ABSTRACT

THE SUBCHASER DEBATE: INFLUENCES ON U.S. SUBMARINE CHASER DESIGN AND DEVELOPMENT IN THE FIRST AND SECOND WORLD WARS

By

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With German U-boats wreaking havoc on the merchant shipping of the Triple Entente and increasingly jeopardizing citizens of the United States in the process, military and civilian officials in the neutral country began organizing as early as 1915 for what appeared to be an inevitable entry into the First World War. Key among the objectives for U.S. leadership was the suppression of the U-boats. After inspecting the antisubmarine warfare practices and vessels of other nations in the Triple Entente, the U.S. Navy opted for the production of its own specialized antisubmarine warfare craft. These 110-foot wooden vessels would carry the moniker of SC, short for submarine chaser.

It took little time for the submarine chaser to change from a specific vessel type into a broader vessel classification. These small combatant craft were but one part of a broader antisubmarine warfare strategy that constantly changed with the introduction of new technology and new mentalities and were needed to carve out a specialized niche within that landscape.

This thesis utilizes historical records in conjunction with three-dimensional models of three significant eras in submarine chaser construction to evaluate the influence in their design

and development throughout the First and Second World Wars and determine which influences stand out as the most influential in the overall growth of the vessel type.

THE SUBCHASER DEBATE: INFLUENCES ON U.S. SUBMARINE CHASER DESIGN AND DEVELOPMENT IN THE FIRST AND SECOND WORLD WARS

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To those who will follow.

May you build great things upon this foundation.

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CHAPTER ONE: INTRODUCTION

H.L. Hunley, a submarine designed by the navy of the Confederate States of America during the U.S. Civil War, detonated a torpedo against the side of U.S.S. *Housatonic* on 17 February 1864, completing the first successful combat submarine attack in world history (Gunton 2003:12-13). While neither the Confederate sailors nor the submarine survived the attack, the strategy of attacking enemy shipping with submersible stealth weapons would have far reaching ramifications in the century following their deaths. Some fifty years later, the Imperial German Navy deployed far more technologically advanced submarines, the U-boats, as blockading tools to suppress enemy shipping in the First World War. Initially, the U-boats operated by the international rules of the sea, notifying merchants ships of their presence and allowing the crew time to escape prior to sinking the vessel. But unrestricted submarine warfare proved to be safer for the German crews and more efficient for the German strategy, and the Imperial German government committed to it completely in 1917 after fluctuating for the first three years of the war (Manson 2000:6-11). This decision and the ramifications of it saw the United States (U.S) enter the First World War just a few months later.

The first U.S. submarine chasers arrived on the naval landscape of the First World War as offensive weapons designed to pursue and sink German U-boats with the same vigor those U-boats had shown in sinking merchant shipping throughout the early years of the conflict. Admiral William Sowden Sims, commander of U.S. naval forces, viewed suppressing the German submarines as the most important contribution his vessels could make as the nation broke its neutrality and entered the war (Woofenden 2006:10). The SC-1 proved to be a viable option to achieve that objective, but not the final option. First World War era military and civilian officials sought a larger submarine chaser to contend with enemy vessels in deeper waters, resulting in the production of the experimental PE-1 class submarine chaser, known more commonly as the "Eagle boat" (Friedman 1987:38). The advent of the Second World War saw the introduction of another large submarine chaser, the PC-461 class, and its deployment throughout all theaters of the war in several different roles.

The actions that led to the creation of the submarine chaser as a class of U.S. Navy vessel were just as much cultural as they were technological. Germany's decision to implement unrestricted submarine warfare represented shifts in beliefs about the ethics of warfare and the response from other world powers, including the U.S., represented cultural shifts as well. Submarine chasers were reflections of these cultural and technological impacts and, at times, conveyors of their own. The arrival of new weapons such as the depth charge or new antisubmarine warfare tools such as the airplane all negotiated with the submarine chaser to determine how they would impact and collaborate with each other in the broader landscape of antisubmarine warfare.

Research Questions

This thesis evaluated primary and secondary sources to investigate and order the physical influences on submarine chaser design and development. It also assessed the cultural impacts of the individuals and societies with the potential to influence the submarine chasers in an effort to understand the connections between societal shifts, technological shifts, and their manifestation as composite entities in the physical structures of the vessels. The following research questions were proposed to organize this research:

1) How did the capabilities of enemy vessels affect submarine chaser design?
2) How did the opinions of political and military officials affect the development of submarine chasers?

3) Did air power during the Second World War eliminate the need for equipment and construction practices necessary during the First World War?

4) What among these influences was the most significant on the development of submarine chasers during the First and Second World Wars?

Modeling

Initial research efforts began with an eye towards investigating physical remains of submarine chasers but shifted towards the utilization of McNeel's *Rhinoceros 3D* software to construct three-dimensional models of the SC-1, PE-1, and PC-461 class submarine chasers. This method of using ship models as digital archaeological sites is similar to techniques used by ECU graduates William Sassorossi in his thesis, *Defending the East Coast: Adapting and Converting Commercial Ships for Military Use* (2015), and Kara Fox in her thesis, *Matters of Steel: Illustrating and Assessing the Deterioration of the World War II Merchant Freighter* Caribsea (2015). Sassorossi utilized color-coding in highlighting specific areas showing adaptations on merchant vessels converted for military use, while Fox paired three-dimensional models of *Caribsea* with photogrammetric models of the physical site of the shipwreck to discuss deterioration and site formation processes (Figures 1 and 2). Because submarine chasers were mass produced small combatants more likely to be scrapped or sold after conflicts ended, extant examples of physical remains for all three classes of submarine chaser used in this study were difficult to find and often in a severely deteriorated state. The models filled this void and allowed for the assessment the vessels in the scope of the research questions by highlighting specific characteristics such as armament, propulsion, or hull design. The models were utilized alongside ship plans and historical documents to compare and contrast the vessels with each other and the submarines they often faced in antisubmarine warfare operations.

