concomitantly for ease of handling, and speed. Physics dictate that a longer ship is a faster ship, all other things being equal. If all other things were not equal, then owners and clients accrued benefits in other areas, and we must ascertain what those were if we conclude that speeds did indeed remain more or

[50] This is what we transport all our goods in now.

less constant even with increased size. We will need to consider the issue in some detail. Changing a major aspect of a ship's design means changes in other major aspects as well.

cargo, load and trim—High stowage value means light, bulky cargoes. They weigh less than water so they do not have a significant impact on displacement,[51] but they take up lots of space. *Low stowage value* cargoes do not take up much space but sink the ship down in the water. So an example of the former would be timber and an example of the latter would be iron. What makes it more interesting is that packing can change a high stowage value cargo into one less so. Tobacco and cotton are good examples. Once packers figured out how to compress them and pack them in barrels and bales, their nature as cargo changed.

The *fluyt* was an excellent vessel design for high stowage value cargoes.[52] Such a vessel needs capacity but not great displacement. If a cargo to be transported consisted primarily of gold, one would need a very different sort of ship. One would also probably need cannon for defense, and would engage something like a galleon—or later a warship—for that purpose.

size—With a bigger ship we have more capacity and more speed, both of which are inherently desirable. As with all these factors, though, it is not that simple. Wood ultimately limits maximum size, but that is not an issue with merchant ships in our period. The depths of harbors and inlets limit size as well, which is why the Dutch became so adept at coming up with shallow-draft designs. For the most part, in this

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[51] Displacement is the volume of water that the underwater portion of the ship displaces. That volume increases as she sinks lower into the water.

[52] The hulking Dutch timber buss is a more extreme example.

period, though, the realities of the markets and the need to spread risk limited size. Ships tended to grow over time as the population of the Atlantic World grew. Still, a savvy shipper would take care not to employ vessels that he could not fill.[53] While limiting size limits speed, that was not an issue in most trades either, as we will explore.

crew skill—The sailor on a sailing ship was an integral part of the machine in a much more literal sense than today's mariners are[54]—but only if he possessed the skills to help operate it and the constitution to apply those skills under the demanding conditions of the sea. There were never enough skilled sailors to man both the growing merchant fleet and the growing navies built to fight the incessant wars of the period—wars whose naval components only expanded over the course of the period. In most trades, it was an absolute advantage to minimize the number of skilled sailors needed to run the ship, and to minimize the skill level required to do so.

armament—Cannon were long heavy hunks of solid bronze or iron—overwhelmingly iron in our period—firing round heavy hunks of solid iron, propelled by powder stored in large heavy casks, and operated by crews of several men per gun, who had to have some idea what they were doing, and required lots of food and water to keep them functioning. When cannon went off, they recoiled—or tried to, if restrained—and put tremendous strain on ship timbers. So to accommodate both their weight and the strain of their use, ships had to be more heavily built, which added weight and cost. Cargo capacity was reduced. Operational expenses were increased. Nevertheless, in areas

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[53] See Davis, 72.

[54] The role of the development of technical skill among users of a technological innovation in reducing total labor costs over time is called the Horndal Effect. See Rosenberg, 15-16.

and during times when war or the threat of piracy, and the lack of consistent naval escort, made unarmed voyaging too risky, armament, with all its drawbacks, was deemed necessary. The value (desirability) of cargoes had to be able to bear the increased cost of transport. During times of peace and in places where depredations were not a concern, shipping rates could go down and it could be profitable to ship lower-value cargoes. It was the Dutch who first took advantage of the technological and commercial benefits of building ideal cargo carriers for peaceful trade, unencumbered by defensive armament and its requirements, and it made them a whole lot of money. That, in turn, exposed them to armed English jealousy, which manifested itself in a series of Anglo-Dutch Wars.

crew size, and thus cost—Perhaps the pivotal question for Ralph Davis was the cause of the marked reduction in crew size and thus increase in ton-per-man ratio after the mid-18th century—a development certainly apparent in the transatlantic trades. Economic historians studying productivity were keenly interested in that question too. Labor is usually the highest cost in any business requiring labor. So the desirability of reduction in crew size is obvious. What is not so obvious is how it was achieved. It was a combination of political, economic, and technological factors, but we need to sort that out. Progress on that is a major goal of this project.

The foregoing assumptions, methodological approaches, and analysis maps come into play as we turn to the research and examine what the different sources have to tell us about the people who paid for, operated, and built these ships, and about how they were designed the way they were and why.

Chapter Three: Ships and Ship Owners

Merchant ships only existed because merchants needed them and were willing and able to pay for them. Within the bounds of technological capability, financial and material resources, and state prerogatives, merchants' priorities and desires determined what those ships were. Archival work in merchants' papers did not yield much technical detail on those ships, but it did yield evidence of what those guiding priorities and desires were, and were not, and what some of those limiting constraints were.

Merchants from both sides of the Atlantic ordered and operated ships from both sides of the Atlantic. As time passed, more of those merchants were American, more of the ships were built in America, and the ships built in America grew larger.[1] All of that reflects and supports the growth of the Anglo-American economy. Shipping and shipbuilding were important "invisible earnings" for British America, contributing to the rise in productivity demonstrated by economic historians over the past half-century. By 1800, the most successful American shipping firms—say, the Browns in Rhode Island and the Crowninshields and Derbys in Massachusetts—ordered and sailed East Indiamen to Asia to compete directly with the European powers, while forty years earlier, they were engaged almost exclusively in coastal and down-island trade with small vessels—sloops, schooners, brigs.

[1] That was not a linear process. Most of the shift happened after 1750.

The basic type nomenclature for Atlantic merchant ships, 1600-1800

Including an introduction to the basic types of vessels discussed in the rest of the study is important, as we will be using information on who built and owned what types, where and when, and referring back to type nomenclature in subsequent chapters.

A word of warning is in order here. The etymology of watercraft names is one of the most byzantine subjects one can take up. In our period—but more so in the earlier part of it than the later—vessels tended to be named by their hull form and/or intended use, while in later years, into our own time, they tended to be named by their rigs. The freedom with which people of the period employed nautical terminology fits well with their casual approach to orthography.

Frequently, trying to determine whether vessel use changed over a period of time means first determining whether it was the vessels themselves or what people called them that changed. That can be near to impossible. The best plan of attack for the problem is difficult—a positive match between a vessel description from the written record to an archaeological site.

Coastal and island traders

In general, these vessels were the smallest ocean-going merchantmen. They carried the great bulk of trade between American ports and between American ports and the West Indies. They were much less common on, though certainly not absent from, trans-Atlantic passages to and from Europe and Africa. The overwhelming majority were built in the Americas and operated by American merchants, even early in the period.

Shallop[2]—The shallop was an early coastal craft, employed from the earliest days of English exploration and settlement, and the term remained in use at least into the 1750s.[3] A one- or two-masted work boat, usually 18 to 28 feet long, sometimes at least partially decked, the basic type remained ubiquitous after other terms for them became more common (such as 'Chebacco boat'). The sail area was small, and the sails did not require booms,[4] thus preserving the crew from the constant threat of a cracked head. Shallops were frequently carried as tenders on larger vessels.[5]

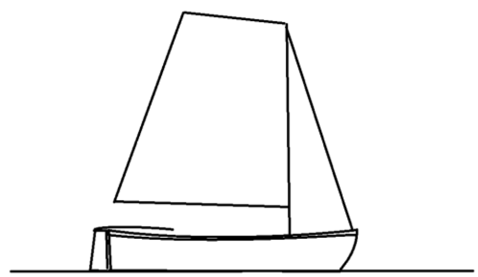

Figure 3 Shallop.

Sloop[6]—The sloop, for our purposes, was a single-masted coastal and island trader. It is helpful—especially for the 18th century—to distinguish it from the *schooner*, which was

[2] The word is pronounced "shal-LOPE," similar to French "chaloupe" and probably related etymologically to Dutch "sloep" and English "sloop." All of that etymological inbreeding is most helpfully suggestive of how vessels actually developed and how loose and mutable all these terms were.

[3] Thomas & James Wharton Jr. ship book 1756-1758, HSP.

[4] The boom is the spar to which the foot or bottom edge of the sail is attached.

[5] See Howard I. Chapelle, *American Small Sailing Craft: Their Design, Development and Construction* (New York: Norton, 1951), 10-20; and William A. Baker, *Sloops & Shallops* (Barre MA: Barre Publishing Co., 1966), 1-37.

[6] See etymology for the shallop.

similar in all respects, but had two masts. The sloop dates to the beginning of the period and remained in service throughout, though its share of the trade relative to the schooner seems to have declined from the mid-18th century.[7] Sloops relied primarily on a large mainsail, either square or fore-and-aft, as drawn here.

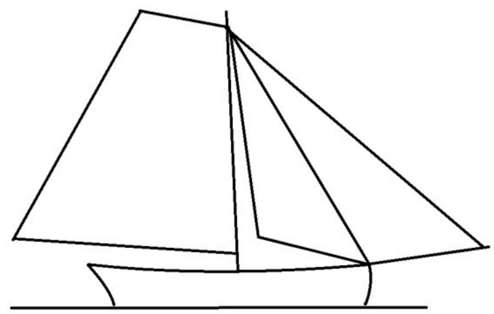

Figure 4 Sloop.

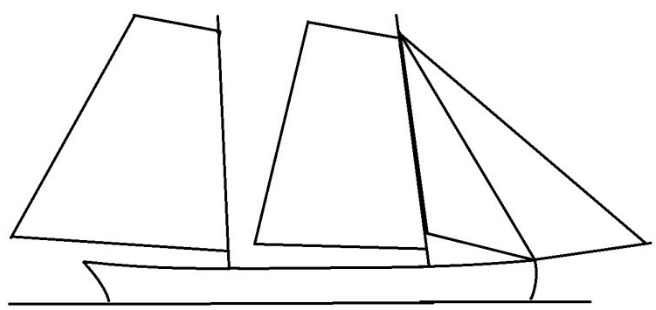

Figure 5 Schooner.

Schooner—The two-masted coastal and island type either became much more common as the period progressed, or the use of the term did, or both—most likely both. In any case, it remained a popular workhorse into the 20th century, while the single-masted sloop

[7] An investigation into why that was would be a worthwhile project.

did not.[8] Schooners relied primarily on two fore-and-aft sails. They frequently sported square topsails, and triangular staysails and jibs in the bow.

Ocean traders

The line here is as blurry as every other line in nautical affairs of the period. Schooners and larger sloops engaged in ocean passages, and the vessels defined here spent plenty of time in coastal and island trades. However, the bulk of commercial ocean passages in our period were made in these vessels.

Brig (or brigantine)—Merchants, shipbuilders, and officials used these terms interchangeably in this period, as their papers make clear. By the mid-18th century, the term referred consistently to a two-masted, square-rigged, medium-sized vessel, and by that point, they were ubiquitous in the Atlantic. The brig is almost identical to the *snow*, with one distinguishing difference.

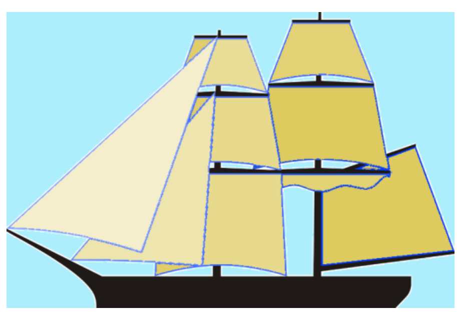

Figure 6 Brig.[9]

[8] See Marquardt, *The Global Schooner*; and MacGregor, *The Schooner: Its Design and Development from 1600 to the Present* (Barnsley UK: Pen & Sword Books, 2003).

[9] https://upload.wikimedia.org/wikipedia/commons/a/ac/Brig3.png

Snow—In the brig, as illustrated above, the spanker, or driver—the aftermost bottom sail—was attached to the mainmast (aftermost mast) like most fore-and-aft sails. In the snow, this sail was attached instead to a separate short trymast set just behind the mainmast. So technically it can be thought of as three-masted, but it never is in this form. Snows could be somewhat larger than brigs, but frequently they were in roughly the same middle size class in Atlantic merchant service. For our purposes, this is primarily a mid- to late 18th-century vessel.

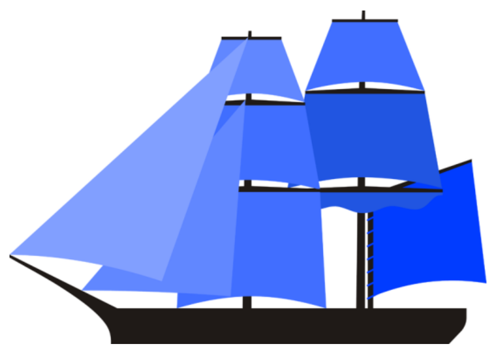

Figure 7 Snow.[10]

Ship—The term "ship" is both generic and specific. Generically, it refers to any vessel larger than a boat. What that means is somewhat up for grabs, but it helps to think of a ship as a vessel that is intended for open-water service.[11] So, a schooner is a ship, a brig is a ship, etc. Specifically, especially later in our period when vessel names became more

[10] https://commons.wikimedia.org/wiki/File:Snow.png

[11] The current popular term "tall ship" has no historical meaning for the early modern period.

closely tied to rigs, a ship was a square-rigged vessel with three masts and square sails on all three.[12] In the earliest years of the period, the mizzen (aftermost) mast frequently carried only a lateen mizzen sail.[13] That was true of Columbus's *Santa Maria* and of Christopher Newport's *Susan Constant*.

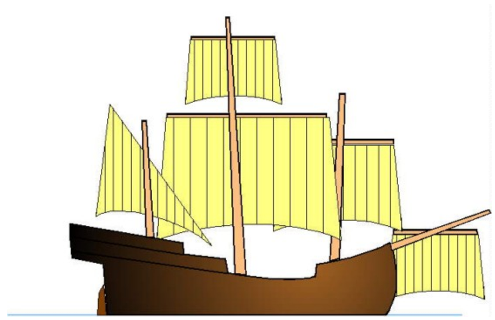

Figure 8 Early ship.[14]

The small galleons that founded and supplied the first tentative English colonies carried this rig, though their hulls were not as relatively bulky as this late-medieval carrack's.

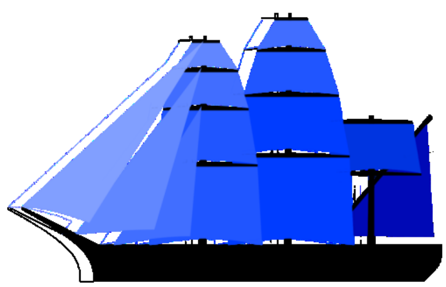

Figure 9 18th-century ship.[15]

[12] If she only had square sails on the forward two masts, she was a bark.

[13] A lateen sail is a triangular sail, but hung from a long yard rather than a stay (rope). Its origin is Mediterranean.

[14] https://commons.wikimedia.org/wiki/File:Carrack_rigging.png

The later ship rig split its sail plan into more sails, and carried triangular headsails.[16] The lateen mizzen in this diagram is an earlier version—later examples carried the gaff spanker we see in the diagrams of the brig and snow. This vessel would have probably also carried the by-then-ancient spritsail—the square sail slung under the bowsprit pictured in the carrack diagram.

Ships were not always larger than brigs and snows, but the largest vessels in service were ships. They were the earliest vessels to cross the Atlantic in the early modern period, and the type most consistently in service throughout the period.

Ship owners and ship technology

So, even among these most common types, merchants had plenty of choice in ordering and buying and utilizing their ships. Using the historical record to determine what choices they made is much easier than using it to determine why they made them, but we will attempt both. It is worth keeping in mind that records are much better for the 18th century than for the 17th, and that there was much more Atlantic maritime commerce underway in the 18th. So the level of confidence we can place in our interpretations will differ accordingly.

At least some ships were built and sailed out of most ports of trade in British America, from Newfoundland to the Lesser Antilles. By far the largest producer of ships on the western side of the Atlantic, and the largest center of shipping interests from the

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[15] https://commons.wikimedia.org/wiki/File:Alternate_fully_rigged_ship_sail_plan.png

[16] A study of why that is, combining experimental archaeology and maritime economic history's data, would be worthwhile.

mid-1600s, was New England, specifically Boston and the Merrimac River of Massachusetts and New Hampshire, with the Delaware Valley, especially Philadelphia, a clear second.[17] On the other side, no port came close to London in importance, though Liverpool, Bristol, and Glasgow would become important centers of Atlantic trade in the 18th century. The Thames Estuary was the center of British home island shipbuilding throughout the period, though important numbers were built in the northeast, the south coast, and Liverpool, especially in the 18th century.

As a general pattern, in the early years of the Empire, English merchants ordered ships from English yards, and employed them in trans-Atlantic trade to and from American, African, and Caribbean ports. Meanwhile, American merchants ordered smaller vessels from American builders, employing them in coastal trade and in supplying provisions to the West Indies, returning with tropical produce, especially sugar products. This coastal and island trade remained consistent in character and grew in

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[17] See Bernard Bailyn, *The New England Merchants in the Seventeenth Century* (Cambridge, MA: Harvard University Press, 1955); James Hedges, *The Browns of Providence Plantations: Colonial Years* (Cambridge, MA: Harvard University Press, 1952); John McCusker, *The Pennsylvania Shipping Industry in the Eighteenth Century* (Unpublished bound typescript, Historical Society of Pennsylvania, Philadelphia, 1973); and Simeon Crowther, "The Shipbuilding Output of the Delaware Valley, 1722-1776," *Proceedings of the American Philosophical Society*, 117:2 (April 10, 1973): 90-104. On London, start with Davis; also see Nuala Zahedieh, *The Capital and the Colonies: London and the Atlantic Economy 1660-1700* (Cambridge: Cambridge University Press, 2010); for Liverpool, Francis E. Hyde, *Liverpool and the Mersey: An Economic History of a Port, 1700-1970* (Newton Abbot UK: David and Charles, 1971); R. Stewart-Brown, *Liverpool Ships in the Eighteenth Century* (Liverpool and London: University Press of Liverpool/Hodder & Stoughton Ltd., 1932). For Bristol, see Kenneth Morgan, *Bristol & the Atlantic Trade in the Eighteenth Century* (Cambridge: Cambridge University Press, 1993). Glasgow's primary importance was as a tobacco port; see Jacob M. Price, *Tobacco in Atlantic Trade: The Chesapeake, London, and Glasgow, 1675-1775* (Brookfield, VT: Variorum, 1995).

volume as best it could in a voluble and violent world throughout the period. Over time, though, the character of trans-Atlantic trade changed. First, a few American merchants began ordering trans-Atlantic vessels from New England and Delaware Valley yards, but more British merchants were doing so, as they had the capital and the established networks. Over time, those American merchants ordered a greater percentage of those ships, and some from British yards. Their networks grew as well, along with their capital. They were less likely to be serving as agents for British clients and more likely to be serving themselves and their partners, to whom they were likely to be related by blood or marriage. Although British American merchants risked and made fortunes under the protectionist umbrella of British mercantilism, conflicts large and small flared up around trades where metropolitan and colonial interests clashed, especially in the provisions-for-sugar trade with the French West Indies.[18] Eventually, these conflicts overshadowed the benefits of imperial membership in the hearts and minds of American business and political elites, and thirteen eastern seaboard colonies withdrew, at a terrible cost. By the end of the period, though, American shippers were trading once again within the Empire, and competing with it directly in a more comprehensive way than they ever had, most conspicuously in the East Indies trade, which required unprecedented levels of capital investment and risk on the part of shippers who became rich as they never had before—

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[18] This was at the heart of illicit trade in 18th-century British America, and war with France never stopped it. Neither did imperial efforts, though they did at times force it into convoluted channels. See Wim Klooster, "Inter-Imperial Smuggling in the Americas, 1600-1800," in Bernard Bailyn and Patricia L. Denault, eds., *Soundings in Atlantic History: Latent Structures and Intellectual Currents, 1500-1830* (Cambridge, MA: Harvard University Press, 2009), 141-180; and Allan Karras, "Transgressive Exchange: Rewriting Atlantic Law in the Eighteenth-Century Caribbean," paper presented at Seascapes, Littoral Cultures, and Trans-Oceanic Exchanges, Library of Congress, Washington D.C., February 12-15, 2003.

including the man purported to be the U.S.A.'s first millionaire, Elias Hasket Derby of Salem. The end of our period is when we find the real establishment of an independent American maritime commercial empire that would offer the British serious competition in technology and trade until the implosion of the Civil War in the 1860s, from which the industry would never completely recover.

The records

Reading through the business records of these shippers fills in the details of this general sketch, gives us the opportunity to understand how and why ship owners used their ships, and affords us the chance to hold up the archival record against the predominant secondary literature. We find the largest collections of such records on this side of the Atlantic in the same places we would have found the major shipping centers—New England and Philadelphia.[19] Merchants' papers typically include:

a) outgoing correspondence: Merchants in this world managed their affairs by letter. They wrote to their factors or agents in other ports, to their business partners, to their solicitors/attorneys, to their bankers, insurance agents, and to the masters of their ships.[20] This last usually took the form of a loosely standardized set of instructions for a voyage

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[19] For this study, I used archival collections in New England and Philadelphia, though the vessels and businesses recorded there were built and operated all over the British Atlantic and beyond; Bermuda, Nova Scotia, and west Britain were important sites. New England and Philadelphia, though, present unusually good archival collections in general, and maritime collections are no exception. Significant archival collections certainly exist in other port, museum, and national collections. Future work based on this study should utilize those to the fullest extent possible, though I would expect the evidence they contain to add to, rather than contradict, what is presented here.

[20] *Factors* were partners or employees of an owner or firm who was entrusted to conduct business in destination ports on behalf of the owners. Thus, the master himself was a common factor. *Agents* were contractors who performed the same function; they were not employees or partners. The terms "master" and "captain" are somewhat, but not entirely, interchangeable in the merchant service, though not at all in naval service. The master of a merchant vessel was directly addressed as "Captain," but it is more correct for us to refer to them indirectly as masters.

called Sailing Instructions. An extant Sailing Instructions letter yields quite a lot of information for a short, matter-of-fact document. They are so common and important in this sort of research that an example, with comment, is called-for:

> Cap^{t} John Lovitt Salem New England June 20 1758
>
> You being appointed Master of our Sloop Andrago, Our Orders are that you proceed the first good wind with our s.[ai]d Sloop & Cargo for Barmuda upon your Arrivall there make report & entry according to Law and Dispose of our Cargo to our best advantage & make us Returns in a load of Salt if you can purchase it so as that you are well assured it will pay a good freight here if not proceed with our Sloop & the Effects of our Cargo in Cash or good Bills from Barmuda to Charlestown in South-Carolina & there lay out our Cargo in good Rice some pitch & Tarr & Staves or any other goods that you are well assured will be most profitable to us, If we should not have Effects sufficient to fully load our Sloop, you may fill her up with freight goods. Or if you think it best for us you may draw upon us for as much as will fully Load our Sloop & we will punctually pay your Bills, Write us by all Opportunities make all [the?] Dispatch possible & in all Cases & Circumstances do that which you shall think best for our Interest. We wish you a good Voyage & are your Friends & Employers.
>
> P.S. If you should be Taken going or Coming we would have you Ransome at the best rate you can ---------
>
> Bezaliel Toppan
>
> Tim^{o} Orne
>
> BT
> TO
>
> The above a True Copy of Orders Rec.^{d} from my Employers
> John Lovett[21]

[21] Orne Family Papers, MSS 41, Box 1 Folder 3, PEM-Phillips.

Unpacking this short letter will prove it a treasure chest of insight into how all of this worked.

As shipping agreements go, this was a short one, certainly run-of-the-mill, for a typical island run in a typical sloop with typical cargo. There were thousands of letters just like this one. That makes it more valuable. The instruction to sail with the "first good wind" reminds us that these voyages did not take place on a timetable as ours do. Ships might sit in port for weeks waiting for a wind and tide combination suitable for making way. As much as owners may have wanted to control such things, they could not. Nor could they control the ship's business in destination ports as much as they might have liked—that is clear in agreements like this. Note the leeway given to the master to conduct trade. As much as merchants tried to stay on top of markets in destination ports by devouring newspapers, correspondence, and hearsay, the speed of communication was just too slow. The market conditions that made the voyage attractive in the first place had all too frequently evaporated by the time the vessel made port—a pervasive theme of incoming correspondence, as we will see. So owners gave the vessel's master a degree of latitude that would be wholly unnecessary now,[22] and that meant the master had to act as the owners' agent, whether or not he was actually one of the owners, which he sometimes was, and whether or not the owners had a business agent or "correspondent" in the destination port. Sailing Instructions that bound the master too tightly—that constrained his choices too much—placed greater risk of a financial loss on the voyage. As it was,

[22] Sometimes—more commonly early in the period than later, as a general trend—a supercargo served as the owners' agent on the voyage. That person, too, had to be someone the owners trusted.

such loss occurred all too often. Masters' letters to owners routinely complain of poor market conditions and offer justification for the masters' decisions, in an attempt to shield themselves from culpability for a voyage's failure.

The first choice stipulated here is to Bermuda for salt. Salt was always in demand, so that part was a sensible risk, but if the price were high enough at Bermuda, that cargo would not provide the owners a profit. The owners are placing the onus on Lovett not only to judge the price of salt in Bermuda, but to judge the market conditions for selling it back home. Besides, the salt in Bermuda had already come from elsewhere—most likely the Turks & Caicos—so who brought it there, and on what terms, affected that market. Regardless of whether Lovett chooses to load Bermudan salt, though, he is to comply with Customs laws and procedures. Owners did not want their vessels fined or seized for failure to declare themselves and their cargoes according to the law.[23]

Should Lovett decide not to buy salt, the instructions suggest that he is still to sell the outward-bound cargo in Bermuda for "Cash or good Bills."[24] That was not always the case. Owners frequently gave masters the option of *not* selling the cargo if prices were

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[23] If they intended to smuggle, owners would typically abide by the usual practice of putting such language as we see here in the official sailing instructions, but then they might deliver illegal instructions orally. Regardless, owners used these agreements to shift the onus of any illegal activity onto the master. This might help protect them from vessel seizure and cargo forfeiture in the event that the vessel ran afoul of the customs laws, whether inadvertently or intentionally. Smuggling is an important subject in the maritime history of this time and this world. The place to start is Wim Klooster's *Illicit Riches: Dutch Trade in the Caribbean, 1648-1795* (Leiden: KITLV Press, 1998). On American smuggling in the West Indies during the Seven Years War, see Thomas Truxes, *Defying Empire: Trading with the Enemy in Colonial New York* (New Haven, CT: Yale University Press, 2008).

[24] Bills of exchange were basically I.O.U.s asking the recipient to pay the bearer the amount presented and charge the issuer. These, though, were complicated by exchange rates and the perceived, or actual, creditworthiness of the issuer, and were also traded as commodities themselves, like stock options and securities. Owners also sometimes gave masters the option of selling the vessel if good terms were to be had.

not to their liking, and ships might sail to multiple ports before selling the cargo, or they might sell part of the cargo in one port, where the price for that commodity was attractive, and sail somewhere else to sell the rest, looking for a better deal. This of course drove up cost and risk of damage considerably for the voyage. The master had to weigh the potential gain for doing so against that. In this case, a nearby alternative to Bermuda was Charlestown (today's Charleston), and the commodities specified for that option were the chief products of the Carolinas—rice, naval stores, and barrel staves. The other options offered by the owners were to take freight—goods shipped by others for a fee—or to borrow money ("draw upon us") on the owners' credit to buy a return cargo. Next, the owners instruct Lovett to keep them as well-informed as possible by writing to them frequently. Masters typically did this, though there was no guarantee their letters would reach the owners in a timely manner. Both outgoing and incoming correspondence are full of complaints about letters not received and decisions delayed or made without requested advice. Owners had no idea what had happened to their ships and cargoes without letters. The desire for mail was urgent and insatiable.

Toppan and Orne then urge Lovett to conduct the voyage as quickly as he can. Time equals crew wages—and more time to suffer desertion for better wages elsewhere or personal reasons, more time to succumb to disease, more time to suffer accident. More time underway meant more wear and tear on the vessel and cargo, and the tying-up of capital in them. They close by reminding Lovett of how much trust they are placing in him.

In a postscript, they acknowledge the possibility of interception by privateers or enemy cruisers—this was during the Seven Years War. Maritime predators frequently demanded ransom to let the ship go rather than take her as a prize—it was less profitable, but much easier and allowed the predator to continue the cruise and intercept many more vessels. In such case, there would be nothing for it but for Lovett to get the best terms he could to preserve his own freedom and that of his ship and most of his crew—though it was common practice to take one or two crew members hostage, to be held until the ransom bill was paid (along with a fee for the hostages' sustenance).[25]

What comes through most clearly from one of these letters is the sense of risk. So many things could go so wrong—market conditions, bad business decisions, disease, accident, weather, war—that it is no wonder owners fretted constantly about their ships at sea and cargoes for sale. The risks these people took seem outrageous to us. Yet they had no choice but to accept them and try to mitigate them if they were going to engage in maritime commerce. The ship itself was just one of those risks. The risks we associate with these ships, that seem so stark to us—their plank-on-frame wooden construction, their wind-dependent power source manipulated by human strength with little mechanical advantage, their relatively small size by our standards, the exposure of their crews to the elements and to physical injury or death during normal operations—seem less aberrant when considered in the broader context of risk laid out so clearly by a simple letter like this.

[25] Chet, *The Ocean is a Wilderness*, 57. Chet in turn cites multiple sources.

b) incoming correspondence—The incoming correspondence that most concerns us here is that from masters to owners. Those letters rarely mention anything having to do with the performance of the vessel beyond the duration of the passage and whether the master considers that "good" or "indifferent"—not very good. The overwhelming concern of these letters is business—the business of the master acting as the owners' agent. The following is as good an example as any found. It is from Capt. George F. Blunt from Cape Francois in Saint Domingue (now Haiti) to owner William Hale, 29 August 1799, describing a poor market at Trinidad and his decision to sail from there to Grenada, after selling only the cargo of lumber on deck—not in the hold—for cash:

> ...The wind being far Northerly, a strong Lee Current and the Brig still Very Crank, I could not gain sight of Grenada, and the first Land I could fetch was the West End of St. Croix, the only offer I had there was 40 Doll.s for my Boards only [which is what he got in cash at Trinidad for his deck lumber], and that payable in Rum, there I gained Intelligence of the Cape being open to us, and thinking it not prudent to run to a French Port with Naval Stores on board I sold my Pitch @$4. Tar & Turpentine @$3 & Varnish @55 Cents per Gall. and took Rum in paym.t I then proceeded on for this Infernal port, from whence we had at St. Croix the most flattering prospect of making a grate Voiage on Lumber I arrived here yesterday, and the Current prices of this Day. are, Boards $15, Shingles $1 1/2, Staves & Headings all together $16, Beef $7 1/2 Fish 2@3 if good ...[26]

Mainwaring's *Sea-mans Dictionary* says that a vessel is "crank-sided when she will bear but small sail, and will lie down very much with little wind…"[27] and "a crank-sided ship

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[26] William Hale Correspondence, Box 2 Folder 3, NHHS.

[27] Henry Mainwaring, *The Sea-mans Dictionary : or, an exposition and demonstration of all the parts and things belonging to a shippe* (1644), in *The Life and Works of Sir Henry Mainwaring,* Volume 2, edited by G.E. Mainwaring (London: The Navy Records Society, 1920), e-reader edition published by The Internet Archive, 2007, location 1997.

can never sail well by the wind."[28] That is because a sailing vessel must be able to stand up to the wind to sail to weather, as the wind has its greatest heeling force from forward of the beam (amidships). So Blunt is complaining that his brig will not go to weather well,[29] and thus his options for his next landing are further restricted by that. Blunt, as his other correspondence in this collection reveals, is a perennially unfortunate master, a perennially self-pitying one, or both. He bewails his misfortunes and takes pains to ensure that his owners know that nothing is his fault. Is the brig crank? We cannot know. Perhaps her rig was out of tune. Perhaps she was loaded out of trim or balance. Perhaps she was just a crank design. Perhaps she was not crank at all and the conditions forbade making Grenada. These masters' letters, though, represent a consistent effort at self-justification very much in the writers' self-interest, so we should read them with that in mind.

Most masters' comments to owners on vessel performance—if any—were offhand and vague. After a passage from Massachusetts to Canton in 1800, Capt. Bently of the Brown East Indiaman *Ann & Hope* wrote home that "...our ship Behaves Very Well and tite.."—which is all he had to say about her performance on a voyage of five

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[28] Mainwaring, location 3188. For a better sense of this: In a letter from Capt. John Crowninshield to owner Elias Hasket Derby from the ship *Henry* on 4 July 1791, he writes that, though otherwise a good sailer, the ship "is however very crank & tender & has in fact come so far almost upon her b[eam] ends, & her Spars are so [stighty?] (The top masts) and she has so little spread to her rigging, that we have sometimes been obliged to double reef when we might have carried top Gall[t] sails--we make just enough water to keep her sweet. ..." (Crowninshield Family Papers, MH 15, Box 1, Folder 9, PEM-Phillips). To double reef is to drastically shorten sail area.

[29] Meaning she will not sail as close to the direction from which the wind is coming as she might otherwise, or as another vessel might.

months and ten days.[30] In 1805, John Odiorne wrote from Norfolk to James Locke in New Hampshire that "We have at last arrived here after a long passage of nine days, we are all well and the Ship behaves extremely Well, the Ship Answers your expectations as it respects Sailing to the uttermost, you will without Doubt have received Capt. Adams' letter on this..."[31] The following year, from Alicante, he writes: "The Ship continues good and strong and sails exceedingly well upon an even keel we out sail Capt Robt Follinsbe [?] and Capt Rob.t [?] Bagley by one half which you must thnk is very gratifying to me.------------------------------"[32] These are typical.

> This one is not typical, and perhaps here the exception proves the rule:
>
> The Rangers sailing does not answer the general expectation oweing in a great measure, to her being too deep, very foul, & overmasted. her ballast Laid too high, on Account of its improper Quality, for a Ship of this construction; this, with the extraordinary weight of her lower Masts, occasioned her being very crank. I am paying my whole attention to remedy these inconveniences as much as possible; I am shortening the lower Masts, shifting the Main Mast further aft, and mean to Ballast with Lead as that Article will stow under the lower tier of Water, the less quantity will be sufficient, of course the Ship will be so much the lighter, and Sail so much the faster; and we shall then, I hope, be able to Stow the Cables under the Platform.[33]

That was written by John Paul Jones to John Wendell, 11 December 1777, at the conclusion of *USS Ranger*'s first passage as a new U.S. warship. Jones was expected to take prizes and engage the Royal Navy in combat at public expense, and the performance

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[30] Brown Family Business Records, Box 475, Folder 9, JCB

[31] Shipping Papers (a topical collection), Box 1, Folder 6, NHHS

[32] Shipping Papers (a topical collection), Box 1, Folder 6, NHHS

[33] Langdon Family Papers, Box 1, Folder 7, NHHS

of his vessel had to be a top priority to both him and his paymasters. No merchant master would bother his owners with details like this. The rest of the letters from merchant masters from which the brief quotes above were excerpted are preoccupied almost exclusively with details on market conditions, prices offered, declined, or accepted for goods, and any legal issues the master is handling or seeking advice on from the owners. That material consistently supports the impression we get from the Sailing Instructions from owners—that they are preoccupied with the ship's business, not the ship. It is rare to read praise or complaint about the vessel itself. Where it exists, it is more likely to comment on the ship's condition than on her performance qualities. Those seem more or less taken for granted, as a known quantity. She does what her owners and masters expect her to do. If only the markets could!

c) official documents: crew agreements, portledge bills, passports & rolls of equipage, customs clearances, prize adjudications, crew protests,[34] *privateers' commissions*—We can always make good use of a list of crew signed on to a vessel whose basic specifications we know. The more we know about the vessel, the more useful the list. Of course we want to know about the vessel herself. We also want to know how many sailors, serving in what positions, the owners and master deemed proper to operate her on a particular voyage. If we know what type of vessel she was, and how big, and how she

[34] Crew protests have a misleading name. They are sworn statements, given before a notary, by a delegation of a vessel's crew after an accident or other misfortune, giving a detailed account of the events of that misfortune and especially what efforts the crew made to avoid the misfortune and, if the vessel was lost, to salvage as much of the owners' property as possible. These documents bring maritime accidents in this period to life, and remind us of how bad luck and nature could destroy a vessel despite her crew's best efforts, but we should remember when reading them that their purpose is to exonerate the crew to the owners.

was armed,[35] not only can we figure a ton-per-man ratio for that vessel on that voyage, but we can compare the relationship of crew-to-ship in the list to that of a similar replica, should one be available, and get a better idea of whether she may have been over- or under-manned— there were good reasons why she might have been either. Masters would sometimes sign on more crew than they needed to operate the vessel to pad the crew against desertion, disease, or loss in combat during wartime. If the ship were armed, she might well need more men to make use of that armament than she would otherwise.

These documents in merchants' papers do not provide a consistently complete and large enough source for compiling reliably hard data on ton-per-man ratios for the purpose of ascertaining long-term trends. That is best done with the records kept by port officials of all vessels entering and leaving their ports. Still, there is much they can point out to us (see Table 1, following page).

[35] Customs clearances seem to be the most reliable sources for finding tonnage, armament, crew size, and destination all in the same place. They also list cargo on board.

Table 1: Crew complements and ton-per-man ratios of

27 merchant ships, 1727-1820[36]

Year	Vessel	Type	Tons	Arma-ment	Crew #	Ton-per-man ratio	Destination
1727	*Rainbow*	schooner	40	none	4	10	Newfoundland (from New Hampshire)
1746	*Betty & Molly*	schooner	53	?	5	10.6	Leeward Islands
1747	*Betty & Molly*[37]	brig	?	?	7	?	Barbados
1758	*Andrago*	sloop	70	?	4	17.5	? (prob. Bermuda)
1759	*Betsy*	schooner	?	?	7	?	Guadeloupe
1765	*Morning Star*	brig	120	?	?	?	
1770	*Defiance*	sloop	?	?	13	?	whaling; “western islands or elsewhere” from Providence
1770	*Sally*	brig’t	?	?	9	?	Surinam
1772	*Betsey*	sloop	?	?	13	?	whaling (Providence)
1783	*Active*	brig’t	95	none	7	13.6	Nova Scotia
1784	*Astrea*	ship	300	?	13	23	Dominica
1784	*Astrea*	ship	300	?	15	20	Grenada
1784	*Eagle*	brig	100	none	7	14.3	Virginia (from Lisbon, bound from there to L’Orient)
1785	*Astrea*	ship	300	none	16	18.8	Dominica
1789	*Astrea*	ship	300	?	23	13	Canton
1798	*Ann & Hope*	ship	550	12	60	9.2	Canton
1798	*Benjamin*	ship	169	?	13	13	London
1798	*Cruger*	brig	?	8	13	?	? (privateer)
1798	*Hannah*	brig’t	138	?	8	17.3	?
1799	*Recovery*	ship	?	?	24	?	Calcutta
1799	*Henry*	ship	190	?	17	11.2	Cape Francois
1799	*John*	ketch	?	?	22	?	Spain
1799	*Gadsden*	ship	?	16	50	?	Spain
1799	*Martha*	ship	?	?	17	?	East Indies
1801	*America*	ship	654	?	49	13.3	West Indies
1803	*America*	ship	654	?	30	21.8	France
1806	*John Langdon*	brig	124	none	7	17.7	Guadeloupe
1806	*Anna*	brig	162	none	8	20.3	Guadeloupe
1809	*Jane*	schooner	54	none	5	10.8	Cuba
1810	*Telemachus*	brig	?	?	10	?	?
1820	*Eunice*	brig	?	?	10	?	East Indies

Here we have 27 vessels making 31 voyages, almost all after 1750, when the Anglo-Atlantic maritime economy surged. Over half of the voyages (18) took place during

[36] Shipping Papers (a topical collection), Box 1, Folders 2 and 7, NHHS; Orne Family Papers MSS 41, Box 1, Folders 3, 6 and 9, PEM-Phillips; Wharton Family Papers, Box 7, Folder 2, HSP; Brown Family Business Records, Box 681, Folder 3; Box 682, Folder 2; Box 475, Folder 3, JCB; Derby Family Papers MSS 37, Box 1, Folders 1 and 5; Box 24 (OS), Folder 1, PEM-Phillips; Jones and Clark Papers, Box 1, Folder 2; Box 2, Folder 8, HSP; Crowninshield Family Papers MH 15, Box 19 (OS), Folder 1, PEM-Phillips; Tredick Family Papers, Box 1, Folder 12, NHHS.

[37] It is not possible to determine from these records whether the vessel listed by this name as a schooner and that listed as a brig are one and the same. The assumption here is that they are different.

wartime. Only 14 vessels and 18 voyages permit a ton-per-man ratio calculation. Of those 18 voyages, the records for only 10 list the vessel's armament.[38]

As is usually the case, the records occur with more frequency the later in time we go. In the 62 years between 1727 and 1789, we have 15 voyages—one less than in the 12-year period 1798-1810.

The smallest vessel is the earliest—the schooner *Rainbow,* 1727, 40 tons. Her ton-per-man ratio of 10 reflects the small size of the vessel—her crew is minimal at 4. She is unarmed and making a rather short voyage from New Hampshire to Newfoundland, in perhaps challenging conditions but unlikely to be molested. Everything about her and her voyage is typical for a British American vessel of that time. Two other schooners with complete data present similar information: *Betty & Molly* in 1746, at 53 tons with a crew of 5, a ton-per-man ratio of 10.6, and *Jane*, in 1809, at 54 tons and with a crew of 5 almost identical to the one 63 years earlier (10.8 ton-per-man ratio).

The schooner *Betty & Molly* was headed for the Leeward Islands in 1746 during King George's War. If she was armed, she was not carrying extra crew. She probably was not, given that *Jane* was also sailing to the Caribbean during wartime in 1809, and we know she was not armed and that she carried the same size crew for the same size vessel. These vessels were workhorses, and their small size limited the profit they could make per voyage. It may well be that owners were willing to risk their capture rather than go to the expense of arming them and paying extra crew. Also, owners frequently sent them

[38] For the context of general trends in armament, see Shepherd and Walton, 76, 196-197; and French, "Shipping Productivity," 631.

down-island to be sold along with their cargoes if the master could get a good price. That would save the expense of sailing them back, as well as depreciation of the vessel.[39]

The lowest ton-per-man ratio here, though, is not from a little schooner. It is from the large East Indiaman *Ann & Hope* (1798), built and sailed by the Browns of Providence. *Ann & Hope*, though, was armed with 12 guns and sailing all the way to Canton during wartime—a voyage that could take six months. She stood to make a substantial profit, too, in bringing back high-value East Asian goods.

The highest, and thus most efficient, ratio is for the 300-ton ship *Astrea*, sailing in 1784, 1785, and 1789—in peacetime. The two highest ratios are for the earlier voyages, to the West Indies. The lowest ratio is for a later voyage to Canton. Larger American ships were entering the East Indies trade more and more as the new country recovered from the Revolution and its aftermath. We do not know from these records whether *Astrea* was armed for her voyage to China. It is doubtful, given that an extra seven men probably could not account for both defensive needs and the general increase in crew size we see for these longest of voyages. *Astrea* was not armed for her 1785 voyage to Dominica. In her prior two voyages, to Dominica and Grenada, she carried almost the same size crew—13 and 15—and there is no reason she would have been armed for these two voyages and not for the 1785 one. She sailed to Canton during peacetime. It is much more common to find ordinary merchant vessels armed during wartime. The ship *Gadsden*, of unknown tonnage, was sailing for Spain in 1799 with 16 guns and a large crew of 50. That makes sense.

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[39] This was especially common with Bermuda sloops, which were always in high demand by both English and Dutch buyers.

Privateers, outfitted purposefully—and expensively—for wartime predation, usually carried extra-large crews. The brig *Cruger*, listed here, seems to be an exception—we do not know from these records how large she was, but 13 men is not a large crew to sail a brig and man eight guns. It is possible, though; the Armed Sloop *Welcome*, with seven guns, carried a crew of 12 on military sortie during the American Revolution.[40]

Brigs tended to fall into a fairly narrow size class in the mid- to late 18th century, though, so it would be reasonable to compare the 100-ton *Eagle*'s crew of seven, for transatlantic service during peacetime, to *Cruger*'s of almost double that, even though we do not know *Cruger*'s tonnage. Ideally, a merchant's papers would yield a crew list for a vessel in normal service, and another after her conversion for privateering.

Note that the brigs *Eagle* (1784) and *John Langdon* (1806) carried no guns and seven men on these voyages. Because the later brig was somewhat larger, she has a higher ton-per-man ratio. The owners of *John Langdon* were probably getting a bit more for their money, provided they did not pay too much for the vessel. The brig *Anna*, also sailing to Guadeloupe in 1806, was even more efficient. Her 20.3 ratio is up there with *Astrea*'s. Though she had almost the same capacity as the 1798 ship *Benjamin*, the latter carried 13 men to *Anna*'s eight, for a much lower ratio of 13. *Benjamin* was sailing to London during the Quasi-War with France, though, so one wonders whether she was armed. It does take more work to run a ship than a brig. Exactly how much more work it

[40] Jim Graczyk, personal communication, 6 November 2014.

takes, in terms of numbers of crew for the same size vessel, would be instructive to know. Perhaps modeling and consulting with replica masters can tell us that.

Comparing these brigs reminds us that if owners could accept the risk of operating with a minimal crew, they could increase the efficiency of the operation by operating a larger vessel within the same general vessel class. The brigantines *Active* of 1783, at 95 tons, and *Hannah* of 1798, at 138 tons, reinforce that point. *Hannah*'s ratio of 17.3 is comfortably higher than *Active*'s of 13.6. As Davis tells us, the general tendency was for these vessels to increase modestly in size over time. As John McCusker makes clear in his study of the Pennsylvania shipping industry, owners ordered and bought larger vessels when they could afford to.[41] Aside from the limits of the owners' capital, the limits on size were set by the size of the markets served.

Finally, this small sample of data reminds us that, even though security at sea in the western Atlantic and Caribbean benefited from the eradication of piracy in the area by the 1720s, privateering and enemy cruising during the frequent and long wars in the 18th century required the arming of ordinary merchant vessels and larger crews to defend them, with the expenses incurred accordingly. So, while it may have been possible technologically to increase ton-per-man ratios in this period, political conditions made it difficult to achieve such efficiency consistently without serious increase of risk—and risk, as we have seen, was automatically high for these merchants, even in settled times. In the later part of the period, from which we find the bulk of the records, both the British

[41] McCusker, *The Pennsylvania Shipping Industry in the Eighteenth Century*, already cited. It is a shame this study was never published. It is a gold mine of solid, clearly presented information on shipping and shipbuilding, in which McCusker digests and presents conclusions from an exhaustive data set he compiled himself. The data printout is also in the HSP's collection.

and American insurance businesses were well-developed, and insurance policies for specific voyages are not uncommon in merchants' papers. Premiums varied considerably based on the presumed condition of the vessel, her defensive capability, the value of the cargo, the season of the year, and the real or anticipated political conditions on the route. Especially risky voyages, such as *Betty & Molly*'s to the Caribbean might have been in 1746, were frequently either impossible or prohibitive to insure. The owners took that risk along with the other risks in such cases.

c) journals, ship books and waste books—An initial examination of the ledgers and accounts kept by these merchants, and the masters in their employ, reveals meticulous attention to detail.[42] accounting for every cent paid out and taken in, leaving us in no doubt of what they traded, and for what price, nor of what sundries went into everyday business and the maintenance and repair of ships, and what all that cost. Also fortunate for us is that ship owners took pains to keep expenses separate by vessel. So we can see, even for an ordinary little sloop, what material and labor went into her construction, her fitting-out, provisioning, and maintenance. Of course, we can rarely assume that such records for any given vessel are complete, but an economic historian interested in comparing costs associated with various vessel types from the same narrow period—say, a few decades—could compile such data from a large sample of merchants' papers in multiple repositories and assume rather safely that the level of completeness for those records would be comparable enough, averaged out over the large data sample, to provide meaningful information. This would be ill-advised over a period much longer than that,

[42] I examined such materials in New England and Philadelphia, the principal centers of British American shipping and shipbuilding in the period. They will be cited specifically where they specifically referenced.

as records are so much more complete in general for the later part of the period that making such comparisons from any period prior to 1750 to 1750—1800 would be of dubious merit.

As with their letters, though, the overwhelming bulk of merchants' journals and account books are much more concerned with cargoes for sale than ships in service, reinforcing the already-strong impression that the vessel was a rather stable quantity while salable cargoes were anything but. Prices and qualities fluctuated, demand fluctuated, credit with which to buy goods fluctuated, and merchants were constantly challenged to enter a profit rather than a loss in their ledgers.

d) bills of lading and cargo manifests—While journals were kept in the office, bills of lading and cargo manifests were ships' papers. They tell us exactly what was on board for a voyage, who owned it, how much it cost, how much the owners were charging to ship freight for others, how much of each item was carried, and what units of measurement were used for each. Cargoes were almost always mixed. That helped to spread risk, given the unpredictability of markets. There were exceptions of course—tobacco ships from Virginia would carry little else to Britain after the harvest, but they would certainly return with mixed cargoes. Sack ships would carry dried cod from the Grand Banks fisheries in large volumes, every year, to Europe and the West Indies, but then typically load wine and other Mediterranean products or tropical produce.[43]

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[43] For an introduction to the Newfoundland cod fishery and its wider context—the trade network of which it was an integral component—see Peter E. Pope, *Fish Into Wine: The Newfoundland Plantation in the Seventeenth Century* (Chapel Hill: University of North Carolina Press, 2004). On how sack ships operated, see Olaf Uwe Janzen, "A Scottish Sack Ship in the Newfoundland Trade 1726-27," *Scottish Economic & Social History* 18:1 (May 1998): 1-18.

e) bills and invoices—These make up much of the bulk of ship owners' papers. They bring the everyday details of maritime business almost to life. Frequently just chits of paper with a few mostly misspelled words and a few numbers scrawled on them, they were written by everyone from a humble glazier submitting his bill to an owner for repairing stern-gallery windows, to someone as eminent as a Brown, Crowninshield, or Derby issuing a "pay-to-the-order-of…" From stacks of these, we learn what tradesmen charged for what work at a certain place at a certain time—and how many of those trades a ship owner relied upon—sailmakers, glaziers, masons to build and repair the ship's brick stove, painters, rope makers, coopers, blacksmiths, spar makers, block makers, riggers, caulkers, joiners. To acquire and maintain a good ship, an owner had to know how to find good tradesmen and be able to pay them. The paper chits remind us that payment, especially in the earlier part of the period, was not always in currency—something in chronic short supply. Everyone wanted pounds sterling but most had to settle for something else much of the time. There were colonial currencies whose value fluctuated by location and people's assessments of their worth in the near future. As important as any "colonial currency" were sugar and its sister products, molasses and rum—especially rum.[44] People along the waterfront in this world paid each other in the produce of the sugar cane all the time. Of course no one in the shipping centers of the northeastern seaboard produced the raw products themselves. They imported as much of

[44] See Sidney W. Mintz, *Sweetness and Power: The Place of Sugar in Modern History* (New York: Penguin Books, 1985); Richard S. Dunn, *Sugar and Slaves: The Rise of the Planter Class in the English West Indies, 1624-1713* (Chapel Hill: University of North Carolina Press, 1972); McCusker, *Rum and the American Revolution*.

them as they could from the West Indies, and relied on those imports in large part to keep their maritime economy going and growing. It is no wonder that these ship owners were willing to go to great—including supra-legal—lengths to procure the sugar products they wanted, and to offer their own goods in exchange for them wherever the best markets were—and the best markets were so frequently the off-limits French islands, with no eastern seaboard colonies of their own to supply them with provisions and building materials, and with booming sugar production and no home market for rum in a country where brandy was so well-protected by law and taste.[45] Rum distilling was the number-one industry in New England in this period.[46]

Of particular interest in the stacks of merchants' bills and invoices are bills of sale for ships. These reflect the cost savings owners might realize by buying used versus new. On 2 September 1799, Brown & Ives bought a six-year-old brigantine called *Maria* for $3,200. On 14 February 1801, a George Robinson offered to sell them a new one, when she was finished, for $6,500. No size difference between brigantines eight years apart in age would account for that disparity. Most of it was depreciation. Obviously Brown & Ives thought *Maria* was worth buying, even though six years was plenty of time for a wooden ship of this period to deteriorate badly. The importance of evaluating the

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[45] For an eminently readable account of the early French West Indies by a senior scholar on the topic, see Philip P. Boucher, *France and the American Tropics to 1700: Tropics of Discontent?* (Baltimore, MD: Johns Hopkins University Press, 2008). For a counterpoint to Steele's *English Atlantic*, see Kenneth Banks, *Chasing Empire Across The Sea: Communications and the State in the French Atlantic, 1713-1763* (Montreal: McGill-Queen's University Press, 2002). The French maritime historian Paul Butel wrote a survey of the French Caribbean carrying the history into our own time in *Histoire des Antilles françaises, XVII^e^ –XX^e^ siècle* (Paris: Perrin, 2002).

[46] Jordan Smith's forthcoming dissertation on "The Invention of Rum," examining this most important commodity in the Atlantic World, could be an important new source on this subject. Smith is currently a PhD candidate at Georgetown University.

condition of a used ship before making an offer on her is made quite evident in merchants' correspondence on the matter. In 1777, Nicholas Brown and Christopher Starbuck were considering buying an 80-ton sloop called *Success*. The memorandum of sale, which we would call a listing, claimed she was "a good Sailing Vessel," seven years old, standing rigging one year old, which might mean it was already due for replacement, depending on usage and maintenance, running rigging "pretty good," with sails fit for a voyage to the West Indies—her one-year-old standing rigging and "pretty good" running rigging could reasonably be expected to make at least the one-way trip—as noted, owners frequently sent these smaller vessels down-island in hopes of selling them there rather than bringing them back.[47] Note also here that typically vague description of the vessel's performance—"a good Sailing Vessel."

