Engineering and Design, and their Influence on Fabrication Techniques in Sailboat Design

Amanda Sutherland

Olin College - Spring 2015

The 1800s saw the peak of the sailing industry in the West; magnificent clipper ships dominated shipping and raced across the world's oceans, passenger ships made record times, and yacht racing experienced its beginning. This last set the stage for shifts of epic proportions in the sailing world. The late 1800s showed a dramatic change in the sailing world, connecting it with the engineering in a way it had not before. Suddenly yacht designers were not only expected to create beautiful and fast yachts, but also to create robust machines which pushed the boundaries of the field of engineering and were awe-inspiring enough to capture the attention of the general public. The repercussions of this affected the industry on many levels; the basic materials used changed enough to make the boats unrecognizable, the people working on this industry shifted between designers and engineers, and the media became a driving force behind the boat's fabrication and overall design. This paper will discuss the shifts from wood to metal, and finally to composite materials and factors affecting these shifts through the lens of the sailing industry from late 1800s to the present. Observation of the effects of the role of individuals and institutions shows the media to be perhaps the most influential factor in bringing about the world of sailing as we know it today.

The relationship between engineering and design has historically been a topic of contention, and as the two become more irrevocably intertwined, it becomes difficult to define them in a historical context. Thus, for the purposes of this discussion, engineering and design will be defined as follows. 'Engineering' refers to technical work, done without necessarily having a specific application in mind. 'Design', in contrast, refers to work done towards a specific application. While this can also include technical work, the important difference is that 'design' involves specific thought about the societal or artistic aspects of the work. While these definitions are arguably not true today, they provide a context by which it is possible to compare the last century and a half of changes within this industry.

The acceleration of engineering in the sailing industry can be pinpointed to one designer, Nathanael Herreshoff. Yachts in the mid-1800s were mostly designed by non-engineers, and often by designers who had experts come help them with technical details. Herreshoff was trained as a mechanical engineer at Massachusetts Institute of Technology (Herreshoff, 64), and applied these skills to his passion for sailing. His engineering efforts, like several of his similarly trained contemporaries, would likely have been unappreciated but for his incredible success in the America's Cup race. The America's Cup is the epitome of sailboat racing, and he was the designer of the winning boat for from 1892 - 1920, an achievement unrivaled in the history of the race.

Herreshoff was an equally skilled engineer and designer. Raised in Bristol, Rhode Island, to a sailing family, he started designing and building boats early. His older brother lost his eyesight early in life, and thus Herreshoff learned to do professional designs and use machine shop tools by necessity. Alongside designing boats, he also was a skilled skipper and navigator. Upon reaching college age, he entered the Massachusetts Institute of Technology as an apprentice and learned to work with engines, after which he joined his brother in business and created the 'Herreshoff Manufacturing Company', which was wildly successful. They were renowned first for their advanced motorboat systems, and later for their record setting sailing yachts.

> "Captain Nat is generally considered the designer who used mathematics most, and while he did certainly depend on mathematics in the design of steam engines and in strength calculations, it is my personal impression, after my having watched him work several years, that some natural instinct and superfine sense of proportion enabled him in most cases to proportion things so perfectly that he drew the taper and sizes of things out quite spontaneously, which I for one call pure art." (Herreshoff, 138)

As described by L. Francis Herreshoff, this brilliance was appreciated as much then as now. He had an intuitive sense of boats and sailing which allowed him to make many design decision which would have been impossible to come upon with the understanding of hydrodynamics at the time, and he also understood the importance of testing all elements of his designs before implementing them. As simulation software such as engineers have now were at least a century away when he was designing hulls, he would make model hulls and iterate upon their shape after exhaustive testing. Unlike many of his contemporaries, he had a sufficient understanding of the relevant engineering principles to know metal could make much faster hulls, and therefore devoted years to determining how to use the least amount of metal possible. Eventually he came upon an entirely new system of framing. The existing method, transverse framing, involved holding the shape of the hull with flat profiles perpendicular to and equally spaced along the length of the hull. Longitudinal framing decreased weight by eliminating many of these profiles and replacing them with some long profiles running the length of the boat, which also had the advantage of preventing twist in longer hulls under force. His method significantly cut down on the weight of his boats and yet was incredibly strong, and therefore had an enormous advantage over his competitors (Simpson) (Isherwood). News of Herreshoff's engineering skill spread quickly as his boats continually outpaced their competitors.