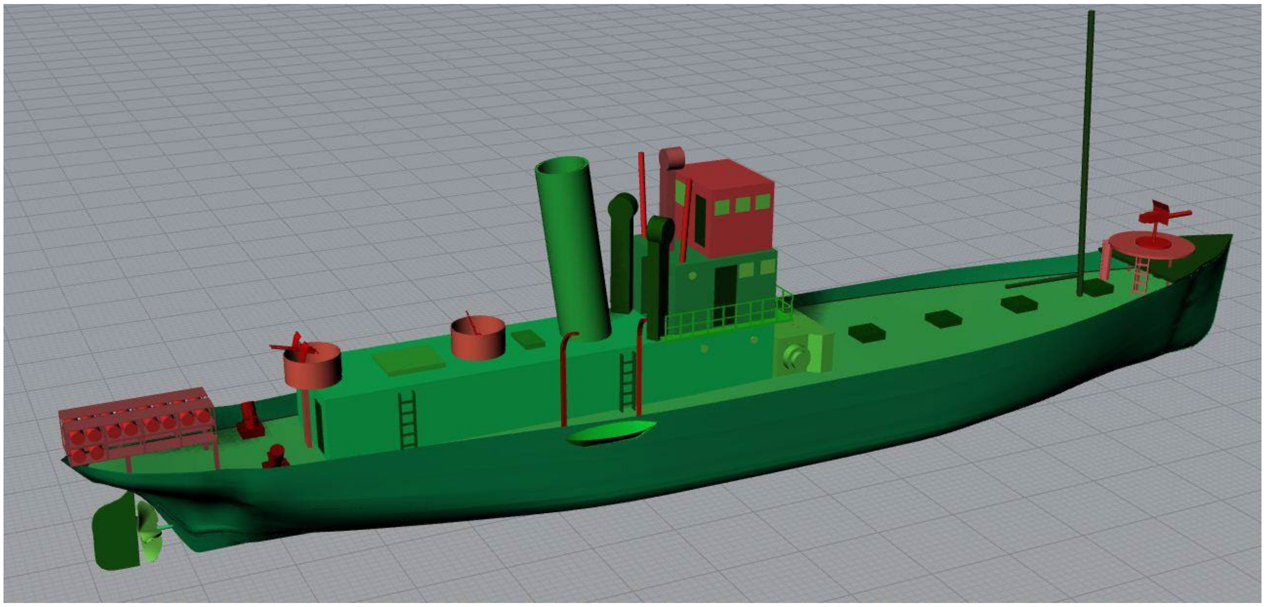


Figure 1: Color-coded three-dimensional model of HMT *Bedfordshire.* The color red is used to show war-time adaptation to a vessel constructed to be a trawler (Sassorossi 2015:157).

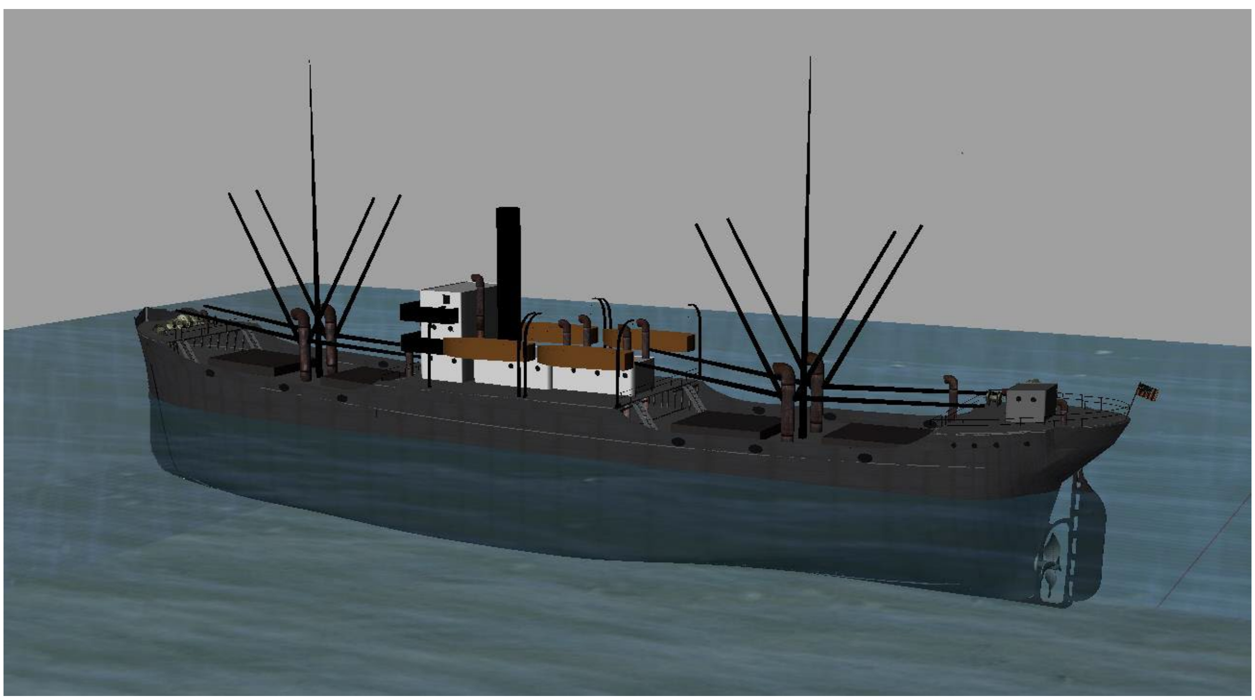


Figure 2. Three-dimensional model of *Caribsea* (Fox 2015:80)

Previous Research

As mentioned previously, this thesis began with a focus on physical submarine chaser remains rather than three-dimensional models. U.S.S. *PC-1084*, a deserted PC-461 class submarine chaser (abandoned in the Cape Fear River, near Fayetteville, NC), was the genesis of this project and research into submarine chasers began with a study of that vessel, its performance in the Second World War, and the life it led after the war concluded. That project evolved as the influences on the design characteristics of PC-461 class submarine chasers were researched and eventually led to the broad study of submarine chaser development that now exists. Extensive research on submarine development and deployment, from the era of the American Revolution up to the Second World War, was also necessary to understand the placement of submarine chasers in the overall scope of the First and Second Battles of the Atlantic.

To understand how people affected the design and development of submarine chasers, several case studies of significant historical figures were conducted as well. This led to further research on their backgrounds and the events that shaped their lives and the environments in which they formed their perspectives. The land conflicts of the First and Second World Wars were also researched extensively, as they affected decision-making and the desperation that led to certain decisions in a significant way.