For over a year, in 1807-1808, Jacob Smith, working for Brown Benson & Ives of Providence, tried to sell the ship *George & Mary*. Just as he thought he had a deal, the ship was damaged in a gale by a ship riding alongside her. His letters to his employers concerning the drawn-out affair span three folders in the collection.[48] Seven years later, Smith was working on another deal—this time, to buy a ship called *Two Catharines*. Smith had been writing to the firm about other ships, but not with the detail or enthusiasm he did about this one.

On 21 September 1815 he wrote from Newport that he had examined the ship thoroughly and spoke with the man who graved her—cleaned her bottom—who said she

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[47] Brown Family Business Records, Box 682, Folder 4, JCB. Standing rigging is the rigging that holds up the masts and the bowsprit. Running rigging is the moving rigging that controls the yards, booms, and sails. All of it has to be adjusted for stretch and kept tarred to prevent rot.

[48] Brown Family Business Records, Box 306, Folders 3-5, JCB.

was worm-free except at the waterline and that her bottom timbers were good. Smith reported that she was well paid (bottom-coated) and caulked from gunwale to garboard strake (rail to keel). He examined the mastheads and they seemed sound. Her captain, Smith wrote, claimed she would carry 500 tons. Smith says he does not doubt she will carry 400 "and will be a Very Good Sailer"and that the owners have recently spent four to five hundred dollars on her. He thinks they can have her from $13,200 to $14,000 depending on terms, and that if so, she was the cheapest ship to be had in the U.S. of equal tonnage. Smith probably was not too happy, then, when on 16 October, he forwarded terms from the captain and co-owner: $15,000, 1/3 St. Petersburg hemp (for rigging) and quality duck (sail canvas), 1/3 cash on delivery, 1/3 cash “Ninety days payable at Either of the Banks of Their State.” The ship would be delivered with adequate cordage for the spars she carried, and all sails. The sail inventory that follows indicates a full suit, but no spares. She would need some spares for the primary sails, or at least significant canvas to make them, before she would be fit for ocean service. She seems to have had a full complement of ground tackle.[49] The captain and co-owner touts her stout construction, for which he provides some supporting details, and says her standing rigging is large for her tonnage, and her running rigging "of Suitable Sizes mad[e] … of the best Saint Petersburg Clean Hemp," sails of "first Quality English duck" of proper gauge ["number"] "and have not been bent." That means he is claiming they have never been used. He lists a full complement of ship’s boats and water casks. Just as a car owner

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[49] Ground tackle means anchors and their associated cordage and accessories. Properly sized anchors and sound anchor cable frequently meant the difference between survival and destruction for a ship and life or death for her crew.

writing a classified ad might list recent work done and care taken, Capt. Dennis reports that *Two Catharines* had her topsides caulked in the spring of 1813 and her decks caulked "about a year ago She has always had a ship keeper to keep her And untill last fall and this spring and Summer the Bow lumber port has allway been kept Oapen and Cabbin Windows---Ower Price for the Ship is Sixteen Thousand Dollars Cash Thomas Dennis…".[50] So perhaps Smith had gotten Dennis to come down a thousand dollars, and agree to accept much of the payment in goods rather than cash, a ubiquitous reality of business transactions in the period, as we have noted. Alas, it seems all Smith's efforts to acquire this ship for his employers came to naught—he wrote on 17 October that he made an offer according to their wishes but it was declined, and that they were so far apart he was sure they would not accept the counteroffer he made. He then moved on to other business.[51]

Note that the priorities of all parties in this exchange were the condition of the ship, her price, and what conveyed with her for that price. We see that now-familiar "Very Good Sailer," and that is the only performance-related comment in the exchange. Her capacity received more attention, with Smith seeming to imply that the seller exaggerated it but that it was generous for her size nonetheless. Merchants wanted the greatest cargo capacity for size they could get, without compromising the ship's sailing ability too much. What "too much" meant, of course, was subjective—and, for us, elusive.

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[50] Bow lumber ports were like gunports cut in the bows, which could be sealed for voyages, through which long timbers such as mast timbers—basically entire tree trunks or sections of them—could be loaded into the hold.

[51] Brown Family Business Records, Box 306, Folder 7, JCB.

f) ships' logs—We are fortunate that entire ships' logs do survive in some number, especially (as usual) for the 18th century, and most especially for the late 18th century. It is worth taking note of what a ship's log contained, as they were quite standardized in format and content. In the late 18th century, printers even produced blank ones for sale. They are on heavy paper and stoutly bound, contributing to their longevity in a hostile environment of moisture, heat, and rough conditions.

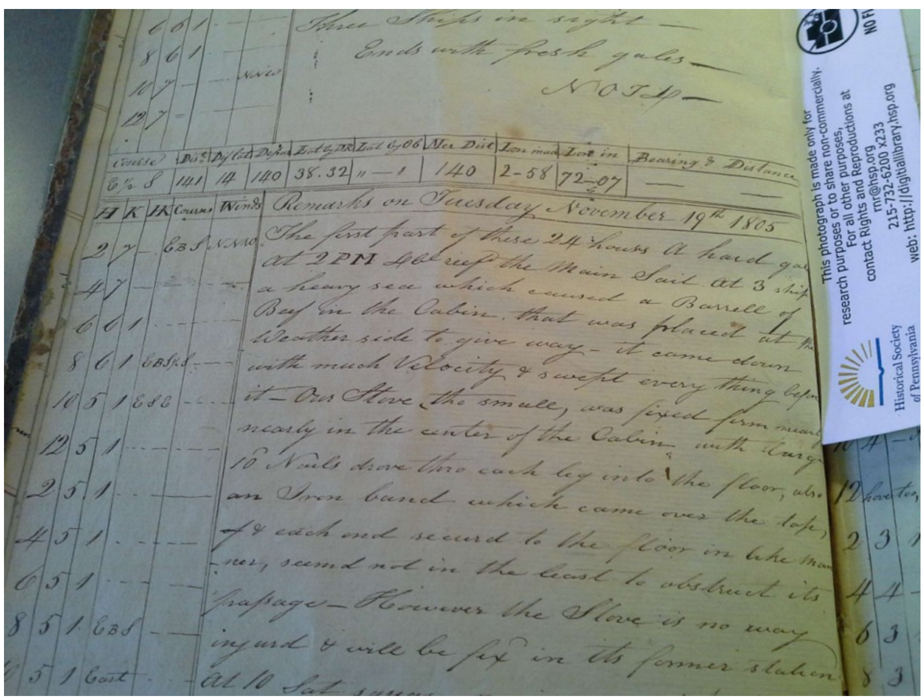

Figure 10 Log excerpt for the snow *George*, 1805-1806.[52]

[52] *George* (ship) logbook, 1805-1806, Am. 6823, HSP.

In the log excerpt shown in Figure 10, the snow *George* is underway from Wilmington, Delaware to Cork, Ireland. On this page, we see the end of one day's entries at the top, followed by the next day's entries, for Tuesday, November 19th. The columns are consistent in logs throughout the period. To the far left is the time, in two-hour increments—ship's time was kept noon-to-noon, since that was when the master took his sun sight, weather permitting, to establish the vessel's latitude as best he could. Sand glasses and bells kept time and told the officers when to change the watch. Running twenty-four hours a day while underway, ships needed a time system distinct from that used on land.

The next columns are for measured speed—Knots and Half-Knots. So, a "5" in the K column and a "1" in the HK column means 5 ½ knots. This was measured using a chip log—a flat piece of wood tied to a string with knots tied in it at regular intervals—hence the measurement of speed in "knots"— wound around a reel. The chip was thrown overboard from the stern, and the line let out, while an assistant watched the sand glass. However many knots ran out in a measured interval of time was the speed. The concept is similar to taking a person's pulse.

This is speed through the water, not speed over the ground or absolute speed. Since absolute speed is distance covered divided by the time it took to cover that distance, absolute speed is better, but at sea, before GPS, very difficult if not impossible to obtain. By keeping up with speed through the water and time underway since leaving a known fixed point, masters could estimate their position using deduced, or "dead," reckoning, but this was seriously vulnerable to significant error caused by currents from ahead, astern, or abeam, slowing or speeding the vessel, or pushing it off course at an angle, or a combination of both—and by leeway, the sideways-pushing effect of the wind, and by the inherent inaccuracy of chip logs.

This is a good place to discuss vessel speed at some length. While the log kept underway could only provide speeds over the ground or absolute speeds once fixed points of land were observed, those fixed points were noted in the log, marking the official beginning and end of a voyage. Finding the distance between those, and dividing that by the time the vessel spent underway from one point to the next—passage time—gives the average absolute speed of the voyage. Because sailing vessels almost never sail the most direct route from one point to the next, owing to their need to take advantage of wind direction, or fight it, sailors—and experimental archaeologists—find it useful to employ the concept of *velocity made good* (VMG).[53] Let us suppose that the destination is upwind—not unreachably upwind, but far enough upwind that the vessel must sail hard on the wind (close-hauled) to reach it. This is the most uncomfortable and usually least-efficient way to sail. Unless forced to, by the presence of a lee shore or other hazard, masters would rarely elect to sail close-hauled. They made better speed and subjected the vessel and her crew to much less punishment if they bore away some. In our example, though, doing so means no longer sailing directly toward the destination. In general, that is preferable, as vessel speed will increase, perhaps making up for the less-direct route, or

[53] See Whitewright, "Technological Continuity and Change,", 1-19; and Anton Englert, "Trial voyages as a method of experimental archaeology: The aspect of speed," in Blue et al., *Connected by the Sea*, 35-42.

coming close.[54] So if the straight-line distance between beginning and end point is, say, 2,000 nautical miles, the vessel might actually cover, say, 2,300 nautical miles to make the passage. Her average speed through the water is 2,300 miles divided by the time it took her to do it. VMG, though, is not the speed the vessel is making through the water—it is the speed she actually makes toward her destination over the course of the voyage, no matter her course changes and the changes in wind speed and direction. So in our example it is the straight-line distance to her destination—2,000 miles—divided by the time it took her to get there—the time it took her to actually sail 2,300 miles through the water. Since, by that calculation, it took her more time to cover less distance, VMG is lower than average speed made good over the voyage. VMG is a true indicator of vessel performance, taking into account the vessel's sailing characteristics, the judgment of the master in route planning and in taking advantage of wind shifts and changes in sea conditions. We can calculate VMGs from the information presented in most log books, and we can use VMG calculations from replica trials to make comparisons. Passage times are generally unsuitable for evaluating relative vessel performance, subject as they are to so many external and variable forces.

Passage times have something important to tell us nevertheless. If we compare log speeds and average speeds over the course of a voyage, we see a clear picture of the speed ceiling of ocean sailers. Any good ship, properly laden and equipped and well-sailed, could make a good turn of speed. True tubs were rare, as they would have pushed the capacity-performance continuum too far in the former direction to be satisfactory. It

[54] The answer to that question can be computed trigonometrically, and some masters would have known how to do that.

was common, in steady breezes and reasonably well-behaved seas, for vessels to make *hull speed* and even to sustain it for periods of time ranging from hours to days. Hull speed is worth a brief explanation. A displacement hull—any hull that does not plane, so any ship hull other than that of a hydrofoil, cannot climb out of the trough of its own bow wave—the wave it makes as it pushes through the water.[55] The hull speed is easy to calculate—1.34 multiplied by the square root of the vessel's length at the waterline. So the hull speed of a vessel 80 feet at the waterline—typical of a middling commercial ship in the 18th century—is just under 12 knots. Even respectable average speeds on ocean voyages, though, were but a fraction of the vessel's hull speed—2 to 3 knots was typical. A host of impediments lined up against a vessel's making anything close to hull speed over the course of a passage, including surface friction from bottom fouling, periods of light winds or calms, storms which kicked up rough seas through which the vessel had to labor, foul winds—winds from unfavorable directions—contrary or side-setting currents, and gear failures.

Returning to the snow *George* on her journey to Cork: She dropped anchor at 5 pm on Thursday 19 December in Cork harbor. Calculating her average speed for the passage gives us 3.64 knots.[56] Note the speeds her master recorded in the log excerpt. 6 and 7 knots were common. Elsewhere in the log, he records speeds up to 10. This is the

[55] A vessel can, however, certainly exceed hull speed by surfing, and frequently will do so at sea. Surfing is accelerating down the front of a wave. The wave does not have to be breaking. The hull speed of the author's own 28-foot sailboat was 6.6 knots, but she would surf under full sail at 9 knots.

[56] Distance traveled: 5,193 kilometers. 1 kilometer = 0.539 nautical mile, so 2,799 nm in 33 days, minus 1/2 day on the front end and 7 hours on the back end, added together = minus one day total, leaving 32 24-hour days. That's 768 hours. 2,799 nm / 768 hours = 3.64 knots average speed, for a ship capable of measuring 10 knots through the water.

norm for these logs. If conditions had allowed these ships to maintain their best speeds over most of a passage, passages would have been at least twice as fast if not more. They almost never did, though, as the vagaries of weather and sea conditions retarded a ship's progress even when the crew did what they could to maximize her speed at all times and in all conditions—and this log, like most, records constant sail changes in reaction to changing conditions—adding sail as winds grew lighter, taking it off as storms built, with luck before something broke.

So minor differences in the performance speed of a vessel were likely to make very little difference in the passage times she could accomplish. The 3.64-knot average speed calculated for *George*'s transatlantic is perfectly respectable for the period. It is difficult, in that light, to imagine any incentive to exert effort, expense, risk, and loss of relative capacity in an attempt to increase performance speed in an ocean-going merchantman. What a vessel like *George* really needed, beyond a fair hull and stout construction, were good sails, sound rigging, proper maintenance, proper lading, and enough hands to accomplish the never-ending hard work of putting up and taking in sails to keep her moving at her best speed in the Atlantic's exhausting swings between dead calm and howling gale. When John Crowninshield reached Bordeaux in *America* in 1803, he wrote an utterly scathing letter home to the family firm, excoriating the owners with bitter sarcasm for sending the ship out on the cheap, at the expense of himself and everyone else in her: He says he did not have enough hands to "carry sail handsomely" and so his passage was much slower than it should have been, and that though the crew did their best to take in sail for rough weather, "we are half man[n]ed" and it is not fast enough, "every rope breaks" and their sails are torn up. "…this is the real effects of small economy--". He says a proper-sized crew would have made a difference of 20 days underway.

> you all ought to know what sailors are after a disagreeable, hard, labourious, tedious long passage----------ask them what kind of a ship is she-------why Sir as damned a thing as ever swam-----how so does she leak----ask her pump ports------does she strain---ask her seams--------does she sail fast---see what a passage we had-----------how is her rigging & sails-----we had neither when we left home & if possible less now, … [but] with a full crew every thing goes smooth & easey & in fact such is all before the wind....
>
> then ask each -- what kind of a ship are you in----by God sire as fine a ship as ever swam-- -- does she leak---not a drop---- ------ does she strain, never------is she well found---certainly ------does she sail fast, very--------this is the very ship we want, & she will sell well-----will the other I fear not----"

He goes on to castigate them for not providing adequate spare rigging and sailcloth. He compares the paltry sum it would have cost with the substantial cost in labor of the longer passage:

> but if you ment we should run under last reefed topsails all the way then I grant we were compleatly man[n]ed------- ---------…
>
> …I hope to God you will have a poverty auction ------- even the T[op] G[allant] top rope was either taken out or left on the warf-------------- T[op] G[allant] sheets would not hold a 10 knot breeze ------"
> "puttyed ports (for fear of hurting the paint if paid with pitch) is an excellent thing to keep out water on a cold Europe winter passage-----[no it is not—he is being facetious]…
> ...what will you say---how many excuses have you to make-----------the America not in in 50 days....what think has become of John --- --- have you heard of the America yet--------------...then an old man picking his teeth they dont say much but they fear she is gone-------
>
> (how much better & to our credit & perhaps her exit would have been the more honourable---for one of the boys coming from the post office allmost out of breath-------sir the America is in Bordeaux in 16 days---by heavens is it possible)
>
> [Later he uses superstition as another way of commenting on an ill-fated passage] …& don't you remember after they sailed we remarked that

> one of the white hens stood up & crowed in the long entry------& that our great black cat sat to the fire backwards & wisked her tail left handed. & at the same time what was that which hapened to Johns white horse-------all ominous of squalls---then you will begin to realise how astonishingly oversighted you was to send us to sea in so miserable a plight --- ---

Captain Crowninshield is pointing out that, because he was undermanned for the conditions in an ill-equipped ship, he had to run the vessel under reduced sail even when she could have carried more, because he did not have the manpower to spare for the constant physical labor of going aloft and changing sail. Apparently, his dismal prediction that the ship would be difficult to sell once he reached France was borne out. He reached France on 29 November and did not manage to sell her until 31 March, and at that he was displeased with what he got for her.[57] He makes a compelling case that penny-wise-and-pound-foolish was a dubious strategy for risk management in this business.

Returning again to *George*'s log: The Course column is for entering the compass course. Note that we do not see degrees here, as we would now. Courses were read and recorded using the point system—a point was 11 ¼ degrees, but mariners did not think in degrees. There are 360 degrees, but only 32 points. Given the limits of precision of every other means of measurement available, there was no need to bother with the precision offered by the degree system on a compass. On a sailing vessel in motion in open water, it took skill to read an average course correctly at all, as the compass card swung one way

[57] Crowninshield Family papers, MH 15, Box 4, Folder 8, PEM-Phillips.

and the next with the motion of the ship in the waves and wind.[58] The courses we see here are East by South, East by South ½ South, and East South-East. Just as with speeds, these are estimates, averaged from a period of time underway, whose trustworthiness depended much on sea and weather conditions and the skill and alertness of the man at the helm.

Winds were measured using the same point system, but described in terms of the direction they were coming from, rather than direction heading toward, as with vessel course. So the log can tell us roughly what point of sail[59] the ship was on at a certain time in certain conditions.

At the end of a day's entries, we find the master's best estimates of distance run for that day, position, average speed and best speed. In the Remarks column we can read his observations about the weather, and about gear breaking and being repaired, which was almost constant—"hands occupied in mending rigging" or something similar is one of the most common remarks. Sometimes Remarks include crew behavior and morale, and the master's own assessment of the voyage's progress. Here, as so often happens in these, we are reminded of how violent this experience was. A barrel of beef broke loose when the snow was hit by a particularly vicious sea and did much damage in the cabin. It could have killed someone.

The carefully drawn straight lines, neat entries, and elegant sweep of penmanship offer an impression of tidiness and control that utterly belies the reality of what was

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[58] On a modern small yacht, it is futile to expect to steer a compass course with more precision than five degrees in any sea—if the water is at all rough.

[59] Point of sail is angle to the wind, which determines the sail plan likely employed.

really happening on a ship like *George* on the Atlantic. Here is literally an attempt to impose order on chaos, a strong and widespread human impulse, particularly obvious here. The tidiness and system of habit of the logbook also belie the reality that the information recorded there could only be trusted to a strictly limited extent. A diligent master always had a good idea of where he was, but that would not necessarily keep him and the lives and property in his care off a reef or a lee shore.

Once the vessel made port, the ship's log shifted to the business of selling and unloading cargo, procuring and loading a new cargo, trips into town—or farther—on ship's business and for mail, repairs and reconditioning of the ship, watering and provisioning, and concerns related to the retention, desertion, and recruitment of crew, as well as their health, or lack thereof. These sections remind us that, while voyages were long by our standards, time in port was even longer. While maritime economic historians have shown that efficiencies in this area improved over time, contributing materially to the growth in shipping productivity, some of the basic realities of the entire period militated against, and limited, such improvement.[60] While populations grew, demanding more goods and services, and the density of population centers and plantations grew concomitantly, allowing ships to dock or anchor closer to more sources of product, those changes only went so far. Density was still low enough in most places—and land

[60] For the inherent inefficiency of trying to load cargoes from scattered plantations, see James Hedges, *The Browns of Providence Plantations: Colonial Years* (Cambridge, MA: Harvard University Press, 1952), 28. Hedges describes trying to load molasses at Surinam. The best-known example of a particular trade that improved its cargo-handling and –loading efficiency dramatically over the period is the Chesapeake tobacco trade. See Jacob M. Price, *Tobacco in Atlantic Trade: The Chesapeake, London, and Glasgow, 1675-1775* (Brookfield, VT: Variorum, 1995); and John F. Wing, "Shipping Productivity in Maryland's Tobacco Trade, 1689-1759," *International Journal of Maritime History* 20:2 (December 2008): 223-239.

transport inefficient enough—that ships typically spent weeks or months waiting to finish loading and unloading even late in our period. Financial, technological, logistical, and political obstacles stood in the way of artificial port and harbor improvements in the period, though major projects were attempted—and to some extent successfully concluded—later in the period. These, however, were most evident in major British port cities—London, Liverpool, and Bristol.[61] Business networks grew and gained experience, but communication was still no faster than ships could sail, though there were more ships to deliver mail and news. Market volatility meant that masters might drop anchor fully intending to fulfill their sailing instructions, only to have that hope dashed by prices and product availability. Owner William Hale's papers contain a printed letter soliciting his business from the House of Jacques & Theodore Rocheteau & Company of Surinam, agents:

> ...There is no market, more exposed to sudden changes, than that of Surinam, and it has often happened, that in the short space of a week, sometimes of one day, a voyage, that would have been the most advantageous, had the vessel arrived, but a little while before, proves ruinous, from her arriving two or three days later; it would there, be essential, to keep up a correspondence, with some good character there, in order, to be advised, what may best suit the market, at any particular time.[62]

Like most advertisements, this one claims more than was likely to be delivered. While it was always advantageous to have a reliable correspondent at a destination market, if the market at Surinam really were that volatile—and it may well have been—it is doubtful

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[61] See Francis Hyde, *Liverpool and the Mersey,* already cited; Gordon Jackson, *The History and Archaeology of Ports* (Tadworth UK: World's Work, 1983); Adrian Jarvis, ed., *Port and Harbour Engineering* (Aldershot UK: Ashgate, 1998); and Alan F. Williams, "Bristol Port Plans and Improvements of the 18th Century," *Transactions of the Bristol and Gloucestershire Archaeological Society* 81, 1962.

[62] William Hale Correspondence, Box 2, Folder 1, NHHS.

that a correspondent would be able to shield owners and masters from that, given the speed of communication versus the speed of the market's ups and downs.

Perhaps demand for lumber was high on a certain island when you left with your load of lumber, but if you knew that, so did your competition. If you were the tenth schooner to drop anchor there with a load of lumber within the month, chances were you would either find your cargo unsalable there, or you would be selling at a loss. Logs and masters' correspondence are full of just that misfortune. At that point, if you decided not to leave, you might decide to sell at a loss and procure a cargo to make up for it, but that would likely take weeks or even months. You would have to find a buyer, assess that buyer's liquidity or credit, come to terms, do the paperwork, have the cargo transported to the vessel, load the cargo—which you could only do if you had unloaded your own cargo—and you could only do that with care or you risked capsize from instability. If the cargo needed to be fully unloaded, the crew was frequently put to work loading ballast, which was exhausting and time-consuming, and they might have to unload that ballast again once a new cargo was procured. It was worth finding cargo that could serve as ballast, actually. Recall poor Captain Blunt, sailing all over the islands trying and failing to find good prices for his cargo. In 1799, he wrote from Antigua, reporting that he had loaded 1,150 bushels of salt "@ 3/3. it will save buying Ballast at 1 Dollar per ton. & tho high will Answer as well as Rum..."[63] If a cargo could serve as ballast, that was worth considering as part of its value.

[63] William Hale Correspondence, Box 2, Folder 1, NHHS.

If all this were finally accomplished, you might run into trouble with the officials and have to waste even more time trying to sort out your clearance and port duties. The sad saga of Captain Blunt has gone from bad to worse. From New York, he writes of his latest misfortunes in Jamaica, from whence he has just landed after a 37-day passage:

> ...to Crown the Voiage and Compleat my unhappyness, was refused a Clearance by the Mean and Dirty Colle[cto]r for having 6 Puncheons Saint Croix Rum on board ...and had been knowingly and fairly reported for Exportation, and Bonded in the penalty of £2000, at Port Antonia where I first Entered the Vessell, in Jamaica, I Immediately made my will, and set off for Kingston by land to wate on the Govonor , (thinking never to return from such a Journey in such a Country),
>
> after daneing attendance on the Govonor 6 or 7 Days I obtained his Special order for my Immediate Clearance, and returned to Montego Bay on 3d Nov.r and saild on the 4th, But previous to all this, Mr. Bolt of Saint Anna, who had promised me the Freight for New york as far as the Word of a Gentleman was binding Sold his Sugar and Coffee and Disapointed me there, -------------- after getting on the Coast of America finding the weather Cold and Windy, my riging & sails much shattered from beating through the Gulf. and being short handed, (John Brown having deserted at Montego Bay) 15 Chances out of 20 of Being Blown off to the West Indies again the Rivers being froze up and many Dificulties attending the procuring another Cargo at Portsmouth the low prices it bairs (Our Country Lumber) in the West Indies, the Wretched payments we meet with here, Rum the sacrifices we must have Made to fitt her away again Out of Rum, putting all those together and suming up the Whole, I judged it Most prudent for the Intrest of all to make this port, hopeing you will Not Censure the step, ---- here we can realize the Cash, and obtain a higher price than at any port in the United States, ----------- I Could have Chartered the Brig at Montego Bay. to bring a load of staves and heading from Wilmington or Savannah at 50 Dollars Freight payable in Rum, I would not accept it.[64]

Blunt then proposes a venture to Wilmington, North Carolina. The owners confer amongst themselves and reject it firmly. It is apparent that by that point whatever confidence they had in Blunt's business judgment was limited. Some of that may have

[64] William Hale Correspondence, Box 2, Folder 5, NHHS.

been that all his vacillations came through in print, in his copious outpourings to the owners. Most of it was surely that the owners had sat home through a series of miscalculations and consequent losses.

On 19 June 1794, the Brown brig *Friendship* left Providence for Bayonne, France. Her voyage log ends 18 July, for a 30-day crossing—unremarkable for a transatlantic passage in that direction. Master Henry Olney writes in the log that he has unloaded her full cargo of flour, rice and fish by 8 August. Three days later, they took on three boat loads of ballast—it was unsafe not to. By the 13th, they were working on repairs and maintenance. Those lasted the rest of that month and, apparently, all of September. On the last day of that month, Olney writes that they are just sitting there waiting to get paid for the cargo they unloaded two months ago, and for official permission to load brandy. That loading did not begin until just before Christmas. On 13 February, they were waiting to load more. Same for 21 March. Same for 2 May. They finally sailed for St. Thomas on 26 May. They had been in Bayonne for over ten months.[65]

j) shipbuilding agreements—This was the primary quarry of the archival research. If a merchant were to go to the expense of buying a new ship, built to his specifications, what would those specifications be? What would he dictate to the shipwright, and what would he leave to the shipwright's discretion?

For the most part, shipbuilding agreements were formal documents, drawn up with fairly standardized language, though varying in detail, signed by all parties, and

[65] Brown Family Business Records, Box 733, Folder 1, JCB.

witnessed. Detailed reference to such agreements in correspondence was rare, but we will consider an exception to that rule.

Some ship owners had direct experience running vessels at sea, and some did not. South Carolina magnate Henry Laurens was a planter and merchant with no direct maritime experience, and that is reflected in his order for a ship from England. Laurens does not specify much technical detail in his order:

> You know that I do not take upon me to be a good Judge of Shiping, therefore let it suffice that i say I would have a Ship of about 700 Barrels burthen as well built as possible, having an eye to profit & shall have no objection to a good Cabin & some little expence to decorate the whole.[66]

Such a brief and vague commission turned out to be the exception, but even this tells us much about owners' priorities. The first stipulation is capacity, and that is typical. Owners primarily saw ships as conveyances of their goods to market, and so the characteristic of a ship they were most concerned with was how much of what cargo she could carry. Given the owner's perception of the size of the intended market, and the limits of his credit and capital, the more the better. Next, Laurens wants her as well-built as possible without costing him so much that he cannot make a profit with her. He is willing to provide a nice cabin for her master, which should help him entice someone worthy to serve in that capacity, and to make the ship look nice, which will reflect well upon her owner in foreign ports. We find in merchants' papers that gilders and carvers are routinely on the payroll when a ship is ordered or refitted. Such aesthetics mattered enough to owners that they were willing to incur costs for them. It is clear, though, that

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[66] Philip M. Hamer, ed., *The Papers of Henry Laurens,* Volume 3 (Columbia: South Carolina Historical Society, 1968-1976), 366.

Laurens is perfectly willing to trust whatever builder he commissions—and, as it turns out, his agent in England, a captain he charges with overseeing her construction and delivery—entirely when it comes to matters of design and performance.

While researching colonial shipbuilding for his dissertation in 1968-1969, Joe Goldenberg found an unusual correspondence in the Coates and Reynell Papers at the Historical Society of Pennsylvania.[67] Spending a month looking for something similar in that repository made it clear how unusual it was. It is found in an exchange of letters between John Reynell in Philadelphia and Daniel Flexney in London. Reynell is acting as agent for Flexney, having a ship built for him by the successful Philadelphia builder Charles West. This was a typical role American merchants played for their better-capitalized counterparts in England, especially before 1750. The first letter, from Flexney, dated 24 May 1740, is primarily concerned with the usual business of goods and prices, but two lines of it read: "...if thou hast no allready begun I desire thee build a vessel about L 120 Tun Square Sternd beleive to be a Brig will sail with least expence & lett her be finished with all possible expedition ..."[68] A 120-ton brig was a typical mid-sized Atlantic merchantman of this period, as we have noted, and Flexney tells us why.

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[67] The book eventually resulting from that project, *Shipbuilding in Colonial America* (Charlottesville: University of Virginia Press, 1976), is still the only monograph on the subject. Goldenberg's archival sources were the starting point for the archival research for this project. Thanks to Professor Goldenberg, who is retired now, for personally providing advice on this.

[68] Coates and Reynell Family Papers, Box 2, Folder 8, HSP. The "thee" lets us know that Reynell and Flexney are Quakers; Quakers formed their own business networks around the Atlantic World, as did other groups with ties of religion or political leanings or extended kinship.

We find a follow-up reference in a letter of 19 June 1740, unusual because it describes the details of the ship and expresses a technical opinion on nautical matters, if only in passing. Reynell writes back to his client:

> Have agreed with Charles West to Build a Square Stern Vessel of 55 foot Keel, 21 foot Beam, 10 foot Hold, 4 foot betwixt Decks, 12 foot Rake 3 of which to be in the Keel and 9 [?] Inches [?] Dead Rising for thy [Custom?] to be lanch'd the 1st of May next. Could not get her done sooner by any good Carpenter besides am informed, it would be a great Disadvantage to the Vessel to plank her up in Winter am to give him £4 6 June. Would not advise thee to make a brigantine of her their large Booms soon beat [?] 'em to Pieces, in my Opinion a Snow is a much Handyer vessel.[69]

The specifications listed here do not just indicate size. The specification for "Rake" and for "Dead Rising" (deadrise) indicate aspects of the shape of the hull and thus the design of the vessel. It is not clear whether Reynell or West came up with those specifications. Reynell politely suggests to Flexney that he exercise patience, as building a vessel out of wood takes time to do properly and the construction schedule must take into account how the seasons of the year affect the exposed timbers. The final sentence here, advising Flexney to specify his new vessel as a snow rather than a brigantine, is one of only two such explicit opinions found in merchants' papers in two months of work in five archives with extensive collections of such papers from our period. Obviously a fair number of owners—or at least builders and masters—had to believe that the snow offered advantages over the slightly simpler brig, but it would be worthwhile to explore, experimentally, what those advantages were.

On 6 July, Reynell includes the following in another letter:

[69] Coates and Reynell Family Papers, Series 1, Volume 4, John Reynell letter book 1738-1741, HSP.

> As the vessel I had agreed with Mr. Charles West to build for thee is not yet put up have desired him to get a keel 3 foot longer, that it may do for Capt. Stephenson w[hi]ch he has promised he will, and certainly I think 21 foot Breadth will be full narrow for that length.[70]

We can read into this that Captain Stephenson, who, later letters reveal, Flexney uses as his man-in-the-yard and probably senior captain at sea, has voiced the opinion that the keel should be extended, and thus the vessel made longer for her breadth, and that Reynell believes that at that length, she needs to be 21 feet in the beam. Too narrow a ship will not stand up well to her canvas. Apparently there was some discussion of this—perhaps Flexney was concerned that broadening her would increase his cost even more, which it probably did, but Flexney's side of that correspondence was not located, if indeed it exists. The next letter mentioning this ship is dated 14 December, from Reynell:

> The new ship is raised, we are obliged to make her 21 foot Broad. Agreeable to my former agreement, or the Carpenter would not build her. I cannot help being of the Opinion that she will be abundantly the better for it, much more than the Cost of it will be. If she had been made narrower, it would have been a greater Disadvantage to thee, than [then] the Carpenter, and he was Unwilling to make her any Deeper then [than] our former agreement which I thought was full deep for warr Time. However we got over that.[71]

Reynell and West were probably in cahoots here. We do not know how much of the insistence on changing the beam was Reynell's and how much was West's. We do know that a builder of West's stature would have to uphold his own standards for the sake of his reputation. If he was convinced a narrower beam would make for a bad ship, it is completely believable that he would refuse to build her so. The builder's eye was a

[70] Coates and Reynell Family Papers, Series 1, Volume 4, John Reynell letter book 1738-1741, HSP.

[71] Coates and Reynell Family Papers, Series 1, Volume 4, John Reynell letter book 1738-1741, HSP.

powerful guide, and still is in wooden shipbuilding. This passage also reminds us that, though Flexney may have had the money, his control over what was happening in the yard in Philadelphia was limited. He had to trust Reynell and West. That was another owner's risk he incurred.

Formal shipbuilding agreements, as we might expect, tend to be more detailed the larger the vessel—and thus the more money and work being risked on her. These agreements are clearly as much about risk management as sailing instructions and insurance policies. A short one, for a small vessel, reads much like the excerpt from Reynell's letter to Flexney in 1740. Twenty years after that, William Peirce contracted with Joshua Coffin and Samuel Hale, all of Newbury, Massachusetts, on 5 September for "The Hull of a Small Vessel Designed for a Sloop...," to be 40 feet on the keel, 6 feet 4 inches in the hold, 17 feet in the beam, planked outside with 2 ½ inch thick sound white seasoned oak, with ceiling plank (inside lining) 1 ½ inches thick. Deck planks were to be 2 ½ inches thick and free of sap and rot, timbered with good sound white oak, top timbers[72] to be all white oak, short quarter deck "as Customary for such Vessels.." a long floor, but short floor timbers, about 7 inches deadrise. The builder was to find the spars—mast, boom, bowsprit and gaff—and was to launch her, caulk the treenails, and find a rudder, tiller and windlass, grave her and stop the worm holes, and launch her before 8 December. The owners were to contribute all iron nails, pitch, turpentine, and oakum.

[72] Top timbers are the upper parts of the frames, above the water line.

The price per ton was three pounds one shilling and four pence, to be paid in West Indies good, corn and/or money.[73]

Again we see design details specified here, and we do not know whether those were specified by the builder or by the owners. Perhaps the owners, if they were knowledgeable and experienced, expressed design preferences to the builder, who translated those into quantifiable specifications. Note that there is no capacity specified here. That omission was more common for these small vessels than for ships. Any good builder, though, would have been able to translate a roughly specified capacity to the dimensions we see here. The rest of the agreement—the bulk of the agreement, and indeed of all these agreements—sets out details of *scantlings* and construction. *Scantlings* refers to specifications for sizes of timbers to be used—particularly thickness. More detailed agreements set out the fastening method and fasteners to be used—what the owners are about here is ensuring stoutness of construction. Mention of seasoning, and of timber quality—"free of sap and rot"—point to a consistent concern with quality of construction, promoting seaworthiness and durability. Seasoned white oak was generally the timber of choice for shipbuilding in the Atlantic, especially for structural members (frames). A specification for that is also a quality-assurance specification. The mention of a "short quarter deck, 'as Customary for such Vessels'," lets us know that all parties concerned herein know what sort of vessel they are talking about. Sloops of this size carried far more cargo, far more cheaply, than freight wagons on dirt roads in this period.

[73] Shipbuilding contract William Peirce, 1731-1778, MSS 0.549, PEM-Phillips.

Two months may seem a short time to build such a vessel, but this was not atypical. If the timber were already seasoned, it was possible. Correspondence and journals in shipwright's papers indicate that delivering vessels on time was routine. Delivery dates were always specified in these agreements, as were payment terms. As we would expect, those terms usually acknowledged the necessity of at least partial payment in goods—preferably sugar products. For all but the smallest vessels, a specified rate per ton was common.

So the agreement touched briefly on the design of the vessel—the type, and rig, were pre-assumed—and the rest of it, like any business agreement, is concerned with protecting the interests of all parties—of risk mitigation. We have explored a range of risks assumed by merchant owners, and the strategies they employed to mitigate those risks. The other party to such an agreement as this—the shipwright—had his own money and labor to venture, and his own risks to mitigate. A better understanding of merchant ships demands an understanding of the people who actually built them, and these building agreements provide a useful place to start, so we will not leave them just yet. How ship design and construction worked in this world, though, merits its own chapters.

Chapter Four: Ships and Ship Builders

On 6 June, 1661, John Browne of Jersey, on behalf of himself and two other merchants, signed a building agreement with shipwright William Stevens of Gloucester, Massachusetts, for

> one new shipp of sixty eight foot long by the keele & twenty three foot broad from out side to out side & nine foot & half in hold under the beame, with two decks, fore Castle, quarter deck & round house; the decks from the mainmast to the forecastle to be five foot high, with a fall at the fore Castle fifteen inches & a raise at the mainmast to the quarter deck of six inches, the great cabbin to be six foot high, and the said Stevens is to find timber & plank, trunnells, pitch & tarr & ocum [oakum] & to finish the hull & lanch the said vessell by the last of July one thousand six hundred sixty two and the said Mr. Browne & Company is to find all iron work, carved work & joyners in time convenient soe that the work be not hindered for want thereof – In Consideration whereof the said John Browne in the behalf of him self & company doth covenant & grant to & with the sd Wm Stevens to pay or cause to be paid to the sd Stevens or his assigns the just sum of three pounds five shillings for every tunn of the said shipps burthen in such kind and maner as followeth … dated the sixth day of June in the year of our Lord one thousand six hundred sixty one …[1]

Only 40 years after the first settlement in New England, the shipping industry there was already viable, and competition between shipwrights there and their counterparts in the old country would only grow over time.

[1] Essex County, Massachusetts Deeds, Book 2, p. 47, courtesy of Steve Klomps of the Peabody Essex Museum. Steve was generous enough to share some of the agreements he has found over many years of researching shipbuilding in Essex County, and he provided context for those, as well as for those that research for this project located in the Phillips Library.

"sixty eight foot long by the keele & twenty three foot broad…"

The quickest way to get a sense of where a vessel sits on the tub-to-greyhound continuum is to calculate her length-to-beam ratio.[2] The broader she is for her length—the lower the ratio—the closer to round she is. A perfect square would have a ratio of 1. The narrower she is for her length, the sleeker she is. Narrow beam, though, works against both capacity and initial stability,[3] so we find merchant ships of the entire period staying within a fairly narrow range—roughly 2.5 to high 3s. The ship ordered by Browne is to have a length-to-beam ratio of 3.23. The ship Reynell would have Charles West build for Daniel Flexney in 1740 was to have a ratio of 2.76. This helps give the lie to the common assumption that 17th-century ships were much tubbier than their descendents. Much of that impression, especially for later 17th-century ships, is imparted visually by *tumblehome* and high *castling*.

Digging into design and construction I: the case of tumblehome

Tumblehome is the curving-inward of the topsides toward the rail, as opposed to the topsides rising straight up or flaring out. It tended to be much more pronounced in the 17th century than in the 18th.

[2] It is important to use the same length measurements in comparisons. Keel length, rather than length overall, is the usual length measurement in a contract such as this.

[3] Other factors, though, can increase ultimate stability vis-à-vis a beamy vessel.

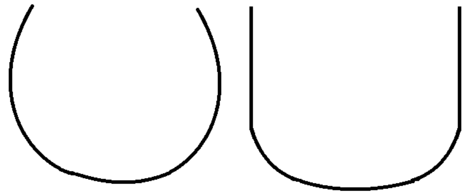

Figure 11 Tumblehome (on left).

Tumblehome, like any other aspect of design, has its pros and cons. The pros and cons that matter most to us as historians are those that mattered to the people who designed and used these ships. While it is true that they may have perceived pros and cons that did not actually exist, as with their medical practices, it is just as important for us to learn about those to understand the cultural and technological milieu of ship design. Having said that, none of the evidence of any type gathered for this project points clearly to a misapprehension of hydrodynamic or aerodynamic principles applied to ships actually built.[4] Delving into a discussion of that aspect of design allows us to consider a range of design and construction criteria. First, we always have to remember that any aspect of design or construction will manifest influences other than "pure" hydrodynamics or aerodynamics. A ship is not a theoretical construct. It is a material construct manifesting a set of competing imperatives and thus compromises. Consider this excerpt from Captain John Smith's *Sea-man's Grammar*, one of our most relied-upon published primary sources for 17th-century nautical know-how. Note that Smith uses the term "howsing" to mean what we call tumblehome.

[4] There is one possible exception—see Chapter Five, p. 181.

> The howsing in of a Ship is when she is past the breadth of her bearing she is brought in narrow to her upper works [her topsides narrow above the point of maximum beam]: it is certain this makes her wholsome in the Sea without rowling [rolling], because the weight of her Ordnance doth counterpoise her breadth under water, but it is not so good in a Man of War; because it taketh away a great deal of her room, nor will her Tacks ever so well come aboard as if she were laid out aloft, and not flaring, which is when she is a little Howsing in, near the water, and then the upper work doth hang over again, and is laid out broader aloft, this makes a Ship more roomy aloft for men to use their arms in, but Sir Walter Rawleigh's proportion, which is to be proportionably wrought to her other work is the best, because the counterpoise on each side doth make her swim perpendicular or straight, and consequently steady, which is the best.[5]

One does not need the ability to analyze these remarks as a naval architect might to glean some insight from them. Note that much of what Smith lays out here is not about maximizing vessel performance as a watercraft, but about carrying ordnance, interior accommodation, and ease of working and defending the vessel. To make the point most clearly that every ship is the product of compromises, we can reduce that to its absurd extreme. Every ship is, first and foremost, a compromise between the ideal attributes of a watercraft on the one hand and the ideal attributes of a carrying vessel on the other. The ideal watercraft, one might argue, is a racing catamaran or trimaran—basically knifelike foils in the water with enough air in them to be buoyant, bridged together to provide lateral stability, or resistance to heeling forces, with giant aerodynamically optimized sails providing so much power that these craft plane most of the time. These are the only

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[5] John Smith, *The Sea-man's Grammar and Dictionary, Explaining all the difficult Terms in Navigation, and the Practical Navigator and Gunner: In Two Parts* (London: 1691 edition, Google e-book facsimile), 52. This is the same John Smith of Virginia fame. The reference to another famous English adventurer, Sir Walter Raleigh, is specifically to a set of principles of ship design Raleigh wrote in 1612. Those may be found in William A. Baker, *The New Mayflower: Her Design and Construction* (Barre, MA: Barre Gazette, 1958), 37-38.

vessels that have ever beaten the sailing records of the 19th century clipper ships, but they will barely carry a handful of miserable crew. The ideal cargo carrier, on the other hand, would be of a shape that maximized the amount of volume for a given length, width, and depth. That shape is a rectangular box, and a box does not move through the water very well. So there is the fundamental compromise of the design of every cargo ship ever—how to make a reasonably hydrodynamic box.[6]

As the ship heels, or leans laterally in response to the pressure of wind on the sails and waves on the hull, tumblehome will not offer as much resistance to the water as straight or flared sides would. In that sense, does tumblehome sacrifice some stability? English maritime historian Richard Barker argued that "at normal angles of heel" it did not, compared to flared topsides.[7] Naval architect and marine engineer Dan Walker is unequivocal that it does.[8] Is "normal angles of heel" the key to that contradiction? It stands to reason that, once the vessel has rolled past her maximum beam, her inward-sloping topside will not offer as much resistance to further immersion as a straight or flared topside. On the other hand, we have "Walton's observation that tumblehome delays the immersion of the deck edge at large angles of heel…but the other side of the coin is that righting moments are reduced, and the hull may roll further."[9]

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[6] See Chapelle, *The Search for Speed Under Sail,* 43-44.

[7] Barker, "Why tumblehome?" *Mariner's Mirror* 84:1 (1998): 95-97.

[8] Dan Walker, personal communication, 3 June 2014.

[9] Barker, "Why tumblehome?" 97. Righting moment is the force that resists heel and wants to return the ship to the upright position.

Tumblehome could bring heavy guns closer to the centerline. Did that contribute to stability? Ship archaeologist Jon Adams says it is a given that it did not, referring to it as a well-known fallacy, at least by the 18th century. He does not know whether it was known as such earlier. He points out, though, that tumblehome did have an "indirect benefit, as by lightening the deck structures above the waterline it lowered the centre of gravity and this may have been part of the thinking behind reducing castling."[10] An assumption that such a universal aspect of ship design for such a long time—two centuries—was primarily due to a "fallacy" must be rejected, even if some—like John Smith—subscribed to that fallacy at some time. A discussion in *The Mariner's Mirror* emphasizes several benefits of tumblehome, in addition to Adams':

- the inward-sloping topsides made it easier and safer to come alongside the vessel for boarding or loading and unloading, especially if she were rolling at all;
- the shrouds and backstays—the standing rigging holding up the masts, attached at the sides and stern of the vessel and to the masts—could be tensioned in a more direct line;
- it was easier for the shipwright to find, and pay for, shorter deck beams;
- it would make it much easier to careen the ship;[11]
- it would reduce wave stress on the hull and decks compared to flared topsides.[12]

To all this we must add the observation that small open boats tend to have flared topsides, especially in the bow, and this helps keep them dry inside. It also increases buoyancy as the flare resists immersion. Open boats, though, do not have decks, and it would seem from the foregoing that tumblehome's advantages have much to do with decks—keeping

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[10] Adams, *A Maritime Archaeology of Ships*, 179.

[11] In the absence of dry dock facilities, which were rare, ships' bottoms were repaired and cleaned by bringing them into shallow water, attaching stout ropes to their mastheads, and pulling on those to lean them as far over as possible to expose as much of the bottom of the ship as possible.

[12] Barker, "Why tumblehome?", which refers to previous entries in the discussion as well as other works; J.V. Bartlett, "Why tumblehome?", *Mariner's Mirror* 83:4 (1997): 478.

them strong, keeping them light, and keeping them dry. Small boats do not weigh much—neither do their structural members, nor their cargo.

The comparisons we have been making are between sides tumbled-home and flared sides. What about straight sides, which have been the norm since the 19th century, when tumblehome in wooden ships was reduced to just a slight vestige of what it had been? Straight sides are universal now, but we build in steel, so no material or structural considerations would have carried forward into our time.

We could have a number of similar discussions, one about each aspect of design and construction—bluff bows, square sterns, deadrise, framing patterns—and none of those issues are 'put to bed' in maritime scholarship. It is striking, in a way, that we should still be discussing, and wondering, and disagreeing about a basic design and construction aspect of 300- to 400-year-old ships. It should be clear, though, from this discussion of tumblehome that these issues are woven into their context in several dimensions. It seems as though, as soon as something makes sense and we think we can stake a claim to an opinion, something else comes up to contradict it. It feels akin to pulling a thread.

That does not mean we should throw up our hands. No historical subject matter lends itself to easy explanation. We have to weigh all the evidence and come to tentative conclusions based on where it seems the aggregate of the evidence is pointing—and rarely if ever will that evidence point to one factor to the exclusion of all others as explanatory. We are not done with the question of tumblehome, but if we are asked whether it is this factor, or that factor, or this other factor, that explains it, our first answer should probably be 'yes,' and after that we can set about trying to rank the factors in order of importance. That is what doing history so frequently looks like. Explaining tumblehome, in that sense, may well look like explaining the fall of the Roman Empire.

Digging into design and construction II: Castles in the sea

The other distinctive design characteristic that, as a rough rule of thumb, makes earlier ships easy to distinguish from later ones is their higher castles—especially stern castles. The historical record does allow us to trace a fairly linear devolution of these from medieval ships through galleons and into later 17th-century vessels. The castles tend to lower until, by the mid-18th century, they are gone. It is worth pointing out that later 17th-century ships—including, in all likelihood, the one ordered by Browne and his partners in 1661—did not look like *Mayflower II, Susan Constant, Sea Venture,* and the other small English galleons of the early exploration and settlement period.[13] They had much lower stern castles and their forecastles did not protrude much above the waist—the lowest upper deck, amidships. Illustrations of merchant ships from the 17th century are uncommon. We have the detailed, expert sketches of the Van de Veldes, father and son, in the major maritime museums of the UK and the Netherlands, and that is a singular, priceless resource. We also have the drawings made by mariners, whether sketches or graffiti on walls and stones. Notable among those is the work of Edward Barlow, who started his career afloat as a seaman and ended it as a master. Barlow's journal was published, and that is also a singular resource. Barlow made a point of drawing every

[13] For an illustration of the basic changes in ships from the Middle Ages to the 19th century from a leading expert, see John Harland, *Seamanship in the Age of Sail*, 36-37. For a clear idea of what one of those small early galleons looked like, see Figure 18, *Mayflower II*, p. 253.

ship he served on, as well as harbors and islands and other features he knew would be useful to other mariners. On the following page is Barlow's drawing of a ship called *Mayflower*, launched in 1676, of 150 tons and 14 guns, Barlow writes, and "a very pretty ship." He sailed on her on a voyage carrying corn from England to Tenerife. This would have been an ordinary Atlantic merchant ship of the time.[14] The ship ordered from Stevens by Browne would likely have closely resembled this one, though it is unlikely that the fancywork on the stern would have been quite so impressive on a New England-built ship.

[14] Edward Barlow, *Barlow's journal of his life at sea in king's ships, East & West Indiamen & other merchantmen from 1659 to 1703,* two volumes, transcribed by Basil Lubbock (London: Hurst & Blackett, 1934), 281.

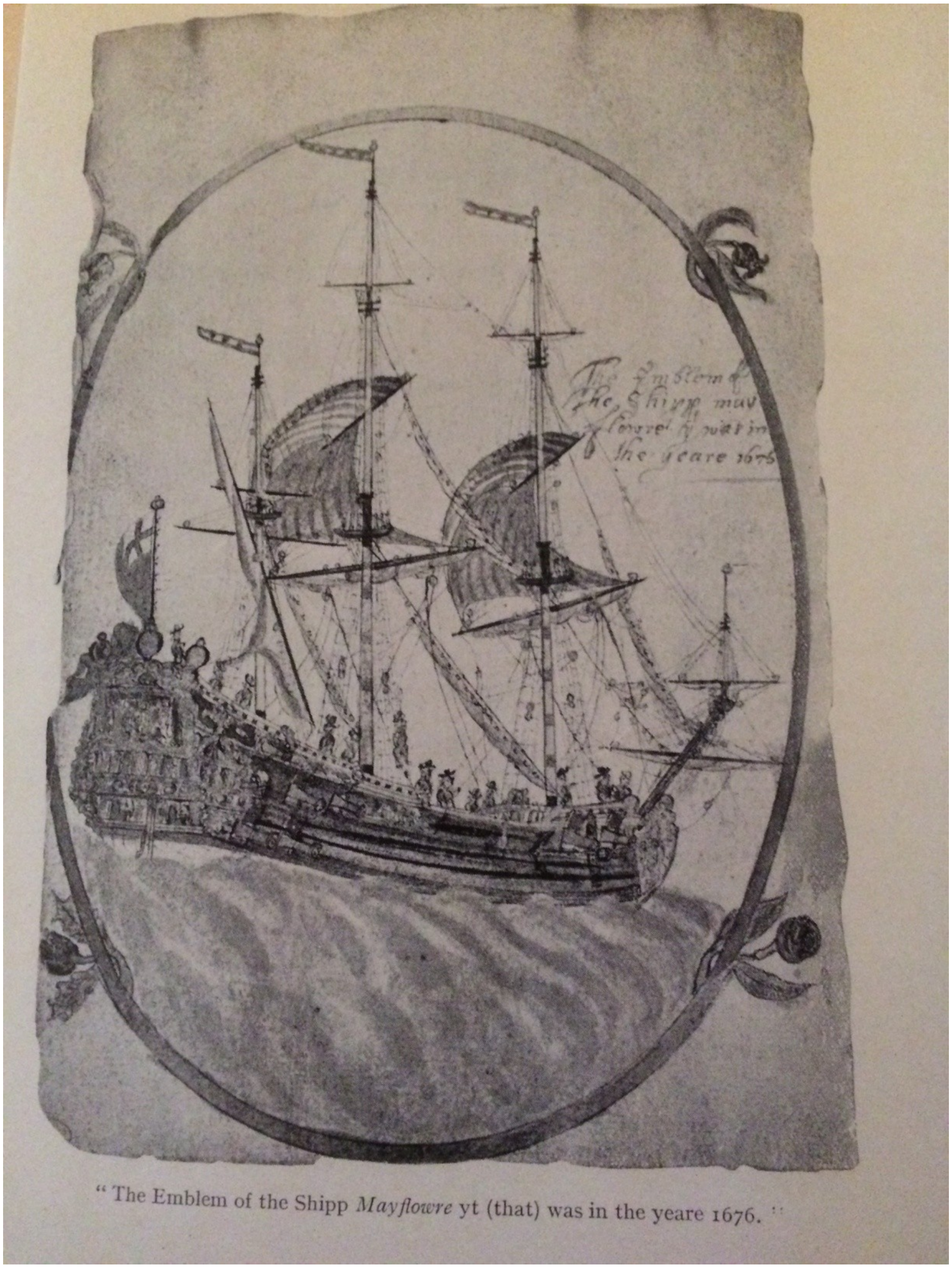

Figure 12 Ship *Mayflower* by Edward Barlow.[15]

15 *Barlow's Journal*, plate 283.