Of all the advances Herreshoff brought to his industry, one of the greatest paradigm shifts was the introduction of metal as a hull fabrication material. Unlike his contemporaries, he did not believe metals hulls were somehow lesser boats than their classic wooden counterparts, and knew from the work he had done that he could build something much faster. It became obvious after his first metal yacht Defender won her race in 1895 that metal fabrication was a viable option and his methods spread rapidly to the rest of the yacht industry. Herreshoff's influence over the yacht industry is significant as it shows how one individual could bring about a rapid change in world of sailing. The constant press coverage, whether it was critical or complimentary, brought attention to his work and therefore his successes were quickly adopted by other designers.

The second hull fabrication paradigm shift came far after Herreshoff's time, and brought the move from metal to composite materials. Composite materials have enabled many new doors to be opened in the worlds of engineering and design and therefore it is arguably a more historically significant shift than the transition from wood to metal, and the way it came about has almost no parallels to the latter. While Herreshoff brought about a swift influx of metal construction, the development of composite fabrication was almost entirely the work of the navy.

World War II brought with it a scarcity of light metals such as aluminum; aluminum a light and strong metal, and therefore was in high demand during the war. The focus was on having as much aluminum flying for the air force as possible, and therefore the navy could not justify the need for large quantities of aluminum for their smaller craft. Thus, they began experimenting with composite materials which had hitherto been used only on a small scale, as Mouritz et al describe.

> "While composites are now being considered for a diverse range of naval applications, for many years these materials were used only in a few non-critical ship structures and in small boats. Composites were first used immediately after the Second World War in the construction of small personnel boats for the US Navy. These boats proved to be stiff, strong, durable and easy to repair, and these attributes led to a rapid expansion of composite use in other types of US naval craft between the mid-1940s and 1960s." (Mouritz et al, 1)

As Mouritz shows, the success of composites for small personnel boats did not bring the use of composites directly to the boat industry. The navy is not in the business of advertising their new technology for national security reasons, and therefore composite materials were not immediately

embraced. Further in contrast with the shift to metal, when composites began be used they did not begin at the high end and work down. The first significant usage of composites outside the navy was by the Pearson Yachts manufacturing company, which specialized in making low cost boats for personal use. Success came quickly after they developed a particularly robust method of using resins, and the widespread use of their smaller boats encouraged them to design larger scale sailboats (Mitchell). The first composite hull to appear in the America's Cup was the KZ 7 in 1986, a fiberglass hull. After she did well in the Cup races, fiberglass and other composites were much more accepted and spread to other top-tier sailing venues. The response to KZ 7 was almost precisely the same as response to Herreshoff's *Defender*, when critics first claimed the design would never work, and after it proved successful they changed claiming it was cheating. In both cases, the press forced people to pay attention to the new technology and started conversations around it, which then made it implemented more quickly.

The difference in the time response the shifts from wood to metal, then metal to composites, is almost directly correlated to the influence of the sailing public and media. When the navy made technological advances in composite materials around WW2, people who cared about boats did not hear about their work and therefore could not express their opinions. In contrast, when Herreshoff debuted *Defender* with her metal sides, anyone in the area of his shop in Bristol, Rhode Island knew about it and had an opinion on it. Rhode Island was one of the country's foremost shipping centers in the country, and during Herreshoff's time was home to many shipyards. Thus, once news had spread in Bristol it rapidly spread to the rest of those people interested in the sailing industry. As with most sports where the spectators are closely linked with the sport itself and therefore often consider themselves experts, Herreshoff was almost instantly under fire for his design. This criticism was amplified by the difficulties with Defender, as described by Simpson.

> "The 123-foot *Defender* was equally astounding, due to its radical construction; it featured steel framing, bronze plating up to the waterline and aluminum topsides. As might be expected, when placed in the ocean's saline, the boat's galvanic corrosion was immediate. It won the race, and then began dissolving." (Simpson, 35)

The issue with corrosion inspired further criticism from the media. Most claimed the issue clearly showed metal was not feasible and should be scrapped. The critics only fueled Herreshoff's passion to make it better; it had been so successful in other ways, he wanted to prove to his contemporaries that it was a superior fabrication material so they would want to use it. When he followed through and made a

successful metal hull, *Columbia,* it blew away both the competition and his critics. The New York Times claimed his competitor Watson "had made Shamrock a close copy of Columbia, [...] and if Herreshoff cannot improve upon her, I am sure Watson could not beat her" (New York Times, Yachtsmen Think Cup Race Will Be Close.). Once again, he proved his design and they went away singing his praises once again. Thus, his invention was validated in the eyes of his competitors. The navy did not have this direct connection with the general boat public due to military secrecy, and therefore their influence took longer to be implemented.