Structure

Chapter One of this thesis serves as an introduction that outlines the project's goals and structure. Chapter Two details the historical background of both submarine and submarine chaser development in an effort to lay the framework for the study. An understanding of the timelines for both vessel types and how those timelines fit together is essential for effectively assessing influences. Chapter Three examines selected theoretical concepts for thinking about how technology and culture interact with each other. Because the influences on submarine chasers were the result of both technological shifts and cultural ones, clarification of the framework for thinking about those shifts is necessary as well. Chapter Four illustrates the methodology used to conduct this study. Numerous historical sources, both primary and secondary, were used to collate the information throughout this study. It also explains in greater detail the processes used to develop the three-dimensional models used in later sections to address the proposed research questions. Chapter Five pairs the models with the historical research to highlight the reasons for each submarine chaser's construction and discuss the mechanical details and contemporary thoughts on the pros and cons of each vessel. Chapter Six joins those results with the theoretical concepts discussed in Chapters Two through Four to analyze the submarine chasers in the context of the research questions. Chapter Seven offers conclusions on the results of this study.

CHAPTER TWO: GERMAN U-BOATS AND THE COUNTER-DEVELOPMENT OF U.S. SUBCHASERS

The U.S. Navy submarine chaser programs were part of a broad antisubmarine warfare strategy developed through two generations of Allied experimentation on the subject. To understand the development of this vessel type and determine the factors that affected its growth, a concise history of submarine development and antisubmarine counter-development is necessary. This chapter will highlight German submarine development and the Allied response to its deployment, as well as the unique conditions leading to the creation and growth of the U.S. submarine chaser program.

German Submarine Development

In the midst of the First Schleswig War, fought between the German Confederation and Denmark from 1848 to 1851, soldier and inventor Wilhelm Bauer ruminated on a solution to the Danish blockade of the German coast. After leaving the Bavarian Army and joining that of Schleswig-Holstein as an officer of artillery, Bauer submitted his *brandtaucher*, or diving incendiary, to the Ministry of Marine and earned funding to construct a model in Kiel. The 70 cm x 18 cm x 29 cm model was driven by clockwork and managed to dive and travel horizontally across Kiel Harbor for five minutes before surfacing again (Rössler 1975:10). The model was made up of two hulls, an outer made of copper and an inner made of two ballast cylinders, and the vessel was able to dive or surface based on the pistons inside the cylinders. It could be steered by a movable rudder at the stern and included a window in the front and entry hull at the rear. Though his superiors were fascinated by his creation, the lack of funding within the navy prevented Bauer's design from being replicated in a full-sized model.

A few months later, in the summer of 1850, Bauer received the money necessary to finally construct his model. However, the budget failed to cover the entire projected cost and Bauer was forced to reduce the thickness of the hull, strength of the frames, and expand the distance between each frame (Rössler 1975:10-12). These reductions in material resulted in the submarine buckling at a depth of 9.4 meters (30 feet) and rapidly crashing to the bottom. The leaking valves caused the vessel to take on too much water, sticking it to the bottom with Bauer and his crew trapped inside. After a six and a half hour wait, the pressure equalized in the vessel and allowed the men to open the conning tower and float to the surface. Bauer spent the following two decades traversing Europe in an effort to gain funding for his submarine development. He first arrived in Great Britain, where languishing construction efforts and a hollow but seriously taken threat to offer the submarine plans to Russia resulted in his hasty exit from the island nation. Left with few other options, Bauer did indeed approach Russia about his invention, leading to construction of the *Seeteufel* (Sea Devil) in November of 1855 (Gunton 2003:12). By the spring of 1858, he had run 134 trials, including one failed attempt to use the *Seeteufel to* attach a mine to a ship. Financial disagreements forced Bauer out of Russia and back to Berlin, part of what was by then the Northern German Confederation, hoping to earn financial backing from the Prussian War and Naval Ministry. After a brief stint back in Britain, he returned to Prussia in 1864 with much improved plans for the fourth rendition of his "underwater fighting ship." The *Küstenbrander* (Coastal Incendiary) was to be powered by a single-drive internal combustion engine for both surface and submerged propulsion, with a top speed of 8 to 9 knots (Rössler 1975:13). It would be fitted with a controllable-pitch propeller for optimum propulsion and a transverse propeller for maneuvering, as well as hydroplanes for rapid diving. The vessel's armament would be made up of five underwater guns and, due to an innovative air purification system, could operate a maximum of 48 hours underwater before the crew needed to resurface. However, technology of the time was not developed enough for Bauer's engine and underwater guns. The turbine systems lacked the ability to operate independently of outside air and the guns pierced metal underwater at a very limited range, but his inventions laid out the framework for future German submarine construction (Rössler 1975:14).

In the meantime, submarine specific weapons developments were also taking a huge leap forward. On the other side of the Atlantic, where the American Civil War was raging, the Confederate Navy quickly realized that it was outgunned and outnumbered, and its strategy of commerce raiding was stifled as the Union increased the number of vessels patrolling Southern ports (Littlefield 2015:410). This discrepancy in offensive ability led to an aggressive phase of naval experimentation spearheaded by Commander John R. Tucker's Charleston naval squadron. The impact-triggered mine, known as a torpedo at the time, was developed by Confederate Captain Francis Lee and deployed in large numbers throughout the southern states with varied success. However, stationary devices deployed in river and harbor mouths would do no damage to an enemy with no intentions of entering those kill zones. An independent phase of Confederate submarine experimentation was the result, with the semi-submersible CSS *David* and completely submersible *H.L. Hunley* launched in 1863 and 1864 respectively. Both vessels employed Lee's impact-triggered mines as their primary weapons, attaching the explosives to long spars and using the low profile of the vessels to stealthily approach and ram Union blockading vessels. CSS *David* became the first submersible ever to explode a torpedo against the hull of an enemy vessel when it attacked U.S.S. *New Ironsides* on 5 October 1863, while *H.L. Hunley* completed the first successful combat submarine attack by ramming and sinking U.S.S. *Housatonic* in Charleston Harbor on 17 February 1864. However, neither vessel escaped unscathed. CSS *David* was nearly swamped when the column of water caused by the explosion extinguished its coal fired engines. *H.L. Hunley,* a hand powered vessel, was lost with all hands in the shockwave resulting from the detonation of their spar torpedo (Gunton 2003:12-13). These attacks demonstrated that while the submarine was indeed a viable weapon of war, serious adjustments would need to be made to its armament to improve its sustainability.