Conventional wisdom has it that later castles were vestiges of the fighting platforms that gave taller ships an edge in combat when ship-to-ship fighting was less about cannon volleys and more about small-arms fire at close range, boarding, and hand-to-hand combat. As that situation reversed itself, there was selective pressure to reduce castling, due to its weight, cost, and windage. As with any de-escalating arms race, though, letting this guard down took time and caution. The evidence suggests that, as far as the naval aspect of this is concerned, the conventional wisdom is correct. Here is as good an example as any of why such a study as this is worthwhile. We have a reasonable explanation for this gradual change, including why it was so gradual, supported by evidence. Why not just put it to rest?

We just came up with the answer to that question in the discussion of tumblehome—because there is always more than one factor in play. Selective pressures to retain or discard a technological characteristic are multiplex, not simplex. So even if we accept that the decrease in castling was a de-escalating arms race, which the evidence suggests we should, we should also assume that other pressures existed and that if we are to understand this design aspect, we need to find those. We will re-visit the issue later in this chapter, and in Chapter Six, when we turn our attention to analyzing experiences with replica ships. Meanwhile, we should return to William Stevens' yard, and to shipbuilding.

"…the said Stevens is to find timber & plank…"

Wood does not have to be made. It grows—it is there for the taking. Just about anywhere Europeans decided they wanted to settle in the Americas, they found trees. In fact, they found trees we do not find now—much older, taller, bigger ones than we allow to grow. When the *Sea Venture* wrecked on the Bermuda reefs in 1609, the would-be Virginia colonists waded ashore, found trees and built themselves two new ships out of them. Wood was readily available.

The skills for working it were also readily available. Shipwrights in Europe had been teaching new shipwrights how to build wooden ships for hundreds if not thousands of years. Specific techniques varied widely and evolved, but basic concepts of how to put a seaworthy vessel together out of a multitude of specially selected or specially cut timbers were proven.[16]

Wood had no rival as a shipbuilding material in the western world in this period—and long before, and for a short time after. If we understand the realities of wood as a material, and as a commodity, then we understand something key.[17] That requires understanding the limitations as well as the advantages of wood—a natural resource that, like all other natural resources, would become problematic by the end of this period, given the inexhaustibly extractive and exploitative nature of western economic growth.

Wood's most obvious suitability for shipbuilding, next to its availability, is its buoyancy. It floats, unless it is completely waterlogged—hence the term. While it is true

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[16] For a technically grounded introduction to eighteenth-century shipbuilding in British America, see VanHorn, already cited. VanHorn provides a summary discussion of the major 18th-century shipbuilding treatises, and she compares what she finds in the treatises to the evidence presented by the remains of six vessels found and analyzed by archaeologists. Another important introduction that provides a useful counterpoint to the usual focus on New England is Converse D. Clowse, "Shipowning and Shipbuilding in Colonial South Carolina: An Overview," *American Neptune* Volume 46 (1984): 221-244.

[17] See Amy Mitchell, "A Comparison of Wood Use in Eighteenth-Century Vessels" (Master's thesis, East Carolina University, 1994).

that the buoyancy of a ship is created by the water it displaces and the air within it, the fact that shipwrights and mariners appreciated the buoyancy of wood—and that some drastically over-estimated its importance—is borne out by the not-uncommon suspicion of iron ships in their early days.

A more important characteristic of wood as a building material for watercraft is its outstanding strength-to-weight ratio. For smaller craft, only the latest, best, and most expensive composites can rival wood in that regard. Even high-quality fiberglass hulls cannot approach wood's strength-to-weight ratio.[18]

Wood can be worked with hand tools and low-heat fire—forced induction not required. Its relative softness compared to stone and metal means it can be shaped as desired by human muscle power. A handful of adult humans can build a good-sized wooden ship, given the time. With no need for foundries, heavy machinery, or other sophisticated physical plant, builders of ordinary-sized wooden ships can work outdoors, with hand tools, just about anywhere with land clear enough for the ship, next to navigable water.[19]

Some trees contain natural bends and curves from which *compass timbers* can be derived—curved or bent structural pieces. The trend over our period was for this characteristic to move from being a great advantage to being a great problem, as adequate sources of compass timber were used up faster than new trees could grow. In 1661 in Massachusetts, we can assume William Stevens would be able to go out in the woods and

[18] Wood has by no means been abandoned as a building material for smaller craft in our rich, high-tech society, even for performance-oriented craft whose builders have no interest in "heritage." Strength-to-weight is a major reason for that.

[19] They may not have needed foundries, but they did need to buy iron bolts and nails.

find specific trees with particular branch-fork patterns for specific structural members. In fact, he had probably identified and marked such trees already—perhaps years earlier. A century later, that would not be as easy around the shipbuilding centers of New England and the Delaware Valley. In England, of course, it had become difficult much earlier—except in the forest reserves kept by the Crown for naval use. In such timber-growing repositories, trees whose branches spread such as to provide compass timber were protected for that reason.[20]

Shipwrights, then, had to have an eye for the right tree for the right job. When the right trees grew scarcer, he had to adapt his design and construction techniques to fit the available materials—or move. Usually, this meant figuring out a way to make up a structural piece by joining together smaller pieces, instead of using one ideally shaped compass timber. The archaeological record shows us clear evidence of that.[21] Whether it was fashioning composite pieces where one would have been preferable, or scarfing together a long structural member out of multiple pieces because no single timbers of sufficient length were available, shipwrights had to consider the inherent weaknesses in joints, and in some cases reinforce the structure by improvising a new technique. They could not use the same techniques to build ships with different materials, and they were frequently not in control of exactly what materials were available to them.[22] They had to

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[20] Rodger, *The Command of the Ocean*, 192.

[21] See VanHorn, 187-188. Among the wrecks she analyzed, this was prominent on the British vessels, reinforcing the hypothesis that a lack of suitable compass timber would have hit England before it hit British America—adding to the growing competitive advantage of American shipbuilders.

[22] That they—and their customers—wanted to control the timber used in construction is quite evident from the attention to timber type, quality, and scantlings in the shipbuilding agreements.

adapt. The six wrecks from our period found in American waters that Kellie VanHorn analyzed showed more variance than consistency in how they were executed. VanHorn found no rule that could explain how all of them were designed and constructed.[23] Six vessels is a small data sample, as VanHorn points out, but it adds to and reinforces other evidence we have pointing toward the pressures to adapt and responses to those pressures that indeed show adaptability and adaptation.

Even if the timber available was ideal, wood does have inherent drawbacks, like any material, and those drawbacks did much to determine the reality of building and operating a ship in our period. First, of course, wood rots. Fungi and bacteria eat it. All they need is water and oxygen, and they can irreversibly compromise the structural integrity of a large timber in a matter of months. The war against rot was constant. In his treatise of 1711, William Sutherland indicated that the old method of placing floors and lower futtocks—the lowest and next-lowest pieces of a ship's frame—next to each other had been shown to cause rot in the timbers, so he recommended leaving some space between them.[24] More than a century later, no less a personage than Michael Faraday delivered a lecture to the Royal Institution in which he announced success in his experiments with mercuric chloride—"corrosive sublimate"—in preventing rot even in

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[23] VanHorn, 171. VanHorn concludes that her evidence cannot support a theory of framing pattern evolution proposed by Morris et al. (already cited), with the exception of some indication that cant frames in the bow section came later than square frames, which that theory included. See, however, the discussion of Riess and the Ronson ship in the next chapter.

[24] VanHorn, 48.

timbers subjected to a completely anaerobic environment.[25] The Admiralty conducted trials of Faraday's method for five years, declaring it a success in 1833.[26] This ship-rot business was an important problem indeed. For ships operating in temperate waters, so was the *teredo* worm—actually a mollusk that bores into any unprotected submerged wood. Hence all the attention paid to paying and sheathing a ship's bottom.[27]

Decay always won in the end. All ship owners could hope for was to stave it off until the vessel was no longer fit for the service the owners had her in. It was common for owners to sell vessels while they were still fit for their originally intended service, and still worth some money, before expensive major repairs became necessary. Such was the case with the *George & Mary* and the *Two Catharines*. If a ship survived all the other dangers she was constantly exposed to, eventually she would be rotten enough that she would be condemned and broken up, or abandoned in some out-of-the-way cove or river bend.

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[25] They knew then that mercury was toxic, and Faraday added that he had treated cloth with the substance, then repeatedly washed it to show that, once bound to the organic matter, the mercury would not release.

[26] Michael Faraday, "On the practical prevention of dry rot in timber," published account of a lecture by Faraday at the RI on 22 February 1833, (London: John Weale, High Holborn, 1838), Pamphlet Vol. 249 No. 18, Library of the American Philosophical Society. The APS Library's pamphlet collection contains two other items on the subject from our period: Edmund Saunders, "An Address to the Owners of Ships, &c., in particular, and in general to all who have an Interest in preserving Timber under Water" (Plymouth: M. Haydon & Son, 1790), Pamphlet Vol. 116, No. 3; and Henry Guest, "Observations on sheathing vessels: seasoning timber; the proper time to fall timber; the nature and what force it is that causes the sap to rise; with a number of other valuable observations" (New Brunswick, NJ: A. Blauvelt, 1805), Pamphlet Vol. 1162, No. 7.

[27] Paying is coating with pitch, or tallow. Sheathing earlier consisted of sacrificial planking with a layer of pitch and animal hair (felt, basically) between that and the actual hull. Beginning in the 1760s, shipwrights increasingly turned to copper, which is biocidal, but it introduces dissimilar-metals electrolysis issues when in contact with iron, and can thus corrode fasteners quickly if not isolated from them. See Gareth Rees, "Copper Sheathing: An Example of Technological Diffusion in the English Merchant Fleet," *Journal of Transport History* New Series 1 (1971-1972): 85-94.

Rot was not the only inherent drawback of wood that worked against the longevity of the ship. So much of the shipwright's skill was focused on making the strongest and most watertight joints possible in a vessel made up of hundreds if not thousands of pieces of wood, each of which was at least somewhat flexible. Such a structure, when put in service, would then be subject to constant stress, flexing it and straining it in three dimensions. Water could potentially enter the hull in a thousand different places.[28]

"…trunnells, pitch & tarr & ocum…"

This is why it was so advantageous to the shipwright to have the longest timbers—and thus the oldest, tallest trees—possible, and to have compass timbers in the shapes they needed. The fewer joints and holes there were the better. Naturally curved timbers also helped stave off rot. Cutting curved pieces out of straight timbers unavoidably exposed cross-grain and left sapwood in the ends of timbers, inviting rot, as the heartwood is the most rot-resistant, and wood takes in moisture through the end-grain where its cells are cut across.[29] Hence we find the stipulation in the 1760 Peirce building contract that "Deck pl.ank … be 2 1/2 in thick and free of sap and rot…"[30]

"Trunnells" is a corruption of "tree nails"—thick round wooden pegs, pounded into exactly sized holes, to join two pieces. Shipwrights used trunnells along with iron

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[28] There were no adhesives—on which we rely so heavily now in wooden vessel construction. As Captain Walter Rybka noted, "…about the time we ran out of good trees, we invented good glue" (Walter Rybka, telephone interview, 21 April 2015). Unfortunately for our shipwrights, there was actually enough of a lag between the two that they had to be inventive to compensate for the lack of ideal timber.

[29] Adams, *A Maritime Archaeology of Ships*, 180-181.

[30] Joshua Coffin Papers, 1647-1862, MSS 0.549, PEM-Phillips.

bolts and nails for different fastening purposes. They were labor-intensive to make and use, but they could not corrode as iron did nor did they work themselves loose under stress as easily. They were used throughout the modern age of wooden ships.

Pitch and tar were pine products, and thus major export commodities for British America, especially the Carolinas. They were the most readily available and widely used products for waterproofing. Ships' bottoms were "payed" with pitch, and hemp rigging was tarred to keep water out of it and stave off rot. Sailors were called tars because they always had the stuff on them and on their clothes. It was unavoidable.

Oakum is loose fiber, twisted into strands, pounded into the seams between the planks of a ship's hull before caulking. Sailors made oakum out of old rope that was no longer fit for rigging service. It was a time-consuming but necessary menial task to which the crew was frequently put when there was nothing else pressing to do. Recall the brig *Friendship* from Chapter Three, languishing in Bayonne for ten months. Capt. Olney records in his log several times that he has the crew picking oakum.[31]

In the Stevens agreement, Stevens is to procure the trunnells, pitch, tar, and oakum, but which party was responsible for securing which materials varied. Regardless, Stevens would be responsible either for using those products skillfully himself, or subcontracting with other tradesmen to do it. Ship caulking was a skilled trade in itself. Full-time caulkers could be found in the major shipbuilding centers throughout this world, then and later.

[31] Log of the brig *Friendship*, Brown Family Business Records, Box 733, Folder 1.

All this work may seem menial and archaic—perhaps un-technological—but it was central to the employment of this technology. All wooden ships leaked, but if a ship leaked badly enough, she could ruin her cargo or, worse, sink. Pumps were human-powered. The stories of crews working the pumps around the clock to save a damaged ship are testaments to human endurance, but human endurance has limits. So the shipwright could not pay too much attention to jointing, fastening, strengthening, and sealing. He had no choice but to find new solutions to those challenges as his available materials changed.

The other inherent weakness of the wooden ship, besides her vulnerability to rot and leaking, was structural rigidity—particularly, longitudinal structural rigidity. With so many joints and so many pieces, fashioning an interlocking structure that would hold its shape under the stresses of motion in a seaway over a period of years was quite a challenge. Failure to maintain longitudinal rigidity resulted in one of two conditions, both of which were seriously detrimental to the ship's hydrodynamic performance, let alone her integrity. The first was sagging, in which the middle section of the ship drooped relative to her ends. The second was hogging, in which the ends drooped relative to the middle. William Hutchinson, in his well-known treatise, recounts his first job as a supervising shipwright, building a merchantman for the Jamaica trade, 90 feet on the keel. He built her on concave stocks as a prophylaxis against hogging, and recommended building all vessels on stocks with a concavity of two inches for every 30 feet of length.[32]

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[32] William Hutchinson, *A Treatise on Naval Architecture,* Fourth Edition (London: Conway Maritime Press, 1970), v-vi. Originally published 1794.

The thought was that, as the ship settled with age and use, her originally slightly convex keel would become horizontal, not concave. There is a rough analogy to the modern flatbed trailer, built with a curve so that it will not sag under load. Hutchinson did not believe that a slightly convex keel was detrimental to performance.[33]

In 1737, Blaise Ollivier was sent by the French government to observe shipbuilding in the naval dockyards of England and Holland. His comments on hogging in English vs. French ships point out the factors the shipwright had to consider in combating this problem:

> The English claim that their ships hog less readily than do ours, and that is true. Many causes contribute to delay this hogging in the English ships. 1st, the treenails which fasten the planking and the ceiling to the frames provide a more solid fastening than do our nails. 2nd, the bow and the stern of the English ships weight proportionately less than those of our ships, since the riders forward and aft have neither lower nor upper futtocks; and since the counter and the stern-galleries extend less beyond the perpendicular of the sternpost, and since the head is burdened with a bowsprit which is less thick and with rigging which is less weighty than is the case with our ships, 3rd the English ships are finished and caulked up to the waist when they are launched, whereas our ships are caulked but as far as the load waterline or at most to the middle deck ports. ... they are never lightened of all their ballast as are ours each time they are graved.[34]

So, of all the other considerations the shipwright had to keep in mind when deciding just how to approach all the elements of design and construction Ollivier mentions, he also had to consider longitudinal rigidity. Hogging was closely connected to the bearing of armament. As the 17th century went on, there was a trend in English construction to

[33] The major drawback of wood not addressed here is its flammability. That is because, aside from providing effective pumps, there was nothing the shipwright could do to mitigate that risk.

[34] Blaise Ollivier, *18th Century Shipbuilding: remarks on the navies of the English & the Dutch from observations made at their dockyards in 1737*, trans. and ed. David H. Roberts (Rotherfield UK: Jean Boudriot Publications, 1992), 161.

increase displacement in the ends as a countermeasure.[35] That means broader, not sharper, bows and sterns. The structural problems of wooden construction have much to do with why we would never see the knife-like prows of modern steel warships on vessels in our period.

From the cradle to the graveyard: longevity

With all the skill and care and time, proper materials, proven techniques and clever improvisation going into a ship, how long would she last before the entropy ruling all of nature claimed her, and she was quietly towed to the breaker's yard or to that out-of-the-way cove or river bend and left there.

The longevity of merchant ships in our period has been a matter of some discussion. Some of that discussion is centered on the issue of British-built vs. American-built ships. For a long time, British merchants held on to the opinion that the latter were almost always inferior—that they might have been cheaper, but that you got what you paid for. Lord Sheffield, who consistently and publicly decried American competition with home-based shipping and shipbuilding, claimed American ships would only last five or six years, but John McCusker says this was almost surely an exaggeration, and that the real average was probably more like ten.[36] It is clear that some amount of irrational conservatism—mixed with the general British arrogance toward the colonies and the colonials—is responsible for this attitude. In 1799, Lloyd's of London, however, rated

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[35] Baker, *The New Mayflower*, 33-34.

[36] McCusker, "The Pennsylvania Shipping Industry in the Eighteenth Century," 121, 125.

southern-American-built ships their A-1 rating at the time—twelve years.[37] So at least in their probably dispassionate judgment, these were fine vessels, and we should not paint British prejudice with too broad a brush. Southern live oak had managed to gain recognition for its outstanding combination of rot-resistance and strength by that point, obviously. It had taken time, though, and the southern shipbuilding industry remained small.[38] Live oak is too hard to be worked easily with hand tools, once it has seasoned. In the South, the wood could be worked green, but by the time it could be transported to New England, it would have hardened. It would be the 19th century before New England yards, with their new industrial tools, could make full use of Southern live oak in their yards.[39]

Marshall Smelser and William Davisson complicate the matter, writing in the same year as McCusker. Examining New York Navy Office records from 1715 to 1764, they found that the average age of the ships listed there was 4.7 years, and that only 9.4% were over ten years old. What was most striking, though, is that the British-built ships

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[37] McCusker, "Pennsylvania Shipping Industry," 126. Lloyd's rating determined the terms and price of ship insurance. The higher the rating, the longer the ship was expected to last—hence the year range assigned to it. For perspective, consider that, while in 1799 an A-1-rated ship was expected to stay in service for twelve years with her original integrity, in 1911 Lloyd's rated the German steel bark *Peking* A-1, with a projected service life of 100 years. She is no longer in service, but she is still afloat.

[38] See Clowse, "Shipowning and Shipbuilding in Colonial South Carolina," already cited.

[39] Warren Riess with Sheli O. Smith, *The Ship That Held Up Wall Street* (College Station, TX: TAMU Press, 2015), 54.

tended to be twice as old as those built in America. They attribute this to construction methods—thus casting an aspersion on British-American shipwrights.[40]

Christopher French followed up on this in 1991, and his findings remind us of the inherent limitations of data from one source—a linchpin of most scholarly disagreements on shipping productivity over the past 50 years. French looked at ships trading between London and Virginia or Jamaica, and says that, while their age was always relatively low, it was "also noticeably higher than the mean age of vessels trading between London and New York." The former averaged 7.2-7.7 years.[41] French, though, supports the Smelser-Davisson conclusion that British-built ships lasted about twice as long, and he also attributes that to construction methods. He points out that the British-built ships were bigger, and that bigger ships were more expensive to build—thus it was more compelling to build them to last—especially since bigger ships were also likely to be more profitable if properly employed.[42]

The listed age of a ship in a document, though, is not the same thing as how long she lasted. These studies tell us that, on these routes at these times, there were more old British-built ships than old American ones. That does support their conclusions, to be sure, but it does not prove that British-American building methods resulted in lower

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[40] Smelser and Davisson, "The Longevity of Colonial Ships," *American Neptune* 30 (1973): 16-19. It was much more common at the time, though, for the prejudice to attribute the relative inferiority to the quality of timber used; the belief was, simply, that English oak was better.

[41] Christopher J. French, "The Longevity of Ships in Colonial Trade: Some Further Evidence," *International Journal of Maritime History* 3:1 (June 1991): 158. Thanks to Prof. French for suggesting related sources.

[42] French, "Longevity," 161.

durability. Were some of these ships pulled off these routes after a time and employed in other service? Were ships on other routes, or at other times, older or younger, on average? Recall too that, in her small data sample of wrecks found on this side of the Atlantic, VanHorn found evidence for economizing on timber in the British-built, not American-built, vessels. Those were smaller vessels, though, than those considered by Smelser, Davisson and French.

Merchants' and shipbuilders' papers provide additional information. When Brown, Benson & Ives purchased the brigantine *Maria* in 1799, she was six years old.[43] The sloop *Success* was seven years old when considered for purchase by Brown and Starbuck.[44] That same year, 1777, they either bought or thought about buying the sloop *Bonetta*, estimating her age at eleven.[45] The Crowninshield ship *America* was in that family's service in 1796, and sold by them in 1803 after John Crowninshield's miserable transatlantic crossing to Bordeaux, after which indications are she was to continue in Atlantic service.[46] The Derby ship *Astrea*, already in West Indies service in 1784, was deemed fit enough for a voyage to the Far East in 1789-90.[47] The Browns' papers first mention their brig *Harmony* in 1774-1775.[48] Further records indicate she was still in their

[43] Brown Family Business Records, Box 676, Folder 3, JCB.

[44] Brown Family Business Records, Box 682, Folder 4, JCB.

[45] Brown Family Business Records, Box 682, Folder 5, JCB.

[46] Crowninshield Family Papers, MH 15, Box 1, Folder 1; Box 4, Folder 8, PEM-Phillips.

[47] Derby Family Papers, MSS 37, Box 1, Folders 5 and 8, PEM-Phillips.

[48] Brown Family Business Records, Box 682, Folder 3, JCB.

service in 1794.[49] There is no sense in performing statistical calculations on such a small sampling. What it can tell us is that these American-built ships in service to these merchants were between six and twenty years old.

A correspondent to the British Society for the Improvement of Naval Architecture pointed out the importance of environment to this issue when he wrote, in 1791, that of two identical ships, one on station in a hot climate would be useless in 12 years, while one on station in a cold climate might last 30 or even 40 years. He cited British colliers as an example of the latter.[50]

Whether American and British shipwrightry differed in such a way as to make American-built ships less durable is a question for which we need much more archaeological evidence to answer, though more studies along the same lines as Smelser's and Davisson's and French's would help too. VanHorn's evidence suggests that, if so, it is unlikely to be attributable to disparities in know-how, as she found no "clear distinction between regions of build or even between the two nationalities." Variations "appeared to relate more to vessel type or perhaps the individual practices of shipwrights than location of construction."[51]

Analogous to the evolution of the reputation of the Japanese automobile industry from the 1970s to the present is the likely possibility that American-built vessels were

[49] Brown Family Business Records, Box 683, Folder 8, JCB.

[50] "A Collection of Papers on Naval Architecture," Part I, Society for the Improvement of Naval Architecture, reprinted in London by *European Magazine*, Pamphlet Vol. 744, No. 3, Library of the American Philosophical Society, 57. Colliers were also stoutly built, which is why Cook's first long-distance voyager was a converted collier.

[51] VanHorn, 216.

probably not as well-built overall as their Thames-built counterparts at first, and that that gap closed over time, leaving the reputation to play catch-up, as opinions harden once formed and passed down. Where that analogy breaks down is that certainly by 2000 the average American car buyer had a very positive impression of the quality of Japanese cars. None of the evidence considered here indicates that British ship buyers ever felt the same way about American-built ships. We cannot trust the cultural history here—the clear record of prejudice—to tell us anything conclusive about the actual quality of the built product. To better understand the craft of the shipwright, and the relationship between that craft and the market for its products, we should investigate this issue further, being very careful about generalizing, as VanHorn is right to highlight "the individual practices of shipwrights." What do we know about those "individual practices"?

The mysterious art: unlocking the shipwright's secrets

To an outsider, the shipwright's craft would have seemed a mysterious art based on secrets. The trade of the shipwright was an artisanal craft with an advanced skill set, and like every other such craft in the European world, it had organized and structured itself according to the guild system in the Middle Ages. Any craft guild had two main purposes: 1) to protect the interests of its members, especially their trade secrets; and 2) to control the standards for the craft; and 3) who would be admitted to practice the trade. According to "Records of the Worshipful Company of Shipwrights" of London, published in 1939 by the Company's archivist, the first records of the London shipwright's guild appear in 1387-1388 under Richard II. The first company Ordinances appear in 1428, and punitive Ordinances—formal power to enforce craft standards—were granted in 1483.[52] So by the time Browne and his partners ordered a ship from William Stevens of Gloucester, the organized and regulated craft of shipbuilding would have been considered an ancient one in the English-speaking world.

This ancient craft does seem to present to us some inscrutable arcania—if for no other reason than by leaving so much for us to guess at. Returning to the Browne-Stevens agreement, we can ask how, with only these barest of specifications, did the parties involved know how to actually build this ship—how to shape her hull, where to put her masts, how tall they should be, how broad her yards should be, how much camber to her decks, and on and on? Even if we have a shipbuilding agreement that specifies every dimension and detail necessary for us to reconstruct the vessel—and a few do come close to that—how can we know *why* those dimensions and details were selected as opposed to others?

From the shipbuilding agreements alone, we cannot. We will have to turn to other sources. First, though, we need to understand the craft of the shipwright—and to do that, understand the shipwright himself.

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[52] A. Charles Knight, in C. Harold Ridge, "Records of the Worshipful Company of Shipwrights, Vol. I 1428-1780," (London: Phillmore & Co., Ltd., 1939). Knight was the Clerk and Solicitor to the Company at the time. Peter Wrike found this booklet, reproduced it, and included the reproduction in the supplemental material to his research report for *Godspeed* and *Discovery* prepared for the Jamestown-Yorktown Foundation in 2002. Wrike did contractual research for the 2006-2007 *Godspeed* and *Discovery* replicas for the Jamestown Yorktown Foundation. His report on that research may be found at the library of Jamestown Yorktown Foundation, The Mariners' Museum, and at Joyner Library at East Carolina University (Peter J. Wrike, *The* Godspeed *and* Discovery *of London and Virginia, 1606-7,* Final Report and Drawings, 2002). It is worth noting, though, that the actual vessels should not be considered products of Wrike's research. JYF, and especially Eric Speth, who was in charge of the project, did not agree with some of Wrike's conclusions and recommendations (Speth, telephone interview, 14 August 2015).

Artisanal craft

Shipwrights in our period were highly trained but usually poorly educated. They learned what they needed to know in the shipyard, not in the classroom. They did not need formal mathematical or mechanical training.[53]

Vernacular craft is manufacturing for one's own use. In our period—and, for the most part, in our own time as well—vernacular craft is also artisanal craft, an approach to manufacturing that is best understood—by a modern reader—by contrasting it to mass production in the factory system, overseen by formally trained engineers and technicians. To understand vernacular and artisanal craft, we need the insights of the discipline of folklore, but we need to import those insights without also importing romanticism.

Folklore, as an academic discipline, grew out of the 1960s counter-culture, as a reaction to modernity—a modernity its devotees found as distasteful and discouraging as the 19th century Romantics found theirs.[54] Both movements found modernity dehumanizing. The individual and society were under assault by corporatism, automation, mechanization, technological control, and ephemeral mass popular "culture" that was little more than commercial advertising. By studying, resuscitating, and

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[53] Larrie D. Ferreiro, *Ships and Science: The Birth of Naval Architecture in the Scientific Revolution, 1600-1800* (Cambridge, MA: MIT Press, 2006), 23.

[54] Of course, we can point to antecedents, including the European *volk* movements of the interwar years (which are now perhaps hopelessly tainted with Nazism, but that is reading history backward); and indeed Romanticism itself. For an introduction to folklore as a discipline, see Richard M. Dorson, ed., *Handbook of American Folklore* (Bloomington: Indiana University Press, 1983); Eliott Oring, ed., *Folk Groups and Folklore Genres: A Reader* (Logan: Utah State University Press, 1989); Barre Toelken, *The Dynamics of Folklore* (Logan: Utah State University Press, 1996); Regina Bendix, *In Search of Authenticity: The Formation of Folklore Studies* (Madison: University of Wisconsin Press, 1997); and Martha C. Sims and Martine Stephens, *Living Folklore: An Introduction to the Study of People and Their Traditions* (Logan: Utah State University Press, 2005).

perpetuating cultural traditions, both movements sought to push back the effects of modernity on the human psyche. It is not surprising, then, that in addition to folktales, folksongs, and traditions of dress and ritual, folklorists began to pay close attention to vernacular and artisanal craft. Here was the way people made things before Henry Ford—before factory magnates reduced work to repetitive mundane tasks, before the money-man de-skilled the craftsman, sentencing him to wage slavery. The potential intellectual pitfall in studying artisanal craft should now be clear. If the modern factory system is "bad," then artisanal craft must be "better." As always, such value judgments will not aid our understanding of either in its proper historical context.[55] They can predispose us to color our perception of the shipwright and his assistants in the shipyard. Folklore is now a mature discipline and such a taint is not ubiquitous in its scholarship—but it is present.

Having pointed out the danger and its origins in the very roots of the discipline, we can apply what folklore and its related academic enterprises have to tell us about artisanal craft to understanding what was behind shipbuilding agreements and shipbuilders' business records.[56] Here is where folklore meets up with the history of technology. Folklore does not tend to use the word "technology," and histories of

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[55] Henry Glassie seems to make no attempt to hide such a bias in his own work, and that transparency makes his scholarship stronger than it would be if he did. See especially *Material Culture*, 172-173, 236-237, 255-257, and 344-349.

[56] The nature of vernacular and artisanal craft remains consistent enough that observing it in our world can tell us much about how it worked in the past. See Michael Owen Jones, *Craftsman of the Cumberlands: Tradition and Creativity* (Lexington: University Press of Kentucky, 1989); Butler, ed., *The European Origins of the Small Watercraft of the United States and Canada,* already cited; Taylor, *Boat Building in Winterton, Trinity Bay, Newfoundland,* already cited; Annmarie Adams and Sally McMurry, eds., *Exploring Everyday Landscapes: Perspectives in Vernacular Architecture*, Vol. 8 (Knoxville: University of Tennessee Press, 1997). Fred Hocker suggests *Tidecraft: The Boats of South Carolina, Georgia and Northeastern Florida, 1550-1950*, by Rusty Fleetwood and William C. Fleetwood, Jr. (Tybee Island, GA: WBG Marine Press, 1995) as an addition to this list.

technology do not tend to include the word “folklore.” Understanding how artisanal craft works, though, is necessary for understanding the history of technology. Who develops technology and why? How is technology transmitted? When and why is technology conservative, and when and why does it change rapidly? What is the relationship between a society and its technology? These are the important questions in the history of technology, and the study of artisanal craft has much to contribute to answering them.

Recall the expression “jack-of-all-trades,” and the less-often-repeated follow-up to it, “and master of none.” The combined expression is pejorative, especially in the context of a society in which skilled trades operated within the craft guild system. We, though, tend to drop the second part and use the first part as a compliment, describing someone versatile and handy—which, in our world of hyper-specialization, is an uncommon and useful person. In a small community—like any town in 17th or 18th-century British America—people had to be adaptable to make a living. Specialization was a luxury few could afford, because there was usually not enough of a market for that specialty to sustain full-time employment in it, and with currency scarce, ordinary people could not afford to pay for services as easily as we can. Less insularity from the climate reinforced the need for flexibility. Farm work is seasonal in the temperate zone, and most working people in our period outside the few cities were engaged in agriculture at least some of the time. Fish run at certain times of the year. Wood should be harvested at certain times and not others. We know that much commercial sailing was accomplished with seasonal or short-term labor,[57] and the same was true for boat- and shipbuilding. We do not need to read archival documents or history books to know how this worked. We can do studies like David Taylor's of boatbuilding in Newfoundland in the late 1970s—or just read them.[58] The boatbuilders Taylor studied were born around the turn of the 20th century in the fishing villages of Newfoundland. The boats they built followed a tradition of design and construction that had been proven effective in local waters in the 17th century, but the builders still tinkered with that design and construction, experimenting with small changes, adapting old designs to newer engines, newer materials, and evaluating whether or not they found those experiments satisfactory. They built boats some of the time, and did other work some of the time. They built most of their boats in the winter, when they were not fishing. They could build boats in their work sheds, out of the weather. They built boats for themselves, and boats for customers, but boatbuilding was not a full-time business.[59]

Traditional designs, traditional construction methods, traditional tools—those were learned, by observation and supervised work, from a young age. A master boatbuilder—any master craftsman—does not merely replicate what he was taught,

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[57] See Daniel Vickers, *Farmers & Fishermen: Two Centuries of Work in Essex County, Massachusetts, 1630-1850* (Chapel Hill: University of North Carolina Press, 1994); and Daniel Vickers with Vince Walsh, *Young Men and the Sea: Yankee Seafarers in the Age of Sail* (New Haven, CT: Yale University Press, 2005).

[58] Taylor, *Boat Building in Winterton*, already cited.

[59] Project research yielded archival evidence of only one full-time, exclusive boatbuilding business, and that was in Philadelphia—one of British America's few major cities—in the late 18th century (Boyer Brooke and John Wilson, boat builders, Account Book, 1783-1790, Am. 930, HSP).

however. David Taylor noted that experienced boatbuilders could recognize each other's work. Masterpieces bear the distinctive trademarks of the master.

Gerald Pocius was not writing about boats in *A Place to Belong*.[60] He was writing about how people who lived what we would consider an unusually traditional life, in a small village in Newfoundland, adapted old things, mixed old things and new things, rejected new things that they saw no need for, and discarded old things and old ways that no longer served practical needs, in an unself-conscious approach to life born of a reality that could not afford the nostalgic attachment to old things for the sake of their oldness that has come to be called "heritage."

Archaeologist Nick Burningham reports from his own field experience: "I was able to watch the change in design of the last decade of engineless sailing ships in Indonesia – fashion was important there. Few people wanted a new ship that looked like it had been built a decade or two previous."[61] Those boatbuilders were not building boats for "heritage." They were building them for work. As artisans, they were no doubt proud of their skills and proud of the inherited nature of those skills. Artisanal boatbuilders building for work, though, would laugh heartily at the suggestion that they should use sails if they had access to Yamaha® outboards.[62] When we talk about artisanal craft, we are not talking about some sort of hidebound reactionary traditionalism. During the long

[60] Gerald L. Pocius, *A Place to Belong: Community Order and Everyday Space in Calvert, Newfoundland* (Montreal: McGill-Queen's University Press, 1991).

[61] Burningham, personal e-mail, 4 May 2015.

[62] Arctic sea hunters using traditional hunting techniques do indeed use Yamaha® outboards. Relying solely on traditional techniques is only done when required by law—law imposed on those communities by the modern European nation-states that took over their land and them.

transition from lapstrake to carvel planking of ships in northern Europe, once carvel had become associated with newer, 'prestige' ships and clinker construction was old-fashioned and associated with peasant vessels, ships were built in the old clinker shell-first method but with carvel planking above the waterline—the part of the ship that could be seen. Archaeologist Daniel Zwick offers this as an example of *'prestige-biased transmission'* .[63]

Some of the retention of the stern castle was fashion—or at least aesthetics. To their builders, they would have looked proper. There is no necessity for the stern works to look just as they do on these ships, even if we assume they did not detract from performance. The almost-delicate point to which the stern castle comes on *Duyfken* makes the most sense as an aesthetic flourish of sorts.[64] On the other hand, we may well wonder if the stout and sturdy appearance of early 17th-century ocean-going ships offered some sense of confidence and reassurance. It would be worthwhile to enlist an expert on 17th-century European visual taste to comment on whether this aspect of design fits into an identifiable broader aesthetic context of the culture.

The way vernacular-artisanal boatbuilding worked forty years ago is, to a large extent, how it worked 300 years ago. It is a major reason why we should reject the notion that commercial ship design and construction in this period was a technology held prisoner by unimaginative traditionalists who sought only to preserve their own livelihoods—a technology in dire need of rescue by modern, enlightened, educated men

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[63] Zwick, in Adams and Rönnby, 55. It is also important to note here that carvel construction above the waterline also would have made the vessel lighter and stronger.

[64] See photo of *Duyfken* replica, Figure 15, Chapter Six.

with the wider interests of the state at heart—as late 18th-century British propaganda would have us believe.

In this story, while the elite social-political establishment did have much control over naval construction and the East India Companies, the artisanal shipwrights—and their clients, of course—retained control of all other commercial construction throughout our period and beyond. Those members of the late 18th-century British elite who published the bulk of the contemporary commentary we have on shipping have a much better chance of warping our historical understanding than they did of displacing the independent shipwright from his yard.

So who were these shipwrights?[65]

Shipwrights were much less likely to build for their own use than boatbuilders, though they did do so, as ships were expensive enough that they usually required corporate ownership. As we have seen, ships were usually owned by partnerships. In fact, it was common for someone to own as little as 1/16th of a ship.[66] This makes perfect sense. It allows someone to venture a risk in the investment within that person's means, and with limited financial exposure. By combining the investments of several people, the risk is spread and the burden is too—after all, your ship might come in, or it might not.

[65] Besides Goldenberg's *Shipbuilding in Colonial America*, already cited, see the recent social history of New England shipwrights by Joseph Cullon, "Colonial Shipwrights and Their World: Men, Women and Markets in Early New England" (PhD dissertation, University of Wisconsin, 2003).

[66] These fractional ownerships could be willed and inherited, so widowed spouses, sons or daughters sometimes (and not infrequently) came into ownership without having actively pursued such ownership in the market.

In small yards building small vessels in small villages, we find the closest similarity to the kind of boatbuilding David Taylor observed in Trinity Bay. The builder might build for his own use, or only build for others. He might go in with a partner or two and build a sloop, or he might start building one on speculation, hoping to find a buyer for her while she was still on the stocks. This was true in 1661 and it was still true in 1800.

David Lowell was a small-time shipwright, carpenter, ferry-boatman, and short-haul captain-for-hire in Amesbury, Massachusetts in the late 18th century. We have his journal from 1781 to 1801.[67] Some highlights from it present the characteristic—and necessary—versatility of someone in Lowell's position as well as anything could.

On Saturday, 16 January, 1792, Lowell notes that he began work on a sloop for Captain William Coombs. So right away we know that New England shipwrights are building during the winter, despite the harsh weather. January in Massachusetts is cold—and in the 18th century it was colder. Lowell writes down observations on the weather more than any other item. Weather dictated when he could work on the sloop and when he had to take care of necessities. He managed to raise the sloop by the 6th of February and had her frames "up to lay" by the 9th. On 18 April, he says he launched Capt. Coombs's "schooner"—the best explanation for the change is that Captain Coombs decided to change the rig after construction had started. It would be helpful to know why, but Lowell does not say, and that is typical. He refers to the vessel again as a schooner,

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[67] David Lowell Account Book, MSS 1229.1, PEM-Phillips.

though, later in the journal, noting that he and 6 other men were due wages for repairing her.

So in three months, in an 18th-century New England winter, with the necessities of survival always pressing, David Lowell built and launched a commercial schooner. Today's backyard boatbuilder, with his dreams bigger than his bank account, spends years building or restoring a vessel ¼ - ½ the size of what Lowell built—and his bank account is bigger than Lowell's would have been if he had had one, which he almost certainly did not.

On 30 April, Lowell launched another schooner, and finished work on it on May 4th. He had not mentioned that vessel before, but it is fairly certain that pieces of this journal are missing, and that it was bound or re-bound after being written, as it is not always in chronological order. By 16 June, he had completed much work on another schooner, which he launched on 12 July. He records the launch of another schooner 30 March of the following year, and a brigantine the following September. So from 16 January, 1792, to 5 September, 1793—less than two years—David Lowell built or helped build five vessels.[68]

Meanwhile, he was operating a ferry boat from Amesbury to Newbury, across the Merrimac(k) River. He was freighting goods on his own schooner, which he also employed for towing other vessels on the river. Meanwhile, he kept building vessels, getting paid in British currency, U.S. dollars, and rum. One summer, he worked on an aqueduct and a barn.

[68] "Built" is not meant to suggest that he built them alone, but that he was in charge of the project.

One need only read the catalog listing for the Samuel Coker Account Book for a good idea of what Coker was up to:

> Account book kept by Samuel Coker [from 1749-1774], shipwright, grocer, and dry goods merchant, of Newbury, Mass. Includes descriptions and prices of items sold, tallies of days Samuel spent working on ships, and tallies of days his employees spent working on ships.[69]

Gideon Woodwell worked with his "boy," Nat Hunt, and usually charged customers for partial construction—laying a deck, planking one side of a schooner. He charged different customers different rates for different work, suggesting a negotiation process for pricing. He too was paid in currency and goods in various combinations.[70] Woodwell's account gives the impression that perhaps he was not the primary contractor for these vessels, but subcontracted for someone else who was.

Richard Hacket (1716-1767) kept an account book, from which some loose papers—account statements, chits, receipts—survive, evidence of his getting along by selling groceries, day labor, including plowing, oar-making, and a little mast-making.[71] William Hacket (1739-1808), though, took advantage of the growing population and economy of New England to become a prominent shipbuilder. His surviving records are quite different—here we find a collection of formal shipbuilding agreements.[72] Steve Klomps of the Peabody Essex Museum provided a context summary of the Hacket

[69] Samuel Coker Account Book, MSS 1086, PEM-Phillips.

[70] Gideon Woodwell Account Book, 1755-1771, Woodwell Family Papers, 1752-1884, MSS 222, Box 1, Folder 1, PEM-Phillips. It is not clear whether Nat Hunt was an apprentice, a slave, or hired labor.

[71] Hacket Family Papers, MSS 228, Box 1, Folder 1, PEM-Phillips.

[72] Hacket Family Papers, MSS 228, William Hacket Papers.

contracts that encapsulates the growth and change of this area's maritime economy, and political situation, in the 18th century. Most of the early William Hacket contracts are for Banks fishing schooners of 60 to 90 tons. A fairly standard type at that time and place, they "did not require detailed specifications." After forming a partnership with his cousin John in the 1770s, William could design and oversee the building of larger vessels, as John's yard could accommodate those. They built larger merchant ships until the Revolution, built the frigate *Alliance* for the Continental Navy, which acquired a reputation as the finest of her type in that service, and after the war began building the large frigate-style merchantmen for the new East India and China trades.[73]

The fishing schooners Klomps mentions were already famous in the British Atlantic by the Revolution and would remain so into the early 20th century. The Hacket partners were the shipbuilding equivalent of the Crowninshields and the Derbys by the Federal period, when they were building much bigger ships. Their contracts were detailed and clearly indicative of a sophisticated understanding of their craft. While they tell us what the specifications were, though, they still do not tell us why.

For that, ironically enough, we return to a more humble—and unlikely—source—David Lowell's account book. In the final section of what is left of it, we find that Lowell has copied down substantial sections of a shipbuilding treatise. We do not know which

[73] Steve Klomps, personal e-mail, 30 June 2015.

treatise it was, or how he managed to see a copy of it.[74] His handwritten heading is, "A Rule to Proportion Masts & Spars."

Digging into design and construction III: the treatises and the glory of proportion

We have plans of warships from both centuries, and a smattering of specifications and builder's contracts for merchant vessels, but few plans for 18th-century merchant vessels and none for the 17th century. The most important written source for information on 17th and 18th-century ship design and construction is a small number of treatises on shipbuilding—some published at the time, some of those obscure and some well-known, and others never published in their own time but re-discovered and published in ours.[75] For the most part, these were written by shipwrights or public officials involved in naval construction, either writing for an audience assumed to be well-versed in the craft or dismissive of what later authors saw as the outmoded and arcane ways of the traditional artisan and enamored of the new "science," with its promise of universal principles

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[74] Lowell provides enough information that it might be possible to figure out which treatise it was, given the time to compare their calculations and given dimensions.

[75] The treatises I refer to are: Edmund Bushnell, *The Compleat Shipwright*, Sixth edition (London: For Richard Mount, 1699); Frederik H. af Chapman, *Architectura Navalis Mercatoria*: *The Classic of Eighteenth Century Naval Architecture* (Mineola NY: Dover Publications, 2006); John Charnock, *An History of Marine Architecture,* Volume II, ECCO facsimile (London, 1801); F. Dassié, *L'Architecture Navale, contenant la maniere de construire des navires…* Google e-book via archive.org (Paris: Chez Jean de la Caille, 1677); Leonhard Euler, *A compleat theory of the construction and properties of vessels: with practical conclusions for the management of ships made easy to navigators,* trans. Henry Watson (London: J. Sewell, 1790); William Hutchinson, *A Treatise on Naval Architecture*, already cited; Brian Lavery, ed., *Deane's Doctrine of Naval Architecture, 1670* (Annapolis, MD: Naval Institute Press, 1981); Mungo Murray, *Treatise on Shipbuilding, 1765, Includes translation of Du Hamel du Monceau's treatise of the same year* https://archive.org/stream/treatiseonshipbu00murr#page/n0/mode/2up;
Ollivier, *18th Century Shipbuilding,* already cited; W. Salisbury and R. C. Anderson, eds., *A Treatise on Shipbuilding* and *A Treatise on Rigging Written About 1620-1625*, The Society for Nautical Research Occasional Publications Number 6 (London: The Society for Nautical Research, 1958); Marmaduke Stalkartt, *Naval Architecture or the Rudiments and Rules of Ship Building,* Google Books facsimile (London, 1781).

universally available and the opportunity to impose centralized, standardized control on ship design.[76] However, finding material from a treatise copied into David Lowell's journal proves that at least to some extent, the material in these treatises was something useful to a practical tradesman far from the naval dockyards.[77]

Lowell writes that to find the height of the mainmast of a ship, "Multipli the Wedth and Depth together of the Ship then Multiply by 3 and divide by 5 gives the Length the Ship's Main Mast in Yards-----" So it goes for the rest of the journal. The length of every spar is a proportion of the length of something else. For the mainmast, take the length of the lower deck, and the extreme breadth, and adding them together, take half—that is the length of the mainmast.[78] So it goes in every treatise on shipbuilding surviving from this period. The answer to the question *how did they design these ships?* is, ultimately, "by proportion." The beam is in certain proportion to the keel,

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[76] For an introduction to this subject, Larrie Ferreiro's *Ships and Science,* already cited, will do nicely, and it is recent. All English treatises of the period owe much to a manuscript called "Fragments of Ancient English Shipwrightry," attributed to Matthew Baker c. 1570, in the Samuel Pepys Library, Magdalen College, Cambridge. For such a long period, there are not many, reminding us that ship design and construction was overwhelmingly artisanal. They are listed in the bibliography as published primary sources, along with two important French treatises and one in German. William Baker discusses the English treatises in *The New Mayflower*, and allows the non-specialist some insight into how he used them to help him design *Mayflower II*. (A treatise discovered later, and published in 1994, long after Baker had done his work, provided some guidelines and dimensions for merchant ships not available to Baker and not available to Brian Lavery when he worked on the design for the 1991 *Susan Constant* replica, but according to Peter Wrike, both designs fell within the parameters of what is specified in the tables published in 1994. For the manuscript, see Richard Barker, "A Manuscript On Shipbuilding, Circa 1600, Copied by Newton," *Mariner's Mirror* 80:1 (February 1994): 16-29; for the 1991 *Susan Constant*, see Lavery, *The Colonial Merchantman Susan Constant 1605* (Annapolis, MD: Naval Institute Press, 1988); for Wrike's comments, see Peter Wrike, "The Jamestown Replicas," in Jenny Bennett, ed., *Sailing Into The Past: Learning from Replica Ships* (Barnsley UK: Seaforth Publishing, 2009), 120-133.

[77] Fred Hocker pointed out that, with the exception of Sir Anthony Deane, who wrote his treatise for Samuel Pepys, treatises were written for those who already knew how to build ships, and that is why they leave out so much of the technical detail we would love to have (Hocker, personal communication, 18-19 August 2015).

[78] David Lowell Account Book, MSS 1229.1, PEM-Phillips.

the depth in hold in proportion to both, and so on. The proportions are complicated, and exhaustive. The actual proportions vary some—but usually not much—from author to author. The clear overall impression is that, within a rather narrow range of variance, the proportions for building certain types of vessels were generally agreed-upon. Some of the questions left us by the shipbuilding agreements can be answered in the treatises: "Put a Sloop's mast halfway between one Third & one Quarter of the Keel from forward or from the Rake forward----"[79] For us, though, this is still frustrating. We want to know why. Why do you put a sloop's mast there? Why is the fore yard 7/8 of the main yard? If David Lowell knew the answers to those questions, why would he bother writing this down so carefully and wasting paper and ink which could not have been cheap for him?

Scholars studying old ships today want to see the kind of proof—the kind of supporting evidence—that comes out of a modern laboratory. We want to see test results, computer analysis computations—or their equivalents. In the 18th century, though, there were no such equivalents. There was experience—inherited and adapted—and there was the eye of the artisan. The proportions so carefully listed in the treatises, and the calculations necessary to come up with specific dimensions that remained faithful to those prescribed proportions—offered an accessible means of transmitting inherited knowledge to those who wished to inherit that knowledge. They do not give us the information we need, because their intended recipients did not need that information—in fact, it would never have occurred to them.

[79] David Lowell Account Book, MSS 1229.1, PEM-Phillips.

British naval historian Brian Lavery, who did the research behind the 1990-1991 replica (currently operational) of the small English galleon *Susan Constant* at Jamestown, Virginia, and who published a book on her based on that research, also edited a modern edition of the *Doctrine of Naval Architecture* by Sir Anthony Deane, Master Shipwright of two naval dockyards under Charles II, who knighted him. Lavery sums up Deane's *Doctrine*—written for Deane's friend Samuel Pepys—by saying that Deane's calculations, while "impressive" in number,

> are purely geometric, giving a means of forming the shape of the ship. With the exception of the calculation of the draught of water, they give no indication of the likely performance. He also attempts to impose a series of proportions on his design. ... This is, of course, not a truly scientific system, for it depends entirely on the experience or prejudices of the builder, and often it would have to be modified in practice.[80]

The laboratory may yield answers the treatises cannot. In the next chapter, we will discuss how laboratory analysis can help us understand the ramifications of certain aspects of the design of actual vessels on hydrodynamics, and investigate the effects, if any, of changes in hull form on hydrodynamics over the period.

Unlocking the shipwright's secrets—some of them, at least…

In a fairly recent study of sea power during this period, Richard Harding observed, "How far shipwrights contributed more generally to design and quality improvement is, currently, unclear. It is also unclear how theoretical sciences contributed to design and longevity."[81] Considering as a whole the extant archaeological literature on colonial-

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[80] Lavery, ed., *Deane's Doctrine*, 22.

[81] Harding, *Seapower and Naval Warfare*, location 2755.

period American shipwrecks, it is clear that construction was accomplished by different builders using a variety of techniques and materials to achieve roughly the same end.[82] This lends credence to Nick Burningham's notion that "[s]omeone could decide that ships ought to be designed in some theoretical way. It would make no difference to the many shipyards scattered around the Netherlands on muddy shores and river banks."[83] There is no reason to think Burningham's view would not have applied just as well across the Atlantic. H.H. Holly, writing for the Pilgrim Society of Massachusetts in 1969 on the remains of the early 17th-century vessel called *Sparrow-Hawk,* wrote of the treatises that, while they give us valuable information about the construction of naval vessels, we have no reason to think that the shipwrights building the craft we are considering "adhered

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[82] In addition to VanHorn, already cited, and Morris et al., already cited, see: Adams, "*Sea Venture*: A second interim report—part 1," already cited; Gregory D. Cook, "The Readers Point Vessel: Hull Analysis of an Eighteenth-Century Merchant Sloop Excavated in St. Ann's Bay, Jamaica" (Master's thesis, Texas A & M University, 1997); Amanda M. Evans, "Defining Jamaica Sloops: A Preliminary Model for Identifying an Abstract Concept," *Journal of Maritime Archaeology* 2:2 (December 2007): 83-92; Fred Hocker, "The Clydesdale Plantation Vessel: Savannah River, South Carolina," in *Beneath the Seven Seas*, edited by George F. Bass (New York: Thames & Hudson, 2005), 192-193; Michael Krivor, "Archaeological Investigation of an Eighteenth-Century British Merchant Vessel in Chub Heads Cut, Bermuda" (Master's thesis, East Carolina University, 1998); Brad Loewen, "Ships and Shipbuilding / *Navires et Construction Navale:* Recent Advances in Ship History and Archaeology, 1450-1650: Hull Design, Regional Typologies and Wood Studies," *Material Culture Review/Revue de la culture matérielle* 48 (Fall/Automne 1998), available at : http://journals.hil.unb.ca/index.php/MCR/article/view/17791/22170, accessed 10 February 2015; David Moore and Corey Malcom, "Seventeenth-Century Vehicle of the Middle Passage: Archaeological and Historical Investigations on the *Henrietta Marie* Shipwreck Site," *International Journal of Historical Archaeology* 12:1 (January 2008): 20-38; David Moore, "Anatomy of a l7th Century Slave Ship: Historical and Archaeological Investigations of the *Henrietta Marie*" (Master's thesis, East Carolina University, 1989); Harry Pecorelli, "Archaeological Investigation of the B & B Wreck (38B1672): An Eighteenth Century Plantation-Built Vessel, Charleston, South Carolina" (Master's thesis, East Carolina University, 2003); Christopher R. Sabick, "His Majesty's Hired Transport Schooner *Nancy*" (Master's thesis, Texas A&M University, 2004); James C. W. Southerley, "Cedar on the Reef: Archaeological and Historical Assessments of the Eighteenth Century Bermuda Sloop, Exemplified by the Hunter Galley" (Master's thesis, East Carolina University, 2003); Allan J. Wingood, "*Sea Venture*: An interim report on an early 17th century shipwreck lost in 1609," *International Journal of Nautical Archaeology* 11:4 (November 1982): 333-347; and "*Sea Venture* Second interim report—part 2: the artefacts," *International Journal of Nautical Archaeology* 15:2 (May 1986): 149-159.