The America's Cup is the direct antithesis of the navy's influence. It is intended as a show of sailing skill and technological superiority, whereas the navy makes every effort to keep their work hidden. The Cup was originally a race around the Isle of Wight, it was renamed the 'America's Cup' after the yacht *America* won and defeated the British navy. After the navy lost, no militaries have championed a boat.

> "The *America* won because its owners experimented with novel nautical technologies and spared no expense in building it (some things never change). In the 19th century, a ship in private hands that could beat the best that the British had to offer was something extraordinary — an example of private money rivaling the power of a great nation. The Cup has been a totem to tycoons ever since." (Fisher)

As Fisher describes, the rivalry between these tycoons created an environment in which the sport became a spectacle, and thus channeled interest to sailors and non-sailors alike. The interest fueled by the intensity of the competition and the impressive new technologies is a direct byproduct of the power of the people backing the teams. The 2013 Cup was a "naked clash of egos" (Fisher) between team backers and it has been so almost from the beginning of the Cup races. During Herreshoff's time this competition between the backers was shown in the daily newspapers where papers would favor a one backer or another, and the public would react accordingly.

The arrival of the internet and social media transitioned the America's Cup coverage from local to nationwide coverage. Today the America's Cup is heavily covered on social media, all matches are available online, and the TV station NBC aired live coverage of the event to an average of 328,000 viewers between September 7th and 22nd (Young). The event has been specifically been tailored to be interesting to those who are not already inclined to watch it; the races are much shorter, the boats are incredible engineering feats and look the part, and it is generally expressed as an extreme sport.

Suddenly interest in sailing is reaching whole new audiences, and it is directly the result of the increased media presence.

Figure 1: The AC72s, the 2013 America's Cup boats. (Lord, "34th America's Cup")

The AC72s incited polarizing commentary across the internet. The critiques and commentary echo similar concerns from Herreshoff's time.

> "It's getting faster and more dangerous, and that attracted the major networks, [p]eople going back to the Romans, they're bloodthirsty. [...] Why do you watch football? You want to see the pileups. You want to see these crashes." (Newton, "Billionaire Death Race")

Countering the critics are the overwhelming numbers of articles citing the technological advances, ranging from the new fabrication methods used for the sails and the hull, and the augmented reality visualizations shown below. Augmented reality technology projects information such as heading, boat speed, wind speed and direction, marks, and path traveled onto the real-time video stream, all of which are difficult to see or infer from a plain video. To make this possible, the Oracle team hired the two electrical engineers who brought the celebrated first down line to football and tasked them with designing a "tracking, telemetry, and augmented-reality system for the races" (Honey and Milnes). Their system entirely changed the way the race is viewed; viewers know exactly what is going in in the race, and umpires make their decisions based on the information from the system, thus propelling sailing beyond most major sports in the use of technology for rulings. It is now no longer necessary to know the nuances of sailing understand or be excited about a Cup race. Bringing a massive engineering presence

to the Cup strategically brought engineers from many fields into the sailing industry, and thus widely expanded the community around it. This community of interested technological enthusiasts, in turn, encourages Cup designers to further push the boundaries of the technological paradigms and produce a spectacle which will capture an even larger audience.

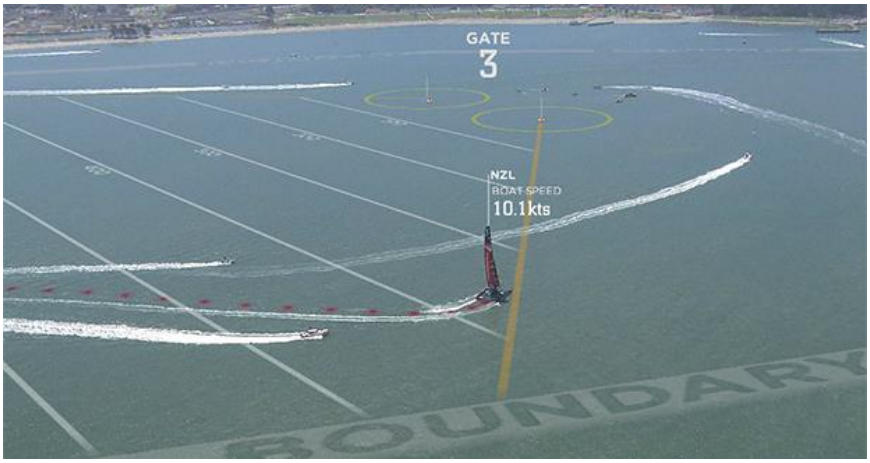

Figure 2: Video from helicopters and position data directly from the boats is inserted into a live television feed through the AC Liveline system, which makes them into graphics.