Austrian Navy Captain Giuseppe Luppis was the first person to consider the idea of an independently propelled torpedo, speculating that either steam or clockwork could be used to propel a warhead guided by a line (Gunton 2003:19). Following the denial of his idea by the Austrian government, Luppis presented it to English inventor Robert Whitehead. Two years of development resulted in a rough production of what would come to be known as the Whitehead torpedo, first produced in 1866. By 1868, the 22-foot explosive device include a balance chamber mechanism connected to horizontal rudders in order to correct fore and aft tilt, as well as its own depth engine, gyro steering engine, and depth indicator. Both the Austrians and the British took immediate interest in the invention, with the former purchasing the patent in 1867 and the latter providing a financial contribution of 15,000 pounds sterling for the rights to the design and manufacture of the device (Gunton 2003:20; Kelly 2011:47). A delegation from the North German Navy visited Whitehead at the Firma Stabilimento Tecnico (Signature Technical Plant) in Fiume, Italy in 1869 and, in their new role as the Imperial German Navy, followed up the visit with the purchase of Whitehead torpedoes from the Austrian government and Whitehead. The first combat success of a Whitehead torpedo, the sinking of a Turkish sentinel boat in Batum Harbor by Russian torpedo boats in January 1878, only increased the German (and overall European) desire to perfect the use of the torpedo in naval combat (Kelly 2011:50). However, it would require the action of a mortal enemy to spur the Imperial German Navy into joining this new weapons technology with the increasingly pragmatic submarine technology of the late Wilhelm Bauer.

By 1904, France was the greatest proponent of the submarine in the world. John Holland, an Irishman working for the American government, developed a promising and practical submarine design in 1900, and by 1904 the French were in possession of 26 such vessels with 13 more on backorder. By 1906, they possessed a combined 131 submarines, with 82 of those intended for offensive operations. In contrast, the Imperial German Navy's submarine fleet was struggling under the direction of Vice Admiral Alfred von Tirpitz. The early vessels were gasoline-fueled, unable to deploy for more than a night due to poor range and lack of crew accommodations, and incredibly difficult to sail in the North Sea due to their low freeboard (Kelly 2011:353-354). While Tirpitz had been a driving force in the Torpedo Inspectorate's development of German torpedo doctrine, he was loathe to pour financial resources into what he viewed as an unproven technology. He viewed the German submarine as dispensable due to its lack of seaworthiness in the open ocean, though he noted that he would be open to their use as commerce raiders as soon as they proved capable of overseas voyages (Tirpitz 1919:138). In 1906, the Torpedo Inspectorate launched exactly what Tirpitz requested. *U1* was tested in the North Sea in September and delivered to the Reichs-Marine-Amt, or Imperial Navy Office, on 14 December 1906 (Rössler 1975:19). After reviewing the vessel for themselves, the office stated:

1. It is a diving boat of reasonably large displacement. Its capabilities on the surface are such as to meet the difficult water and weather conditions of the German Bight.
2. It has paraffin-burning engines. Our defense policy lays the greatest emphasis on operational safety. Petrol engines cause a very large number of accidents and these

> are caused by explosions which have occurred especially often in England. Prior to 1904 it would have been impossible to build such a boat (Rössler 1975:19-21).

The confluence of Bauer's early experiments with submarines, German doctrine and development in the use of Whitehead torpedoes, and the introduction of the less flammable Körting heavy-oil engine allowed the Imperial Navy to develop submarines capable of staying out at sea for extended periods of time and attacking enemies in their own territorial waters (Gunton 2003:16). While the submarine fleets of other European powers like Britain and France by far outnumbered that of Germany, the vast majority of their vessels were old, obsolete, and good for little other than harbor defense (Kelly 2011:356). The wisdom and patience of Tirpitz allowed the Imperial Navy to capitalize on the very best features of all the available technologies of the day to create a stealth weapon unlike any ever launched before. The *Unterzeeboot*, or U-boat, was poised to change the scope of naval warfare forever.

On 5 September 1914, U-boat Kapitänleutenant Otto Hersing started the *kleinkrieg,* or war of stealth, off the Firth of Forth on Scotland's eastern coast. As the British Scout-class light cruiser HMS *Pathfinder* moved out towards the open ocean, Hersing fired a single torpedo from his submarine, *U21*, and waited patiently to see if his attack would succeed. The torpedo struck HMS *Pathfinder* less than a minute later, causing a massive explosion in the main magazine that sank the ship almost at once and killed 259 of the ship's 360 crew members (Edwards 1996:9). It was the first time since the *Hunley* attack that a combat submarine attack was launched on enemy shipping. Two weeks later Kapitänleutenant Otto Weddingen sank the 12,000-ton armored cruisers *Aboukir, Hogue,* and *Cressy* in just over an hour, killing 1,460 British sailors in the process (Showell 2006:45-48). Lacking the technology to detect submerged U-boats, the British pursuit following the attack was essentially pointless. Weddingen's *U9* calmly took its leave of what is still known as one of the most devastating days in the history of the British Royal Navy.

The ruinous days for British shipping, military and civilian, continued as the Imperial German Navy continued to improve its communication and define its preferred submarine characteristics more clearly. The arrival of wireless telegraphy (or radio) allowed deployed U-boats to communicate information about potential targets and coordinate attacks on convoys (Grant 1969:10-11). To speed up the process of submarine construction and conserve material the type UB-I submarine, intended to be a coastal operations vessel, was authorized in 1915 (Stern 1991:10). Though these submarines were able to meet the expectations for production speed they were incredibly small, short ranged, and lightly armed as a result. Type UB-I submarines had a surface displacement of just 127 tons, a range of 1,600 nautical miles, and were armed with two small 45-cm torpedo tubes (Showell 2006:53-54). The class was scrapped after the construction of only 17 submarines and succeeded by the type UB-II, which carried a surface displacement twice that of the type UB-I, was more heavily armed with two 50-cm torpedo tubes and had an increased range of 6,650 nautical miles (Showell 2006:54). Its arrival on the naval battlescape coincided with the official declaration of what would come to be known as unrestricted submarine warfare.