[83] Burningham, personal communication, 6 April 2015.

closely, if at all, to these ideas. Then, as now, small vessels were built in a large number of small construction yards scattered all along the seaboard. The various builders naturally developed their own ideas…."[84] Archaeologists like VanHorn have been investigating that opinion since, and the evidence they have uncovered and interpreted tells us that variation, not uniformity, was the rule for ordinary merchant ships. At first glance, that may not be apparent, but examining how different shipwrights put together their vessels makes it clear. VanHorn compared the keels of the six wrecks in her study to the prescriptions for keels in the Mungo Murray treatise, one of the best-known of the 18th-century English treatises, to see if any of them matched his prescriptions. None did.[85]

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[84] H.H. Holly, "Sparrow-Hawk: A Seventeenth-Century Vessel in Twentieth-Century America," Pilgrim Society Booklet Series (Boston: Nimrod Press, 1969), 14-16.

[85] VanHorn, 178.

Chapter Five: Analyzing Ship Design

The previous chapter on shipbuilding, based on the documentary records left by shipbuilders and their clients, and supplemented heavily with a discussion of artisanal craft, raised questions about ship design that it could not answer. Now, we need to add the insights of interpretive archaeology, and its attempts at hypothetical reconstructions and design analysis, and what computer modeling and testing can tell us about design and performance characteristics. Much of the information we will consider in this chapter would be intellectually dangerous to work with, though, had we not already considered the issue from those perspectives. Once we delve into technical analysis—and especially once we start discussing the use and results of computer modeling—we risk presentism and anachronism as we have not thus far. With risk, though, comes the chance for reward—undertaking such an effort promises insights we would not otherwise obtain.

The danger is built into the questions we are pursuing. What can technical analysis with modern tools tell us about the inherent performance characteristics of these vessels—their speed potential, their hydrodynamic resistance, the efficiency of their shapes as watercraft, their stability? How can modern technical analysis weigh in on period debates over ship design? To be safe, we have to add the following questions right away. Why do those things matter to us? Did they matter to them? If so, why? If not, why not? If we are going to compare a 17th or 18th-century hull form to any set of modern standards, we had better take great care not to assume, unconsciously, that those modern standards are *the* standards and thus what we are doing is measuring the older designs against those standards, and evaluating them the same way we grade students' papers. That will teach us no history whatsoever.

This is not to suggest that we start off with a sort of relativism so complete as to be absurd. Of course the laboratory can tell us that a certain design has an inherent stability of X, and that another design has an inherent stability of either greater-than or less-than X. It is what we do with that information that requires historical responsibility.

Comparing and contrasting designs widely separated by time compounds the danger, of course. Assuming that the same standards and priorities governed ship design in 1620 and 1780 will not do. We would be obliged to demonstrate that. The information that follows will make it clear that we would be sorely tried to do so.

Asking the questions, mindful of the dangers, should yield some factual information on design, and it is difficult to ponder the *how's* and *why's* of something without the *what's*. As we know from Chapter Four, we need more *what's*. For that, we can use the same computer analysis programs today's naval architects and marine engineers use to design vessels and test those designs before actually building anything. We can do this by digitizing plans—either of originals or replicas. The computer makes a 3-D model based on those digitized plans, and it can then measure such things as block coefficient, stability, and hull form resistance. Ship archaeologists are doing this now—after bringing together everything they know from their archaeological finds with everything the historical record can tell us to hypothetically, virtually reconstruct a period vessel from partial remains.

First: considering the written record on ship design

We already know about the “glory of proportion.” For the 17th century, this is so much bigger than ship design. It gets at the cultural centrality of understanding natural reality geometrically. So much of what we would call "scientific," they understood in terms of geometry and proportion, including the cosmos itself. This was the age of Kepler, trying again and again to figure out how to reconcile the heavens to a set of interlocking geometric forms. This is the larger cultural milieu, the direct tie of technology to ontology.[1]

This is not to suggest that an aesthetic sensibility predisposed 17th-century shipwrights to design their ships to an abstract concept rather than practical considerations. Jon Adams turns that on its head when he rejects the idea that “hulls were designed by methods of some geometrical elegance which had little to do with performance….” He counters “that the geometric procedures developed to generate the complex underwater body was elegantly simple.”[2] All that we know about this culture and its shipwrights would suggest that, to them, they were designing for both—they would have assumed that “geometrical elegance” and “performance” were to be found in the same place. That is the cultural milieu.

As the age of Kepler gave way to the age of Newton, did the centrality of proportion begin to give way as well? If so, to what? If so, did that “what” have something to do with Newton? We do know, for what it is worth, that Newton himself

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[1] For a work placing maritime technology in its cultural context with exceptional depth and breadth, see Robert Hicks’ *Voyage to Jamestown: Practical Navigation in the Age of Discovery* (Annapolis, MD: Naval Institute Press, 2011).

[2] Adams, *A Maritime Archaeology of Ships*, 179.

was interested in maritime technology. His invention of a sextant is fairly well known. Much less so is the discovery of a shipbuilding treatise he copied in his own hand—that, we did not find until 1994.[3] That was an important find, aside from the association with the most important scientific mind of the age, for it contained tables of proportions specifically labeled for merchantmen. We learned from it that the design interpretations of William Baker and Stan Potter,[4] Brian Lavery and Eric Speth, executed in the replicas of 17th-century ships operating on the U.S. east coast, fit within the parameters of proportion provided by those tables, even though none of those experts had access to this information when they did their work.[5] So we have more reason now to trust their insights, and whatever we can learn from studying the designs they produced.

Newton, though, did not write that treatise—he just copied it, around 1700. His profound innovations in scientific thinking only made themselves widely felt in the 18th century. Did they make themselves felt in ship design?

Larrie Ferreiro's book, already cited, is called *Ships and Science: The Birth of Naval Architecture in the Scientific Revolution*, *1600-1800*. Unpacking that title and its relationship to the contents of the book will tell us some things we need to know. First, the word "science" as we use it, and as he uses it in the title, is contemporary. In the early modern European world, "natural philosophy" was the common term. What they called "naval architecture" did not coincide with what we call it now until the end of the period.

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[3] Barker, "A Manuscript on Shipbuilding, circa 1600, Copied by Newton," already cited.

[4] Potter was the naval architect for the current *Susan Constant*, among other period replicas.

[5] See Wrike in Bennett, *Sailing Into the Past,* 120-133.

As far as “birth” goes, Ferreiro is being precise. Naval architecture as we practice it was born during this period, as he thoroughly demonstrates, but that is about the extent of it—as he also thoroughly demonstrates. The great European scientific minds identified the principal mathematical problems of the discipline, and worked hard to solve them.

Probably the most important success in that endeavor in our period was the calculation of the metacenter by Pierre Bouguer, the central character of Ferreiro’s book.[6] The natural philosophers pushed their understanding of fluid dynamics well beyond where it had been, but the application of their insights to the design and construction of ships in their own time was minimal: "Ultimately, the invention of the metacenter did not have any practical effect on ship design during the 1700s," Ferreiro concludes.[7]

So, again, what of Newton? As it happened, Newton came up with a form of least resistance for ships. Ferreiro demonstrates, as only a trained naval architect could, that Newton was wrong.[8] The French Navy, the most committed of Europe’s navies to the new naval architecture, was interested. However, despite the partial adoption by the French Navy of the bow of least resistance concept, leading to the opinion “both inside and outside France” that the French navy was superior “in using theoretical hydrodynamics to design fast ships,” Ferreiro shows that “this was an inaccurate

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[6] The metacenter, “in fluid mechanics, [is] the theoretical point at which an imaginary vertical line passing through the centre of buoyancy and centre of gravity intersects the imaginary vertical line through a new centre of buoyancy created when the body is displaced, or tipped, in the water, however little” (http://www.britannica.com/science/metacentre). Now, the concept is central to predicting stability.

[7] Ferreiro, 249.

[8] We remember our geniuses for what they got right and how that changed our world. When we remember what they got wrong, and what they did that does not matter to us ”scientifically”—Newton was a committed alchemist—they become more interesting as historical subjects.

conclusion at best," because other conditions were more important in determining the speed of a ship than hull form, particularly "the sail plan and material, the condition of the hull (clean or barnacle-encrusted), and most important, the skill of the commanding officer and his crew."[9]

The Royal Navy, too, took Newton's concept seriously enough to experiment with it, but in 1778 Frederick II, King of Prussia, wrote a letter to Voltaire remarking that the "English have built ships with the most advantageous section in Newton's opinion, but their admirals have assured me that the ships did not sail nearly so well as those built according to the rules of experience." A similar account was repeated by John Charnock in his history of marine architecture.[10]

It may be surprising to learn that such a singular genius as Newton could get something wrong that probably seems more pedestrian a matter to us than, say, correctly figuring out why the moon rotates around the earth, what light is made of, and the basic laws of bodies in motion. No other example could more plainly point out something of central importance to all studies of this subject: it is devilishly difficult stuff. Nothing else could better clarify the importance to the history of technology of making sure that the theory of the singular genius/heroic inventor remains properly buried. Not even Newton could do what would take an unknowable number of mostly unknown people a couple of centuries to do, and only a serious shift in technological need—a need that did not exist in this period—would provide the impetus for the incorporation of the new naval

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[9] Ferreiro, 143.

[10] Ferreiro, 139. Charnock's work was published at the end of the period.

architecture into shipbuilding. They would be building new kinds of ships then, and without a long record of successful precedent to base those on, they would need something else—something that would help them predict what would work and what would not. A major advantage—perhaps *the* major advantage—of today's technical-analysis capability over a period shipwright's is predictive power. Naval architects can predict performance characteristics without building anything. The greater the financial and human risk undertaken in the building of that something—the bigger the ship, the more expensive she is to fit out, the more people she carries—the more compelling such predictive ability becomes. So it should not surprise us that the hardest push for "naval architecture" was from naval quarters.

There is a cultural dimension to the struggle of naval architecture to make itself relevant in this period. Ferreiro titled his first chapter "'Mere Carpenters,'" introducing the deep prejudice held by some of the educated elite against artisanal shipwrights. The title comes from a translation of Spanish constructor Jorge Juan y Santacilia's 1783 *Examen maritimo*, in which he claims that "[t]oward the end of the last century…[t]he Construction of Vessels was abandoned to mere Carpenters; and it was not considered that NAVAL ARCHITECTURE was based on a constant application of Mechanics and Geometry…"[11] Ferreiro notes that the French constructor Pierre Lévêque, who loosely translated Santacilia's treatise, "added the notion that constructors were incapable of applying theory to design" and, more broadly, that "[m]any contemporary observers of

[11] Ferreiro, 23.

the field also held the opinion that constructors who built ships without having a theoretical basis for their designs were somehow inferior to other naval professionals."[12]

In England, this later 18th-century frustration with traditional shipwrightry was also deeply rooted in fear of the French. Victory in the Seven Years War gave the British psyche no respite from anxiety about its chief imperial-naval rival. Those who worried most about the French maritime threat surely, if grimly, felt vindicated by the disastrous War of American Independence, and of course after the French Revolution, the British Empire poured all the resources it could into the Royal Navy, which would find itself fully deployed for most of a 25-year period, with the very survival of the Empire on its shoulders.[13]

Yes, but why would the British naval establishment fret so much about a French maritime threat when British forces were usually victorious at sea? Ferreiro suggests that British shipwrights would have shared that puzzlement, given the overwhelming success of its warships against their enemies—Royal Navy vessels captured "five times as many enemy ships as its nearest rival, France—all without the benefit of the metacenter or the calculus." So, he speculates that a British ship constructor's response to "the new theoretical developments coming from France, or on the system of rigorous technical schooling for French and Danish constructors" might well have been "'So what?'"[14] Here

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[12] Ferreiro, 23.

[13] The naval establishment wanted control of construction as well as design, and there was a deep mistrust of merchant builders contracting for the Royal Navy. See Roger Knight, "Devil Bolts and deception? Wartime naval shipbuilding in private shipyards, 1739–1815," *Journal for Maritime Research* 5:1 (April 2003): 34-51.

[14] Ferreiro, 296.

we have that cultural divide between those attracted to the promises, however vague, of the new thinking we call the Enlightenment and those who did not feel the need to be Enlightened to do a proper job. There is an instructive irony here: The French—and the Danes, and whoever else was open enough to the tenuous promises of theory-based naval innovation to employ it in their yards—were looking for any leg up that might narrow the gap between them and the British.[15] None of them could hope to match British numbers and sheer force. Perhaps technical advantage would help compensate for that. This is the military-technological thinking of the underdog—of the Confederates with their ironclads and submarine, of Hitler with his wonder-weapons. The irony turns on British paranoia. The supreme maritime power of the day, Britain, feared for that supremacy, paying close and anxious attention to any threats, real or imagined. The British did not need the bow of least resistance or the metacenter or natural philosophers in their dockyards. They saw the French using these things, though, and it only exacerbated their fear of being overtaken technologically by their archenemy. So they took comfort in embracing the promise of scientific shipbuilding as a matter of what we would call national security—a promise that would, as Ferreiro points out, prove chimerical.

That the fear was real, regardless of what else was, is made amply clear by the formation and publications of the Society for the Improvement of Naval Architecture in 1791, as the threat of Revolutionary France loomed dark and low. Contributors wasted no time in reminding subscribers of the long-held British fear that French ships were faster

[15] It is also ironic that the early 17th century Dutch merchant ships were built using the most thoroughgoing artisanal methods—the opposite of what the naval architects were about—and yet those vessels were an integral part of a commercial competition with England so successful that it helped set off the Anglo-Dutch Wars. We will return to Dutch vs. English merchant ship design in that early period.

than their own. In the Preface to the Society's proceedings for that year, reprinted in *European Magazine*, the author recalls a discussion in a British shop during the Seven Years War, when it was going badly for Britain, lamenting the lack of "Science" in British shipbuilding and contrasting it with the French who had schools and institutes to study it.[16] Four pages later, he writes:

> The candid Ship-builder will readily confess there is not one improvement in our Navy, that did not originate with the French...every officer in the service coveted the command of [captured and refitted French ships] in preference to those built in England.[17]

Ferreiro might suggest that this author would have had some trouble finding a "candid Ship-Builder" who would express such an opinion. In the concluding essay, though, we have it again: "...the French, actually surpassing us in this most important art, have derived many advantages from this superiority in time of war."[18] Ferreiro states flatly that there is no evidence that French ships were inherently faster than British ships. He attributes the bulk of a naval vessel's performance to the performance of the crew and the upkeep of the ship.[19] The perception was real, though, and the perception was strong. The rest of the papers and letters in this collection, ranging from thoughtful commentary on technical matters by experienced captains, to an essay by no less a person than Benjamin Franklin, to short rants by disgruntled amateurs, take British ship design and construction to task, questioning, and in some cases railing against, the most basic elements of period

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[16] "A Collection of Papers on Naval Architecture," Part I, iv.

[17] "A Collection of Papers," Part I, viii.

[18] "A Collection of Papers," Part I, 64.

[19] Ferreiro, 177.

ship design—the bluff bow and tapering stern, or “cod’s head and mackerel’s tail”, Hutchinson’s dicta on the prevention of hogging, and revisiting bow form and resistance. There was a restless spirit in the naval establishment as Britain considered the doings across the Channel with growing alarm—and this was, to be sure, the naval establishment—the head of the Society was the Duke of Clarence, naval officer and the future William IV, and the roster of members is title-heavy.[20]

At this point, the reader may be wondering why we have ventured so far into Whitehall and the naval dockyards and away from William Stevens, David Lowell, and Charles West—and their counterparts in, say, the northeast of England. This “naval architecture” subject, though—and the written record of debate and discourse on ship design in this period—is so heavily naval in its orientation that such a side trip was unavoidable if we were to familiarize ourselves with it. To understand the cultural context of ship design and construction at the time, and to place the published primary sources in proper context, we needed to have a look at what the literate were thinking and writing about the subject. This material is the fount of the view that artisanal shipwrightry was a reactionary, hidebound traditionalist’s petty fiefdom—that this technology, so vital to the survival and prosperity of the Empire, was dangerously constipated, and that leaving it in the hands of ‘mere Carpenters’ would not do. The previous chapter claimed that late 18th-century British propaganda would have us believe that here was a technology in dire need of rescue by modern, enlightened, educated men with the wider

[20] For the context of the Society for the Improvement of Naval Architecture, see N.A.M. Rodger, “Navies and the Enlightenment,” in Pieter van der Merwe, ed., *Science and the French and British Navies, 1700-1850* (Greenwich UK: National Maritime Museum, 2003), 5-23. Rodger writes that, once the Society’s recommendations proved ineffectual in practice, it faded away.

interests of the state at heart. This is the propaganda referred to—these articles were published—the Society saw to that. The likes of David Lowell were not publishing articles in *European Magazine*.

Our ultimate purpose here, though, is to explore what the tools of naval architecture can teach us about ships not designed by naval architecture but built by people dismissed and disparaged by the advocates of naval architecture, so we now need to turn our attention to design criteria and problems in ordinary merchant ships—which are related, but not identical, to those of warships.

Capacity and displacement

It was noted in Chapter Three that merchants wanted the greatest capacity they could get for the size ship they were building or buying, without compromising sailing ability "too much." The ideal was "the Connection of Swiftness and Capacity, the great Objects to be pursued in Ship-building."[21] Capacity is generally expressed in tons. What "tons" meant where and when is almost as byzantine a subject as ship-type-name etymology, and a subject about which we would probably be completely at sea without John McCusker, who not only explains the different types of "tonnage" to us, but ties the evolution of ship measurement (in tons) to an evolution in ships.[22]

Three parties, with some conflicts of interest, were interested in the tonnage of a ship—the owner, the builder, and the taxman. The owner wanted the most capacity he could get—the most cargo he could fit into the ship—but the owner was paying the

[21] Stalkartt, *Naval Architecture or the Rudiments and Rules of Ship Building*, xxii.

[22] McCusker, "The Tonnage of Ships," already cited. Also see "Colonial Tonnage Measurement: Five Philadelphia Merchant Ships as a Sample," *The Journal of Economic History* 27:1 (March 1967): 82-91.

builder by the ton, so when it was time to pay the builder's bill, he could wish for the vessel's tonnage to be less. The taxman charged the owner duties based on tonnage, so again, the owner could wish the tonnage to be less when duties were due. There is an analogy here to the valuation of a house. The homeowner wants the appraised value on the low side, to minimize property taxes. When it is time to sell, though, the seller wants *that* appraisal on the high side, to increase the selling price. Tax appraisal values are lower than private appraisal values and selling prices.

McCusker defines the three types of tonnage for our period. *Cargo tonnage* is how many tons of cargo the ship could carry. It does not equate to "tons burthen/burden" as that term was "often applied in situations where the terms were only a legal fiction".[23] *Measured tonnage*—also called "shipwright's" or "carpenter's" tonnage—was an actual measurement taken during construction which the owner had to agree to and could verify if he wanted. The builder's charges were based on this figure.[24] *Registered tonnage* was legal tonnage—the figure written on all official documents pertaining to the vessel including Customs and Navy Office Shipping List records. Taxes and duties were based on that figure.[25]

In the 17th century, as McCusker explains, the formula for calculating cargo tonnage used length, breadth, and depth, but did not take into account *block coefficient*. It was noted earlier that the shape providing the greatest cargo capacity for a given length,

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[23] McCusker, "The Tonnage of Ships," 26.

[24] McCusker, "The Tonnage of Ships," 26-27.

[25] McCusker, "The Tonnage of Ships," 26-27.

breadth, and depth is a rectangular box—a block—but that of course will make a terrible sailer. Any ship's hull will just fit inside an imaginary block defined by her length, breadth, and depth. The proportion of that block's volume actually taken up by the ship is her block coefficient. So the sharper she is in the ends and the more deadrise she has—the steeper the angle from her keel to her topsides—the less of that block she will take up, and the lower her block coefficient. A vessel designed for speed will have a lower block coefficient than one designed more for capacity. Everyone knew, of course, that a ship did not actually carry what she would carry if she were a box defined by her length, breadth, and depth, and so the long-established custom was to discount the measured tonnage for taxes and duties. As the years went by, though, the general trend was for block coefficients to increase—for cargo ships to carry more cargo for their dimensions. Before 1700, Parliament recognized that this was costing revenue, and disallowed the discount, but that was ignored by owners and builders and overlooked by officials. If it had not been, McCusker says, taxes and duties would have increased by up to 50%. By the mid-18th century, cargo tonnage was greater than both measured and registered tonnage, and that was no secret at the time.[26] This means hull design had changed in a way that increased capacity without costing speed. If we can explain that change, we will have explained a significant contributing factor to the productivity of the merchant shipping fleet in the British Atlantic. If merchants could ship more goods at the same speed in the same size ship, they did not necessarily need a bigger ship with its increased costs in construction, manning, and maintenance. They could respond to population and

[26] McCusker, "The Tonnage of Ships," 28-29.

market growth much more efficiently, and merchant ship technology could thus keep up with the changing demands of the world it served at the least possible cost. The early evolution of the round ship into something closer to the box form, mentioned in Chapter Two, carried on. Can a laboratory analysis of reliable plans, whether original or reconstructed from reliable specifications, and archaeological remains, for a comparison of block coefficients, provide support for McCusker's assertion?

We might well ask whether shipwrights, with their obviously sophisticated skill set, could not have come up with a more accurate way of measuring the capacity of a rounded vessel than by using the dimensions of a box. The answer is yes, but it was complicated and time-consuming. Among the most noteworthy features of *Deane's Doctrine* of 1670 are two methods Deane presented for doing that.[27] He does not claim to have invented either method—though Pepys claimed it for him—but said that both methods were available to anyone who had the skill and was willing to take the trouble. Brian Lavery, who edited the current published version of the work, says the methods "developed slowly over the years."[28] That should sound familiar by now. So shipwrights were trying, and by Deane's day, they had largely succeeded. It is worth pointing out what they were after, though, and what they were not.

When we speak of the size of a ship today in terms of volume, we use *displacement* in tons. That is based on Archimedes' Principle: The upward buoyant force that is exerted on a body immersed in a fluid, whether fully or partially submerged, is

[27] Lavery, ed., *Deane's Doctrine*, 72.

[28] Lavery, ed., *Deane's Doctrine*, 25.

equal to the weight of the fluid that the body displaces. Ferreiro, however, says that the principle was "often poorly understood in practice" and had to compete with an incorrect Aristotelian theory of floating and sinking "due to the relative weight of the material or the shape of the body."[29] What practical shipwrights wanted to predict was the load waterline of their vessels when laden. If the vessel did not swim at her ideal load waterline, but sank too deep or floated too high, that would adversely affect her performance and her stability—perhaps critically. Deane's calculations were not for displacement—they were for calculating interior volume and thus capacity, which would allow for calculating the load waterline. This required a painstaking series of measurements involving the imaginary partitioning of the ship's interior into small sections, and adding the volumes of those sections together. Given the difficulty, and given that time is money, we may have here yet another impetus to reproduce the "bones" of a proven design for a given size and purpose.

It took an Act of Parliament to change an Act of Parliament, so legally prescribed formulae for these calculations changed glacially. As we have seen, however, those formulae meant money either in or out of the pockets of the owner, and so they influenced design. The influence of arbitrary rules externally imposed on a technology is inherently problematic. It imposes a selective pressure on the technology that can alter it in ways that are detrimental to important aspects of its function.

[29] Ferreiro, 195.

The stability problem: introduction

We know that it was not uncommon for 17th-century English merchant ships to be girdled after construction to increase stability. Girdling (or furring) involved nailing an extra layer or two of planking just above, at, and just below the waterline.

To cite one example: Captain John Narbrough, in command of the flagship *Prince* in the Third Anglo-Dutch War in 1672, commented on her:

> I do believe the ship will bear a good sail, for she stands at her bearing. Girdling the ship would make her one of the finest ships in the whole universe, for it would make her much more floatier and carry her guns higher, and she would bear the better sail and be a better and securer ship to receive shot, and I believe it will not prejudice her sailing.[30]

Smith's *Sea-man's Grammar* mentions the technique as a solution for a "crank-sided ship"—a ship that will bear no sail.[31] William Baker, the naval architect and ship historian who designed *Mayflower II* and other 17th-century replicas, found from his extensive research that "during the period in question more English ships were furred than those of any other nation."[32] Mainwaring said the same thing 300 years or so earlier, but he was not so detached about it:

> I think in all the world there are not so many ships furred as are in England, and it is pity that there is no order taken either for the punishing of those who build such ships or the preventing of it, for it is an infinite

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[30] R.C. Anderson, ed., *Journals and Narratives of the Third Dutch War, Publications of the Naval Records Society, Vol. LXXXVI* (London: Navy Records Society, 1946), 71.

[31] Smith, *Sea-man's Grammar*, 53.

[32] Baker, *The New Mayflower*, 6.

> loss to the owners and an utter spoiling and disgrace to all ships that are so handled.[33]

Ferreiro says builders did not know why the technique worked, but they knew that it did.[34]

That brings up one of the major themes to be discerned from this study and one of the keys to understanding this technology. One does not have to know why something works to know that it does. Much of what we know about the aerodynamics of sailing, we learned from aviation—we learned well after the fact. The development of successful steam engines—and the quest for more efficient ones—led to the science of thermodynamics, not the other way around.

Girdling was a drastic solution to poor stability. The preferred first solution was adding ballast. Recall, though, the note about load waterline. If the ship needed so much ballast that she floated too deep, especially if that meant her point of maximum breadth was below the waterline, that carried negative consequences for stability and performance. Ferreiro says that stability problems were not usually inherent to the design, but due to loading and seamanship issues.[35] It is certainly true that, as we discussed in Chapter Three, proper loading and ballasting were critical to the ship's stability. The evidence we have already cited, though, will not allow us to have done with this by citing Ferreiro's generalization. We have too many complaints about the

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[33] Mainwaring, *The Seamans Dictionary*, location 2291.

[34] Ferreiro, 191.

[35] Ferreiro, 191.

deleterious effect of the 1694 English tonnage calculation rule on design, and we have to deal with the earlier 17th-century English method of determining the midship bend.

Stability: Tonnage, taxes, and English merchant ship design

In 1694, the English adopted a rule by which the official capacity of the ship was to be calculated using length, breadth, and half-breadth instead of depth in hold. That was a matter of convenience, as it would be quite difficult to measure the depth in hold of a loaded cargo vessel. The reason for the substitution of half-breadth was that, at the time, half-breadth was seen as roughly equivalent to depth in hold for most merchantmen.[36] As soon as such a rule was adopted, though, it created an incentive for rule-beating—specifically, an incentive to increase either height or depth in hold, and thus capacity, tax-free. These people we are studying, though, were right to hold proper proportion in the esteem they did. One cannot increase one major dimension of a ship and not alter the others accordingly without risking the ruination of the ship's performance and/or the ruination of the ship, her cargo, and her crew.

For the complaints against the practice, we can start with the accomplished half-English, half-Swedish ship constructor Frederik Henrik af Chapman, author and illustrator of the priceless *Architectura Navalis Mercatoria* (1768), who attacked the rule for not taking into account height or depth, and opined that it led buyers to buy ships too broad for their length, thinking it would save them money, when actually it would not.[37]

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[36] Moore, "Anatomy of a l7th Century Slave Ship," 123. The methodology Moore uses in his hypothetical, on-paper reconstruction of this vessel is an impressive exercise in understanding, presenting, and using all the information he had access to on the subject. We will return to it in some detail presently.

[37] Any increase in breadth for a given length goes against what all the evidence suggests is the general trend in British Atlantic merchant ships in the period.

He dismissed the idea that anyone would build a ship too deep just to beat the rule, because that would be too great a folly for him to consider at all likely.[38]

William Hutchinson's comments on the matter focus on excessive height:

> …[I]t is known from experience that many a fine bottom has been spoiled for sailing fast, by having too great a top built upon it, which, I have been told by ship-builders, is owing to that unfair and erroneous method of calculating their tonnage for measurement by half the breadth for the depth, for payment, instead of the whole depth they are built; which latter practice ought in justice to take place between the builders and owners, to be a check upon owners who want unproportional height, in order to gain more stowage and accommodation for people and passengers, &c. by which their ships are made defective in those important points abovementioned.[39]

The "important points abovementioned" are that, first, a ship built too high will be crank, and that because she is crank, she will have to be over-ballasted and/or over-loaded, and thus her sailing and speed will be compromised. Note, though, that Hutchinson is decrying excessive height, not excessive depth. The only mention found of period ships actually being built excessively deep in response to this tonnage rule was a citation by David Moore of an article by Sir George C.V. Holmes written in 1907.[40] Excessive depth (draft) carries with it the significant drawback of limiting what harbors a ship may use.

Did the 1694 tonnage rule have a stultifying effect on the designs of English merchant ships until the 1770s? If so, if block coefficients were generally increasing, as McCusker tells us, how bad could that have been in terms of overall fleet efficiency? Was the chief cost the failure to attain what might otherwise have been a gain in average

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[38] "A Collection of Papers," Part II, 1792, Pamphlet No. 6, 48-81, Article III.

[39] Hutchinson, 34.

[40] Moore, 123.

speed? If so, would that have made any ultimate difference in passage times? These are questions we now have the background to ask and to explore.

The 1694 rule cannot explain any stability problems with English ships of *Mayflower*'s vintage. We can trace stability questions in English ships, though, all the way back to Elizabethan naval constructor Matthew Baker. This becomes a midship bend issue—the second major design aspect we need to consider.

Stability: The Mystery of the Midship Bend

The midship bend refers to the principal frame of the ship's skeleton—the frame that determines her maximum beam (breadth), and thus the overall shape of the hull—since breadth and length are related by rules of proportion. After the keel was laid, this frame would be the next piece of the ship to be raised and attached. How shipwrights arrived at the shape of the midship bend is a principal interest of ship archaeology.

The midship bend is a compound curve. No matter what precise shape the shipwright had in mind, the goal was to produce a "fair" curve—with no bumps or angles. The trick to that is to join the smaller, single curves that make up the entire shape in a way that ensures a smooth flow of one into the other. There are basically three ways the shipwright could do that. They were not mutually exclusive.

First, he could simply join together the component pieces of the frame—five would be a typical number—to form the approximate shape and dimensions he had in mind, and then fair the joint areas with tools. Second, he could use flexible battens—long strips of wood—to define the curves. Neither of these methods required drawing anything or using mathematics or geometry. It was entirely done by hand and by eye, based on experience and rules of thumb. This is how Ab Hoving, formerly of the Rijksmuseum in Amsterdam, and well-published expert on 17th-century Dutch ships, presents early 17th-century Dutch building techniques.

> The Dutch method was ad hoc, executed by men who used old rules of thumb and never used compasses to draw a circle, only to measure (take a foot in a pair of compasses and run it point over point along a long plank to count the feet). There is no real trustworthy quote in Dutch literature even suggesting predefined main frame shapes existed in the Dutch method.[41]

That brings us to the third method—defining the midship bend by drawing arcs of circles with a drawing compass—either full-size on the ground or to scale, on paper. This method allows the translation of prescribed proportions and dimensions to an actual shape before actually building the frame. The mathematics required to do that are rudimentary, provided one has access to a treatise or at least tables of dimensions and proportions, and tutelage by someone who knows the method.[42] In the literature, and in the ongoing discussion based on it, we refer to this method as the "tangent-arc method," as it relies on arcs of circles and lines tangent to those to define the fair compound curve. There is, however, more than one tangent-arc method, and the resulting shape is determined by which one the designer uses. The debate is over who used this method, who did not use it, and which specific method they used, if they used it at all. That cannot

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[41] Hoving, personal e-mail, forwarded by Paul Fontenoy, 2 April 2015. Also see Hoving, "Early Shipbuilding Literature in the Dutch Republic," *Nautical Research Journal* 58:3 (Autumn 2013): 163-164. Hoving most recently laid out his understanding of Dutch artisanal building (in which design and construction are inextricable) in *17th Century Dutch Merchant Ships: Text, Photos, and Plans for the Ship Modeler* (Florence, OR: Sea Watch Books, 2014), 36-40.

[42] Following Donald Johnson's instructions for drawing a four-sweep tangent-arc midship bend, which we will discuss presently, yielded the result it was supposed to, minus proper scale, which was not attempted. It required no mathematics other than simple arithmetic, and it seems to be something that could be taught in under an hour.

be resolved here. The issue is still at the leading edge of research. We can consider a summary of what experts know about it, and tie the issue back to that of the stability of 17^{th}-century English ships.

We start with a three-sweep tangent-arc system described by Matthew Baker (1530-1613) in the earliest known English treatise on ship design and construction, "Fragments of Ancient English Shipwrightry," held by the Samuel Pepys Library at Magdalen College, Cambridge. The provenance of parts of it is somewhat cloudy, but it is clear that Baker did write much of it, in the late 16^{th} century. William Baker used the earlier Baker's method for drawing the midship bend for *Mayflower II*, as his research indicated that is how it would have been done originally.[43] Indeed, all evidence indicates that, in England at least, Matthew Baker's prescriptions for ship design were influential for at least a century after his death.[44] The problem, as far as Nick Burningham is concerned, is that either a three- or four-sweep tangent-arc method produces a hull form featuring "a midsection with narrow floors and little initial stability--the arcs will not reconcile except when the floors are very narrow ...." He points out that such a hull, extant today in the replica *Mayflower II*, could not "stand up without ballast and could not safely take ground in drying harbours...." Using the replica *Mayflower* as his example, he points out that she "...[was] so heavily ballasted that the main deck was at the waterline and the gun ports were too close to the waterline to be opened at sea." While acknowledging that the tangent-arc system as he describes it led to some

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[43] Baker, *The New Mayflower*, 77.

[44] Accordingly, they have been influential in the design of every thoughtful replica of an early 17^{th} century English ship in our own time—raising issues we will take up in the next chapter.

successful warship designs, he finds "its application to English merchant ships…puzzling."[45]

William Baker's diagrammatic representation of a three-arc method based on Matthew Baker supports Burningham's observation—about fairly narrow floors, at least.[46] Brian Lavery's midship-bend diagram of the current *Susan Constant* replica also depicts a hull with narrow floors, but not shaped the same as *Mayflower II* or Burningham's diagram of the Matthew Baker three-arc method.[47] By the time we get to Dassié's *L'Architecture Navale* of 1677, we see fourteen diagrams of midship forms, varying significantly, and those with similar construction lines—the dotted lines indicating the method for deriving the curves—to Baker's show hulls with much broader floors and reduced height relative to beam.[48] *Deane's Doctrine* also shows a tangent-arc-derived midship bend with broader floors than what Burningham drew.[49] Like Dassié, though, Deane wrote in the 1670s.

Did English merchant ships use Matthew Baker's three-arc system to form their midship bends in the early 1600s? If so, did that produce hulls whose initial stability left something to be desired, leading to over-ballasting, which in turn compromised other

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[45] Burningham, "Early Seventeenth-Century Ships," in Bennett, ed., *Sailing Into The Past*, 111. Matthew Baker did not only describe a three-arc method—see Adams, A *Maritime Archaeology of Ships*, 132-136.

[46] Baker, *The New Mayflower*, 77.

[47] Lavery, *Susan Constant*, 61. Lavery also used Thomas Harriot's notes on shipbuilding "to the extent possible." See Jacqueline Stedall, "Notes made by Thomas Harriot (1560-1621) on ships and shipbuilding," *Mariner's Mirror* 99:3 (2013): 325-327.

[48] Dassié, *L'Architecture Navale*, 78.

[49] Lavery, ed., *Deane's Doctrine*, 69.

aspects of performance and utility? If so, did shipwrights move away from such a midship bend by the 1670s?

It is clear that one can produce a variety of midship bends using different tangent-arc methods. The tangent-arc method *per se* does not inevitably produce a Matthew Baker-esque midship bend, and thus does not necessarily introduce an inherent instability—if indeed Baker's method does carry that fault with it, which the evidence strongly suggests it did.

The way out of this thicket combines a thorough familiarity with the period manuscripts on ship design and construction, some archaeological remains and the training and experience to analyze and interpret them, and access to a marine engineering computer lab.

Analyzing ship design: Archaeology and the computer lab

Jon Adams worked on the remains of *Sea Venture*, the English galleon wrecked on the Bermudan reefs in 1609, and then set out to reconstruct her hull—digitally—from all the available evidence. Then he would be able to analyze that virtual hull.[50]

Adams took data from all the English manuscripts from 1545 to 1670. Because *Sea Venture* was a typical Atlantic wreck—only her bottom timbers survived—the only data from her wreck that Adams had access to were her flat of floor and the floor sweep radius.

[50] Adams, *A Maritime Archaeology of Ships*, 111-151.

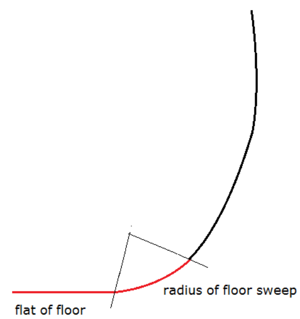

Figure 13 Flat of floor and floor sweep radius

Adams needed to look at the relationship of the wreck's flat of floor and radius of floor sweep and compare that relationship to the relationship between those dimensions prescribed or described in the period manuscripts, and see how close a match he could find. Then, because of the centrality of proportion, he would be able to extrapolate the other important relationships and reconstruct the major lines of the hull.

Adams drew four midship sections to a common scale and superimposed them. Each was based on a different source—two from Baker—one three-arc and one four-arc—one from Wells, c. 1620, and one from Deane, 1670. The chronology shows a "progressive drift in the principal design criteria."[51] It also shows that "the curvature they produce is not dramatically different."[52]

Adams graphs the two dimensions from 1545 to 1670 and shows a fairly linear increase in the flat of floor as a percentage of breadth, and a corresponding, also mostly

[51] Adams, *A Maritime Archaeology of Ships*, 140.

[52] Adams, *A Maritime Archaeology of Ships*, 140.

linear decrease in the radius of floor sweep as a percentage of breadth over the same period. So, judging by the manuscripts, English floors grew wider and thus the percentage of the total breadth made up by floor sweep radius decreased concomitantly. The overall shape of the curvature of the midship bend otherwise remained quite consistent, the most obvious change being from more of a wedge shape to the hull early on to a more rounded shape. We see an increase in that round-shape tendency as we move into the 18th century, though Adams points out that the change in the flat of floor to floor sweep radius trend leveled off after Deane (1670).[53]

Locating *Sea Venture* on that time continuum, Adams then extrapolated all the dimensions needed to come up with a hypothetical midship bend of which he could be confident, and then of a complete set of lines for the hull.[54] The latter he generated by putting the data into "an industrial lines-fairing package" called *Wolfson Shipshape*. The provisional results he reports from the performance analysis are most important for us here. They prove that the virtual model of *Sea Venture* is "very stable." Adams tested the model using different heights for the center of gravity, to represent different lading scenarios, and found that the righting moment—the force trying to bring the hull back upright—got stronger as the angle of heel increased. Properly battened-down, he says, the hull "would recover from an angle of heel well past 45 degrees. This indicates a considerable sea-keeping ability for *Sea Venture* and ships of her general form." Adams

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[53] Adams, *A Maritime Archaeology of Ships*, 141.

[54] Adams, *A Maritime Archaeology of Ships*, 146-7.

reminds us that what sank *Sea Venture* was leaking from grounding damage, not instability. She had ridden out a hurricane for four days prior.[55]

Adams used Admiralty Library MSS 9 (c. 1620-1625), anonymous but attributed to John Wells, for *Sea Venture's* midship bend and thus the basis for her hull lines, because the dimensions it specified worked most closely with *Sea Venture*'s recorded tonnage of 300. So this model was not based on Matthew Baker and thus cannot help us evaluate the stability of Baker's design specifications. Adams does not fault William Baker's use of Matthew Baker's model for *Mayflower II*. He seems to consider William Baker's reasons sound—for one thing, *Mayflower* was considerably smaller than *Sea Venture*, so it is reasonable that her builder would have used a different set of proportions for her.[56] So an important task of doing a hypothetical reconstruction like this is being able to decide what manuscript source or sources to use as a basis. That requires being able to compare real data—archaeological, and/or recorded data on the specific vessel—to what is in those manuscripts. Using one source will give much different—perhaps wildly different—results than will using another.[57]

So it would seem—so far—that we have no contradictions here— that it is reasonable to say, as Burningham did, that ships based on Matthew Baker's 1570s model would have less inherent initial stability than alternatives. Adams is telling us that early

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[55] Adams, *A Maritime Archaeology of Ships*, 145.

[56] Eric Speth of the Jamestown-Yorktown Foundation discussed the importance of altering proportions to properly suit the design of a smaller vessel versus a larger one, in reference to his design work on the current *Godspeed* and *Discovery* replicas (Speth, telephone interview, 14 August 2015).

[57] Adams, *A Maritime Archaeology of Ships*, 143-145.

17th-century English ship design was moving away from what Burningham criticized about Baker's model—indeed, that it had been moving away from that already when Baker came along. Archaeologists like Adams and naval architectural historians like Brian Lavery and William Baker discuss and debate significant changes taking place in time spans as short as 20 years. This technology was not static.

Adams' work is current (2013). Such efforts, though, using more or less the same body of source material we have now, minus the important addition of current archaeology, go back at least to William Baker in the 1950s. While most similar efforts by archaeologists on ships of this period have originated from the other side of the Atlantic, there are exceptions.

Twenty-seven years ago, David Moore[58] undertook a hypothetical reconstruction of a c. 1700 Atlantic slaver, the *Henrietta Marie*, based on her remains in the Marquesas Keys, for a master's thesis project.[59] His report on the methodology he used, the assumptions he made, and how he weighed the disparate sources at hand clearly describes the process, not only for undertaking an archaeological reconstruction, but for designing an accurate replica of a 17th-century vessel—or any vessel for which we have no plans or detailed specifications. The necessary source-use strategy for such efforts we could sum up as "take what you can get and make the best of it." Summarizing how he arrived at a full set of lines from a scattered pile of evidence, literally and figuratively, reveals much about how we can and cannot clear away the mist shrouding the secrets of design.

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[58] David Moore is now the underwater archaeologist for the North Carolina Maritime Museum at Beaufort. He has worked more recently on the wreck of the *Queen Anne's Revenge* (1718).

[59] Moore, "Anatomy of a 17th Century Slave Ship," 109-151.

We should not overlook the fact that even knowing the name of this vessel gave Moore a vastly better chance of accomplishing his goal. Positive identification allows for a much more focused and reliable search in the historical record. We will see in the following summary how much advantage he took of this.

Moore's first assumption was historical. Slavers were not purpose-built at the time, so he was free to consider other contemporary merchantmen comparatively. His second was also historical. He would not assume that a small merchantman would have the same hull form as a similarly sized warship. That supports the position taken in this study that, while warships and merchantmen were certainly related, we should be skeptical about any assumption of similarity between them; such an assumption carries a burden of proof. Moore's work was too early to use the manuscript copied by Newton c. 1600, discovered in 1994, which listed separate specifications for naval and merchant vessels. The issue may well be related to that of trends in arming merchant ships; the possible connection should be investigated.

Moore also assumed that slavers would be on the faster end of the merchant ship continuum. This would certainly not be universally applicable. As Moore himself acknowledges, slavers were not purpose-built, and we know that it was routine for owners to modify interior arrangements for a slaving voyage and then re-convert the ship for general cargo use for the return voyage.[60] Moore justifies this assumption by noting

[60] On slavers, see Marcus Rediker, *The Slave Ship: A Human History* (New York: Viking, 2007), Kindle Edition. Rediker notes that we do start to see specialized slavers after 1750, at least in Liverpool; those were further modified in accordance with 1780s changes to legislation on the slave trade (location 1164). Once the trade was abolished in 1806-1807, craft typically seen in any smuggling enterprise showed up on the slave coast more and more, especially fast schooners such as the "Baltimore clippers."

that slavers seem to have been popular with pirates. He only cites two examples—Sam Bellamy's *Whydah Galley*, captured in 1717, and Blackbeard's *Concorde*, captured around the same time and re-named *Queen Anne's Revenge*. He is stretching himself a bit in claiming that "Slave traders … tended to adopt suitable technology more quickly than the normal cargo carriers. As such, slavers could be considered as 'state of the art' merchant vessels of a particular period."[61] Neither Moore nor anyone else, though, can get around the paucity of such evidence as he has here, and someone unwilling to stretch that evidence as far as it will go will never make it to a hypothetical reconstruction. That is why such reconstructions are only useful if one knows the assumptions that went into them. Knowing what went into those assumptions *is* knowing what we know about these ships.

Moore used iconography—artwork—as an important source—this is typical. Using it requires evaluating the likelihood that the artwork is technically accurate, and interpreting it accordingly. Usually, the presence of ordinary merchant ships in period artwork is coincidental— they are part of the general scenery, as in the print of the London Custom House c. 1714 Moore uses, which shows three ships anchored in front of the building. The depiction of the vessels checks out against what we know from other sources. There are no obviously unrealistic details, as is frequently the case given that most illustrators did not have nautical backgrounds and were not interested in such detail. This print depicts two types of small ship—two are 'galley-built' and one is 'frigate-built.' Moore knew from the archaeological and documentary record that *Henrietta Marie*

[61] Moore, "Anatomy," 115-116.

was ‘frigate-built,’ and he knew from scale that these vessels are of similar size, so he could use details of topside hull form, deck arrangements, and rig from the print in his reconstruction.

He brought together the records of seven vessels of similar age, size, and purpose whose plans either happened to be in museum collections or were reconstructed by museums from rare documents. Moore believed, from her name and from the historical record, that *Henrietta Marie* was French-built, like *Concorde/QAR*. She left on her final, fatal voyage from Jamaica, and by the Jamaica register, she was "foreign-constructed." Her namesake was the French queen of Charles I. In King William's War, the English took 1,279 French prizes.[62] One of those could well have been the *Henrietta Marie*. So he looked for features he could identify as distinctly French.[63] One of his seven vessels had been analyzed by Chapelle in *The Search for Speed Under Sail*—the *Advice Prize*, a French prize taken into the Royal Navy in 1704—which as usual is the only reason plans of her survived—for which we have a very early foreign-built Admiralty draught. Moore believed this vessel would provide "the only detailed structural characteristics of French-origin … [she] was reputed to be fast and was more sharply ended than comparable English ships."[64]

From *Deane’s Doctrine*, Moore took the *Roebuck*, a 6th rate (smallest-class) warship of 129 tons. His justification for using a warship was that this one was

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[62] Moore, “Anatomy,” 128.

[63] He does not mention using French archives or museum collections. The French-English barrier is still a high one in our field, unfortunately.

[64] Moore, “Anatomy,” 115, citing Chapelle, *Search for Speed*, 38, 42.

approximately 20 years older than his subject, and he accepted Brian Lavery's opinion that merchantmen in this period were roughly 20 years behind warships technologically—an opinion that cries out to be held against the archaeological record as the latter continues to grow.

The next task was for him to go through all the considerations dictated by the tonnage formulae and rules we went over earlier in the chapter—all the stuff McCusker explained and the considerations dictated by the 1694 tonnage rule. Otherwise, the fact that Moore knew the registered tonnage of *Henrietta Marie* at 120 would have been at best rather useless to him and at worst led him widely astray. He used the 1694 formula to determine the "unknown major dimensions of keel length, breadth, and hold depth…." With keel length to breadth, breadth to depth, and tons burden, he could manipulate the formula "in reverse to reveal these measurements." Not knowing exactly which formula was actually used for the *Henrietta Marie* "should be a moot point in view of the approximate similar values of hold depth and one-half breadth exhibited during the period."[65] So Moore could now posit the major dimensions of the vessel. Then he returned to his French-built theory and hung more assumptions on that. This gives us a good idea of the kinds of convergences and divergences we would find between shipbuilding practices of the different European maritime powers.

"Available evidence suggests a convergence of naval technology between

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[65] Moore, "Anatomy," 125. Moore assumes that any increase in depth, or height, to beat the tonnage rule would have happened later. It would be worth testing that assumption as more archaeological evidence presents itself.

England and France during the late 17th century."[66] We know Deane "conducted naval intelligence...around French ports...between 1668 and 1671." The king even ordered him to build warships based closely on French designs, which they then had access to. The French were also directly observing English design and construction. It is possible, then, that a 1690s French merchantman could exhibit characteristics shared by both nations in the 1670s, going back to Lavery's assumption about the 20-year warship-merchantman technology gap. Rigging and ship expert R.C. Anderson examined the possible English-French convergences and divergences in a series of article in *Mariner's Mirror* on comparative naval architecture, 1670-1720, using Deane's *Doctrine* and Dassié's 1677 *L'Architecture Navale*.[67] Moore quotes Anderson's summary of the numbers comparison, according to which French ships were somewhat shorter for their beam, and deeper than English ships, and shared or diverged in other specific characteristics of design.[68] Anderson discusses two French reports from 1670 and 1672, which indicate, according to Moore, that "English vessels were '…far more 'fregates'—lower in the water—than French…."[69] Anderson gave Moore plenty here to look for when he went back to the archaeological record.

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[66] Moore, "Anatomy," 129. Moore's source was A.W. Johns, "Sir Anthony Deane," *The Mariner's Mirror* 11:2 (1925): 164-193.

[67] Anderson, "Comparative Naval Architecture, 1670-1720, Part I," *Mariner's Mirror* 7:2 (1921): 38-45; "Comparative Naval Architecture, 1670-1720, Part II," *Mariner's Mirror* 7: 6 (1921): 172-181; "Comparative Naval Architecture, 1670-1720, Part III," *Mariner's Mirror* 7:10 (1921): 308-315. Note that these articles are far too early to have taken into account any shipwreck archaeology.

[68] Moore, "Anatomy," 132, citing Anderson, 85.

[69] Moore, "Anatomy," 134, citing Anderson, 89.

Turning to that, Moore demonstrates the good archaeologist's knack for extrapolating important information from creative observation—in this case, making clever dimensional extrapolations from artifacts recovered. He could ascertain timber thickness in the vicinity of the weather deck by the width of the surviving lead scupper liners that had to exactly fit those timbers, and by the surviving through-hull fasteners—"miscellaneous forelocked ringbolts and chainplate bolts." "The angle of the bottom link on several deadeye chain assemblies also provides a clue to the amount of 'tumblehome' present on the *Henrietta Marie*."[70]

Moore assumed *Henrietta Marie* to have been a three-masted ship based on two of the comparative ships on his list and Custom House ships from the print. Davis tells us that from 1680 to 1720, ships normally went from two-masted to three-masted at around 50 or 60 tons, and that this was true for both English and foreign vessels.[71]

Moore then presents eight columns of dimensions for the ship, each column derived from a different written source. How he came up with that reveals how we can use those proportions discussed in Chapter Four.

He derived the figures for one column by applying a "correction factor" to a set of rigging component proportions in Deane's *Doctrine* for a 6th rate warship, and noted that doing so gave him scantlings measurements that came "very close to those measured on the *Henrietta Marie*….[72] He computed the dimensions in another column from other

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[70] Moore, "Anatomy," 134.

[71] Moore, "Anatomy," 135. Davis also tells us that this dividing line moved up the size scale as time passed. By the 1750s, it was around 200 tons.

[72] Moore, "Anatomy," 138.

proportions in Deane's *Doctrine,* based on calculated length of mainmast. Both those columns “apply to warships and can therefore be associated with the Deane/Dassié analysis and perhaps subject to Lavery's twenty-year lag period," Moore writes.[73] The next two columns are based on rules in the 1711 treatise *The Seaman's Speculum*.[74] Selecting proportions from the treatises and from the records of the seven ships he judged appropriate rough analogues, and comparing all of that to the archaeological record of the *Henrietta Marie*, brought Moore to his reconstruction, which is quite detailed. She would be drawn “as a small ‘frigate-built’ ship.” Moore includes features such as the shape of her bow, transom, stern with quarter galleries and cabin windows, the size of her cabins and the heights of their ceilings, and a hull incorporating both French and English specific design characteristics. He notes that all three of the main treatises he used give very close measurements for sternpost rake and length, stem rake, and transom width. He concludes that French design was incorporating Dutch characteristics as well by the time his ship was built, and speculates that such a vessel had become “a 'frigate'-built' ship with Dutch 'fluyt'-design influences, i.e., deeper, fuller body with 20-25 year old naval lines and rig. This is only an observation based entirely on preliminary investigation, however,” he notes, “and will require additional research to verify.”[75] It will be important to remember this hybrid “'frigate'-built' ship with Dutch

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[73] Moore, “Anatomy,” 138.