The America's Cup encapsulates much of the relationship between engineering, design, and the sailing industry, as it represents the third and final stage of public access to sailing technology. The first stage involves Herreshoff's influence, with its strong link between engineering and design. Then comes the navy, which is strong both in terms of engineering and design, but almost all of the design aspect is hidden from the public. The America's Cup is highly similar to Herreshoff's influence, but on an even larger scale. The strong media presence is a significant indicator of how long it will take for a new engineering feat to be implemented, but not because media attention indicates the quality of the proposed idea. Media attention alerts the sailing community to significant new advances, which then raises expectations for the designers of the Cup and similar large sailing events. As sailing has historically been a battle between powerful figures, in races and in the world's navies, those with the power to make a significant paradigm shift are pressured to appease their public. Our definition of engineering is pure technical work, and our definition of design is this technical work as applied to a certain area. Engineering does not capture the attention of the general public and is only important to those directly

involved, whereas design is relatable to a wide variety of people, especially when amplified by the media. Thus, engineering shifts are inherently less likely to be implemented quickly than design shifts.

Bibliography

Shields, William M. *Theory and Practice in the Study of Technological Systems*. Diss. Virginia Polytechnic Institute and State U, 2007. N.p. Print.

Skene, Norman L. *Elements of Yacht Design*. Dobbs Ferry, NY: Sheridan House, 2001. Print.

Herreshoff, Francis Lewis. *Capt Nat Herreshoff: The Wizard of Bristol*. Dobbs Ferry, NY: Sheridan House, 1953. Print.

Simpson, Richard V. *Herreshoff Yachts: Seven Generations of Industrialists, Inventors, and Ingenuity in Bristol*. Charleston, SC: History, 2007. Print.

Isherwood, Joseph W. "Economy in Modern Shipbuilding." *Shipping, A Weekly Record of Marine Transportation, Supplemented by Ship Construction and Outfitting Notes and News* 3.1 (1918). *Shipping Publishing Co.* Print.

Kim, Dave Dae-Wook, Daniel John Hennigan, and Kevin Daniel Beavers. "Effect of Fabrication Processes on Mechanical Properties of Glass Fiber Reinforced Polymer Composites for 49 Meter (160 Foot) Recreational Yachts." *International Journal of Naval Architecture and Ocean Engineering* 2.1 (2010): 45-56. Web.

Mouritz, A., P. Burchill, K. Challis, and E. Gellert. *Composite Structures* 53.1 (2001): 21-42. *Review of Advanced Composite Structures for Naval Ships and Submarines*. Composite Structures, July 2001. Web. 20 Feb. 2015.

Jones, Dyer. Personal Interview with Dyer Jones of the Herreshoff Museum. 1 December 2014.

Fisher, Adam. "The Boat That Could Sink the America's Cup." *Wired.com*. Conde Nast Digital, 09 May 2013. Web. 04 Mar. 2015. <http://www.wired.com/2013/05/americas-cup-boat-crash/>.

Lord, Doug. "34th America's Cup: Multihulls! - Page 31 - Boat Design Forums." *Boat Design Forums RSS*. N.p., n.d. Web. Accessed Dec. 21, 2014. <www.boatdesign.net/forums/multihulls/34th-americas-cup-multihulls-34612-31.html>.

Young, Eric. "How Many People Watched the America's Cup? - San Francisco Business Times." *Bizjournals*. San Francisco Business Times, 26 Sept. 2013. Web. 25 Apr. 2015. <http://www.bizjournals.com/sanfrancisco/news/2013/09/26/how-many-people-watched-americas-cup.html>.

Honey, Stan, and Milnes, Ken. "The Augmented Reality America's Cup." *IEEE Spectrum*. IEEE, 29 Aug. 2013. Web. 25 Apr. 2015. <http://spectrum.ieee.org/consumer-electronics/audiovideo/the-augmented-reality-americas-cup>.

Newton, Casey. "Billionaire Death Race: Inside America's Cup and the World's Most Dangerous Sailboat." *The Verge*. Vox Media, 03 Sept. 2013. Web. 25 Apr. 2015. <http://www.theverge.com/2013/9/3/4672686/billionaire-death-race>.

"Enterprise on the Water." *American History*. Smithsonian: National Museum of American History, n.d. Web. 1 May 2015. <http%3A%2F%2Famericanhistory.si.edu%2Fonthewater%2Fexhibition%2F2_3.html>.

Unknown. “Yachtsmen Think Cup Race Will Be Close.” *New York Times* [London] 9 Sept. 1901: Page 7. Print.