On 4 February 1915, Admiralstab Hugo von Pohl, commander of the German High Seas Fleet, issued a declaration that the waters around Great Britain and Ireland were to be designated a war zone (Edwards 1996:14). He specified that any enemy merchant ships sailing through the war zone would be sunk immediately, and even neutral vessels were at great risk of being attacked. This expansion from North Sea hunting to what amounted to a submarine driven blockade of the entire British Isles meant that U-boats would now range out into the North

Atlantic. As the hunting range of U-boats increased in size, the UB-II was followed up in 1917 by the type UB-III. Though still classified as a coastal operations vessel, the type UB-III was without doubt a sea-going submarine. Its displacement expanded to 516 tons, its range to 8,500 nautical miles, and the armament to four torpedo tubes in the bow, one in the stern, and an 8.8 cm deck gun for surface combat, all while reaching a top speed of 13.6 knots and sacrificing just five knots in speed when submerged (Stern 1991:11). By the end of the First World War, 84 type UB-III U-boats would be produced in 11 different variations. Several would reach U.S. territorial waters and attack U.S. merchant shipping by the end of the war, foreshadowing what would become a protracted and bloody Second Battle of the Atlantic initiated by their direct descendants 20 years later.

Though the Treaty of Versailles of June 1919 expressly forbade Germany from possessing any major new weapons or expanding its military beyond defensive capabilities, the Reichsmarine, successor of the now defunct Imperial German Navy, almost immediately began disobeying the Allied Powers' mandates. In 1920, the Inspectorate for Torpedoes and Mines was established in Kiel to gather relevant documentation about U-boat development, track surviving U-boat officers and designers, and work with private shipyards to maintain their submarine-proficient construction crews by contracting them out to foreign shipyards (Stern 1991:12). The Reichsmarine then covertly funded the creation of the Submarine Development Bureau in July 1922, concealed from the public eye by a front as an engineering firm for shipbuilding. The Bureau continued the work of the Inspectorate for Torpedoes and Mines in consolidating U-boat knowledge and outsourcing it for design experimentation. Research initiated by Kapitänleutenant Hans von Mellenthin and continued by the Submarine Development Bureau identified the Type UB-III and UC-III, a minelaying submarine, as appropriate designs for continued development and based plans for foreign submarine contracts on their First World War templates (Rössler 1975:90-91). The first of these contracts, a 570-ton boat designed for the Argentinian Navy never came to fruition but a request from the Turkish Navy for two submarines based on the UB-III design was completed in 1926 and delivered by a crew of "retired" German naval officers in 1927 (Stern 1991:12). This practice of Submarine Development Bureau-constructed submarines being delivered by undercover Reichsmarine submariners would repeat itself with three UC-III-based minelaying submarines for the Finnish Navy and an enlarged UB-III-based submarine completed for Spain in 1930, thought this was retained by the Germans after the Spanish Government encountered financial troubles.

Germany's submarine development shifted from backdoor to brazen as Adolf Hitler's Nazis consolidated power. The beginning of 1933 saw the allocation of funding to the Reichsmarine to begin construction of a U-boat base at Kiel-Wik and two submarines thinly veiled as *Motorenversuchboots,* or motor research boats (Stern 1991:13). These 250-ton boats, codified with the name MVB-II, were to be used as training vessels for U-boat crews. By the fall of 1933, the MVB-II construction plan expanded to six vessels with two additional larger MVB-I submarines on order as well. However, the actual construction of the vessels was delayed as Hitler attempted to avoid provoking Great Britain and the other Allied powers. This deference ended on 18 June 1935 with the signing of the Anglo-German Naval Agreement, which validated the German stance that the Treaty of Versailles was unjust regarding military development and allowed Germany to construct submarines openly as long as their tonnage remained at one-third that of the Royal Navy's submarine fleet (Stern 1991:13; Showell 2006:71-72). This left Germany, which by the time of the Agreement had fourteen MVB-IIs and two MVB-Is staged for construction, with just 14,000 tons to work with. The newly christened Kriegsmarine elected to scrap plans for large submarines and bridge the gap between the smaller MVB-IIs and larger MVB-Is with a 500-ton boat designated as the MVB-VII. Dropping all pretense early in 1935, the Kriegsmarine redesignated the MVB-VII design as the Type VII. Perhaps the most famous of the U-boat types, over 700 Type VII U-boats were constructed in six different variations by the conclusion of the Second World War (Stern 1991:14).

The Type VIIA and VIIB U-boat designs, were essentially modernized versions of the First World War Type UB-III (Showell 2006:79). The Type VIIA increased in size from the 180-foot (ft) long, 516-ton displacement of its predecessor to a 211.5-foot long vessel with a 626-ton displacement. Improved diesel engines, electric motors, and new hydraulic systems to replace the wire controls of the previous generation allowed the Type VIIA to achieve 16 knots on the surface and 8 knots while submerged with a range of 4300 nautical miles (Stern 1991:14). In armament it mimicked its First World War predecessor, as it was equipped with five torpedo tubes, could carry six additional torpedoes onboard for extended patrols, and was armed with a deck gun for surface combat. However, the rear torpedo tube sat well above the pressure hull and could often freeze solid during cold weather operations making the weaponry unusable (Showell 2006:81). A competition between it and the older but larger Type MVB-I submarine demonstrated that the Type VIIA carried most of the desirable qualities submarine commanders wanted but could benefit from incorporating some of the technology of the Type MVB-I. The new Type VIIA was replaced by the newer Type VIIB after the construction of just ten submarines. The Type VIIB was an improvement on its predecessor due to the addition of twin rudder technology from the MVB-I which increased its underwater turning radius, six and a half feet of additional length which allowed for increased torpedo and fuel storage, and a 2-centimeter (cm) deck gun to its formidable arsenal (Stern 1991:17). A second negotiation of the

Anglo-German Naval Agreement in 1937 allowed Germany to increase its submarine tonnage to 45 percent of that of the British Royal Navy, which subsequently allowed the production of 24 of the highly improved Type VIIB U-boats.