[74] Moore, “Anatomy,” 139. Recall from Chapter One that mast steps on the keel tend to survive. Mast steps on deck would not.

[75] Moore, “Anatomy,” 140-142.

'fluyt'-design influences” for our last archaeological-reconstruction case study, for it will show up again there.

That takes us through the process of a hypothetical reconstruction based on all the types of evidence available to us. Moore did not take the step Adams did of conducting performance analysis on his virtual model, but he could have. He had gotten that far in the process.[76] Note all the assumptions made, how they fit together, and how much detail Moore was able to incorporate into his model based on those assumptions, the educated guesses they led him to, and the archaeological record. With all our records on such vessels so incomplete, putting together enough evidence to push an analysis this far requires putting all the pieces from different types of sources together, somewhat akin to completing a dinosaur skeleton from fragments found all over the world.

We also get a clear sense from the Moore case of the interplay between technological inputs from rival powers in the Atlantic World. Those powers did have some distinctive tendencies and traditions, but they inevitably blended as ships were captured and studied, foreign agents visited their rivals' dockyards, like Ollivier, and Deane, and shipwrights emigrated.

The way forward with analyzing ship design is by doing what Adams and Moore did. The next chapter is about what we can learn from replicas, but building and operating replicas is seriously expensive, and much of what we can learn about the behavior of different hull variations, we can learn in the lab—which also affords us the luxury of quickly and easily making modifications to those forms and testing what-if

[76] In 1989, though, the necessary applications were neither as available nor as sophisticated.

scenarios. What if we do stability calculations as Adams did on *Sea Venture*, using various centers of gravity to represent different lading scenarios, on a progression of hull forms using midship bends from all the sources Adams looked at? How significant would the differences be?

Another basic aspect of watercraft design we could test in the lab is *resistance*—resistance to the water presented by the ship's hull. The less the resistance, the less effort or energy is required to propel the ship.

Resistance and the fish-form hull

At this point, we have already paid proper attention to the problem of speed, based on log books, passage times, the importance of capacity, structural dictates of wooden construction, and even the concept of hull speed.[77] We have also noted Ferreiro's comment that, in this period, surface friction from roughness and fouling was more important to ship speed than hull form resistance. That does not mean no one paid any attention to hull form resistance. Ferreiro's book is full of discussions on the subject. We know that Newton worked on resistance, and thought he had come up with a hull form of least resistance. The French navy partially adopted that, as mentioned earlier.[78] The treatises focus much attention on the matter.[79]

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[77] Recall that hull speed is the maximum speed a displacement hull can attain without surfing, constrained as it is by the trough of the wave it creates as it moves through the water. The formula is $1.34\sqrt{LWL}$ (length at the waterline in feet), for a speed in knots (nautical miles per hour). No one knew this at the time, and it would not have mattered if they had.

[78] Their prominent constructor Blaise Ollivier, though, thought little of the idea (Ollivier, 183-184).

[79] See for example Euler, *A compleat theory of the construction and properties of vessels*, already cited, 184-185; Henri-Louis Duhamel Du Monceau, a translation of whose 1765 treatise is included in Mungo Murray's, *Treatise on Shipbuilding,* already cited, 57; Stalkartt, 9.

We know that mariners and shipwrights of the time paid proper attention to the flow of water by and under the hull. Most contemporary sources mention the importance of getting a smooth flow of water to the rudder, and not creating strong eddies—what they called “dead water”—behind the stern.[80] Some English ships from the beginning of our period—such as *Mayflower* and *Susan Constant*—may seem to give the lie to that, as they carried their flat transoms to the waterline, presenting an un-fair angle to the water and creating just such turbulence at the stern, but that was a compromise that allowed the carriage of guns low in the stern, with their opening ports. Much more common in most of our period was an upswept run aft intended to provide fair flow and clean water for the rudder, as seen in Figure 14 below.

Figure 14 Upswept after section.[81]

[80] For example, see Stalkartt, already cited, 2: "Then fix the lower part of the transom clear of the load draught of water, that the boat may have no dead water to drag after her.”

[81] Model of 1778 American frigate *Alliance*, Independence Seaport Museum, Philadelphia. Photo by the author.

Opinions varied on specific aspects of hull design vis-à-vis resistance. Attempting to treat that subject thoroughly would constitute a thesis in itself. One chief aspect of design, though, was consistent throughout the period, and any study of ship design needs to ask why. That is the fish form—the cod's head and mackerel's tail, so famously illustrated—some say for the Queen herself—by Matthew Baker. Fish-form hulls have disappeared from commercial shipping, but we still see them in airplanes, submarines, torpedoes, and modern touring kayaks. The idea that modern hydrodynamics could not support a fish-form hull must be rejected. We must assume, as we do with any other aspect of ship design, that they offer pros and cons relative to alternatives, and then set about trying to determine what those are, keeping in mind as always that we are more interested in our subjects' ideas of pros and cons than in our own.

Summing up the concept of the form reads something like this. The bluff bow provides buoyancy. It rides up on the waves rather than burying itself, and it pushes the water aside. The rest of the underwater hull then allows the water to flow cleanly back to the rudder. Tapering the hull aft encourages the water's swift travel.

We are already familiar with factors selecting for the bluff bow—buoyancy, capacity, the fight against hogging—to which we can add that room in the bow provides for the stowage of long, heavy anchor cable and a number of anchors.[82] Does it knife through the water like a yacht's? No, but these were not yachts.[83] Laying all other

[82] A point Chip Reynolds made (Reynolds, Skype interview, 8 January 2015).

[83] Jim Graczyk, Drew McMullen, and Joakim Severinson all made comments indicating that a modern sailor on a period replica will notice how differently the bluff bow behaves in the water than a modern yacht's bow (Jim Graczyk, personal communication, 6 November 2014; Drew McMullen, telephone interview, 8 January 2015; Joakim Severinson, personal communication, 19 March 2015).

considerations aside, we are always left with speed versus capacity. We cannot, however, dispense with the bluff bow in a short paragraph. Think of the sharp concave prows of the great 19th century clipper ships—why did those dispense with the bluff bow, and what was the cost/benefit balance?

It is not necessary to leave the period to question the feature—contemporaries were happy to do it, especially late, when that "restless spirit" swirled around elite British maritime circles. Naval constructor Marmaduke Stalkartt wrote a treatise in 1781, dedicating it with permission to His Majesty, with the hope that it could advance the interests of the Empire. Stalkartt set out from the beginning to defend the bluff bow, the placing of the maximum beam forward of amidships—the traditional shape.[84] Ten years later, though, a contributor to the Society for the Improvement of Naval Architecture's proceedings cited French experiments that, he claimed, proved that bow form was immaterial to resistance.[85] In a letter to the Society of 26 June 1791, Charles Gore claimed to have done experiments proving that the fish-shape theory was wrong, and advocating further experiments to corroborate that. If Gore is the source of the "Observations on the resistance of fluids..." that follows the letter, which is unclear, though the content is consistent, he described model experiments showing that the solid of least resistance had its maximum breadth amidships, and a sharp entry, and the fish

[84] Stalkartt, already cited, i-ii, 30-32.

[85] "A Collection of Papers," Part I, Paper V, 25. The author of this paper also claimed that the same experiments showed no difference in performance for straight versus curved waterlines—something else Stalkartt had a definite opinion on (see Stalkartt, 9).

shape did not do as well.[86] Earlier in this collection of letters and essays, we find an even stronger dismissal:

> The idea that ships ought immediately to taper or become narrower from the midship bend or frame, that the closing of the water behind them may push them forward, is a vulgar error; that the shape of fishes ought to be copied in ships, is another; as the analogy does not hold good. Yet those two ideas have occasioned great blunders in naval architecture.[87]

It is worth pointing out, though, that one need not subscribe to the above justification for the tapering-aft to support such a feature.

Fluid resistance theory was still an elusive quarry in this period. What is worth investigating is whether well-designed ships made some sacrifice in resistance inherent to the fish-form hull. If so, how much? We have seen how unlikely it was for small gains in a ship's speed through the water to make a practical difference in her passagemaking. Were the advantages ascribed to the tapering-aft from amidships real? If we find in the laboratory that there is little or no resistance penalty for this form, that could support the notion that long experience—a form of evolution in human technology—had worked. If we find that there was a resistance penalty, we will be required to weigh that against other pros and cons of the fish-form hull. It would be worthwhile to test different known hulls, all of which offer some version of the fish-form, comparatively.[88]

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[86] "Some account of the institution, plan, and present state of the society, of the Society for the Improvement of Naval Architecture: together with the premiums offered by the Society, list of subscribers, rules and orders, of the Society: and 3 original letters, addressed to the committee, from Sir Charles Middleton, Bart. and Messrs. Gore and Patton, on subjects of naval architecture" (London: Society for the Improvement of Naval Architecture, 1792), 17-18, in the collection of the Library of the American Philosophical Society.

[87] "Some account…", 14.

[88] In doing so, it would be worthwhile to start with Frederick Henrik af Chapman's 18th-century experiments with models, comparing his conclusions to our own.

The more confident we can be in how "known" our "known hulls" really are, the more confident we can be in the information we extrapolate from them. Moore and Adams were limited there by the limitations of their archaeological remains. They had to rely on the treatises for their reconstructions—as did William Baker, and Brian Lavery. If there is enough of a ship left that the archaeologist can discern her actual, rather than hypothetical, dimensions and proportions, though, then we can turn that on its head. We can come up with the design methodology through what is called 'reverse naval architecture,' and hold that up to the surviving manuscript sources. This is our best chance to shake free of the tyranny of the treatises—and to understand how prescriptive vs. descriptive they were, and clear up some of the mystery of the connection between naval and merchant ship design.

'Reverse naval architecture': Warren Riess and the Ronson ship

The most promising work on deciphering the design technique used to build an actual ordinary Atlantic merchant vessel is Warren Riess' on-going 'reverse naval architecture' analysis of the Ronson ship, unearthed in Manhattan in 1982, which Riess eventually concluded was the *Princess Carolina*, built at Charleston c. 1717 for local owners.[89] As is almost never the case with American underwater archaeology, enough of the hull was intact for Riess to make measurements that, after thirty years of head-scratching and on-again, off-again work, he was able to match to a design technique

[89] See Riess with Smith; archaeologist Kelby Rose also employed computer-aided "reverse naval architecture" in his analysis of the *Vasa*'s design, overcoming the unusual problem of how to virtually "take apart" an intact vessel for the kind of analysis commonly performed on disarticulated remains. See Kelby James Rose, "The Naval Architecture of *Vasa*, A 17th-Century Swedish Warship" (PhD dissertation, Texas A&M University, 2014). Rose hopes to employ the application he used on *Vasa* to understand other partially intact wrecks.

involving simple circles and proportions that do not match those specified in the treatises for naval vessels and other ships deemed important at the time. Riess sketched out the preliminaries of his discovery in his first book on that ship, and he is currently working on a more thorough technical analysis and explication of the technique, which he expects ultimately to publish as a sequel.[90]

The Ronson ship did not sink—she was deliberately buried as landfill. That accounts for her state of preservation. The archaeologists were able to determine that she was about 100 feet overall, 82 feet on deck, 65 feet on the keel, 24 feet in the beam, 9 feet in the hold, and about 11 feet total draft fully laden. She carried her maximum beam about 30 feet aft of the bow, carried that 24 feet aft, and then slowly tapered toward the stern. Her floors were relatively flat. She was built more for capacity than speed. She would have been 130-200 registered tons depending on the local formula used. He would later determine she was ordered as a 200-ton ship.[91]

Recall how much work David Moore had to do just to determine some of those hull characteristics. This thing was a ship archaeologist's dream. Riess, though, might say, "Be careful what you wish for." The Ronson ship bedeviled him for so long because he knew he had enough that he should be able to find the solution to the design, but that solution kept eluding him. Riess kept trying different arc radii, but could not get the centers of arc to quite match up well enough that he could be sure he had found the correct radius. He realized that to some extent he was being thwarted by hull distortion—

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[90] Riess, personal communication, 18 August 2015.

[91] Riess with Smith, 50, 46, 50, 34, 33, 45.

an effect of the massive weight of earth bearing down on the ship's hull for almost three hundred years. Once that was factored out, it became possible to proceed. Eventually, Riess was able to determine that the builder had used the simplest of fractions, based on the ship's beam of 24 feet. He discovered that an arc with radius of 12 feet (1/2 breadth) fit perfectly, and from there determined that he could match the ship's dimensions to simple straight lines and arcs with radii of 4, 8, 12, and 16 feet.[92] It was clear that this South Carolina shipwright had used much simpler fractions in his design than those set out in any of the contemporary treatises.

That is not to suggest that his ship was crude. On the contrary, Riess found distinguishing details of construction that struck him and others as highly skilled craftsmanship—and certainly labor-intensive. Most of the hull was re-buried on-site, and a skyscraper built over it. The bow section, at least, was recovered, and may be appreciated as an example of successful construction outside "the published rules."[93] Her bow did not use cant frames,[94] as would have been expected, but square frames—an older form of construction, so far as we know. To fit the planking properly over these frames, the shipwright had to bevel and shape them very carefully, with great skill. Riess calls them "extraordinary pieces."[95] Cant frames absorb wave shock better than square frames.

[92] Riess with Smith, 46.

[93] Riess with Smith, 38, citing Jay Paul Rosloff, "The Water Street Ship: Preliminary Analysis of an Eighteenth-Century Merchant Ship's Bow," master's thesis, Texas A&M University, 1986.

[94] Cant frames radiate from the perpendicular toward the stem, as opposed to square frames, which remain perpendicular, are made progressively smaller, and whose outside edges are beveled to allow for the shape of the bow.

[95] Riess with Smith, 34-5.

A bow built with the latter requires more frames, "massive breast hooks," chocks, and hawse pieces between the frames, such that the bow becomes almost solid. This is heavier and uses more wood for the same strength. The Ronson ship is a late example of the use of square frames in the bow.[96] This varies from 18th-century warship construction, but supports Lavery's idea that merchant ship techniques tended to be more conservative. "It is not clear whether this was because of strictly traditional forces or because the availability of greater amounts of timber in America made square frames more practical for this ship," Riess writes. [97] As discussed in the last chapter, both the availability of materials and the predilections of individual shipwrights had much to do with the variety of finished vessels we actually find in the mud. "The care with which the shipwright had built the ship was impressive," Riess writes. "We saw no indications of any labor-saving shortcuts taken." He did notice that not every piece used for a structural timber was "perfect," and "the spacing of frames was not as systematic as we expected" from studying naval vessels and plans. They had strong evidence, though, that the ship had made more than once transoceanic voyage, and that the builder had been "resourceful in using what curved timbers he could obtain and shifting their position a bit when necessary to build a properly shaped, strong ship."[98]

We established in Chapter Four that any attempt to separate "design" from "construction" with these ships is arbitrary. We have to pay particular attention to those

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[96] Riess with Smith, 42.

[97] Riess with Smith, 46.

[98] Riess with Smith, 37.

aspects of construction that strongly influence design, such as the availability of compass timbers. What Riess mentions here about the shipwright's "using what curved timbers he could obtain and shifting their position a bit when necessary" connects us to the 17th-century Dutch design-to-construction nexus explained so well by Ab Hoving, who built a large model of a Dutch *fluit* to understand the construction method indicated by the archaeological record. These famous Dutch cargo vessels were known throughout the European world to be cheap to build and cheap to operate. Hoving shows that the quick and dirty framing method certainly contributed to the "cheap to build" side of that.

The Dutch method Hoving describes involved a partial frame-first, partial plank-first technique. The bottom was planked after the keel was laid but before the floors and lower futtocks were installed. Alternating planking and framing continued up the sides. Hoving describes this as "not a very neat process. The builders simply took curved grown pieces of wood into the ship and fitted them wherever they matched the hull's shape." In the archaeological record, he says, we can recognize Dutch ships by these "arbitrarily placed and untidy looking frames." This was fast, cheap construction, making best use of materials and saving labor by allowing a "quick fit."[99]

Hoving is not saying they were unsound ships any more than Riess is saying that about the Ronson ship. It is worth pointing out here, though, that this method would have been problematic to execute in a ship intended for a full complement of guns. Framing had to be heavy and regular to accommodate gun ports and gun weights. The *fluit* was, as is well-known, unarmed.

[99] Ab Hoving, "The Fluit," *Nautical Research Journal* 42:1 (March 1997): 33-34.

We should also note that VanHorn describes similar rough, improvisational framing techniques in her wreck sample, discussed in the last chapter. It may be that, with no top-down control over the builder of such vessels, they were freer to improvise than those working in larger, more hierarchical yards or, certainly, in naval yards. Burningham posits an important plausible connection to a wider 17th-century Dutch cultural and socioeconomic context when he opines that "the Dutch, because of their less hierarchical society and artisanal ship design could adapt most quickly and successfully."[100] Based on the archaeological evidence *in toto*, we can widen the geographic scope of that theory beyond the Netherlands. Recall what Burningham wrote. "Someone could decide that ships ought to be designed in some theoretical way. It would make no difference to the many shipyards scattered around the Netherlands on muddy shores and river banks." Warren Riess is showing us the same thing for South Carolina. Kellie VanHorn pointed out how difficult it is to find consistent tropes in the framing of ordinary British American merchant ships. When asked if we might apply his comment to the North American eastern seaboard, Burningham said "Yes, in truth we have little idea how the great majority of ships were designed."[101]

We will know more, though, once we have done with Riess and his *Princess Carolina*. Riess compared the basic shape of his ship with those presented in period works—particularly Chapman's *Architectura Navalis Mercatoria*, whose plates are famous for their stunning detail. By superimposing the profile of the general cargo area,

[100] Burningham, personal e-mail, 5 May 2015.

[101] Burningham, personal communication, 6 April 2015.

analogous to the midship bend, of the *Carolina*, Chapman's profile of an English merchant frigate, and Chapman's profile of a Dutch flyboat (*vlieboot*), a common contemporaneous merchantman, Riess clearly shows that the *Princess Carolina* is a combination—whether deliberately or not—of the two forms—just as Moore concluded the *Henrietta Marie* probably was. Considering Riess' comments on the ship's design, we can appreciate how significant it is to have this depth of hard evidence on an ordinary Atlantic merchantman of 1717.

The stem profile, or side-on view of the curve of the bow, was a "true arc of 16-foot radius" at the notch of the main structural member, the stem, where the plank ends were joined to it. The bluntness of this traditional bluff bow "did not allow for a fast ship…." "The stern … was a familiar square tucked stern of an English merchant frigate…providing "a long keel structure for speed and sailing ability." Riess then makes his most important claim—that the design of this ship "may answer Ralph Davis's question, raised in *The Rise of the English Shipping Industry*, about how British ships became more efficient in the 18th century." Davis surmised that British shipwrights studied Dutch and French ships captured in the War of Spanish Succession (1702-13). He also suggested—though he cautioned that this was conjectural—that "the main technical development in English shipbuilding of the early 18th century was the adoption…of the hull forms used earlier by the Dutch which made possible a high carrying capacity in relation to the ship's main measurements."[102]

[102] Davis (2012 ed.), 62-63. Davis is speaking here of the increase in shipbuilding in north-east England at this time, and the frequent mention of "pinks" in connection with that output. The word "pink" is related to the word "pinch"; it suggests a stern that narrows as it rises. Though it was a common term, it is vague, like

Riess suggests that the “development or trial of this type of ship in the early 18th century appears logical in retrospect. British merchants and shipwrights alike knew the qualities and drawbacks of their frigates as well as those of the flyboats.” If a hybrid were successful, it would “retain much of the frigate’s speed, agility, and defensive fighting ability, while being able to carry more cargo into shallow areas.” By fitting a longer keel, the builder could somewhat counter the poorer windward ability of the flat bottom. “In addition, the flat bottom required less ballast because the shape of the hull lessened its tendency to heel.”[103]

The Carolina coast is a perennially shifting maze of sandbars and shallow inlets. Although Charleston is the best and most important regional harbor, and thus the site of the most important port city of the region at the time, the bar at its mouth restricted the draft of ships that could use it. For any other port in the area, such depth restrictions were more severe. So there certainly would have been good reason to adopt design and construction techniques that allowed for shallower draft while retaining capacity and seakeeping ability—trademarks of Dutch merchant ships, as the Dutch coast is similar.

Can the other noted advantage of Dutch cargo ships Riess notes here—capacity for size—push McCusker’s argument that block coefficients increased in British Atlantic merchant ships into the 18th century—and support Ralph Davis’ conclusion that merchant ships became markedly more efficient as the 18th century wore on? Once Riess can fully 3-D model the Ronson ship in the computer lab, can he establish comparisons between

most nautical terms of the time, and could apply to vessels with varying hull forms. So, while flyboats typically had pink sterns, so did other vessels, and Davis freely acknowledges he is on speculative ground here. This is a perfect example of why he was so keen to have nautical archaeology pursue these questions.

[103] Riess with Smith, 39-41. They cite Davis, 1972 edition, 286-288.

her performance and her capacity and those of comparably sized vessels built for similar purposes throughout the period? How close will that get us toward being able to go back to the maritime economic historians with new information? If any project stands a chance of achieving the kind of breakthrough in technical understanding of Atlantic merchant ships Ralph Davis hoped for fifty years ago, this is it. Modeling studies of this hull will go a long way toward answering the question of whether changes in merchant ship technology had anything to do with the growth of shipping productivity—and if so, how. They will suggest further such modeling studies on remains we have not yet found.

From the lab to the water

Our computer modeling applications are powerful and sophisticated, capable of synthesizing and analyzing complex physical data. Nevertheless, we still do not understand everything about all the forces at work in the ocean and in the air. We should be skeptical about the ability of our models—which we program—to reproduce with complete accuracy the behavior of a ship on the sea, and of the sea on a ship. The ease and economy of studying ships through digital modeling is irresistibly compelling for a host of good reasons, and we should pursue it with gusto. We would do well, though, to think of our weather models, and the wide disparities they produce when meteorologists ask them to predict the track of a hurricane. At that point it is the human meteorologist who has to step in and interpret the information from the models to make a forecast—an educated guess. The limitations of the models reflect the limitations of how well we understand the natural forces at work.

So we should not be prepared to concede that a virtual ship sailing on a virtual ocean can represent with complete accuracy a real ship sailing on a real ocean. For that, we can build real ships and sail them on real oceans.

Chapter Six: The Time Machine? How Can Replicas Help Us Understand the Originals?

In this chapter, we will venture out of the British Atlantic at first, and then return to it. The critics of Atlantic World history as a field—most prominently Peter Coclanis—remind us to take care that we do not conceive of the Atlantic as a discrete system, because it was not.[1] Ship technology went everywhere in this period.

In 1606, the year before the first English settlement attempt on the James River in Virginia, the VOC *jacht*[2] *Duyfken* ("little dove") scouted and charted the coastal waters of what is now the Cape York Peninsula of Australia, becoming the first European vessel known to have explored there.[3] *Duyfken* was built in 1595, so she was already nine years old when she was sent to the other side of the world—see the discussion of ship longevity in Chapter Four. She was already a veteran of VOC service when she went to Asia. Ships like *Duyfken*—and Henry Hudson's, and the ships that went to Jamestown—were small but hardy, maneuverable, were lightly armed to provide some defense—or offense, depending on adversary—and reasonably quick for their size. They were ideal for exploring unfamiliar waters, where getting themselves into danger was a high risk, and the ability to get themselves out of it again would be a high priority. There would be no supporting infrastructure where these ships were going. They needed to be self-

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[1] Peter A. Coclanis, "*Drang Nach Osten:* Bernard Bailyn, the World-Island, and the Idea of Atlantic History," *Journal of World History* 13:1 (Spring 2002): 169-182. For a discussion of the state of the field taking this and other criticism into account, see Alison Games' Forum in the *American Historical Review*, "Atlantic History: Definitions, Challenges, and Opportunities," 111:3 (June 2006): 741-757.

[2] The word, whether in the original Dutch or in the Anglicized 'yacht', always meant a fast, maneuverable sailer, and it still retains that meaning, among others.

[3] For a detailed chronology of the original *Duyfken*, see the Duyfken 1606 Replica Foundation's website: http://www.duyfken.com/original/brave-ship

sufficient—the crews aboard had to operate, maintain, and repair them unassisted. When a ship like *Duyfken* operated as the scout for a fleet, the larger ships stayed offshore where it was safe, and sent the scout vessel in close for in-shore reconnaissance. *Duyfken* survived her exploration of Australian waters. She was judged irreparable at Ternate in the Moluccas in 1608, after participating in a battle with the Spanish. She was thirteen years old.

On 24 January, 1999, in Fremantle, Western Australia, a new *Duyfken* settled into the water—not from wooden slipways, but from a diesel-powered Travelift®. She may not be one of the largest or most famous replica ships from our period ever built, but in important ways, she may be the most ambitious yet attempted. She was designed based on the latest archaeological, iconographic, documentary, and modeling findings, and the Dutch have much to work with from all those sources. The Australians imported European oak from Latvia for her hull. They brought together an international team of shipwrights and advisors. They set themselves the task of teaching themselves how to build the ship the way they knew she would have been built originally—with the 17th-century Dutch combination of plank-first, frame-first construction—a sort of hybrid between the two construction methods that we tend to conceive of in our linear thinking as separate, with the latter having succeeded the former in European construction by the 15th century. *Duyfken*'s shipwrights also had to learn to shape bow timbers using charring over an open fire—a technique no commercial shipwright in the West had used in, literally, ages.[4] This proved slow and frustrating until they figured it out, but they did.[5]

[4] Steam-bending, in a steam chest, as we do now, was a 19th-century technique.

We have as much reason to be confident in *Duyfken's* accuracy as we are ever likely to have in a speculative replica based on multiple sources.

Figure 15 *Duyfken* replica.[6]

Duyfken's sails are flax, her rigging hemp.[7] Never intended as just a floating dockside approximation, *Duyfken* re-enacted her namesake's scouting voyage from the Spice Islands to Cape York, and then she sailed from Western Australia to the Netherlands. The experiences of those seasoned mariners on that ship on those voyages can teach us much about operating these vessels.[8] To that, though, we must add the caveat that, as we go aboard reconstructed vessels, hoist sails, and get underway—or talk

[5] See Nick Burningham and Adriaan de Jong, "The *Duyfken* Project: an Age of Discovery ship reconstruction as experimental archaeology," *International Journal of Nautical Archaeology* 26:4 (November 1997): 277-292.

[6] Photo by Rupert Gerritsen, https://commons.wikimedia.org/wiki/File:Duyfken_Replica_Under_Sail.jpg

[7] On the other hand, she has two diesel engines with feathering props and fuel tanks.

[8] Nick Burningham, "Learning to Sail the *Duyfken* Replica," *International Journal of Nautical Archaeology* 30:1 (April 2001): 74-85. Burningham was aboard.

to those who do that—we would do well to keep in mind Ole Crumlin-Pedersen's caution. "Modern day social and mental constructs and limited relevant knowledge and skills, will inevitably impede our ability to replicate ancient vessels."[9] Crumlin-Pedersen should know. He was a leader of the successful effort to reconstruct and test the recovered wrecks of Viking ships. It is safe to assume that by "replicate" he is not only referring to design and construction, but to techniques of operation. The challenges and opportunities of such an endeavor should become apparent in the ensuing discussion of actual experiences afloat.

This chapter examines working replicas designed and built from all the evidence we have—the documentary record, archaeological record, and iconography— inspired by experimental-archaeology efforts of the last few decades—based on the conviction that the experience of designing, building, and operating such replicas could teach us more than all these sources alone.[10] What can we learn by talking to the people who design, build, and sail these vessels?[11] How do their experiences jibe with what we read in our

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[9] Crumlin-Pedersen, "Experimental archaeology and ships—principles, problems and examples," in Blue et al., *Connected by the Sea*, 3.

[10] This use of the term "replica" is as a blanket term of convenience. It can be useful to distinguish between a replica, which is based on near-complete data on a specific vessel and the materials and techniques used to build it, and a reconstruction, which is based on incomplete evidence gathered from whatever source material about similar vessels might be available, augmented by experiment and educated conjecture. For a concise introduction to these concepts, see Seán McGrail, "Experimental Archaeology: Replicas and Reconstructions," in Bennett, ed., *Sailing Into the Past*, 16-23. By necessity, all 17th century vessels considered here are reconstructions, as complete data for none of them are available. Some, though, are based on more, and sometimes better, evidence than others. See Nicholas]Nick] Burningham, "Experimental Maritime Archaeology," in Claire Smith, ed., *Encyclopedia of Global Archaeology* (New York: Springer, 2014), 2717. For a recent precedent using replica and reconstruction experience to study problems in technological continuity and change in sailing vessels, see Whitewright, "Technological Continuity and Change, 1-19.

[11] Note on interview sources: This chapter relies heavily on the firsthand experience of period replica masters, crews and shipwrights, relayed directly to me either in written form or during recorded phone or

history books—or not? If the received wisdom is second- and third-hand, what might we learn first-hand, by analyzing performance capabilities using on-the-water human experience? If we can understand how these vessels work by working them, then we can not only compare what we learn to what's in the books. We can use that understanding as a yardstick to compare vessels across time and space in ways otherwise impossible. We can examine a certain type of vessel—say, a middling-sized transatlantic merchantman—from 1600 with the same type vessel from 1750. Whatever the results, they should help us better understand the core duality of technological history—continuity and change. When technology does not change, why? When it does, why? When it changes, why does it change in some ways and not others?

The published literature on building and sailing replicas suggested a series of questions as a basis for interviews. The resulting questionnaire is included as an Appendix. The observations of the people who operate these replicas on questions raised by the historical literature focused on six specific technical issues: the mizzen sail, steering systems, headsails, topsails, hull design, and crew—the human component of the machine. These are all interrelated, of course, and that comes through in what follows. A discussion of all six will suggest further questions, and experiments to investigate them. As an aid to readers less familiar with the sail plans of these ships, I have included a labeled copy of Barlow's *Mayflower* sketch, on the following page (Figure 16).

VoIP interviews. I contacted most current working period replicas. The materials used for contacts and interviews, including both protocol and subject matter, may be found in Appendix 1. All of the transcripts and recordings remain in my possession, and may be shared upon request, contingent upon the consent of the subject(s), as per the guidelines of Memorial University's Interdisciplinary Committee on Ethics in Human Research (ICEHR).

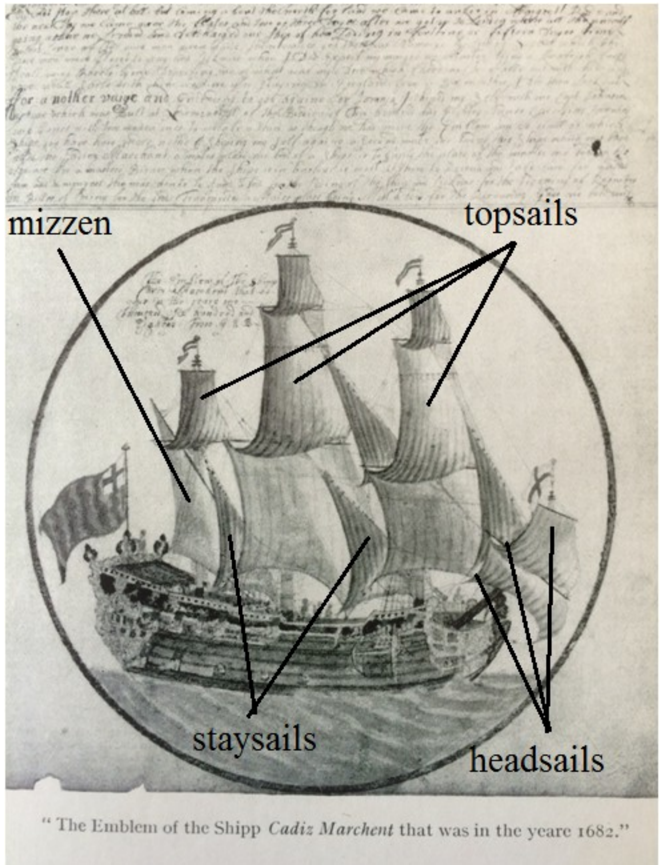

Figure 16 Barlow's *Mayflower*, with labels

First technical focus: the mizzen sail

We read in history books that lateen mizzens were clumsy and eventually, logically replaced by gaff spankers, but not before an intermediate stage where the ships retained the lateen yard but the sail was cut back to the mast—a stage which at first glance seems puzzling.[12] (See Figure 17, following page.)

[12] For a traditional account of the evolution of lateen mizzen to gaff spanker, see G.S. Laird Clowes, *Sailing Ships: Their History and Development* (London: HMSO, 1952), 67-68, and Gilfillan, *Inventing the Ship*, 60-61. Gilfillan attributes the major changes in our period to the old methods' being "sometimes harmful" and "rather useless." Clowes does not offer an explanation for the retention of the full yard with the cut-

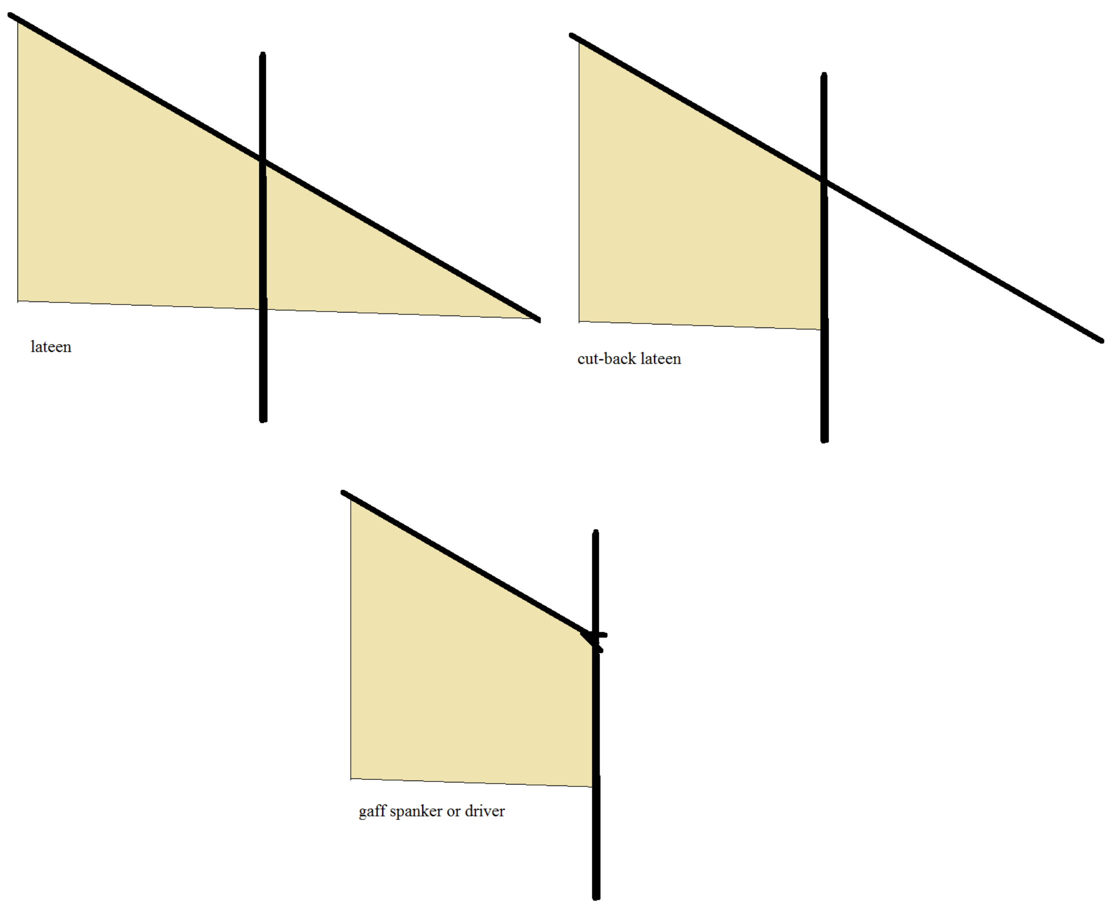

Figure 17 Lateen mizzen sail to gaff spanker

Captain "Chip" Reynolds, master of the replica *Half Moon* in New York has a reasonable explanation for it, because he has spent a lot of time commanding a vessel that actually *has* a lateen mizzen, and he was forced to un-learn what he had been taught as a modern sailor in order to unlock the secrets of an older technology. Reynolds wrote:

> …[Lateen mizzens] are so fundamentally different from other types of more modern sails used for tacking and maneuvering, that until one

back sail, but John Harland does, in his indispensable *Seamanship in the Age of Sail*, 75-76. Thanks to Nick Burningham for pointing that out.

> experiments with them, they seem cumbersome and ungainly. In fact, they are quite handy, elegant in their engineering, and practical in use.

Reynolds speculates that the full-length mizzen yard was retained after the sail was cut back because it was easier to trim, as the yard "could be warped over with better leverage (especially in high winds), than by trimming the sheet." (See Figure 17.) That could be done forward of the quarterdeck area reserved for the officers, he says. The hierarchy on a ship was certainly strong enough to serve as a social factor selecting for a technological preference. "The full-length yard also balanced the weight" of the sail, making it easier to attach the yard to the mast with simpler, cheaper fastening methods.[13]

Almost sixty years ago, William A. Baker wrote that tacking the mizzen was simpler than expected on the new *Mayflower II*.[14] Nick Burningham wrote that "…on *Duyfken* …the mizzen was nearly useless, but would have been helpful in a few specific circumstances had we not been able to use the engines. The iconography shows very strongly that the lateen mizzen was hardly ever set."[15] Captain Eric Speth, perhaps the most experienced master of 17th-century replicas working, agrees with Reynolds that the mizzen is "handy," comparing favorably to the later gaff spanker, though he adds that it requires considerably more manpower to use on *Mayflower II*, a larger ship, than it does

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[13] Reynolds, personal e-mail, 5 February 2015. Parrels and halyards are made of wood and hemp rope, materials and devices already familiar and already aboard.

[14] Baker, *The New Mayflower*, 117-118.

[15] Burningham, personal e-mail, 4 May 2015; and see Burningham in Bennett, ed., *Sailing Into the Past*, 116.

on *Godspeed* or *Discovery*, the two smaller Jamestown replicas.[16] The *Duyfken* experience at sea with the mizzen makes sense to him, and he confirms that the sail is a balancing and maneuvering sail, and would be furled for downwind sailing—which is most of the sailing these ships did, *Duyfken* included—as it would move the center of effort of the entire sail plan too far aft otherwise, making it more difficult to steer the ship on a steady track.[17] To Speth, the most sensible explanation for the retention—and then eventual abandonment—of the full lateen spar once the sail itself had been cut back to the mast is that the spar lent itself to counter-bracing to tack a ship in light winds or to tack a ship that did not tack well—a technique Speth has used often, and an explanation that jibes with Reynolds'. (Again, see Figure 17; consider the leverage of that forward-protruding yard.) Once staysails came into use, says Speth, that forward—projecting yard would have gotten in their way. Adding sails to a rig usually means making significant adjustments elsewhere so that those sails may be properly handled and so that they—or other sails near them—receive clean wind, unblocked by neighboring canvas.[18]

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[16] Eric Speth, telephone interview, 14 August 2015. Capt. Speth has been Maritime Program Manager, Jamestown-Yorktown Foundation, Virginia, for 26 years. Before that, he was in charge of the replica *Maryland Dove* at St. Mary's City. He has extensive experience on at least nine early 17th century replicas and more on replicas representing later periods, including service as master of *Mayflower II*.

[17] See following discussion of tiller and whipstaff steering; Speth says the tiller and whipstaff are difficult to use if the sail plan is not correctly balanced. That is true of a modern wheel system on a modern yacht, so it stands to reason that it would be more true of these larger, heavier vessels (Speth, telephone interview, 14 August 2015). Center of effort of the sail plan refers to the focal point of the wind's force on the sail plan as a whole. If it is too far aft, the wind will tend to push the ship's stern to one side or the other, so the ship will slew rather than track straight downwind. This is not only potentially dangerous, as it could cause a broach in heavier seas. Broaching is coming broadside to the waves, so that they can roll the ship. It is also worth noting that the corkscrewing motion of an unbalanced vessel sailing deep downwind is literally sickening to human beings.

[18] Speth, telephone interview, 14 August 2015. Staysails—fore-and-aft (triangular) sails hoisted on the stays—the standing rigging that holds up the masts—became increasingly common in the 18th century until they were ubiquitous on ships, brigs, and snows.

Captain Sharon Dounce of the *Kalmar Nyckel*, a larger ship than Reynolds' *Half Moon* or Speth's Jamestown ships, writes that the mizzen on her ship "balances the sail plan forward when sailing close hauled." She too notes that it is not useful off the wind. They use it for tacking, but not wearing (jibing). The balance it provides for maneuvers greatly assists with steering the ship. As for handling it, she writes that the sail on its yard

> would likely have been shifted from side to side of the mizzen mast. [T]his is a pain in the neck, but with *Vasa* researchers, we practiced and timed it, as it fit into a tack. Got it down to about 90 seconds, and with available personnel of a normal size crew. It's our easiest sail to set, by far.[19]

We can say, then, that the lateen mizzen functioned well on 17th-century ships as a balancing and maneuvering sail, and that its long yard was manageable given the rest of the sail plan. Speth's suggestion that this yard would have been incompatible with staysails reminds us to assume that changing one element of the ship will have more wide-ranging ramifications than merely changing how that particular element functions. Recall our discussion in Chapter Two of the law of unintended consequences, and think of pulling a thread in a rug. That perspective will prove helpful when we are puzzling over the time it took to make a technical change whose desirability seems obvious to us.

Second technical focus: steering systems

Ship historian Alan McGowan ties the adoption of the wheel to the adoption of the jib (triangular headsail—see diagrams of snow, brig, sloop, and schooner in Chapter Three),

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[19] Dounce, personal e-mail, 24 April 2015. Fred Hocker is the head of those "*Vasa* researchers," and credit goes to Sharon Dounce for making the personal connection to him. Hocker insists on pointing out that, while it may well be possible to execute some maneuvers without the helm, it's clear from contemporary sources (Smith's *Seaman's Grammar* and Mainwaring's *Sea-mans Dictionary*) that other maneuvers required the helm, especially those that involved using the helm in opposition to the sails (Hocker, personal communication, 18-19 August 2015).

claiming that the wheel provided precise enough steering to allow maintaining control while sailing as close to the wind as the jib allows. Losing control while sailing close-hauled could result in an accidental tack, damaging or destroying the rig, and probably wounding or killing crew, or cause the vessel to come to a sudden stop and lie helpless. McGowan's interpretation seemed reasonable, but Nick Burningham, who is in an exceptionally good position to comment on it, disagrees. "McGowan's jib-wheel connection doesn't impress me at all. *Duyfken* steers just as precisely as a wheel-steered ship with a good helmsman at the helm and just as badly with a poor helmsman." On the critical importance of good helmsmanship, he writes from his own experience at sea:

> The challenge is to prevent square riggers from tacking themselves when sailing on the wind. If you luff up aggressively, or the wind shifts significantly, and the sails on the foremast get aback, the ship will be heading round to the new tack before the watch officer can [splutter expletives].[20]

We read that wheels replaced tillers and whipstaffs for steering after 1700 because wheels were so much easier and more effective to use, and authors muse about why it took so long to make that transition. However, replica masters report that actually the tiller and whipstaff method works fine.[21] Technical ship history tells us that the technological impediments in the way of developing effective wheel steering were daunting and took a long time and many failed attempts to overcome. With a satisfactory system in use and difficulties in the way of adopting an alternative, the tiller and

[20] Burningham, personal e-mail, 4 May 2015. When this happens suddenly due to a wind shift, it is called being "taken aback," hence the origin of that expression.

[21] A tiller is, simply put, a stout stick attached to the top of the rudder with which to move it. On ships, this tiller had to be below decks, so a whipstaff—vertical pole attached to the tiller and run up through holes in the lower deck(s), allowed a topside helmsman to move the tiller.

whipstaff were under strong selection to persist. That point does not seem to have made it into general academic maritime history. Steele cites John Harland and Alan McGowan on this subject—strong sources on such matters—but he does not mention the technical difficulties Harland discusses in his *Mariner's Mirror* article.[22] Also, while it is doubtless true, as Steele writes, that wheel steering "dramatically increased rudder control on larger vessels"[23] due to increased mechanical advantage—provided the system was functioning properly[24]—it is important to know *how much* larger those vessels needed to be for that advantage to manifest itself, all other things being equal, if we are to understand the relationship between wheel steering and ship size. The wheel offered advantages beyond the mechanical. Mounted on deck rather than below, it offered a less-restricted view for the helmsman, especially of the sails. With no deck over his head, the helmsman on a wheel-steered vessel could look up and see what the sails are doing while he steered. Hocker gives specific examples:

> The limited view problem is acute in both *Vasa* and *Kalmar Nyckel*. In the former, the helmsman cannot see the horizon, so cannot judge if he is holding a straight course except by the compass, which is problematical due to the lag in compass movement. In *KN*, the helmsman cannot see the sails, so cannot be given a course such as "full and by".[25]

To what extent did that issue select for the adoption of the wheel?

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[22] See John Harland, "The Early History of the Steering Wheel," *Mariner's Mirror* 58:1 (1972): 41-68.

[23] Steele, 49-50.

[24] Samuel Kelly recounts that he once had to cut the steering rope when it took a riding turn over another on the drum, jamming the steering as a pilot was maneuvering the ship through some rocks, and use the tiller to steer the ship (in these systems the wheel actually drives a tiller belowdecks). He says it is the only such incident he was ever aware of, though. Samuel Kelly, *Samuel Kelly: An Eighteenth Century Seaman*, ed. Crosbie Garstin (New York: Frederick A. Stokes Company, 1925), 265-266.

[25] Hocker, personal communication, 18-19 August 2015.

Discussion of steering issues continues among replica sailors. One view holds that seventeenth-century vessels did not rely on their rudders as more modern vessels do, and as we assume vessels must. Sail trim, as Chip Reynolds of *Half Moon* pointed out to me, is the primary means of directional control, with the rudder serving more as a trim tab for fine-tuning.[26] Eric Speth also uses the term "trim tab" to explain the rudder's role to new crew on his ships.[27] Sharon Dounce of *Kalmar Nyckel* concurs: "We play around with our sail plan from time to time, and we can get it balanced enough that we don't need to use any helm to drive the boat…we can just shove the helm in the strap and not touch it at all." This would have greatly increased ease of operation on a voyaging vessel with no automatic self-steering. Dounce says the rudder is for starting a tack but after about 15 degrees, the sails take over the whole process. Speth notes of his largest Jamestown vessel, *Susan Constant*, that she only has 12 degrees of rudder throw, so proper sail balance and trimming are critical.[28] Of the whipstaff, Dounce says "it's so easy to know how much helm you have" unlike with a wheel, where all you know is how many times you have turned the wheel—even a new helmsperson can tell how much rudder angle they have with a tiller and whipstaff.[29] That advantage might be offset by decreasing mechanical advantage of the tiller and whipstaff as rudder angle increases, if the forces involved are great enough. Fred Hocker points out "that the mechanical advantage of the

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[26] Reynolds, Skype interview, 8 January 2015.

[27] Speth, telephone interview, 14 August 2015.

[28] Speth, telephone interview, 14 August 2015.

[29] Dounce, telephone interview, 23 April 2015. Also see Steele, 49-50, and 332, note 39; Harland, "The Early History of the Steering Wheel," 41-68; and McGowan, *The Century Before Steam*, 16.

wheel is constant at all rudder angles, while the advantage of the whipstaff decreases as rudder angle (and thus force) increases, regardless of rudder size."[30] Hocker cautions that replica captains' anecdotes

> [tend] to maintain an older fiction that pre-wheel ships were steered with the sails rather than the rudder, but I believe that this is a misunderstanding. You CAN tack a ship with the sails alone, but that was equally possible in the 19th or 20th century. Both the primary literature (handbooks and ships' logbooks) from the 17th century and the practical experience [show] that the narrow rudder and whipstaff [are] more than adequate to steer a ship, and some operations (tacking and heaving to) require the rudder to operate in opposition to the sails. What is important is sail and helm balance (in ANY sailing ship) – choosing the right sails to set makes a large difference in the workload at the helm and course stability.[31]

So the issue is more complex than the historical literature might lead us to believe, and warrants further investigation, because if we truly understand specific examples of continuity and change, then we stand to gain a better understanding of the overall relationship between technology and the society that used it. If we keep passing down a simple explanation uncritically, that understanding eludes us without our even knowing it.

Much of the evidence points toward increasing vessel size as the imperative driving the installation of wheel steering for mechanical advantage. Captains Dounce and

[30] Hocker, personal communication 18-19 August 2015.

[31] Hocker, personal communication, 18-19 August 2015. Hocker and others involved with *Vasa* are working on a report on steering systems and what they have learned from the recovered Swedish wreck and from replica trials.

Reynolds pointed out, respectively, though, that the Swedish flagship *Vasa* and the great Dutch East Indiamen of the period were tiller-and-whipstaff-steered.[32] Hocker says

> Manwayring believed that the whipstaff was not useful on large ships, but the historical and archaeological evidence does not bear this out. Our calculations show that the whipstaff on *K[almar] N[yckel]* should take MORE effort to handle than that on *Vasa*, yet *KN* can be steered in a storm by a small woman in her 70s….[33]

We have no reason to think that the steering of these larger ships was ineffective, but what if wheel steering on later, larger ships allowed for larger rudders? Burningham disposes of that question. "[I]n general large sailing ships had small rudders irrespective of the steering system."[34] That supports Hocker's comment that what was true of 17th-century ships was true of 18th-, 19th-, and 20th-century ships as well in that regard. So did wheel steering make larger vessels easier to steer than tiller-and-whipstaff systems? Hocker complicates it further by presenting a caveat to the "conventional wisdom … that bigger ships require bigger steering effort and more mechanical advantage." While generally true, the problem is actually "governed by tiller size…the larger vessel will probably not have a tiller proportioned as well to its length."

> By careful choice of geometry, it is possible to cheat a little. *Vasa* gets away with relatively small steering effort due to a narrow rudder and a very long tiller …. *Nyckel* has higher relative steering efforts because it

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[32] Dounce, telephone interview, 23 April 2015; Reynolds, Skype interview, 8 January 2015. This issue is still under investigation.

[33] Hocker, personal communication, 18-19 August 2015. This comment also brings up the interesting complication of how to trust expert primary sources. Mainwaring (or Manwayring) was one of the most experienced and accomplished seamen of his day. As Hocker put it, "[t]his shows that there are areas where replica sailing may not only challenge the received wisdom of the secondary sources, but may reveal errors in perception in primary sources" (Hocker, personal e-mail, 20 August 2015).

[34] Burningham, personal e-mail, 4 May 2015.

> has a proportionally wider rudder and much shorter tiller. This also means that it gets away with a much shorter and more manageable whipstaff….[35]

What Hocker is getting at here is that we have another issue of one component getting in the way of others. Look at any accurate model of a square-rigged sailing ship and you need know nothing at all about how any of it works to be struck by how complicated and crowded it is. A large ship cannot have as proportionally long a tiller as a smaller one. There is no room for it. This brings us back to considering size as the primary—but not exclusive—imperative toward wheel steering in its early years.

We have established that multiple factors always exist for any specific technological continuity or change on these ships. Given that, is there any merit to McGowan's idea that we must consider the wheel and the jib together? If so, is there a correlation between increasing size and the triangular jib? Or is Burningham entirely correct to dismiss that connection?

Third technical focus: headsails

Speaking of triangular jibs, we read that their adoption improved windward ability and ease of sail handling over the clumsy spritsail and sprit-topsail of earlier vessels (see Figure 16—Barlow's *Mayflower* had a spritsail and sprit-topsail for headsails). Yet replica crews report that, once they learned to use those earlier sails, they served to control the head of the ship and assist the rudder in steering her quite handily. This goes back to Alan Villiers and his transatlantic voyage in *Mayflower II* in 1957—the only insight from a period replica found in a maritime history secondary source. John Harland

[35] Hocker, personal communication, 18-19 August 2015.

refers to Villiers' experience in *Seamanship*, as well as in a *Mariner's Mirror* article.[36] Villiers' experience is corroborated by Burningham from his experience aboard *Duyfken*. Of *Kalmar Nyckel*'s spritsail, Sharon Dounce says it is difficult to balance the sail plan without it.[37]

It is clear that much of the specific skill set used every day on a 17th and early 18th-century vessel was lost even before the end of commercial sail. John Harland tacitly acknowledges this when he makes a refreshing break from the dismissive presumption regarding 17th-century designs and rigs that creeps into ship history by rejecting the idea that the sprit-topsail remained in use as long as it did for reasons other than usefulness. To him,

> …it is inconceivable that the seamen and shipbuilders of the day, as practical men, would have tolerated the consequences of poor design unless they saw, or thought they saw, some immediate advantage in so doing. However that may be, the old-fashioned spritsail topsail remains, in my view, pretty much an enigma.[38]

Only experimental archaeology is likely to solve that enigma at this point—if anything can. *Kalmar Nyckel* has a sprit topsail, and Dounce reports that it does contribute to fine-tuning sail plan balance in light air (light wind), but that, while they have experimented with different ways to rig it, it is skill- and labor-intensive to use and requires care to set

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[36] Harland, *Seamanship*, 85; and "The Early History of the Steering Wheel," note 9, p. 65. Both pieces refer to Villiers' *Give Me A Ship To Sail* (New York: Scribner, 1959), 298. Also see Villiers, "How We Sailed the New *Mayflower* to America" *National Geographic* 92:5 (1957): 632.

[37] Burningham, "Learning to Sail the *Duyfken* Replica," 78-79; Dounce, telephone interview, 23 April 2015.

[38] Harland, *Seamanship*, 89.

and douse, and that they do not use it very often.[39] Burningham wrote that the sprit-topsail was rarely set, and that it would have "probably contributed almost nothing to speed through the water under any circumstance."[40] Burningham would no doubt agree that, if the sail were intended as a balancing and/or maneuvering sail, a contribution to speed might not have been expected.

Dounce thinks *Kalmar Nyckel*'s sprit-topsail is undersized, as they have been able to bend a larger sail to the spars in an experiment. A larger sail would more effectively accomplish the purpose. While *Kalmar Nyckel* makes daysails and short coastal trips, the original was a large, heavy voyager, and prolonged light winds can be just as dangerous to a voyaging ship as storms, for different reasons. Any sails that allowed a ship to take full advantage of a light breeze to move a little faster, wallow a little less, or be easier to steer could have been valuable to a voyager carrying fatigued humans and limited stores.

Crews of vessels like Australia's *Duyfken*, New York's *Half Moon*, and *Mayflower II* of Massachusetts, coming out of formative experiences with later sailing rigs, had to figure out how these earlier ships worked through trial and error. Chip Reynolds, for example, said that when he first reported aboard *Half Moon*, having come out of an early 20th century topsail schooner, he was appalled by her rig, assessing it as "sloppy" and "inefficient," and wanted to re-rig her, but soon came to appreciate the machine for what she was.[41] *Half Moon,* though, was designed to be efficient as a long-

[39] Dounce, telephone interview, 23 April 2015.

[40] Burningham, personal e-mail, 4 May 2015.

[41] Reynolds, Skype interview, 8 January 2015.

distance sailer. Captain Walter Rybka of U.S. Brig *Niagara* came out of an 1877 iron three-masted bark,[42] a cargo carrier designed and rigged for economy of operation, and when he reported aboard the replica War of 1812 brig, he guessed that, with her tall rig and light purchases intended solely for speed, power, and maneuverability for short-term emergency service, she would be about 30% more work to sail, even though the two ships shared some basic dimensions. "I was absolutely dead wrong," Rybka says. "It was 200% more work." This is a good reminder of the sharply different imperatives for merchant and naval vessels. The latter do not place any priority on economizing crew—they have very large crews, as cost of labor is no object, so they can have highly labor-intensive rigs that optimize speed and maneuverability without regard for workload. The lighter purchases on *Niagara*—with two-to-one mechanical advantage rather than three-to-one, as those on *Elissa* have, are much harder to work, but work much faster, as less rope has to go through the blocks to get the spar or sail to move. So the *Niagara* can maneuver faster—but only because she has the human power on board to do so.[43]

The aggregate of what they have learned is that it is not helpful to think of the earlier ships as better or worse than their successors. Pros and cons, advantages and disadvantages—those concepts only have meaning in the specific context of the vessel's operating time and place. Early ships do not always strike their compromises in the same places as later ships, but they were well-suited to do what they did when they did.

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[42] *Elissa*, Galveston, Texas.

[43] Walter Rybka, telephone interview, 21 April 2015.

Fourth technical focus: topsails

This is not to suggest that we should avoid comparisons across those space and time contexts. We cannot avoid them, if we are to understand why some things changed and others did not. Both Burningham and Reynolds reported positively on half-hoisting topsails in heavy weather, a technique that involves letting the topsails belly in a stiff breeze—utterly counter-intuitive to a modern sailor—the exact opposite of what we would think to do. They discovered it by trial and error. When they struck the topsails, the ships could not make proper way, but when they flattened them, as we do with modern sails, they were overpowered.[44] Eric Speth reports that he routinely employs this method of 'reefing' on the two smaller Jamestown replicas, and that it works well "from off the wind to a beam reach"—any point of sail where the wind is from perpendicular to the centerline of the ship to dead astern.[45]

Sharon Dounce of the *Kalmar Nyckel,* though, is not as sanguine about the rig of her vessel vis-à-vis that which would offer more versatile options for sail combinations. She remembered an experience in heavy weather in which they half-hoisted a topsail, but it was not a stable set—there was too much chafe, the sail blew around too much, the sail would fill and spill, contributing to the rolling and jerking the ship was enduring in the quartering sea. A smaller lower topsail, as would be found on an 18th-century ship, would have been better than the baggy half-hoisted larger topsail, she says. She was concerned about the topmast breaking the whole time. She attributes the later division of sails both

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[44] See Burningham, "Learning to sail the *Duyfken* replica."

[45] Eric Speth, personal e-mail, 11 February 2016. Unfortunately, he writes, they have not sailed the larger *Susan Constant* enough recently to have experimented with this.

to making it easier to handle, which she thinks it would be, and also to offer more options for setting sail in different conditions. She did say, though, that half-hoisting the topsails definitely gave the ship more power forward—just at a significant cost.[46] Her assessment of this experience on a ship larger than *Duyfken*, and thus with larger sails, might support Burningham's view of the merit for split lower topsails for larger ships—he calls double topsails "a great improvement for big ships."[47] The caveat here is that we need to take into account any changes in the cut of the sails themselves. Burningham himself has found an account of an early 19th century French vessel "lowering the deep-reefed topsails to the cap in very fierce squalls when trying to keep off a lee shore," but he did not mention the size of the vessel.[48]

If the later split topsails were adopted primarily as a labor-saving modification, did handier sail-shortening in heavy air come along as a bonus benefit, as increased capacity for nutrient delivery came along with increased capacity for oxygen delivery in Kinsey's example of the circulatory system? Or was more flexibility in shortening sail the driving factor behind the change? At least for smaller vessels, Burningham suggests we also consider fashion: "The adoption of double topsails in the 1860s is a good example. Double topsails were a great improvement for big ships, but by 1875 nearly all

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[46] Dounce, telephone interview, 23 April 2015.

[47] Burningham, personal e-mail, 5 May 2015.

[48] Burningham, personal communication 5 April 2015.

topsail schooners had fitted double topsails for no obvious reason. I strongly suspect the desire to look up-to-date was at play."[49]

If replica analysis cannot support the idea that some technologies were intrinsically superior to others in terms of performance, then we have even more motivation to look for other reasons why specific technologies gained favor for use in specific situations.

Fifth technical focus: hull design

The biggest challenge to understanding the design side of this replica business is that posed by the nature of artisanal craft, explored in Chapter Four. We established there that one cannot build an ordinary merchant ship from the treatises alone and have any confidence that it will be accurate—that the overwhelming majority of merchant vessels, especially the smaller ones, were built by people who did not need or use a treatise to do it. They could do it because they had learned how to do it as apprentices and journeymen and masters. They might have known some basic math and some basic geometry, or they might not have, but an experienced builder had a highly tuned visual sense based on experience of how closely the complex shapes of the vessel matched what he knew from that experience constituted proper design. Eric Speth recounts that, when experienced builder Jim Richardson was building the *Maryland Dove* replica on the Chesapeake Bay to a William Baker design, he would try to make changes to the design based on what his builder's eye was seeing as the ship took shape, and when Baker would visit for inspections, Baker would protest the changes. The eye of the experienced shipwright is

[49] Burningham, personal e-mail, 5 May 2015. See also the earlier discussion of artisanal craft.

still compelling in our age of plans and computer models.[50] Building replicas, and considering that process from an anthropological perspective, can help us understand the process as it took place in the early modern period, just as observing working boatbuilders can, as we established in Chapter Four.

We also discussed castling in Chapter Four. When William Baker designed the *Mayflower II* in 1955-1957 (see Figure 18, following page), he took pains to reduce weight in the scantlings of the stern castle, and he expected significant windage from it. David Thorpe, one of her crew on her transatlantic crossing in 1957, remembers that "the sterncastle acted like a weathervane but only enough for the ship to take the seas forward of amidships such that she lay comfortably."[51] Her master, Alan Villiers, learned in heavy Atlantic storms that the stern castle and the other characteristics of the ship's hull design allowed her to lie a-hull easily. Lying a-hull is stopping at sea by putting the helm over with no sail up, so that the vessel makes minimal forward or sideways progress. It is a way to ride out storms when continuing to sail becomes too dangerous. Most modern sailing vessels will not do that. They must heave-to, which requires setting some sail against the rudder. That is potentially dangerous to crew, sails, and rig when the weather is violent.[52] All evidence touching on the subject notes the ease with which one of these

[50] Speth, telephone interview, 14 August 2015.

[51] Thorpe, sixth article, Sept 2013, 287

[52] Villiers, "How We Sailed the Mayflower…", 667.

ships could lie a-hull in a storm, to ride just like a duck with her head tucked under her wing, as the old simile goes.[53]

Figure 18 *Mayflower II*.[54]

Chip Reynolds, master of the *Half Moon*, an operating replica intended to represent Henry Hudson's vessel *Halve Maen*, recounted his first experience of sailing that vessel out of a protected harbor and into high seas. The swells outside were high enough that he feared burying the bow—an anxiety heightened by the height of the poop deck—the deck built on top of the stern castle. As he stood on its steep downward slope, he felt almost vertical going down the waves. He was worried about losing the forecastle. The bluff bow, though, was so buoyant that she rose up the other side of the swell without "one splash of water on the deck of the ship." There is no question, as far as Reynolds is concerned, that the bluff bow slows the ship down relative to a sharper one,

[53] Chip Reynolds, master of the *Half Moon* replica, corroborates that, based on his experiences handling her in frightening weather, including Hurricane Floyd. Reynolds, Skype interview, 8 January 2015.

[54] https://upload.wikimedia.org/wikipedia/commons/4/4b/Mayflower_II.jpg

but "it has such buoyancy that it's nearly impossible to bury that bow in a sea." The speed sacrifice is "immaterial" in comparison. In 36 hours, they had "one splash of water" come aboard. With high rails and dry decks, he permitted the crew to move about without jacklines.[55] "It was almost inconceivable to think of getting knocked off."[56] Reynolds' anecdote reminds us again that no design aspect exists independently of others, and changing one means the list of pros and cons of the others will change too. The bluff bow provided enough buoyancy to keep the forecastle protected from boarding seas. The stern, too, would need to be buoyant to support the weight of the stern castle, and the hull would need to be stable enough to resist the higher center of gravity and the windage of the protruding upper works. So moving toward a leaner, sleeker hull would create an imperative to reduce that superstructure considerably. Was there any such trend in hull design in the period? Yes, and we should experiment to get data on the relationship between that and reducing superstructure.

The problem of hull design *historical accuracy* for the 17th-century replicas is compelling and instructive. Differences in design approaches reflect different opinions about how the originals were built—opinions which have evolved over time but have not completely coalesced into consensus—and the different approaches throw into stark relief the challenges of interpreting the evidence, especially when the written evidence—the treatises on naval architecture—does not tell us all that we wish it would. Because replicas are not usually built for experimental archaeology, historical accuracy of hull

[55] Jacklines are ropes modern sailors attach to the decks, to which sailors clip their harness tethers so they cannot be washed overboard.

[56] Reynolds, Skype interview, 8 January 2015.

form is not always a high priority, even if the designers have a good idea of what that accuracy entails, and even if the regulatory apparatus allows such accuracy. Fred Hocker was "the naval architect of record for a sailing replica—a medieval cog in Malmö, Sweden—and … found that the coast guard is often more accommodating in this respect than the customer."[57] William Baker had to make *Mayflower II*'s decks much stronger—and thus heavier—than he knew the originals' would have been, because the replica would have to withstand hordes of dockside visitors on her decks for decades.[58] Still, a design that does not accurately represent what it is supposed to may still offer valuable experimental data. *Kalmar Nyckel* has a hull that is "nothing like a Dutch pinnace of the 1620s," says Hocker. "[I]t is much more like an English frigate of the 1700s, with substantial deadrise, long entrance and run, etc. It thus does not handle like a pinnace."[59] We are lucky that we know enough about Dutch pinnaces of the 1620s for Hocker to be able to say that, and we are also lucky that we can still use *Kalmar Nyckel* as a floating laboratory for learning about sail handling with 17th-century rigs and the handling characteristics of English frigate hulls of the 1700s. The replica may not be ideal, but she is still quite useful as long as we are responsible about interpreting what it is she has to teach.

We have at least two important issues to work on with the 17th-century vessels. The first is the questionable stability of the English ships. Indications are that it was an

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[57] Hocker, personal communication, 18-19 August 2015.

[58] Baker, *The New Mayflower*, 91.

[59] Hocker, personal communication, 18-19 August 2015.

original issue. If so, that should explain why it has been a replica issue as well. Stability comes up in almost every discussion of replica vessels. In almost every case, modifications to replicas have been made to increase inherent stability to meet current expectations for safety.[60] Those modifications, though, are not all the same, and have been most extreme on the replicas of early 17th-century English ships. To some extent, that supports what Adams taught us, discussed in Chapter Five.

Vessels throughout the period depended much more on the stability created by loading and trimming. Our regulatory authorities demand that the stability they stipulate be built into the vessel. There is more to it than that, though. We are replicating machines built by people who had starkly different notions of acceptable risk, and who took very different things for granted than we do. They did not carry life jackets, and that is just a token example of the gulf between 17th-century concepts of "safety" and ours. "…[O]ur seafaring people," mused Benjamin Franklin, "are brave, despite danger, and reject … precautions of safety, being cowards only in one sense, that of fearing to be thought afraid."[61]

We are on much surer footing if we assume that the standard for vessel stability of 1620—if that notion in this context is indeed anything but an anachronism—would have been significantly different from those recommended by today's marine engineers and imposed by the regulatory authorities of modern industrial states. Sharon Dounce says

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[60] Jim Graczyk wrote me: "Modern sailing hulls, even with a traditional look, can recover from as much as a 120 degree roll. *Welcome* [1774] was determined to not return from a 67 degree heel angle." Graczyk was referring to mandatory Coast Guard stability tests, required for vessels intending to carry passengers for hire (Jim Graczyk, personal communication, 5 November 2014).

[61] "A Collection of Papers," Part I, already cited, 23-24.

that the replica *Kalmar Nyckel*'s designers deliberately departed somewhat from the original in order to increase inherent stability.[62] Eric Speth reports that Stan Potter, naval architect for the current *Susan Constant* replica at Jamestown, did the same, and that *Golden Hind* in England has "blisters" on her hull for increased stability, as does Stan Potter's *Elizabeth II* replica.[63] These are the "most extreme" modifications mentioned earlier.

Captain Walter Rybka of U.S. Brig *Niagara* reports that his ship, with its shoal draft, tall Navy rig, and 20 guns, would have been "terrifying" to sail originally, and that they have heavily ballasted the replica both externally and internally and would not be sailing her otherwise. The *Niagara* is an extreme example of another sort. She was a warship built to contradictory imperatives—shoal draft, heavy armament, speed and maneuverability, and accelerated construction—for emergency use, but her case adds to the aggregate evidence suggesting that original "standards of stability" are generally unacceptable to us—as are so many risks routinely taken by 17th and 18th-century mariners.

We are making progress on the issue of stability in 17th-century English ships and replicas, as outlined in Chapter Five. Burningham wrote: "I believe William Baker correctly and faithfully followed his namesake Matthew, and other sources in designing *Mayflower II*, which seems to tell us that the tangent-arc design techniques cannot be

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[62] Dounce, telephone interview, 23 April 2015.

[63] Speth, telephone interview, 14 August 2015.

used to design a useful merchant sailing ship."[64] He goes on to recount the serious stability problems the replica experienced upon launch—stability problems that did not, however, prevent a successful transatlantic crossing. *Nonsuch* experienced similar problems in 1968, and was deemed unfit to cross the Atlantic, though she accomplished extensive work in North American coastal waters.[65] All the evidence supports Burningham on Baker's thoroughness, including Baker's own book on designing the replica, which details his process and acknowledges the problems.[66] Our best hope for more accurate replica hull designs in the absence of plans for the originals, though, is archaeology—and the permission of funding sources and regulatory agencies to build accurate hulls based on that archaeology. That, however, is a tall order, and barring that, we will need to take Timm Weski's advice and rely more on modeling for learning what we need to learn about the performance ramifications of variations in hull design.[67]

Sixth technical focus: the human component of the machine

When we consider the other mechanical force on the ship besides the wind and the water—the humans setting and dousing sails, pulling on ropes, and moving the rudder—we open another enlightening discussion. Indications are that the number of trained crew

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[64] Recall that Burningham explains the tangent-arc method in Bennett, *Sailing Into the Past*, 102, but that he also uses the phrase quite broadly. Chapter Five pointed out that it is helpful to consider that there are many "tangent-arc methods." In this quote, Burningham is specifically referring to the Matthew Baker midship bend.

[65] See Laird Rankin, *Return of the* Nonsuch*: The Ship That Launched An Empire* (Winnipeg: Heartland Associates, 2004).

[66] Dounce, telephone interview, 23 April 2015; Rybka, telephone interview, 21 April 2015; Burningham, personal e-mail, 5 May 2015.

[67] Timm Weski, "The value of experimental archaeology for reconstructing ancient seafaring," in Blue, et al., *Connected by the Sea*, 63-67.

required to work the vessel is comparable for replica and original, though original crews frequently would have been larger in the earlier ships to meet defensive needs and to provide a cushion for casualties to disease and armed conflict. While one might assume that the original crews were tougher and more inured to hardship than we are, we should remember that they were also much more likely to be malnourished, sick, and exhausted. What conversations with replica operators have to teach on this is that the skill and experience of the crew are every bit as central to vessel performance as the primary source literature indicates. As Chip Reynolds of the *Half Moon* put it, referring to the difference in rudder design between earlier and later ships, "you're not going to be able to use the technology to compensate for lack of skill."[68] On the other hand, Sharon Dounce pointed out how much useful work could be done on *Kalmar Nyckel* with unskilled or semiskilled labor. With the simple rig and simple direct steering system, even untrained passengers can haul on a line to move a sail, and even a new helmsperson can feel what the whipstaff is doing to the rudder angle. Her experience with this has helped her understand how the original vessel could function with conscripted landsmen, which they know she carried.[69] Given the perpetual shortage of skilled seamen in this period, lowering the required aggregate skill set would have been advantageous in that respect. In terms of expertise, it may well be that modern replica crews, if they are experienced enough, have better-developed skills in general than their original counterparts. From his experience on the *Kalmar Nyckel*, Hocker writes that the replica crew gets far more sail-

[68] Reynolds, Skype interview, 8 January 2015.

[69] Dounce, telephone interview, 23 April 2015.

handling and maneuvering experience than the original crew would have, because they "complete a passage once or twice every day of the sailing season," whereas the original crew would have spent most of their time either in port or on long passages with less sail changes.[70]

That is not to suggest that the original sailors did not know how to do things that we no longer know how to do the same way. That is what much of the on-board experimentation is about—trying to figure out how best to perform operational tasks, assuming that the original sailors would have figured out the same things over time. What replica experience can teach us is how many able-bodied adult humans it takes to operate a certain vessel rigged a certain way in certain conditions. If we are confident in the accuracy of a replica, we can compare that number to the number of crew known to have served on a similar vessel originally, and if there is a difference, begin to explore why that might be. Was there a shortage of hands on board? If so, why might that be? Local economic conditions may be at work, or the master's—or the ship's—bad reputation may have preceded the vessel to port. If she carried more than she needed for operation, that cost money. Was her master concerned about the aggregate skill level on board, and thought to compensate with more muscle? Was he nervous about encountering predatory vessels?

The method and the problems: Experimental archaeology in the real world

The way we are analyzing information from these replicas is a makeshift form of experimental archaeology. Experimental archaeology has a history and a methodology,

[70] Hocker, personal communication, 18-19 August 2015.

both inside and outside the maritime world, going back to the 1960s.[71] According to a large group of co-authors from archaeology and history who wrote an article for the *International Journal of Nautical Archaeology* 20 years ago, the ideal first step in using a replica vessel for experimental archaeology is to build it exclusively and specifically for use in experimental archaeology.[72] This is the real world, though, and in the real world, multi-million dollar replicas[73] are not ever built exclusively for experimental archaeology[74]—though they may be, and have been, built with the declared intent of being used for that purpose—among others.[75] Nick Burningham writes that, despite the unusual dedication to the research aspect of the *Duyfken* replica project, that aspect alone would never have justified the expense. Commemoration, sail training, and the sailing ship's "ability to capture the popular imagination" are among the chief reasons such

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[71] See Seán McGrail, "Replicas, reconstructions and floating hypotheses," *International Journal of Nautical Archaeology* 21:4 (November 1992): 353-355, for an argument supporting this sort of endeavor by a prominent maritime archaeologist. Also see Burningham in Smith, ed., *Encyclopedia*, 2717.

[72] John Coates, et al., "Experimental Boat and Ship Archaeology: Principles and Methods," *International Journal of Nautical Archaeology* 24:4 (November 1995): 293-301. Also see Burningham in Smith, ed., *Encyclopedia*, 2716-2718.

[73] *Duyfken* is a rather small replica for a full-rigged ship. She cost $3.7 million Australian (1999). In 2014 Australian dollars, that is $5,735,878.70, according to the Reserve Bank of Australia's inflation calculator (http://www.rba.gov.au/calculator/annualDecimal.html). In 2015 CAD, that is $5,513,925.95 (Google Finance, accessed 26 November 2015).

[74] Ole Crumlin-Pedersen listed nine reasons why replicas and reconstructions are built, only one of which is research. See "Experimental archaeology and ships—principles, problems and examples," in Blue et al., *Connected by the Sea*, 3.

[75] See Weski in Blue, et al., 63-67, already cited—Weski is missing more than one important point, including the one Burningham made that full-scale replicas of large ships are never built or operated solely as archaeological experiments. So as a criticism of using replicas, pointing out that what we can learn from them may not justify their expense, and that some things we can learn from them we could perhaps learn from models or smaller-scale replicas, is neither here nor there.

vessels are built.[76] Replica ships have to be able to represent their world and function in ours at the same time. Like every ship ever built, every replica is a set of compromises.

Replicas are built primarily for education, and in order to pay their bills, they need to carry paying passengers and support the weight of crowds of dockside visitors. In order to do that, they have to meet stringent modern governmental safety standards that were unheard-of when the originals were built. They also need the ability to accommodate these visitors and passengers—none of whom will be eating wormy hardtack, drinking fetid warm water from a barrel, or defecating through a hole in the forepeak into the ocean. Replicas carry auxiliary power, so they can go where they are scheduled to be regardless of the wind's caprice, and they carry fuel tanks for their engines and have propellers sticking out of their sterns.[77] They are not ballasted the way the originals were—they carry water tanks, fuel tanks, waste tanks, engines—all heavy, and all down low, out of sight. Weight is not spread vertically as it would have been in the original vessel.[78] Replicas do not carry cargo the way the originals did.[79] Some use

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[76] Burningham, "Tallships and Replicas," [2000] MarStudies 3; (2000) 110 *Maritime Studies* 19.

[77] That engines were installed in a replica so otherwise intently authentic as *Duyfken* is a testament to how convinced we are that they are essential for safety on a passenger vessel. There is much to recommend that. Many a vessel in this period lost with all hands on a lee shore after being embayed would have been saved by an auxiliary engine—if for no other reason than powering ahead at anchor while riding out a storm is the best tactic for avoiding dragging anchor in those conditions.

[78] It is important to distinguish between internal and external ballast when considering possible effects of differences in ballasting on replica vs. original performance. Internal ballast may affect trim and motion differences, which are important, or it may not. External ballast will definitely affect windward ability and leeway—sideways, rather than forward, motion through the water—making major differences in performance. For example, when first built, the current *Niagara* replica made exactly the same leeway as her original sister ship—18 degrees. When fitted with her current external lead ballast, which projects downward from the garboard 30 inches, she made 7. That is a drastic difference. The downward—projecting lateral surface resists lateral motion (Rybka, telephone interview, 21 April 2015).

synthetic materials and in most cases modern construction techniques so they will last far longer than the originals did, providing a much-needed return on investment for the non-profit organizations who build them, and because the timber used in the originals is no longer available.[80] Fred Hocker points out that synthetic sailcloth and rigging are "stronger and more aerodynamically efficient" than their organic original counterparts—that today's synthetic sailcloth is "smoother in finish and tighter in weave, so it has significantly higher aerodynamic performance, harnessing more wind energy per square meter." Because such sails can be set flatter, they are more efficient as airfoils. "Overall, this means more speed and better weatherliness."[81] Those qualities will last longer in service than those of natural-fiber sails. On the other hand, replica masters agree that natural-fiber sails could perhaps provide a safety factor that modern sails do not. If a vessel is overpowered by the wind, and her sails blow out or some of her running rigging parts, she is protected to some extent from losing her major spars or, worse, being knocked down. Modern synthetic sails and rigging are much stronger, and if in good condition, might resist strong gusts well enough to permit a knockdown or sprung mast that might have caused a blowout on an original vessel in the same conditions. When it happened, some wondered whether the knockdown that sank the original *Pride of Baltimore* replica in 1986 in a microburst, with the loss of four of her crew, might not

[79] It is worth considering that the amount of ballast these replicas normally require and their full lines and much bluffer bows than modern sailors are accustomed to remind us that they were built to carry cargo, and as much of it as possible for their size.

[80] Most replicas make use of laminated frames and spars.

[81] Hocker, personal communication, 18-19 August 2015.

have happened with synthetic sails and rigging. Daniel Parrott points out, however, that neither the replica record nor the historical record provides any consistent evidence on difference in resistance to failure between natural and synthetic rig materials; that as far as those records show, whether or not such failures occurred in extreme events was "happenstance." The *Pride* had an older canvas mainsail up when she was knocked down, and it did not blow out. Neither did her new, synthetic foresail.[82] Still, for experimental-archaeology investigations of performance, we would do well to either equip our replicas with natural-fiber sails and rigging as close to the originals as we can get, or at least take into account the differences between the performance of the originals and synthetic reproductions in any evaluations of vessel performance. Like *Duyfken*, the Swedish Ship *Götheborg* has hemp rigging and flax sails, so that the experience of sailing her would be as close to the original as possible. Joakim Severinson, her master shipwright, reports that the hemp standing rigging "moves more than … wire rigging. But we also noticed that this type of rigging is more adjustable than … wire rigging with fixed yards."[83] So there is a specific advantage and disadvantage. The more of those we discover, the easier we can discard simplistic assumptions about what is "better" and what is "progress."

Götheborg's propellers fold, like *Duyfken*'s, and she too was reconstructed based on extensive archaeological evidence from the wreck of the original, as well as the other

[82] Daniel S. Parrott, *Tall Ships Down: The Last Voyages of the* Pamir, Albatross, Marques, Pride of Baltimore, *and* Maria Asumpta (Camden, ME: International Marine/McGraw-Hill, 2003), 288-289. Parrott was at the time captain of the *Pride of Baltimore II*, built to replace the lost replica. Since 2003, he has been a professor at Maine Maritime Academy in Castine.

[83] Joakim Severinson, personal communication, 19 March 2015.

usual sources. Her speed and handling are likely to be very close indeed to a clean-bottomed original.[84] All of these differences between original and replica have to be considered if we're to have any hope of making apples-to-apples comparisons.

Regardless of their historical accuracy relative to each other, though, these replicas are not Disney props. Each one considered here represents years of research, years of traditional wooden shipbuilding experience, and in some cases, a determination to remain as faithful to the original vessel as possible. In important ways, the history of the design, construction, and operation of these vessels is a history of what we have learned about the originals. The clearest example of this is probably the Jamestown fleet, three sets of which have now been built and operated, beginning in the 1950s with the latest vessels built in 2006-2007.[85] There is nothing like having to recreate the thing to force all the questions we might otherwise miss into the fronts of our brains, to weigh sometimes-contradictory evidence, and to justify to other people the judgment calls we make to get the project done. Here the dovetailing between experimental archaeology and shipwreck archaeology is an elegant one. A shipwreck archaeologist like David Moore, trying to reconstruct on paper a small late 17th-century slaver from scattered and battered remains, uses a very similar investigative and interpretive process to that used by naval architect William Baker in designing the replica *Mayflower*. The two projects only diverge when Baker has to make concessions to legality, safety, and practicality in order to have his vessel built. Moore does not have to worry about that. It is those differences—

[84] Severinson, personal communication, 19 March 2015.

[85] The most comprehensive compilation of information on this history is probably Peter Wrike's research report. For an easily accessible digest, see Wrike in Bennett, 120-133.

as well as our own judgments about how closely the design adhered to what we know or think we know about the original type—that we focus on to determine how much we can rely on a built replica as a historical source. What is clear is that, were we to take some of the "makeshift" out of "makeshift experimental archaeology," and conduct some methodologically defensible, planned experiments on board these replicas—as Fred Hocker is doing on *Kalmar Nyckel*—we could rely on replicas as a historical source that much more. The remainder of this chapter elaborates on that thought.

An experimental control?

It should be clear by now that these replicas are never going to provide an ideal controlled laboratory setting for analyzing vessel performance. It should also be clear by now how much we stand to learn from them anyway, if we take care. If we are thinking in terms of laboratory experiments, it may be possible to establish a useful control for replica experiments, using a replica based on extensive historical information. *HMS Sultana* is a prime example, and indeed the ideal scenario for a replica.[86] Benjamin Hallowell, a noted Boston shipwright, built the schooner on speculation in 1767-8, hoping to sell her to the Royal Navy. To that end, he had her sailed to London when she was finished, and the Navy did indeed buy her. Lucky for us, since only the Navy would have ever bothered to survey such a run-of-the-mill small merchant vessel, take her lines off, and make a detailed inventory of her original rig and equipment, as well as her new high-performance Navy rig, and armament. The Navy sailed her back to America to use

[86] Chapelle includes *Sultana* in *The Search for Speed Under Sail*, Chapter 3 (see p. 84 in that chapter). Her history is recounted in *Sailing Into the Past*, Chapter 11 (150-161), co-authored by Drew McMullen and Captain Robert Brittain. McMullen, *Sultana*'s first captain and the President of the *Sultana* Education Foundation, was interviewed via telephone using the standard questionnaire on 8 January 2015.

her as an interceptor, enforcing the tightened Townshend Act customs duties, but by 1773 the burning of the *Gaspée* in Rhode Island and other hostile incidents convinced the Navy that they needed more powerful vessels for this duty, and they brought *Sultana* back to England, sold her, and she faded from history.[87] Fortunately, the records left by the Navy, and all the ship's logbooks, survived. So we know how she was originally designed and built, how she was rigged and re-rigged, what she carried, and how she performed in use configured as both a merchant ship and a small makeshift warship. That depth of knowledge and treasure chest of information made her a perfect candidate for a replica, and we can compare her speeds and performance characteristics with those recorded for the original. *Sultana* provides a rare opportunity to cross-reference replica performance to original performance. That in turn could take much of the speculation out of doing the same with other replicas we have reason to be confident are accurate, such as *Duyfken* and *Götheborg*. The relationship between replica and original performance of *Sultana* might serve as an otherwise-unattainable rule of thumb for hypothesizing that relationship in cases where the historical record is nowhere near as complete.

In order to accomplish that, though, we have to consider all the actual and possible differences between replicas and originals described above. In *Sultana*'s case, this especially means loading, trim, and differences in drag that take into account the propeller on the replica and what was sure to have been a much fouler bottom on the original, as well as issues related to synthetic sails and rigging already discussed. In this case, though, we might have the opportunity to quantify those differences.

[87] For context, see Sarah Kinkel, "The King's Pirates? Naval Enforcement of Imperial Authority, 1740-76," *The William and Mary Quarterly* 3d ser. 71:1 (January 2014): 3-34.

Burningham says of *Duyfken*'s two folding props that they caused "…very little drag and [required] no alteration to the stern. We did trial sailing before even the folding props and engines were fitted." Ferreiro, the historian and naval architect, wrote: "At the slow speeds of 18th-century ships most of the significant resistance was due to viscosity resistance not to wavemaking resistance, so skin friction was the dominant factor for sailing ships, as would be proven in the 1830s."[88] According to archaeologist Colin Palmer, who has tested period reconstruction sailing performance and published on the subject, "the fouling of a hull after one season in tropical waters can more than double the frictional resistance of the hull…"[89] Samuel Kelly relates in his memoir that a grass-fouled bottom of a ship he was in made it "impossible for her to beat to windward"—a dangerous limitation.[90] Propeller drag does not offer anything like that kind of resistance.

It is safe to assume that the replica's cleaner, smoother bottom would more than offset propeller drag—and introduce another difference between replica and original to take into account when making comparisons. Given what we know about synthetic sails, we can assume that a suit of the replica's sails will out-perform the originals of similar age and condition. This is testable. Sail trials could generate hard numbers for the performance of period-accurate sails versus synthetic sails, as long as they were done on

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[88] Burningham, personal e-mail, 5 May 2015; Ferreiro, *Ships and Science*, 175.

[89] Palmer recounts some of his experiences, outlines the difficult problems of measuring sailing performance, even with modern instruments, and points out the efficacy and affordability of using GPS and commercially available chart-plotting software to obtain accurate plots of a vessel's movements relative to fixed references, rather than the perceptions of those on board and the readouts of onboard instruments, which are subject to the distortions caused by the vessel's complex interaction with wind and sea. See Colin Palmer, "Measuring Performance Under Sail," in Bennett, ed., *Sailing Into the Past*, 32.

[90] *Samuel Kelly*, 291-292.

the same vessel in the same condition and in the same operating conditions. We have the capability to quantify the difference in performance in sails and in hull resistance due to fouling and propeller drag. Of course, making a complete suit of cotton or flax sails using period-accurate techniques is expensive, and can only be justified for research purposes, for a vessel that already has a perfectly serviceable suit of synthetic sails. Nevertheless, given the funding and the willingness—and spare time—of the vessel's owners and crew, these experiments could be carried out in such a way as to provide the sort of benchmark proposed here. Such efforts have been undertaken in Europe. They have not been undertaken on this side of the Atlantic, except recently on the *Kalmar Nyckel,* as mentioned.

Differences in internal distribution of weight—and changes in ballasting—affect motion and affect stiffness—how much the ship resists being heeled by the wind. That in turn helps to determine how much sail she can carry in a given wind on a given heading and sea state, and thus her speed and windward performance. We cannot expect a working replica like *Sultana* to rip out her engines, fuel and water tanks, and belowdecks accommodations to load an authentic 18th-century complement of stone ballast and mixed cargo. Barring the construction of a replica more specifically intended for research than any yet built for our period, we would need to rely on calculations by naval architects to determine what differences to take into account between the replica's lading and ballasting and the original's.

All of this is to say that only when we carefully factor in the differences between replica and original can we use the former to learn about the latter. To proceed with experimental archaeology based on existing replicas, researchers would need to contrive a checklist of all differences likely to affect the outcome of experiments, agree on how to factor in those differences, and perform the necessary calculations to complete the checklist.

For further investigation…

Collecting and comparing accounts of experiences on replica vessels raise questions, and hint at answers, that challenge received wisdom and, by pulling us into the nitty-gritty of real-world tangible detail, make it more difficult for us to make the sorts of sweeping generalizations about technological continuity and change that we are so prone to. To move closer to answers—and to raise more questions—we need to devise actual experiments—conduct research using these vessels, as medieval and prehistoric archaeologists have been doing in northern Europe and the Mediterranean for decades. An example would be using *Sultana* to establish comparative performance data between the replica and what is reported in her original logs, as proposed. That could provide a rule of thumb for comparing the performance of an accurate replica to its original counterpart in cases where the historical record was not nearly as complete as it is for *Sultana*. Further proposed experiments for each of the six technical foci of the chapter follow.

First technical focus: the mizzen sail

1. To confirm Speth's idea that the adoption of staysails would have selected for the abandonment of the lateen mizzen yard might only require manipulating a model fitted with both.

2. Replica sailing can give us an idea of manpower requirements for using similarly sized lateen mizzens, cut-back lateen mizzens, and gaff spankers, which might provide insight as to why they occurred in history in that order.

3. We could compare labor requirements for the same sail on different-sized vessels, to advance the investigation of the implications of vessel size for design and rig. Speth reports that more labor is required to use *Mayflower II*'s lateen mizzen than on his smaller ships. How much more? If we could conduct such experiments in similar wind and sea conditions, we could add to our understanding of actual manpower requirements for working the vessel, as opposed to the number of crew a vessel actually carried.[91]

Second technical focus: steering systems

Hocker's observations about tiller length make the wheel vs. tiller-and-whipstaff issue more complex. Given that the earlier system was employed on some of the largest ships of the entire period, the choice of one or the other cannot be explained by size alone. Given also that tillers remained in use on smaller vessels into our own time, size was clearly a factor. We may do no better than a comparative study of the operation of both systems on a variety of trustworthy replicas in real-world conditions, compiling experiences and observations on the advantages of one system on a particular vessel and how the other system might perform comparatively. The goal would be to better-understand the imperatives driving the ultimate ubiquitous adoption of the wheel system on middling and large vessels.

[91] Eric Speth has offered to do comparative experiments with the different-sized lateen mizzens on the three Jamestown ships, as their sailing schedule permits (Speth, personal e-mail, 11 February 2016).

Third technical focus: headsails

1. Further experiments of the kind Sharon Dounce described on the *Kalmar Nyckel* with the sprit-topsail can only add to the little we understand about this mysterious device. If it was tricky to rig and trim, and labor-intensive, why did it persist so long when triangular sails mounted on headstays were already in use?

2. It would be useful to compare how the same vessel performs with and without triangular jibs. Those sails were contemporaneous with the older spritsail throughout the period, so it is unlikely that they superseded that sail entirely. We do not need experiments to know that a triangular jib would be more useful for going to weather than a sprit-topsail. We could, though, use experiments to help determine how much that really mattered.

Fourth technical focus: topsails

1. The first experiment was inspired by Nick Burningham's account of sailing *Duyfken* on ocean passages, where he recounts the discovery of half-masting topsails in stronger breezes to keep the ship upright without losing driving force—the concept behind reefing.[92] Did the type of topsail on those earlier vessels—tall, relatively narrow, cutaway foot—lend itself better to this technique than the later topsails we find on 18th-century rigs? What if the crew of an 18th-century replica tried that technique in similar conditions? Burningham thought this would be worth doing.[93] Is it the case that the

[92] Reefing is shortening sail area by partially furling the sail and tying off the furled section to a spar (yard or boom). It is an intermediate step between a fully hoisted sail and changing down to a smaller sail altogether.

[93] Burningham, personal communication, 5 April 2015.

technique works much better with smaller sails on a smaller vessel? Is that why Sharon Dounce found it unsatisfactory on *Kalmar Nyckel*, or is there another explanation for that?

2. Did split topsails replace single topsails to save labor, and if so, in what way? By making easier work for the same number of crew, or by making the same work for a smaller crew? Maritime economic historians can tell us much about what maritime labor cost in a certain market at a certain time. We know that in general the ton-per-man ratios on British Atlantic merchant ships went up over the course of the period. If split topsails, then, do require fewer crew to handle safely and effectively, that is a promising explanation for their adoption, given the historical record—especially when we consider that increasing size was a major—if not the major—factor in that increasing ton-per-man ratio. If not, then what is at work there? Easing the crew's burden and increasing their safety, as with footropes? Eric Speth attributes split topsails to size increases, and relates their adoption to that of footropes, which he considers an improvement—he believes both were more labor-efficient than lowering sails to the deck or having crew try to go aloft without them.[94] How can we test the question aboard replica vessels by actually having real humans use both set-ups and report the results? That could only strengthen reasonable speculations like Speth's, or send us looking for alternative—or additional—explanations.

Before leaving the subject of rig, it is worth noting that all of the major changes in typical rigs took place contemporaneously with the tendency for the dividing line in

[94] Speth, telephone interview, 14 August 2015.

tonnage between two-masted and three-masted vessels to rise.[95] Are the two tendencies connected? If so, how?

Fifth technical focus: hull design

1. Unless we make some truly miraculous archival find, we can only make progress in our understanding of hull design through archaeology. The written record does not give us enough, and iconography rarely depicts anything below the waterline. *Duyfken* and *Götheborg*, both based extensively on substantial archaeological remains, among other things, are promising. We can trust what they have to teach us about stability, resistance, maneuverability, capacity, and seaworthiness if we take into account differences in lading and ballasting. Government regulations are less strict for vessels that do not carry passengers for hire. Any opportunity to load and ballast a vessel authentically for experiments, crewed by volunteers, would be worth seizing.

2. The stability problem discussed earlier is as compelling as any raised in this study. How much of the stability issue with replicas of period vessels is due to our correct reproduction of unstable original designs, and how much of it is attributable to our loss of the invisible process by which a "design" was translated into a ship—a process the treatises cannot accurately convey to us? Analysis of actual archaeological remains, and methodologically valid experiments, whether with models or replicas, based on those, is the way forward. At the same time, it is worth remembering that cultural history has already offered us something invaluable here. The standards, expectations, and values of a different culture than our own would surely guide the production and use of a different

[95] See Davis (2012 ed.), 73-74.

sort of machine than what we would make. In fact, we would do well not to lose sight of the forest for the trees. We would never build nor use the ships we are studying here at all, except for the specific purpose of reconstructing and understanding a relic.

3. Side-by-side sailing trials of vessels with different hull designs allow us to sidestep time. While it is exceedingly difficult to isolate individual factors contributing to differences, if we can actually experience how two very different vessels from different times compare in the same conditions, we can at least dispel common tacit assumptions and move on from there toward more useful apprehensions of comparative reality. While conducting sea trials with the current *Godspeed* in Penobscot Bay, Maine, Eric Speth took some of the builders and shipyard staff out. They were accompanied by some of the similarly sized late 19th- and early 20th-century schooners still common in those waters. People were surprised, he remembered, at how *Godspeed* sailed, how she carried sail, and how weatherly she was, with the qualification of course that she was a square-rigger and thus could not stay on a windward tack as long as a schooner. They were surprised that she could tack. It is common to assume that square-riggers do not tack, but always wear (jibe). "I do find them to be quite handy," Speth said, speaking of both *Godspeed* and the smaller *Discovery*, "probably because of its size and its two-masted rig, the *Discovery* is delightful to sail and is very, very maneuverable … I can sail it backwards at times. … and *Godspeed*, there are times I can sail it backwards if the wind and the conditions are right." He once had *Maryland Dove* out in the Chesapeake Bay and sailed her with the extreme schooner—'Baltimore clipper'—*Pride of Baltimore,* and in the right conditions

could keep up with her, even with 30-40% less waterline and much less sail area.[96] These early 17th-century ships are full-bodied, capacious carriers, intended to load as much as possible for their size without compromising sailing ability too much. That "too much" is the hard part for us—what does that mean, for those people in that time? Sailing these ships together helps us answer that question. It seems to mean that performance was at least roughly comparable to ships with much sharper lines, much less capacity, and much more labor-intensive and damage-prone rigs. If *Maryland Dove* could keep up with *Pride of Baltimore* in some conditions, that also helps us to understand why we see as little variance in passage times in the age of sail as we do. What these vessels could do was, generally, dictated by conditions, rather than by their own intrinsic qualities.[97] Those qualities, indeed, are best shaped to give the vessel the best chance of surviving those conditions and getting her crew and cargo where they are going.

The more such side-by-side sailing of vessels with different hulls we do, the better. We can carefully set about trying to isolate variables such as load and sail area when comparing their performance, but the more obvious differences are just as important—how close to the wind can each one get? How close are their speeds on the same broad reach? How is the motion? One day of such trials can generate so much information to consider, as nothing else can.

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[96] Speth, telephone interview, 14 August 2015. That is the original, lost *Pride of Baltimore*. The "right conditions" for a square-rigger like *Maryland Dove* to keep up with a fast schooner certainly include a broad angle of attack (sailing off the wind)—the schooner would always have the advantage to weather unless the seas were rough enough to impede her more drastically than her rival.

[97] The most important performance benefit of viable fuel-powered ships was not an increase in inherent speed. It was freedom from the tyranny of the fickle wind.

Sixth technical focus: the human component of the machine

1. How many able-bodied adults does it take to trim the lateen mizzen on a beam reach in 20 knots of wind? How about the same trial on a vessel similarly rigged but X% larger or smaller? How about one equipped with a lateen mizzen yard but with a cut-back mizzen sail? How about one with a more modern gaff spanker?

2. Can we compile data on the number of crew it takes to actually operate a vessel on a voyage from port to port with and without defensive capability? We know how to work those ships and we know how to work those weapons. We could then do the same for a number of vessels, and cross-reference those numbers with the numbers Ralph Davis compiled and re-enter the discussion of how much the increase in tons-per-man ratio over time was attributable to increased security—the point that so compelled Shepherd and Walton.

Jim Graczyk, speaking from his experience on the replica Armed Sloop *Welcome*, gives us a clear idea of how precisely we can do this. The replica *Welcome*, now retired, needed a crew of ten or eleven to “man her under sail.” She carried seven guns—three deck-mounted swivel guns and four deck guns. “For us a full compliment in the gun crew was four gunners, two powder monkeys, one Linstock holder and a master gunner. Under good conditions some of the sail crew would man several guns.” Research in the records of the original ship revealed that when operating as an ordinary merchantman she carried a crew of five or six. When taken into the Provincial Marine, her minimum crew was eight. On military sortie, “she had twelve sailors and twelve soldiers of the King’s 8th regiment of foot.”[98]

3. The human component is a core component of all the experiments proposed above. We are unlikely to find any one factor guiding continuity and change in ship technology in our period more firmly than labor requirements, with the possible exception of capacity-for-size. The two are related through ton-per-man ratios.[99]

In the final chapter, we will consider these questions in the context of what we may conclude, at least provisionally, about these ships from all aspects of the study considered together.

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[98] Jim Graczyk, personal communication, 6 November 2014.

[99] On the human component experiments proposed here, Eric Speth wrote that “We could compile … data fairly easily on sail setting, maneuvering and artillery” (Speth, personal e-mail, 11 February 2016).

Chapter Seven: 'A Very Good Sailer'? Conclusions and Further Questions

What is a ship? At first, a ship is what we see when we look at one. The hull shape, the rig, the sails, the gear—what is reproduced so painstakingly in miniature by modeler August Crabtree, whose creations seem to float in air in their glass cases under jeweler's lights in a quiet black gallery, like stars in space.

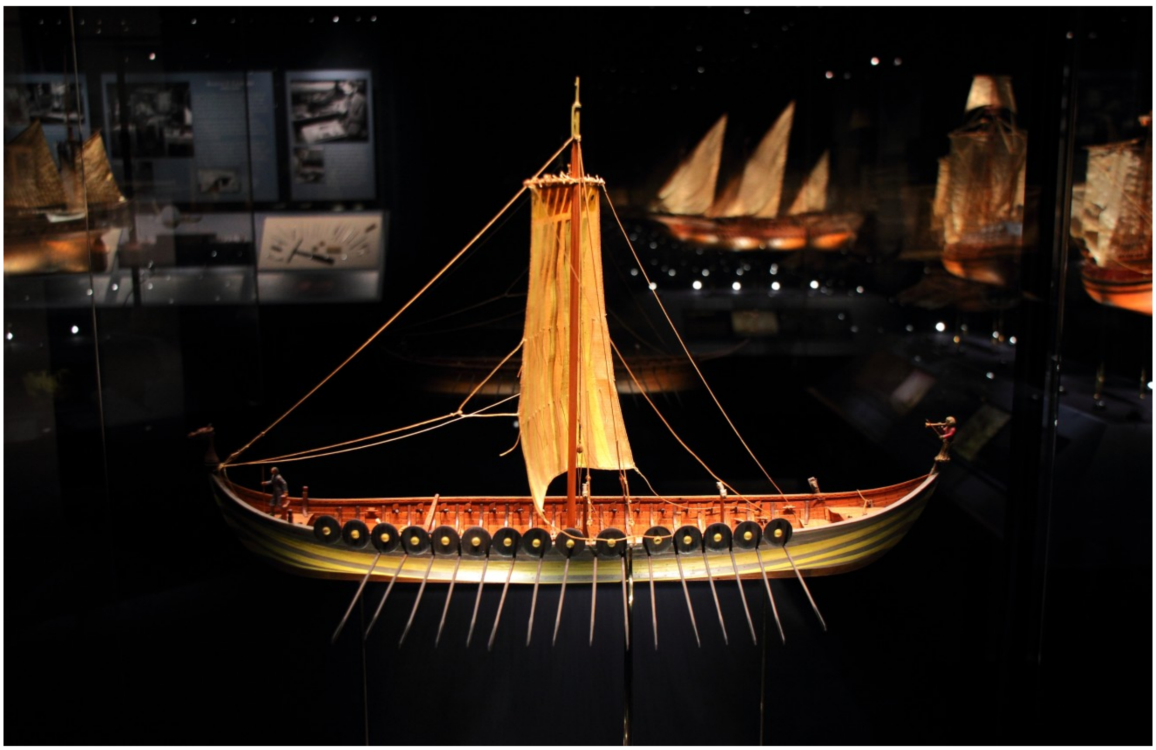

Figure 19 Crabtree Gallery, The Mariners Museum[1]

There is much we can learn about ships from accurate modeling. The exhibit design of the Crabtree Gallery allows the viewer to appreciate the detail as close-up as possible

[1] Photo by Mr.TinDC: https://www.flickr.com/photos/mr_t_in_dc/6713999491/in/photostream/
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without exposing the models to possible damage. There may be no more accessible venue for being taken aback by the beauty of these machines.

Without detracting at all from any of that, this study has sought to consider “what is a ship?” in the opposite direction—by contextualizing the question as much as possible. The ship, as presented here, is also the slime and barnacles on her bottom, the leaky seam above the garboard strake, the slightly out-of-tune foremast, the crew on board as individuals and as a collective, what water she is floating in, or beach she has been abandoned on. How is she loaded and with what? Where is she going? Where has she been? Who owns her? Are they making or losing money on her? Did they build her or buy her? What laws is she subject to? What laws does she evade? How is she like older ships and later ships? How is she different? Why?

The questions we ask here, and the answers we are looking for, could very well help the next August Crabtree build more accurate models of the ships we are studying. That would be a fine thing. That, though, is not why we are asking them. We pursue these questions in the hopes that doing so will teach us more about the world these ships sailed in—the people who sailed them. We are not studying ships to learn about ships, really—we are studying ships to learn about people, and how they were similar to and different from us, and in what ways, and why, so that we can better understand ourselves and our own world. That is why we do history.

Doing technological history with these old ships: overview

The overarching methodological challenge has been to understand continuity and change without teleology—to stay between teleology on the one hand and the denial of any linear evolution whatsoever on the other. While teleology is fallacy, though, progress is not. Progress is real. Human knowledge can and does accumulate, and find its way into technology. What, specifically, constitutes "progress"? In the history of technology, the onus is always on the investigator to make a strong case for why we should accept something as "progress"—and that case had better avoid presentism and unintentional anachronism. It is not difficult to point out ways in which a 1770 ship is different from a 1650 ship intended for the same general purpose. Our task at that point, though, is to avoid falling into the common trap of unconsciously looking for ways to show that those differences constitute an overall improvement—progress—from 1650 to 1770 ships. We like to think that we learn from experience and apply what we have learned to make our lives better. What we tend to overlook is that conditions change, and that the only way to understand technology is in the context of the conditions that produced and used it. The British Atlantic in 1650 was not the same as the British Atlantic in 1770. That may seem patently obvious, but what is not so obvious is the connection between that truism and the distinctive traits of the technology. That is not to suggest that we can never make the case that, for example, split topsails are more effective technology for a 300-ton ship than single topsails for the following X-number of reasons, which handily outweigh the < X-number of advantages of single topsails. The trick, though, is to make the case for an anachronistic counterfactual—anachronism, like poison, can serve a useful purpose if carefully and intentionally applied. Can we show that, if larger 17th-century ships had had split topsails, they would have worked better on those ships than the single topsails they actually had? That exercise hinges on the best possible understanding of what those needs were. That is the rub. That is what this is all about. Conveniently avoiding it makes for facile comparative technological history.

We could make a strong case that a 2015 Buick would have met the wants and needs of 1949 North American drivers better than a 1949 Buick. That argument, though, would be complicated by all the absurdities we would have to agree to accept—no computer technology, alloys that were not available or were not cost-effective then, etc. We stand to have an easier time with the kind of comparative technology proposed here. The materials were the same, the building techniques were largely the same, the infrastructure around the vessels was materially the same. The pace of technological change was, of course, much slower. Doing that right requires keeping that Vessel Analysis Map close by, and making sure to take into account everything on it.

We have to return to the questions raised throughout the study and sum up what answers we have, or may have, or do not have. Ultimately, we need to bring all that to bear on the following questions, suggested by the above methodological recap. Can we make any comparative technological assessments? If so, what does that tell us? If not, what more must we know before we can?

Doing technological history with these old ships: hull form

The 17th-century vessels are the most challenging, simply because the records are so sparse. Be that as it may, understanding them will also help us understand their successors better. So what can we say about the distinctive characteristics of the earlier ships—especially the earliest ones? The two most obvious of those characteristics are those most evident in the early English galleons (*Mayflower, Susan Constant, Sea*

Venture)—tumblehome and castling. Does tumblehome sacrifice stability? If so what kind? How much? What advantages does it offer?

The first response to those questions, as with any other aspect of ship design, is, "How much tumblehome are we talking about?" 18th-century ships had tumblehome—just nowhere near as much as ships a hundred years older. It would be so easy to say that the general presence of pronounced tumblehome on the earlier ships was an inferior design characteristic. That is not helpful. None of the evidence we looked at in Chapters Five and Six support the idea that tumblehome was a significant stability problem. Replica experience and ship history tell us it has advantages at sea. It could be instructive to conduct computer modeling trials in which we analyze the same hull with varying degrees of tumblehome, but if we do that, we should take care to take into account all the possible structural imperatives selecting for and against tumblehome. A ship is made of wooden parts, not pixels or 1s and 0s.