With little complaint about the performance of the Type VIIB, the only motivation to produce further versions of the Type VII U-boat was technological innovation. The innovation in question came in the form of the Sonder-Gerät für active Schallortung (Special Equipment for Active Sound Location), known as the S-Gerät for short. This device was a horizontal sounder, a type of detection device, designed to measure the distance and direction of objects in the water via echolocation (Rössler 1975:145). It allowed deployed U-boats to detect minefields and enemy vessels, but required additional space not present on the Type VIIB U-boat to be equipped. This led to the production of the Type VIIC, which added an additional two feet of length to the control room to accommodate the new detection technology (Stern 1991:19). This adjustment had the side benefits of adding additional space to what had once been a cramped conning tower and an increase in the size of the fuel storage tanks below the control room. The addition of the Type VIIC to the Kriegsmarine's submarine arm coincided with a second renegotiation of the Anglo-German Naval Agreement in December 1938, during which Great Britain conceded and allowed Germany to build submarines at a rate one hundred percent equal to that of the British submarine fleet (Rössler 1975:117). This removal of limitations on German submarine construction allowed for the mass production of their most dangerous naval weapon. The first Type VIIC U-boat was launched in September of 1940 and would be followed into service by over 600 additional Type VIICs by the end of the Second World War (Showell 2006:81). These new and improved versions of the Type UB-III U-boats of the First World War picked up right where their predecessors left off, throttling merchant shipping in the waters around the British Isles and casting an ambitious eye across the Atlantic towards the waters of the United States.

Submarine Chaser Counter-Development

The U.S. entry into antisubmarine warfare and submarine chaser construction was initiated by a declaration made two years before the isolationist nation ever entered the First World War. On 4 February 1915, Admiralstab Hugo von Pohl, commander of the German High Seas Fleet, issued a declaration that the waters around Great Britain and Ireland were to be designated a war zone (Edwards 1996:14). He specified that any enemy merchant ships sailing through the war zone would be sunk immediately, and even neutral vessels were at great risk of being attacked. This official declaration of what would quickly come to be known as unrestricted submarine warfare increased the possibility of U.S. citizens being killed as they traveled the broad expanse of water between their home and Europe. A few months after Admiralstab von Pohl's declaration, his U-boat fleet made such a possibility a reality. On 7 May 1915, the RMS *Lusitania,* a British ocean liner, was torpedoed in an attack that killed 1,198 civilians, many of them women and children, and brought about outrage from the major powers of the Allied cause (O'Sullivan 2014:18). Of those killed in the attack, 128 were U.S. citizens. This action by the German submarine fleet electrified the United States, with many U.S. citizens demanding an immediate declaration of war and the tension dropping only after the German government promised to cease the practice of unrestricted submarine warfare a few weeks later (Daniels 1922:14). However, the U.S. Navy continued to prepare for an eventual conflict with the German U-boat arm.

In preparing for this potential naval war, the U. S. Navy determined that a strong coastal defense was needed to protect commerce moving between major ports on the East Coast from the threat of German submarines (Friedman 1987:19). The initial antisubmarine warfare plan was promoted by Assistant Secretary of the Navy Franklin D. Roosevelt in 1914. This "preparedness" plan, strongly endorsed by the Navy League of the United States, suggested the formation of a 50,000-person naval reserve and the retrofitting of civilian craft with arms and armament (U.S. Naval Institute 1914:1815). This suggested reserve would be made up of honorably discharged seamen pledged to respond quickly to the call of the government should a war with Germany break out. The public enthusiasm of his assistant resulted in incumbent Secretary of the Navy Josephus Daniels polling the U.S. Navy General Board, the navy's advisory body, to determine the desirable characteristics of an acceptable patrol craft. Skeptical of the level of sacrifice private owners were willing to make for the war effort, the board recommended a federally manufactured vessel with strength and a speed exceeding 16 knots highlighted as the most important qualities. The specifications for two prototype vessels, C-253 and C-252, were based on the "Fast" categories put forth for civilian vessels entering the service (Table 1).

Albert Loring Swasey, vice president of the Herreshoff Manufacturing Company of Bristol, Rhode Island, won the contract to build C-253 (Rousmaniere 1992:42). Swasey specialized in the design of fast, oceangoing power yachts, and his prototype reflected this skillset. The vessel, constructed by George Lawley and Son of Neponset, Massachusetts, was comprised of a wooden hull, steel bulkheads, and an underbody designed for rough water. It was powered by three six cylinder, 220-horsepower, gasoline engines, displaced 75 tons, and could reach a maximum speed of just under 16 knots (Friedman 1987:22). While the boat met most of the requirements of the A-Fast class (see Table 1), it rolled terribly in anything less than a calm sea and was deemed unsatisfactory for military use. The 66-foot C-252 was more satisfactory to the Navy, though it was not completed until after the U.S. entry into the First World War and not deployed until the Second (Figure 3).

Table 1. Civilian Patrol Vessel Classification (Friedman 1987:22)

A (Slow)	Must maintain station in a harbor in weather no worse than a moderate gale, maintain a speed of no less than 7 knots, and have an armament of one 1-pound gun and one machine gun.
A (Fast)	Must keep the sea in a moderate gale, have a length of at least 40 feet, a top speed of at least 16 knots, have an armament of one 1-pound gun and one machine gun, a crew of four, and provisions for four days.
B (Slow)	Must ride out a moderate gale at sea, have a length of at least 60 feet, a speed of at least 10 knots, an armament of one dual-purpose gun, at least one 3-pound gun, at least two machine guns, a crew of eight, provisions for five days, a radio, and a searchlight.
B (Fast)	Specifications same as B (Slow) except speed must be at least 16 knots.