If we keep in mind that the merchant owner's number-one priority for hull form was capacity-for-size, then it seems more than reasonable to use that as our primary hypothesis for the decrease in tumblehome—that it increased capacity-for-size, and thus block coefficient. In that case, the primary factor selecting for the decrease in tumblehome is the one that supports McCusker—block coefficients were increasing because capacity-for-size was increasing.

We should consider tumblehome and castling together, because they tended to be found in proportion to one another. Is there more to the devolution of castling than a de-escalating arms race? We are certainly safe in assuming—as we already do—that to a significant extent, castling was vestigial. Again, though, replica experience shows that it has some advantages at sea—or at least that stern castling did, and we find pronounced stern castling after pronounced fore-castling has disappeared. Again, we can do laboratory analysis with different configurations of castling, and we are sure to learn something from that. We should focus those tests on this question: Does decreasing tumblehome without decreasing castling present a problem of top-heaviness that would serve as a compelling pressure to reduce castling concomitantly? It stands to reason that it would, and this is what Jon Adams was getting at. *Sea Venture*, as modeled and tested by Adams, was stable. Would she be with straight sides and the same castling? It is doubtful. Even if she were, she might well prove structurally problematic. We should not forget, too, the possibility that fashion played a role in the retention of the stern castle. Looking at that from the perspective of 17^{th}-century aesthetic history, as suggested in Chapter Four, would be worthwhile.

Speaking of stability—did English merchant ships use Matthew Baker's three-arc system to form their midship bends in the early 1600s? If so, did that produce hulls whose initial stability left something to be desired, leading to over-ballasting, which in turn compromised other aspects of performance and utility? If so, did shipwrights move away from such a midship bend by the 1670s? The evidence points to the answers to those questions being yes, yes, and yes. From experience with the *Mayflower II* and the return of the *Nonsuch* to the graphing of flat of floor versus floor sweep radii by Adams, what we have tells us that the early English galleons were not ideal in this respect, and that English shipwrights were moving away from the earlier midship bend in response.

All of our replicas from that period have modifications to increase their stability. We should do comparative computer modeling, like Adams' comparative analysis, to quantify the inherent stability differences from c. 1600 to c. 1670. It may well be that here we have one of the advantages of Dutch commercial ships in this period—remember *Duyfken*, built in 1595, whose carefully researched replica had no such issues. The evidence strongly supports Burningham on this point.

How much of the stability issue with replicas of period vessels is due to our correct reproduction of unstable original designs, and how much of it is attributable to our loss of the invisible process by which a "design" was translated into a ship—a process the treatises cannot accurately convey to us? For most of the replica research phase of the study, this was the most nagging and compelling question on the list. By now it should be clear that advanced interpretive ship archaeology *à la* Adams and Riess is our best hope for answering this. The question is not as compelling as it once was, given the points made in the preceding paragraph. The evidence encourages us to agree with Burningham that William Baker did his job well and the resulting fault lay with the original design. The history of replica design found in Peter Wrike's research—and Eric Speth's comments on it—makes it clear how well we can do a replica when we approach it the right way—and how well we *have* done it.

Also related to stability is the question of whether the 1694 tonnage rule had a stultifying effect on the designs of English merchant ships until the 1770s. If so, if block coefficients were generally increasing, as McCusker tells us, how bad could that have been in terms of overall fleet efficiency? Was the chief cost the failure to attain what might otherwise have been a gain in average speed? If so, would that have made any ultimate difference in passage times? We cannot answer those questions without clear evidence that 'rule-beating' ships were built consistently to cheat the 1694 rule and suffered technological detriments accordingly. The only evidence we have for that so far is anecdotal. What seems to be a compelling reason to look for such evidence goes back to Davis—we know that the British Atlantic shipping industry was more robust after 1750, and Davis was convinced that had something to do with ships. Is that the correct context for considering the ramifications of the adoption—and then abandonment—of the 1694 rule? Probably so.

When ship historian Alan McGowan wrote that "[h]ull design per se is not a factor in [the] evidence of greater economic efficiency…,"[2] that seemed reasonable—as it did when presented in Chapter One. The evidence presented subsequently tells us that, as an assumption, it is now obsolete.

As we follow ship design through the period, did the centrality of proportion begin to give way? If so, to what? The evidence indicates that the centrality of proportion did not give way. The rules of thumb, the accepted proportions and dimensions of different vessel types, continued to define what went down the slipways. Meanwhile, the mathematical and scientific minds were hard at work trying to apply new concepts to old technology. Some of those minds sat on the shoulders of men who actually spent time in shipyards. For the most part, what they came up with remained experimental in our period, but the calculations and tank tests and modeling they did, encouraged by the

[2] *The Century Before Steam*, 31.

unease of the British establishment at the end of the period, laid the keel for 19th and 20th century naval architecture. In our period, though, artisanal shipwrightry carried on as it always had, with its practical balancing of tradition and innovation, adherence and adaptation. The phrase “carried on as it always had” is not a euphemism for “languished.”

One obvious way in which it “carried on as it always had” throughout our period was with the fish-form hull. Did well-designed ships in our period make some sacrifice in resistance inherent to this hull form? If so, how much? Were the advantages ascribed to the tapering-aft from amidships real? If there is little or no resistance penalty for this form, that could support the notion that long experience—a form of evolution in human technology—had worked. If we find otherwise, we will be required to weigh that against other pros and cons of the fish-form hull. We obviously need computer-lab modeling tests on this issue. Again, we have to keep in mind structural considerations as we conduct those. The results of those tests should help us understand why the standard bow form changed in the 19th century, so that we can do a cost/benefit analysis of that change in the context of the specific conditions in which it took place.

Doing technological history with these old ships: sails and rigs

Both computer modeling and replica-based experimental archaeology can advance our understanding of how sails and rigs worked and why improvisation with those sometimes led to wholesale changes in ships of our period. We should devise and conduct real-world experiments, such as those presented in the last chapter, on real ships as much as possible. Computer modeling can give us access to experiments that would be impractical to conduct on a real replica. What if we change the rig on this vessel from a three-masted ship to a two-masted brig? What does that do? We can only do that in the lab. It would be worth doing in the lab, since we know from Davis that more and more mid-size Atlantic merchant vessels were two-masted rather than three-masted after 1750. We can evaluate performance comparatively, and we certainly have the archival evidence from that time period to evaluate relative cost and relative crew sizes.

Can we explain the evolution of the mizzen sail from lateen to cut-back lateen to gaff spanker? Does it have to do with manpower requirements? Vessel size increase? Both of those? The adoption of staysails, as Speth suggests? These questions, too, present opportunities for both experimental archaeology on replicas and for model testing—either in the computer lab or the old-fashioned way. The same applies to investigating the persistence of the spritsail and sprit-topsail.

To understand the evolution of topsails—primarily from taller, narrower single topsails to shorter, wider double topsails—we need to look at cost, complexity, labor requirements—both in terms of humans required and workload on those humans—and any relationship we can point to between those factors and vessel size. Can we prove Eric Speth's attribution of split topsails—and the adoption of footropes—both of which, he says, are more labor-efficient than lowering sails to the deck or having crew try to go aloft without them—to size increases? We should also remember the importance of adjusting sail plan for heavy weather. If we compare the technique of half-hoisting topsails on 17th-century ships and make the comparable adjustment on 18th-century ships with split topsails, considering the results vis-à-vis the difference between the two in how the sails were cut, how will that contribute to an explanation for the change? Finding written accounts in the archives could well prove helpful here too.

Doing technological history with these old ships: steering systems

Recall from the last chapter that Alan McGowan tried to connect the adoption of the steering wheel to the adoption of triangular jibs. Can we establish a connection between sails and steering systems? Or is that coincidental? We may be best–off here attempting to rank—and show relationships between—factors selecting for the adoption of wheel steering—or the retention, as the case may be, of tiller steering, including increasing vessel size, taking into account Fred Hocker's comments about tiller length, helmsman's visibility, viability of wheel steering technology, and the adoption of jibs, if that indeed can be shown to be relevant. We cannot switch out a replica's steering system. What we can do is compare notes on the experiences of using both systems in similar conditions on different replicas. We can switch out systems on a computer model, calculate loads on each, and virtually explore the other factors as well.

We need carefully controlled, methodologically defensible experimental-archaeology trials on replica vessels, to understand and compare different rigs, different hulls, and differences in armament with their associated crew requirements. These trials permit comparisons and contrasts of technologies separated by time. We can tie what we learn from these experiments to what we know about changing trade volumes, labor costs, average ship sizes, ton-per-man ratios, and the relative security of trade routes at different times.

Computer modeling allows us to conduct tests impossible on replicas—either because of the differences between replica and original, or because a replica of the specific vessel in question does not exist. We can test relative stability, relative capacity-for-size, hydrodynamic resistance and relative inherent speed. That will give us a better idea of what continuity and change actually meant for vessel performance in the period.

What we learn from both approaches—experimental archaeology and computer modeling—gives us information to add to the archaeological record, and then to go back to the maritime economic historians like Davis and McCusker and Shepherd and Walton and add something to their attempts to explain the broad trends and underlying realties of the British Atlantic as it developed.

Making the study of these old ships relevant to maritime economic historians

Was technological change in merchant ships a factor, however minor, in the established growth of shipping productivity in the British Atlantic in this period? If so, how?

The Shepherd and Walton thesis is still intriguing—they were too quick to dismiss technology but that was not fatal to their argument. It is still as good a starting point as any for working on the major questions. Is what Shepherd and Walton lumped together as one thing actually two things—related but not the same? Shepherd and Walton ascribe all of the growth in British Atlantic shipping productivity to 1) an increase in security due to the suppression of piracy permitting a decrease in manpower and armament; and 2) more efficient business networks and loading practices shortening turn-around times. The second of those is well-established. It is the first that has always seemed problematic. For one thing, the frequent wars with their cruising and privateering were a far greater threat to merchant shipping than pirates ever were. "But, what about convoys?" is not the answer to that problem. They were not always available, and when they were, not always effective.[3] Merchant ships, we know from the archives, continued to be armed during wartime throughout the period. That, though, leaves the question of what more we can learn about the connection between armament and merchant ship design, especially by considering post-1750 designs. Were the earlier ships designed more like warships than the later ships, primarily because they were intended to be armed? Did "galleon thinking" persist past the use of ships we actually call galleons? If so, for how long? Was there a point in the 18th century when armament was no longer driving evolution in design? One way to test that idea would be to perform laboratory modeling experiments to determine the effects of armament on merchant hulls that we know were not armed. We need to be able to say something about whether there is any discernible link between the design imperatives brought to bear by carrying guns and the general changes in merchant ship design as we move through the period. This could add much to what the data compiled and Shepherd and Walton, Davis, and French have to tell us about general armament trends.

Can we compile data on the number of crew it takes to actually operate a vessel on a voyage from port to port with and without defensive capability for a number of vessels, based on a combination of archival sources and replica-based trials? We certainly know how to operate the ships and how to operate the weapons. We could cross-reference those numbers with the numbers Ralph Davis compiled and add that to the

[3] See Unger, "Warships, Cargo Ships and Adam Smith: Trade and Government in the Eighteenth Century," *Mariner's Mirror* 92:1 (February 2006): 53.

discussion of how much the increase in tons-per-man ratios over time was attributable to increased security.

We know from Davis that Atlantic merchant ships were getting bigger, and that it is a fact of physics that bigger ships are faster ships, all other things being equal. So if ships did not make faster passages in 1800 than they did in 1600, what does that mean? That all other things were not equal. Much of that goes back to Ferreiro and his pointing out that everything from surface friction resistance—from fouling, primarily—to the condition of the ship and her rig to the condition and skill of her master and crew had more to do with making speed than variations in the design and construction of the ship. Another large part of the answer comes from Chapter Three. The winds and seas conspired to push down average speeds for passages well below what the ships were capable of making through the water.

A third part comes from the end of Chapter Five, and Riess' summary comments on the design of the Ronson ship and what that might mean. The overriding priority of capacity, and the efficiency it offered by maximizing what a ship of a given size could carry, was doubtless worth far more to the average owner of the average merchantman than the relatively slight increases in speed he might wring out of the ship at the expense of that extra capacity.[4] Such speed might translate into something useful for, say, a packet boat shuttling back and forth between nearby islands, but as we have seen, on an ocean passage it was likely to amount to naught—at least within the narrow range of sizes that were economically viable. As noted, we need to use archaeology and computer modeling

[4] The evidence presented in Chapter Three certainly supports that.

to explore McCusker's and Davis' contention that block coefficients were increasing, and that we are dealing here with the inverse relationship between capacity and speed for a given size vessel. There is little doubt that McCusker and Davis are right, based on all the evidence presented in this study, and if capacity increased without costing speed, that would have been plenty good enough for these people. It helps explain both why we do not see increases in average merchant ship speed in the period, even as sizes increased modestly, and why that growth in size *was* gradual and modest, even as the growth in the Atlantic World and its trades was much more robust.

Full circle: Doing Atlantic World history with these old ships

How do we correctly relate technological continuity and change in sea-going merchant ships to the larger developments that constitute Atlantic World history in this period?

Ian Steele subtitled his book *An Exploration of Communication and Community, 1675-1740*. He emphasized the connections between the different settlements of the English Atlantic, whether separated by an ocean or just an island-hop away. Connections, networks, lines criss-crossing the Atlantic and Caribbean between Europe and Africa and North America and the West Indies and Central America—that is the stuff of Atlantic World history. Almost every one of those lines represents the track of a merchant ship. The sea was more highway than wall. Clearly the technology of the merchant ship made the whole thing possible. In what ways, though, did it also serve as the primary limiting factor of what was possible? For the most part, by limiting the speed of Steele's "communication" and connections between geographically separated members of his "community." The crux of *The English Atlantic,* though, is that we should set aside our notions of speed to realize that it was not the impediment to the success of this huge endeavor that we would tend to assume. To put that in the terms of this study would be to say that to understand the value and function of a technology is to understand it in the context of its own time and place.

The key to heading off any situation in which merchant shipping could become an impediment to the sustenance and growth of a maritime empire in this time and place was adequate supply. The earliest Virginia settlement attempts did not receive the support from the sea that they needed, so they died out or struggled to hang on until that situation changed. The Spanish Caribbean was chronically under-supplied by Spain because that kingdom's resources were stretched too thin and the mainland to the west became much more important to the Spanish than the West Indies, so the Spanish West Indians turned to Spain's rivals—and their ships—for sustenance.[5] French West Indians turned to the British Atlantic Empire—and the Dutch, and the Spanish—for what they needed because sustenance from France was inadequate. Again, that has to do with resources stretched too thin—France's constant problem in the Atlantic. Frequent wars with the British Empire restricted French shipping. French warships could not remain on station in the West Indies long enough because they did not have the infrastructure in place to perform necessary maintenance. There was no market for rum in France, so French sugar producers had to rely on extra-imperial trade to make any commercial use of that product, and that trade was at best penalized by duties and at worst actively suppressed.

[5] See Elliott's *Empires of the Atlantic World*, already cited.

None of these problems turn on ship technology *per se*. We saw in Chapter Three that the biggest challenge facing shipowning merchants was access to up-to-date, accurate market information. That information could only travel as fast as the fastest vessel. These people could and did build fast "advice boats"—couriers, whose main task was the speedy delivery of dispatches, newspapers, and agents. That, though, was expensive, and while it no doubt helped the situation, it was not something the average merchant could afford to do. Most such boats were government vessels doing government business. So in that sense, the ship was a limiting factor. It would remain so until the telegraph and the railroad and the steamboat, but all those technologies were for some time restricted to terrestrial or inland employment, and made it easier, for the first time in the Atlantic World, to communicate and build community by land and river than by sea. For some time longer, the speed of the ship remained the limiting factor for the speed of transatlantic communication.

Be that as it may, though, it certainly did not limit the growth of the British Atlantic. Steele ends his book in 1740, but the marked economic acceleration of the British Atlantic was post-1750. Even in the earlier period, though, growth was real and the British Empire was consolidating more and more holdings to the west of its own shores.

On the shores of each new colony, there was somebody who could set up stocks and build a ship if properly motivated to do so. The *Sea Venture* castaways in Bermuda are the most famous and extreme example, but what they did, and the benefits derived from it, did not require such dire straits. The New Englanders started doing it as soon as they had learned to survive. Then they built one of the world's top shipping industries, as the flags flying over their courthouses changed.

The ships grew as the Atlantic World grew. Some of their costs increased as supplies of materials dwindled and a growing merchant fleet competed with the navy for an always-inadequate supply of skilled seamen. So their ton-per-man ratios tended to decrease. Their rigs and steering systems were adapted in ways that allowed growth in size without increasing manpower. They were armed for protection during times of conflict and owners dispensed with that burden when they could—or when effective convoys were available, later in the period.

To frame this period in terms of merchant ships, consider the small English galleon, e.g. *Sea Venture*, on the front end and the snow *George*—whose voyage from Delaware to Ireland in 1806 we considered in Chapter Three—on the back end. Recall Adams' characterizing of the small galleon as a ship that was not ideal in any one sense, but taken together, was ideal as a compromise to serve the role for which she was needed in her time and place. She was stout, versatile, defensible, affordable, and reasonably maneuverable. The early Atlantic World could not afford specialization,[6] just as most denizens of its villages and small towns could not, as noted in Chapter Four. A century after *Sea Venture*—or midway through the period we are considering—we have Warren Riess' *Princess Carolina*, which clearly shows characteristics of an English-Dutch hybrid design much more specialized as a cargo carrier and capitalizing on the appropriation of

[6] As Davis wrote, "Seventeenth-century business was not altogether ripe for specialization…," which is why, he says, we do not see "shipowner" listed as a trade or occupation of anyone in the directories of the major British ports in that century (77, 2012 edition).

Dutch technology in the late 17^{th} century. Finally, we have the *George*—which, as a snow, was a type of mid-size ocean-going merchantman very popular in the last half-century or so of the period. Her rig was simpler than *Carolina*'s ship rig. She may well have required fewer crew than a three-masted ship her size. If she were unarmed, as so many merchantman were in the latter half of the period, she could have afforded the risk of that smaller crew, while avoiding the expense of a larger one. These three representative vessels are not intended to suggest a linear progression, but they are indicative of broad trends in the development of the British Atlantic from 1600 to 1800.

From *Sea Venture*'s ill-fated voyage to Virginia to *George*'s routine one to Ireland, shipwrights in the British Atlantic built a remarkable variety of craft influenced by the building traditions of all the Atlantic European powers—and, close to shore, they paddled around in small boats developed by natives and by Africans as well as their own ancestors. Those major types we have considered here may show up most often in the records, but that must not be taken to mean they comprised anything close to the whole British Atlantic merchant fleet. Early in this project, it seemed worthwhile to design a relational database to help keep track of vessel types used in the British Atlantic in this period. As of now, the number of such types in the database stands at 35, for most of which we also find alternate names.[7]

All the vessels considered here were built for owners risking their fortunes—whether meager or substantial—trying to take advantage of volatile markets in a frequently violent world. More of those owners grew richer as the Atlantic World

[7] See Appendix 3, p. 349.

developed, and more of those rich owners were colonials too. No matter how wealthy, though, an owner had to place a large amount of trust in a ship master to buy and sell for him on favorable terms, and to take care of the expensive ship and her expensive crew. Whether they were ordering a small schooner from David Lowell, a mid-size transatlantic snow from Charles West, or an East Indiaman from the Hackets, they wanted to mitigate risk. Contracting with a trusted builder who had acquired a reputation was a way to do that. Owners had to trust shipwrights on important technical matters. They could stipulate specific matters of build quality and design preferences in their shipbuilding contracts, but they had to trust that the builder would abide by those—especially if, like Daniel Flexney, they were on the other side of the ocean. There was only so much an owner could do to mitigate market risk. One way to mitigate overall risk, though, was to order a ship—or buy one already built—by a shipwright who could adapt a proven technology to the needs of that owner and produce a vessel capable of performing the intended service for a reasonable length of time given proper care and luck.

The best of those shipwrights had a knack—a skill honed to an instinct—for adapting a prescribed convention to suit specific needs without compromising the basic recipe for a good ship. They knew how to vary the spice without ruining the stew. They were constrained by the availability of wood and by wood's limitations, but they also took advantage of what it had to offer by improvising construction techniques as available materials required. Design and construction were inextricable, so it worked well that they were directed by the same person.

Shipwrights could offset the disadvantages of, say, having to scarf together the frames out of more pieces than they would have preferred, by adding reinforcements and fastenings. All of those shipwrights worked with a sense of proportion—whether learned in the yard, as was usually the case, or from a treatise—or from both. The latest archaeology, such as Riess', shows us that those proportions could be quite simple, and the resulting vessel would serve well. As for the worst of those shipwrights, it is difficult for us now to discern how much of being a bad shipwright had to do with lack of knowledge and skill, and how much had to do with being willing to acquiesce to the stipulations of an ignorant merchant and build him a bad ship to get paid. William Hutchinson would have blamed merchant and shipwright together for that.

Laws passed for revenue collection, like the 1694 rule, could indeed exert pressure to execute designs with performance and safety problems vis-à-vis alternatives. A predilection of some English shipwrights to build smaller merchantmen according to twenty-year-old stipulations for warships, as may be the case with the use of Matthew Baker's tangent-arc system in small galleons of the early 17th century, may have led to some stability and lading problems. Design adapted to challenges. We do not know that ships were built too deep to beat the 1694 rule—a worse fault than building them too high would have been. Adams shows that English midship bend convention was already moving away from Baker in Baker's own time, and that the small galleon *Sea Venture*, contemporaneous with *Susan Constant* and *Mayflower*, was not designed to Baker's formula. We know that, as size increased, tumblehome and castling decreased, block coefficients could grow, increasing capacity-for-size and thus overall efficiency with no loss of speed in the real world of ocean passagemaking.

Sailors were always adjusting lines and sails anyway, so of course they experimented with different ways of setting up rigs and sail plans. They knew, though, that to change something important would require other changes as well, and the ship under their feet was the only thing between them and the deep blue sea. Considering when and where we find lateen mizzens, triangular staysails and jibs, spritsails, and sprit-topsails, it seems they were perhaps more apt to adopt something new and proven than jettison something old and proven. Such changes had to be approached with caution. These people placed a high value on "prudence." They even used it as a name for their daughters.

The merchant ship was a nexus of managed risks, like every other commercial undertaking then or now. Studying these people's ships makes it clear to us that their risks were different from ours, whether we are talking about their market risks or their risks of physical injury or death. We have to understand those risks, and the attitudes and values of those who assumed them, before we can appreciate how the technology relates to those risks. We cannot just assume, for example, that adopting—or not adopting—footropes for furling square sails had primarily to do with mitigating, or ignoring, the risk to the crew.

We would be no more sanguine about accepting any other of their risks than we would be about signing on for a voyage on one of their ships. It was a different world. In that different world, these ships did what these people needed them to do at a cost they could afford and were willing to pay. That is “good technology”—and that technology kept up. It did not impede the major changes in the Atlantic World. We still have much to discover about exactly how they went about using and adapting their successful technology as operating conditions changed, but we know enough to conclude that these people could and did build ‘a very good sailer.’

Bibliography

Primary Sources

Interviews

(See standard questionnaire, Appendix.)

Dounce, Sharon. Captain, *Kalmar Nyckel*. Skype-to-phone interview, recorded and stored as MP3 audio. 23 April 2015.

Graczyk, James. Former volunteer crew and interpreter, Armed Sloop *Welcome*. Written questionnaire exchange via e-mail, filed. 5 November 2014.

McMullen, Drew. First Captain and President, *Sultana* Education Foundation. Skype-to-phone interview, recorded and stored as MP3 audio. 8 January 2015.

Reynolds, William T. ("Chip"). Master, *Half Moon*. Skype interview, recorded and stored as MP3 audio. 8 January 2015.

Rybka, Walter. Senior Captain and Site Administrator, U.S. Brig *Niagara*. Skype-to-phone interview, recorded and stored as MP3 audio. 21 April 2015.

Severinson, Joakim. Master Shipwright, Swedish Ship *Götheborg*. Written questionnaire exchange via e-mail, filed. 19 March 2015.

Speth, Eric. Maritime Program Manager, Jamestown-Yorktown Foundation. Skype-to-phone interview, recorded and stored as MP3 audio. 14 August 2015.

Personal Correspondence

Burningham, Nick. Archaeologist and mariner, author of published work on *Duyfken* replica and experimental maritime archaeology. Exchange of Facebook messages regarding *Duyfken* sail handling and Dutch vernacular ship design. 5-8 April 2015. Substantive comments on NASOH conference paper (the basis for Chapter Six) via e-mail. 4-5 May 2015.

Dounce, Sharon. Captain, *Kalmar Nyckel*. E-mail detailing experience with lateen mizzen in operation. 24 April 2015; e-mails clarifying earlier conversations, 4 May 2015.

Fontenoy, Paul. Curator of Maritime History, North Carolina Maritime Museum. E-mails recommending published articles on Dutch ship design by Albert Hoving, relaying of lengthy query of mine to Ab Hoving and his response. 2 April 2015.

Graczyk, James. Follow-up discussion via e-mail of design and performance characteristics of Armed Sloop *Welcome*. 30 October – 25 November 2014.

Hocker, Fred. Archaeologist, Research Director, Ship Unit, Swedish National Maritime Museums. E-mail correspondence and full review of replica analysis paper. 18-19 August 2015.

Hoving, Albert (Ab). Formerly of the Rijksmuseum, Amsterdam, expert ship modeler and historian of Dutch shipbuilding and seafaring, author. E-mail via Paul Fontenoy. 2 April 2015; e-mail 4 May 2015.

Klomps, Steve. Controller, Peabody Essex Museum, historian. E-mails. 30 June 2015.

Reynolds, William T. ("Chip"). Follow-up discussions of sail handling and rig of *Half Moon* and 17th-century ships in general. 5-8 February 2015.

Speth, Eric. E-mail correspondence on proposed replica experiments. 11 February 2015.

Videos

Duyfken:

"Aboard the *Duyfken*." YouTube video, 13:28. Posted by "Mick Lynn," 13 February 2014. https://youtu.be/xnS90dsTsoI.

"*Duyfken* in Force 6." YouTube video, 1:16. Posted by "fruitbaxful," 7 October 2010. https://youtu.be/22_OBnwbFig.

"*Duyfken* in the North Sea." YouTube video, 8:39. Posted by "Glenn Williams," 13 April 2008. https://youtu.be/GlihilYmpao.

"The *Duyfken*." YouTube video, 2:02. Posted by "adri2007nl," 6 March 2008. https://youtu.be/HCzrX269VyQ.

Nonsuch:

"Voyage of the *Nonsuch*." YouTube video, 27:06. Posted by "Canada's History," 6 June 2013. https://www.youtube.com/watch?v=2n_83JqlgI4.

Welcome:

"The History of the Armed Sloop *Welcome*." YouTube video, 6:27. Posted by "Maritime Heritage Alliance," 28 September 2013. https://www.youtube.com/watch?v=RzoTdMggUOI.

"Traverse City Documentary, Part I." YouTube video, 5:44. Posted by "Craig Seaver," 22 September 2011. https://www.youtube.com/watch?v=eX0FcHUimNA.

"Traverse City Documentary, Part II." YouTube video, 4:23. Posted by "Craig Seaver," 21 September 2011. https://www.youtube.com/watch?v=eNkU6O3qC_s.

Replica Websites

Susan Constant, *Godspeed*, *Discovery*:

http://www.historyisfun.org/jamestown-settlement/jamestown-ships/

Mayflower II:

http://www.plimoth.org/what-see-do/mayflower-ii

Nonsuch:

http://manitobamuseum.ca/main/visit/museum-galleries/nonsuch-gallery/

Half Moon (Halve Maen):

http://www.halfmoonreplica.org/

Kalmar Nyckel:

http://www.kalmarnyckel.org/

Duyfken:

http://www.duyfken.com/

Götheborg:

http://www.soic.se/en/

Lady Washington:

http://historicalseaport.org/about-us/our-vessels/lady-washington/

Sultana:

http://sultanaeducation.org/

Welcome:

http://www.maritimeheritagealliance.org/welcome

HMB Endeavour:

http://www.anmm.gov.au/whats-on/vessels/hmb-endeavour

Friends Good Will:

http://www.michiganmaritimemuseum.org/friendsgoodwill/

Niagara:

http://www.flagshipniagara.org/

Manuscript Collections

Abbreviations for repositories used in the notes follow their full names below.

Historical Society of Pennsylvania (HSP)

Boyer, Brooke & Wilson Account Book, 1783-1790.

Coates and Reynell Family Papers, 1729-1764.

George (ship) logbook, 1805-1806.

Gregory Marlow Account Book, 1676-1703.

Jones and Clarke Papers.

Joshua Humphreys Papers, 1660-1931.

Log of the Brig *Lydia*, 1808.

Maitland Family Papers, 1729-1896.

Wharton Family Papers, 1679-1891.

John Carter Brown Library (JCB)

Brown Family Business Records

New Hampshire Historical Society (NHHS)

George Boyd Letter Book, 1773-1775.

Langdon Family Papers.

Shipping Papers, 1707-1886.

Tredick Family Papers, 1753-1835.

William Hale Correspondence, 1791-1839.

Phillips Library, Peabody Essex Museum (PEM-Phillips)

Abner Dole Account Book, 1730-1760.

Account Book of David Lowell, 1781-1801.

Account Book of the Horton Family, 1781-1828.

Account Book of Samuel Coker, 1749-1774.

Crowninshield Family Papers, 1727-1891.

Derby Family Papers, 1716-1925.

Joshua Coffin Papers, 1647-1862.

Orne Family Papers, 1719-1899.

Shipbuilding Agreement, 1739.

William Hacket Papers, 1739-1808.

Woodwell Family Papers, 1752-1884.

Published primary sources

Anderson, R.C., ed. *Journals and Narratives of the Third Dutch War. Publications of the Naval Records Society, Vol. LXXXVI.* London: Navy Records Society, 1946.

Barker, Robert. *The Unfortunate Shipwright: Or Cruel Captain*. London, 1795. Google Books digital facsimile.

Barlow, Edward. *Barlow's journal of his life at sea in king's ships, East & West Indiamen & other merchantmen from 1659 to 1703.* Two volumes. Transcribed by Basil Lubbock. London: Hurst & Blackett, 1934.

Boardman, Timothy. *Log-Book of Timothy Boardman*. Albany, NY: Joel Munsell's Sons, 1885.

Bushnell, Edmund. *The Compleat Shipwright*. Sixth edition. London: For Richard Mount, 1699.

Chapman, Frederik H. af. *Architectura Navalis Mercatoria*: *The Classic of Eighteenth Century Naval Architecture*. Mineola, NY: Dover Publications, 2006.

Charnock, John. *An History of Marine Architecture*. Volume II. London: 1801. ECCO facsimile.

Dassié, F. *L'Architecture Navale, contenant la maniere de construire des navires…* Paris: Chez Jean de la Caille, 1677. Google e-book via archive.org.

Elliot, Jonathan. "Remarks and Observations on the Use of Cotton Canvas, as Preferable to Hemp, for the Sails of Ships of War or Merchant Vessels, Supported by the Testimony of Naval Officers, Ship Owners, Captains, &c." Washington, DC: Jonathan Elliot, 1829.

Euler, Leonhard. *A compleat theory of the construction and properties of vessels: with practical conclusions for the management of ships made easy to navigators*. Trans. Henry Watson. London: J. Sewell, 1790.

Falconer, William. *An universal dictionary of the marine: or, a copious explanation of the technical terms and phrases employed in the construction, of a ship. Illustrated with variety of original designs of shiping The second edition, corrected.* London: 1771. ECCO facsimile.

Faraday, Michael. "On the practical prevention of dry rot in timber." London: John Weale, 1838.

Guest, Henry. "Observations on sheathing vessels: seasoning timber; the proper time to fall timber; the nature and what force it is that causes the sap to rise; with a number of other valuable observations." New Brunswick, NJ: A. Blauvelt, 1805.

Hamer, Philip M., ed. *The Papers of Henry Laurens,* Volumes 1-5. Columbia: South Carolina Historical Society, 1968-1976.

Hemphill, James. "Leaves from the Log-Books and Letters of James Hemphill, Mariner and Merchant of Wilmington, 1793-1797." *Papers of the Historical Society of Delaware,* LXIV, 1914.

Hutchinson, William. *A Treatise on Naval Architecture*. Fourth (1794) Edition. London: Conway Maritime Press, 1970.

Kelly, Samuel. *Samuel Kelly: An Eighteenth Century Seaman*. Edited by Crosbie Garstin. New York: Frederick A. Stokes Company, 1925.

Lavery, Brian, ed. *Deane's Doctrine of Naval Architecture, 1670*. Annapolis, MD: Naval Institute Press, 1981.

Mainwaring, Henry. *The Sea-mans Dictionary : or, an exposition and demonstration of all the parts and things belonging to a shippe* (1644). In *The Life and Works of Sir Henry Mainwaring,* Volume 2. Edited by G.E. Mainwaring. London: The Navy Records Society, 1920. E-reader edition published by The Internet Archive, 2007.

May, Charles. "An Account of the Wonderful Preservation of the Ship Terra Nova of London." In Churchill, Awnsham and John Churchill. *Collection of Voyages and Travels, Some Now First Printed from Original Manuscripts, Others Now first Published in English, In Six Volumes, With a General Preface, giving an Account of the Progress of Navigation, from its first Beginnings*. Six Volumes. Third Edition, London, 1747. Google Book, accessed 16 February 2015 at https://books.google.com/books?id=0FVEAAAAcAAJ&lpg=PA343&ots=knNjzh2Iyu&dq=Charles%20May%20An%20Account%20of%20the%20Wonderful%20Preservation%20of%20the%20Ship%20Terra%20Nova%20of%20London&pg=P

P1#v=onepage&q=Charles%20May%20An%20Account%20of%20the%20Wonderful%20Preservation%20of%20the%20Ship%20Terra%20Nova%20of%20London&f=true

Murray, Mungo. *Treatise on Shipbuilding, 1765. Includes translation of Du Hamel du Monceau's treatise of the same year.* https://archive.org/stream/treatiseonshipbu00murr#page/n0/mode/2up

Ollivier, Blaise. *18th Century Shipbuilding: remarks on the navies of the English & the Dutch from observations made at their dockyards in 1737*. Trans. and ed. David H. Roberts. Rotherfield UK: Jean Boudriot Publications, 1992.

Salisbury, W. and R.C. Anderson, eds. *A Treatise on Shipbuilding* and *A Treatise on Rigging Written About 1620-1625*. The Society for Nautical Research Occasional Publications Number 6. London: The Society for Nautical Research, 1958.

Smith, John. *The Sea-man's Grammar and Dictionary, Explaining all the difficult Terms in Navigation, and the Practical Navigator and Gunner: In Two Parts*. London: 1691 edition. Google e-book facsimile.

Society for the Improvement of Naval Architecture. "An address to the public…" London: Society for the Improvement of Naval Architecture, 1791.

_____. *Collection of Papers on Naval Architecture*. 3 volumes. London: The European Magazine, 1791-1793.

_____. "Some account of the institution, plan, and present state of the society, of the Society for the Improvement of Naval Architecture: together with the premiums offered by the Society, list of subscribers, rules and orders, of the Society: and 3 original letters, addressed to the committee, from Sir Charles Middleton, Bart. and Messrs. Gore and Patton, on subjects of naval architecture." London: Society for the Improvement of Naval Architecture, 1792.

Stalkartt, Marmaduke. *Naval Architecture or the Rudiments and Rules of Ship Building*. London, 1781. Google Books facsimile.

Steel, David. *The ship-master's assistant and owner's manual: containing complete information, as well to merchants, masters of ships, and persons employed in the merchant-service*. Sixth Edition. London: 1795. ECCO facsimile.

_____. *The Elements and Practice of Rigging, Seamanship, and Naval Tactics. Volume III—Rigging*. London: 1806. Cambridge Library Collection facsimile.

Saunders, Edmund. "An Address to the Owners of Ships, &c., in particular, and in general to all who have an Interest in preserving Timber under Water." Plymouth UK: M. Haydon & Son, 1790.

Thorpe, David. "The *Mayflower II* Story—Reflections of a Sailor." Part 1. *The Mayflower Quarterly* 78:2 (June 2012): 117-121.

_____. "The *Mayflower II* Story—Reflections of a Sailor." Part 2. *The Mayflower Quarterly* 78:3 (September 2012): 216-219.

_____. "The *Mayflower II* Story—Reflections of a Sailor." Part 3. *The Mayflower Quarterly* 78:4 (December 2012): 324-327.

_____. "The *Mayflower II* Story—Reflections of a Sailor." Part 4. *The Mayflower Quarterly* 79:1 (March 2013): 35-38.

_____. "The *Mayflower II* Story—Reflections of a Sailor." Part 6. *The Mayflower Quarterly* 79:3 (September 2013): 286-290.

Villiers, Alan. "How We Sailed the New *Mayflower* to America." *National Geographic* Volume 92, Number 5 (November 1957): 627-674.

_____. *The New Mayflower*. Leicester UK: Brockhampton Press, 1959.

Wallis, John. "Cono-Cuneus: or the Shipwright's circular wedge." In *A treatise of algebra, both historical and practical…* London: John Playford, for Richard Davis, Oxford, 1685.

Secondary sources

Abell, Sir Westcott. *The Shipwright's Trade*. Conway/Cornell Maritime Press, 1948, 1981.

Adams, Annmarie and Sally McMurry, eds. *Exploring Everyday Landscapes: Perspectives in Vernacular Architecture*. Volume 8. Knoxville: University of Tennessee Press, 1997.

Adams, Jonathan. *A Maritime Archaeology of Ships: Innovation and Social Change in Medieval and Early Modern Europe*. Oxford: Oxbow Books, 2013.

_____. "*Sea Venture*: A second interim report—part 1." *The International Journal of Nautical Archaeology and Underwater Exploration* 14:4 (November 1985): 275-299.

_____ and Johan Rönnby, eds. *Interpreting Shipwrecks: Maritime Archaeological Approaches*. Southampton UK: Highfield Press, 2013.

Anderson, Atholl, James H. Barrett & Katherine V. Boyle, eds. *The Global Origins and Development of Seafaring*. Cambridge: McDonald Institute for Archaeological Research, 2010.

Anderson, R.C. *The Rigging of Ships in the Days of the Spritsail Topmast 1620-1720.* London: Conway Maritime Press, 1982.

_____. "Comparative Naval Architecture, 1670-1720, Part I." *Mariner's Mirror* 7:2 (1921): 38-45.

_____. "Comparative Naval Architecture, 1670-1720, Part II." *Mariner's Mirror* 7:6 (1921): 172-181.

_____. "Comparative Naval Architecture, 1670-1720, Part III." *Mariner's Mirror* 7:10 (1921): 308-315.

Bailyn, Bernard. *The New England Merchants in the Seventeenth Century*. Cambridge, MA: Harvard University Press, 1955.

_____. *Soundings in Atlantic History: Latent Structures and Intellectual Currents, 1500-1830.* Cambridge, MA: Harvard University Press, 2009.

Baker, William A. *Colonial Vessels: Some Seventeenth-Century Sailing Craft*. Barre, MA: Barre Publishing Co., 1962.

_____. *The Mayflower and Other Colonial Vessels*. London: Conway Maritime Press, 1983.

_____. *The New Mayflower: Her Design and Construction*. Barre, MA: Barre Gazette, 1958.

_____. *Sloops and Shallops*. Barre, MA: Barre Publishing Co., 1966.

Banks, Kenneth J. *Chasing Empire Across The Sea: Communications and the State in the French Atlantic, 1713-1763*. Montreal: McGill-Queen's University Press, 2002.

Bankston, J. "Some Notes on Early Spanish Maritime Technology and Practices in the New World." In J.B. Arnold III, ed., *Beneath the Waters of Time: The Proceedings of the Ninth Conference on Underwater Archaeology,* 63-66. Texas Antiquities Committee Publication No. 6, Austin, Texas.

Barker, Richard. "A Manuscript on Shipbuilding, circa 1600, Copied by Newton." *Mariner's Mirror* 80:1 (February 1994): 16-29.

Basso, Keith H. *Wisdom Sits in Places: Landscape and Language Among the Western Apache*. Albuquerque: University of New Mexico Press, 1996.

Batchelor, Jennie and Cora Kaplan, eds. *Women and Material Culture, 1660-1830*. Basingstoke UK: Palgrave Macmillan, 2007.

Bell, Whitfield J., Jr. "Adam Cunningham's Atlantic Crossing, 1728." *Maryland Historical Magazine* 50:3 (September 1955): 195-202.

Bendix, Regina. *In Search of Authenticity: The Formation of Folklore Studies*. Madison: University of Wisconsin Press, 1997.

Bennett, Jenny, ed. *Sailing Into the Past: Learning from Replica Ships*. Barnsley UK: Seaforth Publishing, 2009.

Berry, Stephen R. *A Path in the Mighty Waters: Shipboard Life & Atlantic Crossings to the New World*. New Haven, CT: Yale University Press, 2015.

Bijker, Wiebe, Thomas P. Hughes, and Trevor Pinch, eds. *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. Anniversary Edition. Cambridge, MA: MIT Press, 2012. Kindle Edition.

Blake, John. *The Sea Chart: The Illustrated History of Nautical Maps and Navigational Charts.* Annapolis, MD: Naval Institute Press, 2009.

Blue, Lucy, Fred Hocker and Anton Englert, eds., *Connected by the Sea: Proceedings of the Tenth International Symposium on Boat and Ship Archaeology, Roskilde 2003*. Oxford: Oxbow Books, 2006.

Bolster, W. Jeffrey. *Black Jacks: African American Seamen in the Age of Sail.* Cambridge, MA: Harvard University Press, 1997.

Boucher, Philip P. *France and the American Tropics to 1700: Tropics of Discontent?* Baltimore: Johns Hopkins University Press, 2008.

Bowen, Frank C. "The Development of the Sloop." *Royal United Service Institution Journal* 88 (February-November 1943): 102-106.

Bowen, H.V., Elizabeth Manke, John G. Reid, eds. *Britain's Oceanic Empire: Atlantic and Indian Ocean Worlds, c. 1550-1850*. Cambridge: Cambridge University Press, 2012.

Breen, T. H. "An Empire of Goods: The Anglicization of Colonial America, 1690-1776." *Journal of British Studies* 25:4 (October 1986): 467-499.

Bruyns, Willem F.J. Mörzer. "Research in the History of Navigation: Its Role in Maritime History." *International Journal of Maritime History* 21:2 (December 2009): 261-287.

Burningham, Nick and Adriaan de Jong. "The *Duyfken* Project: an Age of Discovery ship reconstruction as experimental archaeology." *International Journal of Nautical Archaeology* 26:4 (November 1997): 277-292.

Burningham, Nick. “Early Seventeenth-Century Ships.” In Jenny Bennett, ed. *Sailing Into The Past: Learning from Replica Ships,* 100-119. Barnsley UK: Seaforth Publishing, 2009.

Burningham, Nicholas. “Experimental Maritime Archaeology.” In Claire Smith, ed. *Encyclopedia of Global Archaeology,* 2716-2718. New York: Springer, 2014.

Burningham, Nick. “Learning to Sail the *Duyfken* Replica.” *International Journal of Nautical Archaeology* 30:1 (April 2001); 74-85.

_____. “Tallships and Replicas.” *Maritime Studies* 3 (2000) 110 Maritime Studies 19. Accessed at http://www.austlii.edu.au/au/journals/MarStudies/2000/3.html. 5 May 2015.

Butel, Paul. *The Atlantic*. Trans. Iain Hamilton Grant. London: Routledge, 1999.

_____. *Histoire des Antilles françaises, XVII^{e} –XX^{e} siècle*. Paris: Perrin, 2002.

Butler, Joseph T., ed. *The European Origins of the Small Watercraft of the United States and Canada*. Thibodeaux, LA: Center for Traditional Louisiana Boatbuilding and the Museum Small Craft Association, 1992.

Cairns, Kathleen V. and Elaine Leslie Silverman. *Treasures: The Stories Women Tell About the Things They Keep*. Calgary: University of Calgary Press, 2004.

Cann, B. “Notes on the effect of catharpings on shroud tension and mast displacement.” *Mariner’s Mirror* 98:2 (May 2012): 193-199.

Canny, Nicholas. “Writing Atlantic History; or, Reconfiguring the History of Colonial British America.” *The Journal of American History* 86:3, *The Nation and Beyond: Transnational Perspectives on United States History: A Special Issue* (December 1999): 1093-1114.

Carrington, Selwyn H.H. “The American Revolution and the British West Indies’ Economy.” *Journal of Interdisciplinary History* 27:4 (Spring I987): 823-850.

Castro, Filipe V. *The Pepper Wreck: A Portuguese Indiaman at the Mouth of the Tagus River*. College Station, TX: TAMU Press, 2005.

_____. “Rising and Narrowing: 16th-century Geometric Algorithms used to Design the Bottom of Ships in Portugal.” *International Journal of Nautical Archaeology* 36:1 (March 2007): 148-154.

Cecelski, David S. *The Waterman’s Song: Slavery and Freedom in Maritime North Carolina*. Chapel Hill: University of North Carolina Press, 2001.

Chapelle, Howard I. *American Small Sailing Craft: Their Design, Development and Construction*. New York: Norton, 1951.

_____.*The Search for Speed Under Sail, 1700-1855*. New York: Norton, 1984.

Cheney, Paul. *Revolutionary Commerce: Globalization and the French Monarchy*. Cambridge, MA: Harvard University Press, 2010.

Chet, Guy. *The Ocean is a Wilderness: Atlantic Piracy and the Limits of State Authority, 1688-1856*. Amherst: University of Massachusetts Press, 2014.

Christopher, Emma. *Slave Ship Sailors and their Captive Cargoes*. Cambridge: Cambridge University Press, 2006.

Clifford, Sheila Alicia. "An Analysis of the Port Royal Shipwreck and its Role in the Maritime History of Seventeenth-Century Port Royal, Jamaica." Master's thesis, Texas A&M University, 1993.

Clowes, G.S. Laird. *Sailing Ships: Their History and Development*. Two volumes. London: Her Majesty's Stationery Office, 1952.

Clowse, Converse D. "Shipowning and Shipbuilding in Colonial South Carolina: An Overview." *American Neptune* 46 (1984): 221-244.

Coates, John et al. "Experimental Boat and Ship Archaeology: Principles and Methods." *International Journal of Nautical Archaeology* 24:4 (November 1995): 293-301.

Coclanis, Peter A. "*Drang Nach Osten*: Bernard Bailyn, the World-Island, and the Idea of Atlantic History," *Journal of World History* 111:3 (June 2006): 741-757.

_____. "In Retrospect: McCusker and Menard's *Economy of British America*." *Reviews in American History* 30:2 (June 2002): 183-197.

_____, ed. *The Atlantic Economy During the Seventeenth and Eighteenth Centuries*. Columbia: University of South Carolina Press, 2005.

Combs, Edwin L. III. "Trading in Lubberland: Maritime Commerce in Colonial North Carolina." *The North Carolina Historical Review* 80:1 (January 2003): 1-27.

Cowan, Ruth Schwartz. "The Consumption Junction: A Proposal for Research Strategies in the Sociology of Technology." In Wiebe Bijker, Thomas P. Hughes, and Trevor Pinch, eds., *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology,* 253-272. Anniversary Edition. Cambridge, MA: MIT Press, 2012. Kindle Edition.

Craig, Robin. "Printed guides for master mariners as a source of productivity change in shipping, 1750-1914." In *British Tramp Shipping, 1750-1914.* Research in Maritime History Number 24, 121-136. St. John's, Canada: International Maritime Economic History Association, 2003.

Creighton, Margaret S. and Lisa Norling, eds. *Iron Men, Wooden Women: Gender and Seafaring in the Atlantic World, 1700-1920.* Baltimore, MD: Johns Hopkins University Press, 1996.

Crittenden, Charles C. *Commerce in Colonial North Carolina, 1763-1789*. New Haven, CT: Yale University Press, 1936.

Cromley, Elizabeth Collins and Carter L. Hudgins, eds. *Gender, Class, and Shelter: Perspectives in Vernacular Architecture*. Volume 5. Knoxville: University of Tennessee Press, 1995.

Crosby, Alfred W. *Ecological Imperialism: The Biological Expansion of Europe, 900-1900*. Cambridge: Cambridge University Press, 2004.

Crowther, Simeon J. "The Shipbuilding Output of the Delaware Valley, 1722-1776." *Proceedings of the American Philosophical Society*, 117:2 (April 10, 1973): 90-104.

Crumlin-Pedersen, Ole. ""Experimental archaeology and ships—principles, problems and examples." In Lucy Blue et al., eds., *Connected by the Sea: Proceedings of the Tenth International Symposium on Boat and Ship Archaeology, Roskilde, 2003,* 1-7. Oxford: Oxbow Books, 2006.

Curtin, Philip. *The Rise and Fall of the Plantation Complex: Essays in Atlantic History,* 2nd ed. Cambridge: Cambridge University Press, 1998.

Davis, Ralph. *The Rise of the English Shipping Industry in the Seventeenth and Eighteenth Centuries*. London: Macmillan, 1962. Reprint Newton Abbott: David & Charles, 1972. Re-issue St. John's, Canada: International Maritime Economic History Association, Research in Maritime History Number 48, 2012.

Decencière, P. "Three French Sailing Ship Performance Trials." *Mariner's Mirror* 94:3 (August 2008): 276-284.

Deetz, James. *In Small Things Forgotten: An Archaeology of Early American Life,* Revised Edition. New York: Doubleday, 1996.

Devine, T.M. and Gordon Jackson, eds. *Glasgow, Volume I: Beginnings to 1830*. Manchester UK: Manchester University Press, 1995.

Donovan, Arthur. "The Impact of Containerization from Adam Smith to the 21st Century." *Review of Business* 25:3 (Fall 2004): 10-15.

Dorson, Richard M., ed. *Handbook of American Folklore*. Bloomington: Indiana University Press, 1983.

Dunn, Richard S. *Sugar and Slaves: The Rise of the Planter Class in the English West Indies, 1624-1713*. Chapel Hill: University of North Carolina Press, 1972.

Earle, Peter. *The Sack of Panamá: Captain Morgan and the Battle for the Caribbean*. New York: Thomas Dunne Books, 2007.

Elliott, John H. *Empires of the Atlantic World: Britain and Spain in America, 1492-1830*. New Haven, CT: Yale University Press, 2007.

Englert, Anton. "Trial voyages as a method of experimental archaeology: The aspect of speed." In Lucy Blue et al., eds., *Connected by the Sea: Proceedings of the Tenth International Symposium on Boat and Ship Archaeology, Roskilde 2003,* 35-42. Oxford: Oxbow, 2006.

Enthoven, Victor. "That Abominable Nest of Pirates: St. Eustasius and the North Americans, 1680-1780." *Early American Studies: An Interdisciplinary Journal* 10:2 (Spring 2012): 239-301.

Eriksson, Niklas. "Lodging in a Fluitship: The Material Setting of Everyday Life on Board *Anna Maria* of 1694." *Journal of Maritime Archaeology* 10.1007/s11457-015-9134-3. http://dx.doi.org/10.1007/s11457-015-9134-3 (March 2015): 1-19.

Evans, Amanda M. "Defining Jamaica Sloops: A Preliminary Model for Identifying an Abstract Concept." *Journal of Maritime Archaeology* 2:2 (December 2007): 83-92.

Fawcett, Howard H., Jr. "Sailing the Jamestown Ships." *Transactions of the Society of Naval Architects and Marine Engineers* (1958): 46-66.

Feldbæk, Ole. "Danish North Atlantic Shipping, 1720-1814." *International Journal of Maritime History* 10:1 (June 1998): 105-120.

Ferreiro, Larrie D. *Ships and Science: The Birth of Naval Architecture in the Scientific Revolution, 1600-1800*. Cambridge, MA: MIT Press, 2006.

Fischer, David Hackett. *Albion's Seed: Four British Folkways In America*. Oxford: Oxford University Press, 1991.

Flatman, Joe. "Cultural biographies, cognitive landscapes and dirty old bits of boat: 'theory' in maritime archaeology." *International Journal of Nautical Archaeology* 32:2 (2003): 143-157.

_____ and Mark Staniforth. "Historical maritime archaeology." In Dan C. Hicks and Mary Beaudry, eds., *The Cambridge Companion to Historical Archaeology,* 168-190. Cambridge: Cambridge University Press, 2006.

Forty, Adrian. *Objects of Desire: Design and Society since 1750*. London: Thames & Hudson, 1986.

Fox, Robert, ed. *Technological Change: Methods and Themes in the History of Technology*. Amsterdam: Harwood, 1996.

French, Christopher J. "The Longevity of Ships in Colonial Trade: Some Further Evidence." *International Journal of Maritime History* 3:1 (June 1991): 155-163.

_____. "Productivity in the Atlantic shipping industry: a quantitative study." *Journal of Interdisciplinary History* 17:3 (Winter 1987): 613-638.

Friel, Ian. *The British Museum Maritime History of Britain and Ireland, c. 400-2001*. London: British Museum Press, 2003.

Games, Alison. "Atlantic History and Interdisciplinary Approaches." *William & Mary Quarterly* Third Series, 65:1 (January 2008): 167-170.

_____. "Atlantic History: Definitions, Challenges, and Opportunities." *American Historical Review* 111:3 (June 2006): 741-757.

_____. *The Web of Empire: English Cosmopolitans in an Age of Expansion, 1500-1660*. Oxford: Oxford University Press, 2008.