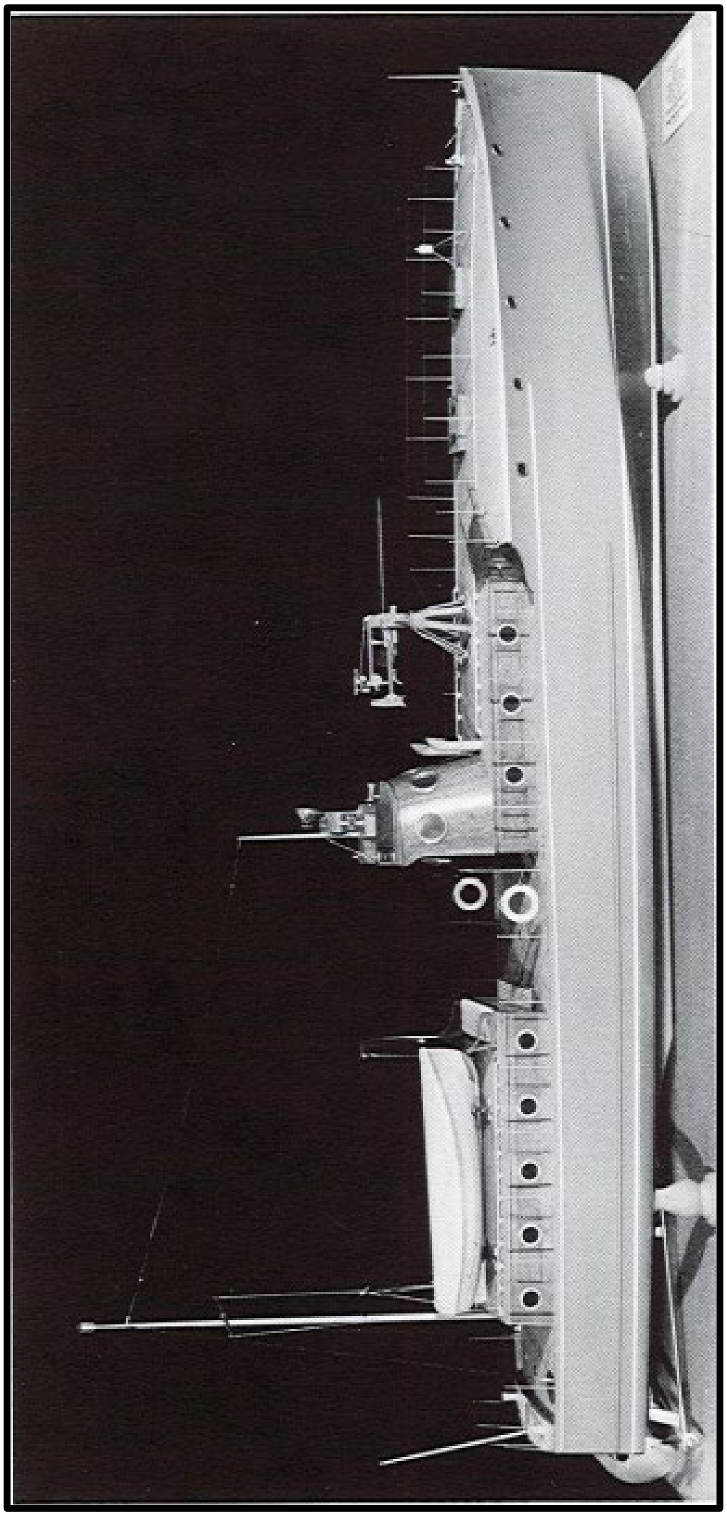


Figure 3. Model of Luders Marine Construction’s 66-foot design (Friedman 1987:23)

Germany's renewal of unrestricted submarine warfare in early 1917 coincided with the design and construction of a class of U.S. vessels designed specifically to hunt them. The 110-foot SC-1 class submarine chaser was based on a previous 80-foot design constructed by the Electric Launch Company (Elco) of New Jersey for the British Royal Navy (Rousmaniere 1992:42). However, the consensus among the U.S. contingent was that the larger coastline and rougher seas of the Eastern Seaboard would require a larger, more rugged vessel. Albert Loring Swasey, now a Lieutenant Commander in the Naval Reserve, was once again brought in to work with the Bureau of Construction and Repair (C&R) on the design of this new subchaser (Woofenden 2006:12). Swasey's design began as a 105-footer but C&R extended the hull by five feet to help the boat achieve the required speed of 16 knots on two 300 brake horsepower (bhp) engines (Friedman 1987:29-30). The General Board approved the 110-footer but shifted its construction from steel to wood to counter labor shortages in conventional shipyards. The vessels were initially equipped with one 6-inch gun and two machine guns, but by the end of the conflict were operating with one forward 3-inch Poole gun, two machine guns, and a Y-gun (Nutting 1920: 67; Friedman 1987:32) (Figure 4).

The SC-1 class was authorized for construction on 4 March 1917, exactly one month before the official declaration of war. In total 441 were constructed, with 403 completed and launched during the war and most being completed by the 1 January 1918 deadline requested by the General Board (Woofenden 2006:12-13, Friedman 1987:31). The theoretical belief was that large concentrations of patrol craft in U-boat operational areas would result in encounters between the opposing vessels and thus enough U-boat sinkings to disrupt the *kleinkrieg* (Friedman 1987:19). Hunting zones were chosen via reports from shore listening stations and directional radio stations, S.O.S. calls, and reports from other patrolling aircraft and