Gardiner, Robert, ed. *Cogs, Caravels and Galleons: The Sailing Ship 1000-1650.* London: Conway Maritime Press, 1994.

_____, ed. *The Heyday of Sail: The Merchant Sailing Ship, 1650-1830.* Edison, NJ: Chartwell Books, 2002.

_____, ed. *The Line of Battle: The Sailing Warship 1650-1840*. London: Conway Maritime Press, 1992.

Gilfillan, S.C. *Inventing the Ship*. Chicago: Follett, 1935.

_____. *The Sociology of Invention*. Chicago: Follett, 1935. Reprint MIT Press, 1970.

Gilje, Paul. *Liberty on the Waterfront: American Maritime Culture in the Age of Revolution*. Philadelphia: University of Pennsylvania Press, 2004.

Gillingham, Harold E. "Some Colonial Ships Built in Philadelphia." *The Pennsylvania Magazine of History and Biography* LVI (1932): 156-186.

Gillmer, Thomas C. *A History of Working Watercraft of the Western World*. 2nd ed. Camden, ME: International Marine, 1994.

Glassie, Henry H. *Material Culture*. South Bend: Indiana University Press, 1999.

_____. *Folk Housing in Middle Virginia: A Structural Analysis of Historic Artifacts*. Knoxville: University of Tennessee Press, 1975.

_____. *The Spirit of Folk Art*. New York: Abrams, 1989.

Glete, Jan. *Navies and Nations: Warships, Navies and State Building in Europe and America, 1500-1860*. Stockholm: Almqvist and Wiksell International, 1993.

Goldenberg, Joseph A. *Shipbuilding in Colonial America*. Charlottesville: University of Virginia Press for the Mariners' Museum, 1976.

Greene, Jack P. and Philip Morgan. *Atlantic History: A Critical Reappraisal*. Oxford: Oxford University Press, 2009.

Hamling, Tara and Catherine Richardson, eds. *Everyday Objects: Medieval and Early Modern Material Culture and its Meanings*. Farnham UK: Ashgate Press, 2010.

Hancock, David. *Citizens of the World: London Merchants and the Integration of the British Atlantic Community.* Cambridge: Cambridge University Press, 1997.

_____. *Oceans of Wine: Madeira and the Emergence of American Trade and Taste*. New Haven, CT: Yale University Press, 2009.

Harding, Richard. *The Emergence of Britain's Global Naval Supremacy: The War of 1739-1748*. Woodbridge, UK: Boydell, 2010.

_____. *Seapower and Naval Warfare, 1650-1830*. London: UCL Press, 1999.

Harland, John. "Catharpings, swifters, and Bentinck shrouds." *Mariner's Mirror* 95:3 (2009): 328-336.

_____. "The Early History of the Steering Wheel." *Mariner's Mirror* 58:1 (1972): 41-68.

_____. *Seamanship in the Age of Sail.* Annapolis, MD: Naval Institute Press, 1984.

Harvey, Karen, ed. *History and Material Culture: A Student's Guide to Approaching Alternative Sources.* London: Routledge, 2009.

Hattendorf, John B., ed. *Maritime History Volume 2: The Eighteenth Century and the Classic Age of Sail.* Malabar, FL: Krieger Publishing Company, 1997.

Hedges, James. *The Browns of Providence Plantations: Colonial Years*. Cambridge, MA: Harvard University Press, 1952.

Hicks, Dan and Mary C. Beaudry, eds. *The Oxford Handbook of Material Culture Studies*. Oxford: Oxford University Press, 2010.

Hicks, Robert. *Voyage to Jamestown: Practical Navigation in the Age of Discovery*. Annapolis, MD: Naval Institute Press, 2011.

Hocker, Fred. "The Clydesdale Plantation Vessel: Savannah River, South Carolina." In *Beneath the Seven Seas*, edited by George F. Bass, 192-193. New York: Thames & Hudson, 2005.

_____. “The Clydesdale Plantation Vessel Project: 1992 Field Report.” *Institute of Nautical Archaeology Quarterly* 19:4 (Winter 1992): 12-16.

Holly, H.H. “Sparrow-Hawk: A Seventeenth-Century Vessel in Twentieth-Century America.” Pilgrim Society Booklet Series. Boston: Nimrod Press, 1969.

Holmes, Sir George C.V. *Ancient and Modern Ships, Part I: Wooden Sailing Ships*. London: His Majesty’s Stationery Office, 1906.

Hornsby, Stephen J. *British Atlantic, American Frontier: Spaces of Power in Early Modern British America*. Lebanon, NH: University Press of New England, 2004.

_____. *Surveyors of Empire: Samuel Holland, J.F.W. Des Barres, and the Making of the Atlantic Neptune*. Montreal: McGill-Queen’s University Press, 2011.

Hoving, Albert. “Early Shipbuilding Literature in the Dutch Republic.” *Nautical Research Journal* 58:3 (Autumn 2013): 163-174.

_____. “Early Shipbuilding Literature in the Dutch Republic, Part 2.” *Nautical Research Journal* 58:4 (Winter 2013): 253-258.

_____. “The Fluit.” *Nautical Research Journal* 42:1 (March 1997): 24-35.

_____. “Seagoing Ships of the Netherlands.” In Robert Gardiner, ed., *The Heyday of Sail: The Merchant Sailing Ship, 1650-1830* in the Conway’s History of the Ship series, 47-51. Edison, NJ: Chartwell Books, 2002.

_____. *17th Century Dutch Merchant Ships: Text, Photos, and Plans for the Ship Modeler*. Florence, OR: Sea Watch Books, 2014.

Howse, Derek. *Greenwich Time and the Longitude*. Oxford: Oxford University Press, 2003.

Hughes, Thomas P. “The Evolution of Large Technological Systems.” In Wiebe Bijker, Thomas P. Hughes, and Trevor Pinch, eds., *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology.* Anniversary Edition, 45-76. Cambridge, MA: MIT Press, 2012. Kindle Edition.

Hyde, Francis E. *Liverpool and the Mersey: An Economic History of a Port, 1700-1970*. Newton Abbot UK: David and Charles, 1971.

Jackson, Gordon. *The History and Archaeology of Ports*. Tadworth UK: World’s Work, 1983.

Jackson, J.B. *Discovering the Vernacular Landscape*. New Haven, CT: Yale University Press, 1984.

Jarvis, Adrian, ed. *Port and Harbour Engineering*. Aldershot UK: Ashgate, 1998.

Jarvis, Michael J. "'The Fastest Vessels in the World': The Origin and Evolution of the Bermuda Sloop, 1620-1800." *Bermuda Journal of Archaeology and Maritime History* 7 (1995): 31-50.

_____. *In The Eye Of All Trade: Bermuda, Bermudians, and the Maritime Atlantic World, 1680-1783.* Chapel Hill: University of North Carolina Press, 2010.

Johnson, Donald S. *Charting the Sea of Darkness: The Four Voyages of Henry Hudson*. Camden, ME: International Marine, 1993.

Jones, Michael Owen. *Craftsman of the Cumberlands: Tradition and Creativity*. Lexington: University Press of Kentucky, 1989.

Karras, Alan. *Smuggling: Contraband and Corruption in World History*. London: Rowman & Littlefield, 2010.

_____. "Smuggling and its Malcontents." In *Interactions: Transregional Perspectives on World History*, edited by Jerry H. Bentley, Renate Bridenthal, and Anand A. Yang, 135-149. Honolulu: University of Hawai'i Press, 2005.

———. "Transgressive Exchange: Rewriting Atlantic Law in the Eighteenth-Century Caribbean." Paper presented at Seascapes, Littoral Cultures, and Trans-Oceanic Exchanges, Library of Congress, Washington D.C., February 12-15, 2003.

Kingston, Christopher. Review of Guy Chet's *The Ocean is a Wilderness: Atlantic Piracy and the Limits of State Authority, 1688-1856*. *Journal of Economic History* 75:3 (2015): 933-936.

Kinkel, Sarah. "The King's Pirates? Naval Enforcement of Imperial Authority, 1740-76." *The William and Mary Quarterly* Third Series 71:1 (January 2014): 3-34.

Kirshenblatt-Gimblett, Barbara. "Objects of Memory: Material Culture as Life Review." In Eliott Oring, ed. *Folk Groups and Folklore Genres: A Reader,* 329-338. Logan, UT: Utah State University Press, 1989.

Klooster, Wim. *Illicit Riches: Dutch Trade in the Caribbean, 1648-1795*. Leiden: KITLV Press, 1998.

_____. "Inter-Imperial Smuggling in the Americas, 1600-1800." In Bernard Bailyn and Patricia L. Denault, eds., *Soundings in Atlantic History: Latent Structures and Intellectual Currents, 1500-1830*, 141-180. Cambridge, MA: Harvard University Press, 2009.

Knight, Roger. “Devil bolts and deception? Wartime naval shipbuilding in private shipyards,1739-1815.” *Journal for Maritime Research* 5:1 (April 2003): 34-51.

Koot, Christian J. *Empire at the Periphery: British Colonists, Anglo-Dutch Trade, and the Development of the British Atlantic, 1621-1713.* New York: New York University Press, 2011.

Kristiansen, Kristian. “Genes versus agents. A discussion of the widening theoretical gap in archaeology.” *Archaeological Dialogues* 11:2 (December 2004): 77–99.

_____. “Discourse and dialogue. Some observations and further reflections.” *Archaeological Dialogues* 11:2 (December 2004): 114-132.

Kupperman, Karen Ordahl. “Before 1607.” *William and Mary Quarterly* Third Series, 72:1 (January 2015): 3-24.

Lane, Frederic. «Progrès technologique et productivité dans les transports maritimes de la fin du Moyen Age au début des Temps Modernes», *Revue Historique* 251 (1974): 277-302.

Larkin, Jack. *The Reshaping of Everyday Life, 1790-1840*. New York: Harper Collins, 1988.

Lavery, Brian. *The Arming and Fitting of English Ships of War 1600-1815*. Annapolis, MD: Naval Institute Press, 1989.

_____. *The Colonial Merchantman* Susan Constant *1605.* Annapolis, MD: Naval Institute Press, 1988.

Leeson, Peter. *The Invisible Hook: the Hidden Economics of Piracy*. Princeton, NJ: Princeton University Press, 2009.

Leggett, Don and Richard Dunn, eds. *Re-inventing the Ship: Science, Technology and the Maritime World, 1800-1918.* Farnham UK: Ashgate, 2012.

Lemmers, Alan and Ab Hoving. “Drawing the Line: Or Why the Rotterdam Shipwrights Would Not Adopt the Amsterdam (English) Drafting Techniques.” *Nautical Research Journal* 52:2 (Summer 2007): 67-81.

Leonard, Adrian. Review of Guy Chet’s *The Ocean is a Wilderness: Atlantic Piracy and the Limits of State Authority, 1688-1856. International Journal of Maritime History* 27:3 (August 2015): 583-584.

Leone, Mark P. and Parker Potter Jr., eds. *The Recovery of Meaning: Historical Archaeology in the Eastern United States*. Washington, DC: Smithsonian, 1988.

Loewen, Brad. “Ships and Shipbuilding / *Navires et Construction Navale:* Recent Advances in Ship History and Archaeology, 1450-1650: Hull Design, Regional Typologies and Wood Studies.” *Material Culture Review/Revue de la culture matérielle* 48 (Fall/Automne 1998). Available at : http://journals.hil.unb.ca/index.php/MCR/article/view/17791/22170. Accessed 10 February 2015.

Maarleveld, Thijs. “Type or technique. Some thoughts on boat and ship finds as indicative of cultural traditions.” *International Journal of Nautical Archaeology* 24:1 (1995): 3-7.

MacGregor, David R. *Fast Sailing Ships: Their Design and Construction, 1775-1875.* Lymington UK: Nautical Pub. Co. 1973.

_____. *Merchant Sailing Ships 1775-1815: Their Design and Construction.* Watford UK: Argus Books, 1980.

_____. *The Schooner: Its Design and Development from 1600 to the Present*. Barnsley UK: Pen & Sword Books, 2003.

MacLeod, Christine. "Concepts of Invention and the Patent Controversy in Victorian Britain." In Robert Fox, ed., *Technological Change: Methods and Themes in the History of Technology,* 137-153. Amsterdam: Harwood, 1996.

Magra, Christopher P. Review of Guy Chet’s *The Ocean is a Wilderness: Atlantic Piracy and the Limits of State Authority, 1688-1856*. *American Historical Review* 120:3 (June 2015): 969.

Mandelblatt, Bertie. “A Transatlantic Commodity: Irish Salt Beef in the French Atlantic World.” *History Workshop Journal* Volume 63 (2007): 18-47.

Marquardt, Karl Heinz. *Eighteenth Century Rigs and Rigging*. London: Conway Maritime Press via ANOVA, 1993.

_____. *The Global Schooner: Origins, Development, Design and Construction, 1695-1845*. Annapolis, MD: Naval Institute Press, 2003.

Martin, Ann Smart. “Makers, Buyers, and Users: Consumerism as a Material Culture Framework.” *Winterthur Portfolio* 28:2/3 (1993): 141-157.

_____ and J. Ritchie Garrison, eds. *Material Culture: The Shape of the Field*. Knoxville: University of Tennessee Press, 1997.

Marzagalli, Silvia. “The French Atlantic.” *Itinerario* 23:2 (July 1999): 70-83.

McCusker, John J. “Colonial Tonnage Measurement: Five Philadelphia Merchant Ships as a Sample.” *The Journal of Economic History* 27:1 (March 1967): 82-91.

_____ and Russell R. Menard. *The Economy of British America, 1607-1789*. Chapel Hill: University of North Carolina Press, 1991.

_____. *Essays in the Economic History of the Atlantic World*. London: Routledge, 1997. Ebrary edition.

_____. "The Pennsylvania Shipping Industry in the Eighteenth Century." Unpublished bound typescript, Historical Society of Pennsylvania, Philadelphia, 1973.

_____. *Rum and the American Revolution: The Rum Trade and the Balance of Payments of the Thirteen Continental Colonies*. London: Routledge, 1997.

McDonald, Roderick A. and Richard B. Sheridan, eds. *West Indies Accounts: Essays on the History of the British Caribbean and the Atlantic Economy*. Kingston, Jamaica: University of the West Indies Press, 2002.

McGowan, Alan. *The Century Before Steam: The Development of the Sailing Ship 1700-1820*. London: Her Majesty's Stationery Office, 1980.

_____. *Tiller and Whipstaff: The Development of the Sailing Ship, 1400-1700*. London: National Maritime Museum, 1981.

McGrail, Seán. "Experimental Archaeology: Replicas and Reconstructions." In Jenny Bennett, ed., *Sailing Into the Past: Learning From Replica Ships,* 16-23. Barnsley UK: Seaforth, 2009.

_____. "Replicas, reconstructions and floating hypotheses." *International Journal of Nautical Archaeology* 21:4 (November 1992): 353-355.

McIlvenna, Noeleen. *A Very Mutinous People: The Struggle for North Carolina, 1660-1713*. Chapel Hill: University of North Carolina Press, 2009.

McMullen, Drew with Captain Robert Brittain. "The Schooner *Sultana*." In Jenny Bennett, ed., *Sailing Into the Past: Learning From Replica Ships*, 150-161. Barnsley UK: Seaforth, 2009.

McNeill, J.R. *Mosquito Empires: Ecology and War in the Greater Caribbean, 1620-1914*. Cambridge: Cambridge University Press, 2010.

Menard, Russell R. "Transport Costs and Long-Range Trade, 1300-1800: Was there a European 'transport Revolution' in the Early Modern Era?" In James D. Tracy, ed., *The Political Economy of Merchant Empires,* 228-275. Cambridge: Cambridge University Press, 1991.

Merrens, Harry Roy. *Colonial North Carolina in the Eighteenth Century: A Study in Historical Geography*. Chapel Hill: University of North Carolina Press, 1964.

Merton, Robert K. *Science, Technology and Society in Seventeenth-Century England*. New York: Howard Fertig, 1970.

Middlebrook, Louis F. "The Ship Mary of Philadelphia, 1740." *Pennsylvania Magazine of History and Biography*, LVIII (April 1934): 127-151.

Miller, Daniel. *Material Culture: Why Some Things Matter*. Chicago: University of Chicago Press, 1998.

Mims, Stewart L. *Colbert's West India Policy*. New Haven, CT: Yale University Press, 1912. Google books facsimile.

Minchinton, Walter E. "Characteristics of British Slaving Vessels, 1698-1775." *The Journal of Interdisciplinary History* 20:1 (Summer 1989): 53-81.

Mintz, Sidney W. *Sweetness and Power: The Place of Sugar in Modern History*. New York: Penguin Books, 1985.

Mokyr, Joel. *The Lever of Riches: Technological Creativity and Economic Progress*. Oxford: Oxford University Press, 1990. Kindle Edition.

_____. *Twenty-Five Centuries of Technological Change: An Historical Survey*. London: Taylor & Francis, 2007.

_____. "Evolution and Technological Change: A New Metaphor For Economic History?" In Robert Fox, ed. *Technological Change: Methods and Themes in the History of Technology*, 63-83. Amsterdam: Harwood, 1996.

Moore, David and Corey Malcom. "Seventeenth-Century Vehicle of the Middle Passage: Archaeological and Historical Investigations on the *Henrietta Marie* Shipwreck Site." *International Journal of Historical Archaeology* 12:1 (January 2008): 20-38.

Morgan, Kenneth. *Bristol & the Atlantic Trade in the Eighteenth Century*. Cambridge: Cambridge University Press, 1993.

Morgan, Philip D. "Maritime Slavery." *Slavery & Abolition* 31:3 (September 2010): 311-326.

Morris, E.P. *The Fore-And-Aft Rig in America*. New Haven, CT: Yale University Press, 1927.

Morris, John W., Gordon P. Watts Jr., and Marianne Franklin. "The Comparative Analysis of Eighteenth-Century Vessel Remains in the Archaeological Record: A Synthesized Theory of Framing Evolution." *Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference 1995,* Society for Historical Archaeology.

Mukherjee, Rila, ed. *Networks in the First Global Age, 1400-1800*. Delhi: Primus Books, 2011.

Mulcahy, Matthew. *Hurricanes and Society in the British Greater Caribbean, 1624-1783*. Baltimore, MD: Johns Hopkins University Press, 2006.

Norling, Lisa. *Captain Ahab had a Wife: New England Women and the Whalefishery, 1720-1870.* Chapel Hill: University of North Carolina Press, 2000.

North, Douglass C. “Sources of Productivity Change in Ocean Shipping, 1600-1850.” *Journal of Political Economy* 76:5 (September-October 1968): 953-970.

Ojala, Jari. "Productivity and Technological Change in Eighteenth- and Nineteenth-Century Sea Transport: A Case Study of Sailing Ship Efficiency in Kokkola, Finland, 1721-1913." *International Journal of Maritime History* 9:1 (June 1997): 93-123.

Paine, Lincoln. *The Sea and Civilization: A Maritime History of the World*. New York: Knopf, 2013. Kindle Edition.

Palmer, Colin. “Measuring Performance Under Sail.” In Jenny Bennett, ed., *Sailing Into the Past: Learning From Replica Ships*, 24-32. Barnsley UK: Seaforth, 2009.

_____. “Reflections on the Balance of Traditional Sailing Vessels.” *International Journal of Nautical Archaeology* 38:1 (2009): 90-96.

Pares, Richard. *Yankees and Creoles: The Trade Between North America and the West Indies Before the American Revolution*. Hamden, CT: Archon Books, 1956.

Parrott, Daniel S. *Tall Ships Down: The Last Voyages of the* Pamir, Albatross, Marques, Pride of Baltimore, *and* Maria Asumpta. Camden, ME: International Marine/McGraw-Hill, 2003.

Parry, J.H. *Trade and Dominion: The European Overseas Empires in the Eighteenth Century*. London: Weidenfeld and Nicolson, 1971.

Parthesius, Robert. *Dutch Ships in Tropical Waters: The Development of the Dutch East India Company (VOC) Shipping Network in Asia, 1595-1660.* Amsterdam: Amsterdam University Press, 2010.

Phillips, Carla Rahn. “The Caravel and the Galleon.” In Robert Gardiner, ed., *Cogs, Caravels, and Galleons: The Sailing Ship 1000-1650,* 91-114. Annapolis, MD: Naval Institute Press, 1994.

Pitt, Ken and Damian M. Goodburn. “18th- and 19th-Century Shipyards at the South-East Entrance to the West India Docks, London.” *International Journal of Nautical Archaeology* 32:2 (October 2003): 191-209.

Pocius, Gerald L. *A Place to Belong: Community Order and Everyday Space in Calvert, Newfoundland*. Montreal: McGill-Queen's University Press, 1991.

_____, ed. *Living in a Material World: Canadian and American Approaches to Material Culture.* Issue 19 of Social and Economic Papers. St. John’s: Institute of Social and Economic Research, Memorial University of Newfoundland, 1991.

Pope, Peter E. *Fish Into Wine: The Newfoundland Plantation in the Seventeenth Century*. Chapel Hill: University of North Carolina Press, 2004.

Price, Jacob M. “What Did Merchants Do? Reflections on English Overseas Trade, 1660-1790.” *The Journal of Economic History* 49:2 (June 1989): 267-284.

_____. *Tobacco in Atlantic Trade: The Chesapeake, London, and Glasgow, 1675-1775*. Brookfield, VT: Variorum, 1995.

Pomeranz, Kenneth. *The Great Divergence: China, Europe, and the Making of the Modern World Economy*. Princeton, NJ: Princeton University Press, 2001.

_____ and Steven Topik. *The World That Trade Created: Society, Culture, and the World Economy, 1400 to the Present*. Armonk, NY: M.E. Sharpe, 1999.

Rankin, Laird. *The Return of the Nonsuch: The Ship That Launched An Empire*. Winnipeg: Heartland Associates, 2004.

Rediker, Marcus. *Between the Devil and the Deep Blue Sea: Merchant Seamen, Pirates and the Anglo-American Maritime World, 1700-1750.* Cambridge: Cambridge University Press, 1987.

_____. *The Slave Ship: A Human History*. New York: Viking, 2007. Kindle Edition.

Rees, Gareth. “Copper Sheathing: An Example of Technological Diffusion in the English Merchant Fleet.” *Journal of Transport History* New Series, 1 (1971-1972): 85-94.

Rhoden, Nancy, ed. *English Atlantics Revisited*. Kingston ON: McGill-Queens University Press, 2007.

Riess, Warren C. with Sheli O. Smith. *The Ship That Held Up Wall Street*. College Station, TX: TAMU Press, 2015.

Robb, John. “Agency. A personal view.” *Archaeological Dialogues* 11:2 (December 2004): 103-107.

Rodger, N.A.M. *The Command of the Ocean* London: Penguin Books, 2004.

_____. “Navies and the Enlightenment.” In Pieter van der Merwe, ed., *Science and the French and British Navies, 1700-1850,* 5-23. Greenwich UK: National Maritime Museum, 2003.

_____. *The Wooden World: An Anatomy of the Georgian Navy.* Glasgow: Collins, 1986.

Rosecrance, Richard. *The Rise of the Trading State: Commerce and Conquest in the Modern World*. New York: Basic Books, 1986.

Rosenberg, Nathan. "Factors Affecting the Diffusion of Technology." *Explorations in Economic History* 10:1 (Fall 1972): 3-33.

_____ and L.E. Birdzell. *How The West Grew Rich: The Economic Transformation of the Industrial World*. New York: Basic Books, 1986.

Rossano, Geoffrey L. "Launching Prosperity: Samuel Townsend and the Maritime Trade of Colonial Long Island, 1747-1773." *American Neptune* 48 (1988): 37-43.

Schlereth, Thomas J. *Material Culture Studies in America*. Nashville, TN: AASLH, 1982.

Shennan, Stephen. "Culture, society and evolutionary theory." *Archaeological Dialogues* 11:2 (December 2004): 107-114.

Shepherd, James F. and Gary M. Walton. *Shipping, Maritime Trade, and the Economic Development of Colonial North America*. Cambridge: Cambridge University Press, 1972.

Sheridan, Richard B. *Sugar and Slavery: An Economic History of the British West Indies, 1623-1775*. Kingston, Jamaica: University of the West Indies Press, 2000.

Shukla, Pravina. "The Study of Dress and Adornment as Social Positioning." *Material History Review* 61 (2005): 4-16.

Sims, Martha C. and Martine Stephens. *Living Folklore: An Introduction to the Study of People and Their Traditions*. Logan: Utah State University Press, 2005.

Smelser, Marshall and William L. Davisson. "The Longevity of Colonial Ships." *American Neptune* 30 (1973): 16-19.

Smith, Claire, ed. *Encyclopedia of Global Archaeology*. New York: Springer, 2014.

Smith, Merril D. *Sex and Sexuality in Early America*. New York: New York University Press, 1998.

Souza, G.B. "Convergence before Divergence: Global Maritime Economic History and Material Culture." *International Journal of Maritime History* 17:1 (June 2005): 17-27.

St. George, Robert Blair, ed. *Material Life in America, 1600-1860*. Boston: Northeastern University Press, 1988.

_____. *Conversing by Signs: Poetics of Implication in Colonial New England*. Chapel Hill: University of North Carolina Press, 1998.

Stammers, Michael. "Slipways and Steamchests: the Archaeology of 18th- and 19th Century Wooden Merchant Shipyards in the United Kingdom." *International Journal of Nautical Archaeology* 28:3 (August 1999): 253–264.

Starkey, David J. "Voluntaries and sea robbers: A review of the academic literature on privateering, corsairing, buccaneering and piracy." *Mariner's Mirror* 97:1 (February 2011): 127-147.

Stedall, Jacqueline. "Notes made by Thomas Harriot (1560-1621) on ships and shipbuilding." *Mariner's Mirror* 99:3 (2013): 325-327.

Steele, Ian K. *The English Atlantic, 1675-1740: An Exploration of Communication and Community*. Oxford: Oxford University Press, 1986.

Stewart-Brown, R. *Liverpool Ships in the Eighteenth Century*. Liverpool and London: University Press of Liverpool/Hodder & Stoughton Ltd., 1932.

Summers, John. "In Small Things Remembered: Historic Watercraft and Canada's Maritime Heritage." *The Northern Mariner/Le Marin du Nord* 2:1 (January/janvier 1992): 15-23.

Swanson, Carl E. *Predators and Prizes: American Privateering and Imperial Warfare, 1739-1748.* Columbia: University of South Carolina Press, 1991.

_____. "'To Procure a Good Freight:' Charles Town Merchants in the Eighteenth Century." *International Journal of Maritime History* 20:2 (December 2008): 111-142.

Taylor, David A. *Boat Building in Winterton, Trinity Bay, Newfoundland*. Ottawa: National Museums of Canada (Canadian Museum of Civilization, Mercury Series, Canadian Centre for Folk Culture Studies Paper Number 41), 1982.

Thomas, Jeannie Banks. *Naked Barbies, Warrior Joes, and Other Forms of Visible Gender*. Urbana, IL: University of Chicago Press, 2003.

Tilley, Christopher Y. *Handbook of Material Culture*. London: Sage Publications, 2006.

Toelken, Barre. *The Dynamics of Folklore*. Logan: Utah State University Press, 1996.

Trimingham, Eldon. "The Development of the Bermuda Rig." *Bermuda Journal of Archaeology and Maritime History* 2 (1990): 127-142.

Truxes, Thomas M. *Defying Empire: Trading with the Enemy in Colonial New York*. New Haven, CT: Yale University Press, 2008.

_____. "Transnational Trade in the Wartime North Atlantic: The Voyage of the Snow *Recovery*." *The Business History Review* 79:4 (Winter 2005): 751-780.

Turner, A.J. "Advancing Navigation in Eighteenth-Century France: Teaching and Instrument-Making in the Port of Rochefort." *Mariner's Mirror* 91:4 (November 2005): 531-547.

Unger, Richard W. *The Art of Medieval Technology: Images of Noah the Shipbuilder*, New Brunswick, NJ: Rutgers University Press, 1991.

_____. "The *Fluit*: Specialist Cargo Vessels 1500-1650." In Robert Gardiner, ed., *Cogs, Caravels, and Galleons: The Sailing Ship 1000-1650,* 91-114. Annapolis, MD: Naval Institute Press, 1994.

_____. "Ship Design and Energy Use, 1350-1875." In Unger, ed., *Shipping and Economic Growth 1350-1850,* 249-268. Leiden: Brill, 2011.

_____. *The Ship in the Medieval Economy, 600-1600*. Montreal: McGill-Queen's University Press, 1980.

_____, ed. *Shipping and Economic Growth 1350-1850*. Leiden: Brill, 2011.

_____. *Ships and Shipping in the North Sea and Atlantic, 1400-1800*. Basingstoke UK: Variorum, 1998.

_____. "Warships, Cargo Ships and Adam Smith: Trade and Government in the Eighteenth Century." *Mariner's Mirror* 92:1 (February 2006): 41-59.

Van den Belt, Henrik and Arie Rip. "The Nelson-Winter-Dosi Model and Synthetic Dye Chemistry." In Wiebe Bijker, Thomas P. Hughes, and Trevor Pinch, eds. *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. Anniversary Edition, 129-154. Cambridge, MA: MIT Press, 2012. Kindle Edition.

Van der Merwe, Pieter, ed. *Science and the French and British Navies, 1700-1850.* Greenwich UK: National Maritime Museum, 2003.

Veit, Ulrich. "'Mission impossible !' Comment on Kristian Kristiansen, 'Genes versus agents. A discussion of the widening theoretical gap in archaeology.'" *Archaeological Dialogues* 11:2 (December 2004): 99-103.

Vickers, Daniel with Vince Walsh. *Young Men and the Sea: Yankee Seafarers in the Age of Sail.* New Haven, CT: Yale University Press, 2005.

Walton, Gary M. "Obstacles to technical diffusion in ocean shipping, 1675-1775." *Explorations in Economic History* 8:2 (Winter 1970): 123-140.

Weski, Timm. "The value of experimental archaeology for reconstructing ancient seafaring." In Lucy Blue et al., eds. *Connected by the Sea: Proceedings of the Tenth International Symposium on Boat and Ship Archaeology, Roskilde 2003,* 63-67. Oxford: Oxbow Books, 2006.

White, Lynn Jr. *Medieval Technology and Social Change*. Oxford: Oxford University Press, 1962.

Whitewright, Julian. "The Potential Performance of Ancient Mediterranean Sailing Rigs." *International Journal of Nautical Archaeology* 40:1 (2011): 2-17.

_____. "Technological Continuity and Change: The Lateen Sail in the Medieval Mediterranean." *Al-Masāq* 24:1 (April 2012): 1-19.

Wilde-Ramsing, Mark U. et al. *The Rose Hill Wreck: Historical and Archaeological Investigations of an Eighteenth-Century Vessel at a Colonial River Landing Near Wilmington, North Carolina*. Kure Beach, NC: NC Dept. of Cultural Resources, 1992.

Williams, Alan F. "Bristol Port Plans and Improvements of the 18th Century." *Transactions of the Bristol and Gloucestershire Archaeological Society* Volume 81, 1962.

Williams, Michael Ann. *Homeplace: The Social Use and Meaning of the Folk Dwelling in Southwestern North Carolina*. Athens: University of Georgia Press, 1991.

Wilson, Garth and John Summers. "Maritime Museums and Material Culture Studies." *The Northern Mariner/Le Marin du nord* 4:2 (April 1994): 31-39.

Wing, John F. "Shipping Productivity in Maryland's Tobacco Trade, 1689-1759." *International Journal of Maritime History* 20:2 (December 2008): 223-239.

Wingood, Allan J. "*Sea Venture*: An interim report on an early 17th century shipwreck lost in 1609." *International Journal of Nautical Archaeology* 11:4 (November 1982): 333-347.

_____. "*Sea Venture* Second interim report—part 2: the artefacts." *International Journal of Nautical Archaeology* 15:2 (May 1986): 149-159.

Wood, Bradford J. *This Remote Part of the World: Regional Formation in Lower Cape Fear, North Carolina 1725-1775*. Columbia: University of South Carolina Press, 2004.

Woodward, Ian. *Understanding Material Culture*. London: Sage Publications, 2007.

Wrike, Peter. "The Jamestown Replicas." In Jenny Bennett, ed., *Sailing Into the Past: Learning from Replica Ships,* 120-133. Barnsley UK: Seaforth Publishing, 2009.

Zahedieh, Nuala. *The Capital and the Colonies: London and the Atlantic Economy 1660-1700*. Cambridge: Cambridge University Press, 2010.

Zwick, Daniel. "Conceptual Evolution in Ancient Shipbuilding: An Attempt to Reinvigorate a Shunned Theoretical Framework." In Jonathan Adams and Johan Rönnby, eds., *Interpreting Shipwrecks: Maritime Archaeological Approaches*, 46-71. Southampton UK: Highfield Press, 2013.

Unpublished theses and reports

Cook, Gregory D. "The Readers Point Vessel: Hull Analysis of an Eighteenth-Century Merchant Sloop Excavated in St. Ann's Bay, Jamaica." Master's thesis, Texas A&M University, 1997.

Cullon, Joseph. "Colonial Shipwrights and Their World: Men, Women and Markets in Early New England." PhD dissertation, University of Wisconsin, 2003.

Krivor, Michael. "Archaeological Investigation of an Eighteenth-Century British Merchant Vessel in Chub Heads Cut, Bermuda." Master's thesis, East Carolina University, 1998.

Mitchell, Amy. "A Comparison of Wood Use in Eighteenth-Century Vessels." Master's thesis, East Carolina University, 1994.

Moore, David. "Anatomy of a l7th Century Slave Ship: Historical and Archaeological Investigations of the *Henrietta Marie.*" Master's thesis, East Carolina University, 1989.

Pecorelli, Harry. "Archaeological Investigation of the B & B Wreck (38B1672): An Eighteenth Century Plantation-Built Vessel, Charleston, South Carolina." Master's thesis, East Carolina University, 2003.

Rose, Kelby James. "The Naval Architecture of *Vasa*, A 17th-Century Swedish Warship." PhD dissertation, Texas A&M University, 2014.

Sabick, Christopher R. "His Majesty's Hired Transport Schooner *Nancy*." Master's thesis, Texas A&M University, 2004.

Southerley, James C. W. "Cedar on the Reef: Archaeological and Historical Assessments of the Eighteenth Century Bermuda Sloop, Exemplified by the Hunter Galley." Master's thesis, East Carolina University, 2003.

VanHorn, Kellie M. "Eighteenth Century Colonial American Merchant Ship Construction." Master's thesis, Texas A&M University, 2004.

Wrike, Peter. "The *Godspeed* and *Discovery* of London and Virginia, 1606-7." Unpublished bound research report, Jamestown-Yorktown Foundation, three volumes, 2002.

Appendix 1

DOCUMENTS USED IN THE CONDUCTING OF INTERVIEWS

MEMORIAL UNIVERSITY

Informed Consent Form

Title: *"Merchant Ship Technology and the Development of the British Atlantic Empire 1600-1800"*

Researcher: Phillip Reid, PhD student, Department of History, Memorial University of Newfoundland, 305 N 23rd St, Wilmington NC 28405 USA, (910) 352-3171, pfr615@mun.ca

Supervisor: Neil Kennedy, PhD, Assistant Professor, Department of History and Department of Archaeology, Memorial University of Newfoundland, St. John's, NL Canada A1C 5S7, (709) 864-8968, nkennedy@mun.ca

You are invited to take part in a research project entitled *""Merchant Ship Technology and the Development of the British Atlantic Empire 1600-1800."*

This form is part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. It also describes your right to withdraw from the study. In order to decide whether you wish to participate in this research study, you should understand enough about its risks and benefits to be able to make an informed decision. This is the informed consent process. Take time to read this carefully and to understand the information given to you. Please contact the researcher, *Phillip Reid*, if you have any questions about the study or for more information not included here before you consent.

It is entirely up to you to decide whether to take part in this research. If you choose not to take part in this research or if you decide to withdraw from the research once it has started, there will be no negative consequences for you, now or in the future.

Introduction

As part of my Doctoral thesis, I am conducting research under the supervision of Dr. Neil Kennedy exploring the role of merchant ship technology in the development of the British Atlantic Empire from the early settlement period until after U.S independence. In addition to archival research and technical analysis of plans and archaeological evidence, I want to examine working reproductions of relevant vessels to learn what I can about their design, construction, and operating characteristics, and I think the best way to do that is to solicit the opinions, judgments, and experiences of those who have significant experience working with these vessels.

Purpose of study:

By adding the information from the working-replica study to that gleaned from other sources, I think I can add materially to our understanding of how merchant ship technology—an under-studied aspect of this period—contributed to, and reflects, the growth and change, as well as the continuity, of the British Atlantic. By accomplishing that, I will also make a new contribution to the history of technology, which has in the past placed much more emphasis on ship technology in the immediately preceding and succeeding periods.

What you will do in this study:

I am asking you to contribute your opinions and judgments—as well as any performance data and/or specifications you or I may deem relevant, regarding the vessel(s) with which you have experience. I have prepared a questionnaire laying out the information I am looking for, to be used as a rubric; it provides both structure and flexibility to you, and it can be used either as the basis for a written response or for an oral interview or series of interviews. That is up to you. I am asking you to agree to let me use the information you provide in my doctoral thesis and in any articles, presentations or books based on the thesis or on the research I am conducting for it. I am asking you to agree to let me properly credit you for your contributions through citations—footnotes, endnotes, textual references, and bibliographic entries—by name, vessel and/or organizational affiliation, date(s) of interview(s), and nature of interview (e-mail, telephone, in-person, etc.), as per the conventions prescribed by the discipline of history for referencing source material in academic works. **The information provided by you will become public and will be attributed to you.**

Length of time:

How long you spend providing the information requested in the questionnaire is largely up to you and determined by how much of the information you have at your command and are willing to share. It also depends on whether or not you and I interact directly or not. I would estimate that the response should take anywhere from one hour to several hours.

Withdrawal from the study:

I will share a draft version of anything I produce—thesis, conference paper, article, book, or presentation—that includes information derived specifically from the information you provided. If you object to my use of that information in that work, you may direct me not to use that information in that work and I will comply. The opportunity to withdraw continues to be available until the work in question is either submitted for publication, presentation, or examination. If I have used your information in a specific work, I will inform you when the applicable deadline is for that work. If you elect to withdraw before the deadline, and you wish to withdraw from the study completely, I will return all the information you provided to you, including any transcripts of interviews, sound or video recordings, or written responses to the questionnaire, and expunge any information derived directly from your contribution from any and all works in which I may have used that information. There will be no consequences for withdrawal.

For the thesis, the target date for submission for examination is December 2015. I will provide a more specific date to you as soon as it becomes clear what that date will be.

Possible benefits:

The information I gather from you and other participants in this study is likely to materially advance the fields of maritime history and the history of technology—fields important to academic history, archaeology, historic preservation, and museum work.

Possible risks:

It is possible that the opinions and judgments provided by the participant are at odds with those provided by other participants or with the conclusions reached by the researcher. It is possible that colleagues and/or employers of the participants could take a negative view of the participant's expressed opinions and judgments. You should consider these possibilities before you agree to participate, and feel free to decline to participate if you think that these risks may apply to you if you participate.

Confidentiality

It is important to understand that, while any information of a purely personal nature you share with me—including personal contact information that you specifically ask me not to share—will be kept private and in my sole possession, your name, professional or organizational affiliation, professional or organizational contact information, and the direct attribution to you of the information you have provided for the study will be **public**.

Anonymity:

If I use the information you provide in this study in the thesis or in any other work produced as a result of the study, your contribution will **not** be anonymous.

Recording of Data:

You and I may decide to use audio recording, video recording, and/or written communication to accomplish your participation in the study. You will always have the right to specify which of those methods you are comfortable with. On the signature page of this form, you can specify which of these methods you agree to use.

Storage of Data:

All records ("data") of your responses to the questionnaire and any other communication associated with your participation in the study will be kept in my sole, private, and protected possession unless you withdraw from the study, in which case they will be returned to you promptly. Otherwise, all **data will be kept for a minimum of five years, as required by Memorial University policy on Integrity in Scholarly Research**. If an archival institution requests that I donate these records to their collection, I will obtain your permission to do that before accepting that request.

Reporting of Results:

The information collected from you may be used in a thesis, in journal articles, books, conference presentations, and reports to my Department or to another unit of Memorial University. The information may be reported using direct quotations and/or personally identifying information.

Sharing of Results with Participants:

I will inform you of how to access the final results of any work in which I have used your information. Theses are now kept in electronic format, so in that case, this will entail advising you how to access that on-line. If the final result is an unpublished work, I will provide you with a copy myself.

Questions:

You are welcome to ask questions at any time during your participation in this research. If you would like more information about this study, please contact:

Phillip Reid, PhD student, Department of History, Memorial University of Newfoundland, 305 N 23rd St, Wilmington NC 28405 USA, (910) 352-3171, pfr615@mun.ca

Supervisor: Neil Kennedy, PhD, Assistant Professor, Department of History and Department of Archaeology, Memorial University of Newfoundland, St. John's, NL Canada A1C 5S7, (709) 864-8968, nkennedy@mun.ca

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research, such as the way you have been treated or your rights as a participant, you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 709-864-2861.

Consent:

Your signature on this form means that:

- You have read the information about the research.
- You have been able to ask questions about this study.
- You are satisfied with the answers to all your questions.
- You understand what the study is about and what you will be doing.
- You understand that you are free to withdraw from the study without having to give a reason and that doing so will not affect you now or in the future.
- You understand that any data collected from you up to the point of your withdrawal will be returned to you

If you sign this form, you do not give up your legal rights and do not release the researchers from their professional responsibilities.

Your signature:

☐ I have read what this study is about and understood the risks and benefits. I have had adequate time to think about this and had the opportunity to ask questions and my questions have been answered.

☐ I agree to participate in the research project understanding the risks and contributions of my participation, that my participation is voluntary, and that I may end my participation.

I agree to be audio-recorded during an interview. ☐ Yes ☐ No
I agree to be video-recorded during an interview. ☐ Yes ☐ No
I agree to the use of quotations. ☐ Yes ☐ No
I allow my name to be identified in any publications resulting from this study. ☐ Yes ☐ No

A copy of this Informed Consent Form has been given to me for my records.

______________________________ ______________________________

Signature of participant Date

Note: Electronic signatures are acceptable for this form.

Researcher's Signature:

I have explained this study to the best of my ability. I invited questions and gave answers. I believe that the participant fully understands what is involved in being in the study, any potential risks of the study and that he or she has freely chosen to be in the study.

Signature of Principal Investigator | Date

"Merchant Ship Technology and the Development of the British Atlantic Empire, 1600-1800"

Working replica study recruitment e-mail

Dear _____________:

My name is Phillip Reid and I am a doctoral student in maritime history at Memorial University of Newfoundland. I have begun research for a thesis whose working title is "Merchant Ship Technology and the Development of the British Atlantic Empire, 1600-1800." My purpose is to understand both change and continuity in the typical merchant ships of transatlantic and coastal service in the Atlantic and Caribbean.

In addition to archival sources and the analysis of plans and wreck evidence using modern engineering applications, I want to take advantage of whatever information I can gather from the experiences of those involved with working replicas of relevant vessels. I believe there is much to be learned about the design, construction, and operational characteristics of the original vessels by drawing on the experience of working replicas—providing the analysis and interpretation are done carefully.

I am hoping you will be interested in participating in this aspect of the project. If you may be, I can send you the questionnaire I have prepared for your review, and if you are still interested, I will forward you the required Informed Consent Form. Once I have a signed copy of that, we can proceed.

If you can think of others who may be good candidates for participation in this study, please advise me of that and I will contact them promptly.

Thank you for your time.

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research, such as the way you have been treated or your rights as a participant, you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 709-864-2861.

Regards,

Phillip Reid
PhD student
Department of History
Memorial University of Newfoundland
St. John's NL Canada

preid@ec.rr.com
(910) 352-3171

Physical address:
305 N 23rd St
Wilmington NC 28405
USA

(I am no longer in residence at Memorial.)

Working replica questionnaire,

"Merchant Ship Technology and the Development of the British Atlantic, 1600-1800,"

a doctoral thesis in maritime history in progress for the Department of History, Memorial University of Newfoundland

by Phillip Reid; Neil Kennedy, PhD, supervisor

Contact information:

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nkennedy@mun.ca

Please feel free to use this questionnaire however is most convenient for you. We can use it as a template for an oral interview, or you can type answers to the questions in the document and send it back. If you are answering the questions in writing and aren't sure about something or have a question, feel free to either note that here or contact me at your convenience. If we are conducting an oral interview, I will send you a transcript of that interview for your approval before using any of the answers you provide.

(questionnaire begins on next page)

I. Authenticity of the reconstruction

1. Upon what historical evidence was the reconstruction based?

2. To what extent did the reconstruction adhere to known period building and rigging practices?

3. To what extent did the reconstruction consciously deviate from those practices?

4. To what extent did the reconstruction utilize "best-guess" practices due to lack of knowledge about actual historical building and rigging practices?

5. Has information come to light since the reconstruction was completed that would likely have changed the reconstruction had the information been available at the time? If so, please explain.

6. How would you expect the reconstruction's performance to be different from the original vessel's, due to deviations from historical building and rigging practices?

    a. If the vessel has synthetic rigging, do you believe that she can carry more sail in certain conditions than if her rigging were natural-fiber? Do you believe that she is more vulnerable to capsize if suddenly overpowered?

    b. If the vessel has synthetic sails, do you believe this would make her more vulnerable to being overpowered before a sail blow-out?

    c. If the vessel has auxiliary power, how do you believe this affects her performance when not under power?

7. How would you expect the reconstruction's performance to be different from the original vessel's, due to deviations in burden from what we would expect the original vessel's to have been under normal operating conditions?

II. Operational Characteristics

1. How many crew does it take to safely and effectively man the vessel, exclusive of armament? How many more does it take if serving the guns is included? Is there any reason to think that these requirements would have been different originally? If so, why?

2. What performance data might be available from your experience with the vessel, such as speeds in various wind and sea conditions under different points of sail and with different sail plans deployed? (I will be happy to take this information in whatever format is convenient. If the information hasn't been extracted from

the ship's logs, it might be possible for me to do that; we can discuss. If you or your crew has experience comparing the results of speed measurements by traditional chip log to those obtained by GPS or other modern methods, that information would be very valuable to me.)

3. From a modern sailor's perspective, are there any historically accurate aspects of the vessel's design and/or rigging that seem superior or inferior to workable alternatives in terms of performance?

4. This study aims to compare typical vessel types from a period of two centuries. For example, one of the specific questions we're interested in is how a two-masted vessel compares to a three-masted vessel of similar size and capacity, as we know that two-masted vessels of medium tonnage became more popular after the midpoint of the 18th century. If you have any experience from which you would feel comfortable making comparative judgments –for example, with other working replica vessels relevant to the Atlantic and Caribbean in the 17th and 18th centuries—please feel free to share those. Your opinions, if incorporated into the study, will be acknowledged as such and properly attributed to you, along with the evidence or experience upon which they are based.

Thank you for this valuable assistance. I will apprise you of the progress of the study and of the inclusion of any of the information you have provided. Of course any further information you wish to contribute later is most welcome.

Please provide your contact information below so that I can keep accurate records of what information comes from whom. If more than one person contributed to your answers, please make it clear who contributed what as much as possible, so that I can properly attribute the information in the study.

Name(s):
Vessel(s) name(s):
Full mailing address where you can be reached:
Best telephone number(s):
Fax (if you have one and use it):
Best e-mail address(es):

Appendix 2

List of vessels discussed in the text

Part 1: Archaeological remains

Name	Type	Nature of remains	Location of site	Date of site
Concorde/Queen Anne's Revenge	English frigate	Partial bottom, submerged	Beaufort Inlet, North Carolina, USA	1718
Henrietta Marie	French-British ship	Partial bottom, submerged	Marquesas Keys	1701
Princess Carolina	British American ship	Partial hull, buried	New York, New York, USA	c. 1735-1740
San Juan de Pasajes	Basque whaler	Partial hull, submerged	Red Bay, Labrador, Canada	1565
Sea Venture	English galleon	Partial bottom, submerged	Bermuda	1609
Sparrow-Hawk	English pinnace	Partial hull, excavated and reconstructed	Cape Cod, Massachusetts, USA	c. 1626

Part 2: Replicas and reconstructions

Name	Type	Status of rep./rec.	Location of rep./rec.	Date of original	Date of rep./rec.
Armed Sloop *Welcome*	British American sloop	Retired, ashore; future operation unknown	Mackinaw City, Michigan, USA	1774	1976
Discovery	English fly-boat	Operational	Jamestown, Virginia, USA	1602	2006
Duyfken	Dutch *jacht*	Operational	Fremantle, Western Australia	1595	1996
Elizabeth II	English galleon	Operational	Manteo, North Carolina, USA	c. 1585	1983

Godspeed	English ship	Operational	Jamestown, Virginia, USA	c. 1605	2006
Golden Hind	English galleon	Retired, dockside	London, UK	1577	1973
Half Moon (Halve Maen)	Dutch *vlieboot*	Operational	Hoorn, The Netherlands	1608	1989
Kalmar Nyckel	Dutch *pinas*	Operational	Wilmington, Delaware, USA	c. 1625	1997
Maryland Dove	English merchant ship	Restricted operational, dockside	St. Mary's City, Maryland, USA	1634	1978
Mayflower II	English galleon	Restricted operational, dockside; under restoration 2016-2019	Plimouth Plantation, Massachusetts, USA	c. 1600-1609	1957
Nonsuch	English ketch	Retired, museum	Winnipeg, Manitoba, Canada	1650	1968
Pride of Baltimore	American topsail schooner ("Baltimore clipper")	Sunk, 1986	Baltimore, Maryland, USA until lost	c.1812	1977
Sultana	British American schooner	Operational	Chestertown, Maryland, USA	1767	2001
Susan Constant	English galleon	Operational	Jamestown, Virginia, USA	1605	1991 check
Swedish Ship *Götheborg*	Swedish East Indiaman	Operational	Göteborg, Sweden	1738	2003
US Brig *Niagara*	American snow-brig	Operational	Erie, Pennsylvania, USA	1813	1990

Part 3: Vessels from the documentary record only[*]

Name	Type	Where built	Date	Source
Advice Prize	Ship	France	before 1704	Moore, "Anatomy," 115, citing Chapelle, *Search for Speed*, 38, 42.
America	ship	USA, prob. New England	before 1796	Crowninshield Family Papers, MH 15, Box 1, Folder 1; Box 4, Folder 8, PEM-Phillips.
Andrago	sloop	British America(?)	before 1758	Orne Family Papers, MSS 41, Box 1 Folder 3, PEM-Phillips.
Ann & Hope	ship	New England	1798	Brown Family Business Records, Box 475, Folder 9, JCB.
Astrea	ship	USA, prob. New England	before 1784	Derby Family Papers, MSS 37, Box 1, Folders 5 and 8, PEM-Phillips.

[*] To avoid redundancy, I have chosen not to reproduce Table 1 here, and not to include vessels discussed only in reference to that table in Chapter 3, pp. 102-106. I have also omitted vessels only mentioned in passing and not discussed.

Bonetta	sloop	British America	c. 1766	Brown Family Business Records, Box 682, Folder 5, JCB.
Friendship	brig	USA, prob. New England	before 1794	Brown Family Business Records, Box 733, Folder 1, JCB.
George	snow	USA; prob. Philadelphia	before 1805	*George* (ship) logbook, 1805-1806, Am. 6823, HSP.
George & Mary	ship	USA (?)	before 1807	Brown Family Business Records, Box 306, Folders 3-5, JCB.
Harmony	brig	British America, prob. New England	before 1774	Brown Family Business Records, Box 682, Folder 3, JCB.
Maria	brigantine	unknown	1793	Brown Family Business Records, Box 682, Folder 4, JCB.
Mayflower	ship	England	1676	Barlow, *Barlow's journal*, 281, plate 283.

HMS Prince	100-gun first-rate ship of the line	Deptford, England	1670	Anderson, ed., *Journals and Narratives of the Third Dutch War,* 71.
Roebuck	6th-rate warship	Harwich, England	1666	Moore, "Anatomy," 115-117, citing Lavery, ed., *Deane's Doctrine*, 112.
Success	sloop	British America (?)	1770	Brown Family Business Records, Box 682, Folder 4, JCB.
Two Catharines	ship	unknown	before 1813	Brown Family Business Records, Box 306, Folder 7, JCB.
USS Ranger	sloop-of-war	Maine	1777	Langdon Family Papers, Box 1, Folder 7, NHHS.
Vasa	warship	Stockholm	1627	see Rose, "The Naval Architecture of *Vasa*, …"

Appendix 3

List of vessel type names and alternate type names

barque longue	
bateau	plat, gondolo
Bermuda sloop	sloop
bilander	brig
boat-canoe	canoe, punt
brigantine	brig, hermaphrodite brig
canoe	kunner, cannow, boat-canoe
catch	
Chebacco boat	
cutter	
felucca	
flat	punt, scow
fluit	fluyt, flyboat
galleon	
galley	ship, brigantine, galley-brigantine
galley-ship	runner
jacht	pinas
ketch	catch, hooker, galliot
lugger	
maître	grand canot
moses	double moses
periauger	periauga
pink	shallop
pinnace	rambargo, ram-barge, galley-ship
plat	
runner	ship, galley, galley-brigantine
schooner	
scow	punt, periauga, flat, radeau, gondalow, gondolo
shallop	sloep, chaloup, slup, longboat, launch, two-mast boat
ship	
skiff	
sloop	Bermuda sloop, Jamaica sloop
snow	brig
whaleboat	
wherry	
xebec	
yawl	longboat