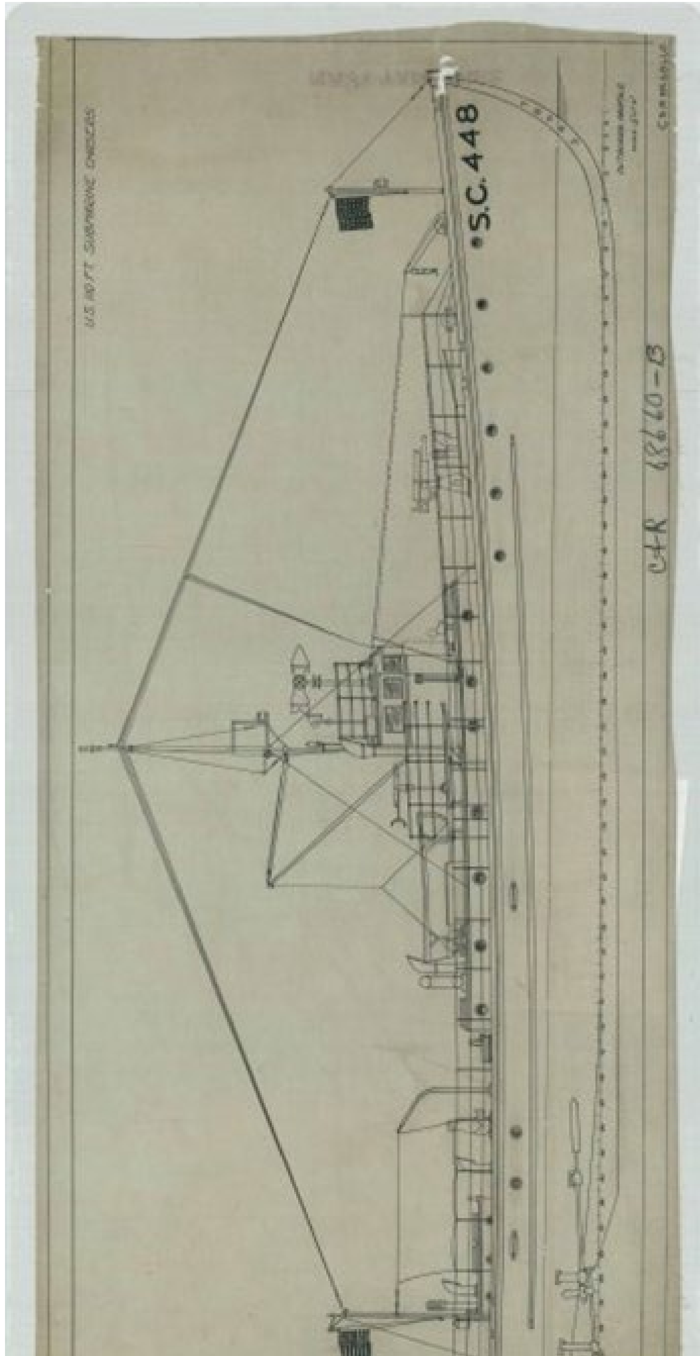


Figure 4. SC-448 Outboard Profile from Booklet of General Plans (Maxson 1918:1).

vessels (United States Navy 1917). In the absence of such reports, anchored, drifting, or running patrols were used to search designated quadrants for submarine activity. Regardless of the method used, proper detection required excellent seakeeping ability and a silent platform, meaning that the vessel's engines needed to be turned off to allow the hydrophone operators to do their work. SC-1 subchasers were equipped with internal combustion gasoline engines to make this process more efficient and operated in groups of three to six vessels to triangulate U-boats through hydrophone detection. These groups were usually accompanied by a larger vessel, oftentimes a destroyer, which aided in attacking the enemy submarine once discovered.

133 SC-1 class submarine chasers were deployed in European waters, with Detachment One located at Base 27 in Plymouth, England; Detachment Two at Base 25 in Corfu, Greece; and Detachment Three at Base 6 in Queenstown (now Cobh), Ireland (Woofenden 2006:181). Each of the bases deployed subchasers in offensive operations against submarines with varying degrees of success. Detachment Two gained the most fame while operating as part of the Otranto Barrage, a blockade of mines, nets, and patrolling vessels laid in the Strait of Otranto to prevent Austrian and German submarines from entering the Mediterranean Sea (Milholland 1936:109-111). In an attack on the Austrian submarine base at Durazzo, Albania on 2 October 1918, a detachment of twelve SC-1 subchasers screened Italian and British cruisers as they bombarded the base, sank at least one submarine, captured a hospital ship, escorted a wounded cruiser after it was torpedoed, and even pushed into shallow water just 800 yards from the shore to perform close bombardments of their own (Daniels 1922:161-164). The effectiveness of the SC-1 subchasers at Durazzo was highly celebrated in the U.S. and the versatility of the vessels in multiple roles noted by U.S. Navy designers. In U.S. territorial waters, SC-1 groups and their escorts faced less frequent but far more alarming action than those in European waters. From 9

June to July 1918, submarine chaser groups encountered or detected three separate intrusions by German submarines in the North Atlantic (Woofenden 2006:191-192). These contacts were followed by two more detections in September. Though German submarines had visited the U.S. coastline as early as 1916, these new incursions represented the threat of longer ranged U-boats arriving in numbers that could truly threaten commercial shipping. Though Armistice of 11 November 1918 ended the fear of submarine attacks for the time being, the imagery of U-boats in U.S. waters would stick in the minds of U.S. naval officials for years to come.

Growth and Development after the First World War

Even while the SC-1 subchasers were being constructed and deployed in 1917, U.S. naval strategists cast a wandering eye towards a larger, more formidable craft to hunt U-boats in waters outside the range of the smaller craft. Secretary of the Navy Josephus Daniels was contacted by famed automobile designer Henry Ford via a letter on 24 December 1917, in which Ford proposed the possibility of mass producing a vessel he described as a "submarine detector-destroyer" using the same assembly line process he used in automobile fabrication (Crowell and Wilson 1921:469). This suggestion intersected with the General Board's plans for a steel flush decked, 175-foot, 400 to 550-ton diesel or semidiesel vessel with a max speed of 20 knots, an armament of one 5-inch gun, one 3-inch antiaircraft gun, one or more 6-pound guns, and 24 depth charges for submerged targets (Friedman 1987:38). Simply put, the U.S. Navy wished to combine the strength of the destroyer with the detection abilities of the submarine chaser. In meetings with the General Board, Ford suggested that he would be able to produce six of these new submarine-detector destroyers for every destroyer produced using traditional methods and Secretary Daniels jumped at the opportunity, though other officials in the Navy were less convinced. Two weeks later, plans were submitted to Ford by the U.S. Navy C&R and he agreed to the production of between 100 and 500 of these new submarine chasers at the specially constructed River Rouge plant in Dearborn, Michigan. The plant consisted of two buildings, the A-Building where steel plate and other boat parts were fabricated, and the B-Building where three parallel assembly lines, two outfitting buildings, and a 202-foot transfer table supported by eleven railroad tracks carried the finished submarine chasers to a launching table to be lowered into a newly constructed canal by hydraulic jacks (Hounshell 1985:188). The final product was the PE-1 class submarine chaser, though it was known more commonly by the moniker "Eagle boat" due to an editorial comparing it to the U.S. national mascot (Figure 5).

The first PE-1 class subchaser was launched on 11 July 1918 and measured 200 feet in length, 25 feet, six inches in beam, had a draft of seven feet, three inches, and displaced 500 tons (Furer 1919:765). Though a diesel or semidiesel propulsion system had been part of the initial request by the General Board, the PE-1 utilized a steam turbine both for ease of construction and because of competition with destroyers for diesel engines. The initial production plan for the PE-1 class was to produce one boat within five months of the initial contract, ten boats in the month following that one, and a standard quota of twenty-five boats per month after 1 November 1918 (Crowell and Wilson 1921:471). However, difficulties in making the boats water-tight and oil-tight hamstrung the pace of the project, with just three boats being completed prior to the Armistice. The end of the war saw a reduced need for the new submarine detector-destroyers and the order for 100 Eagle boats was reduced to 60 by January 1919. The difficulties in manufacturing the boats continuously required extensions of the deadline and the

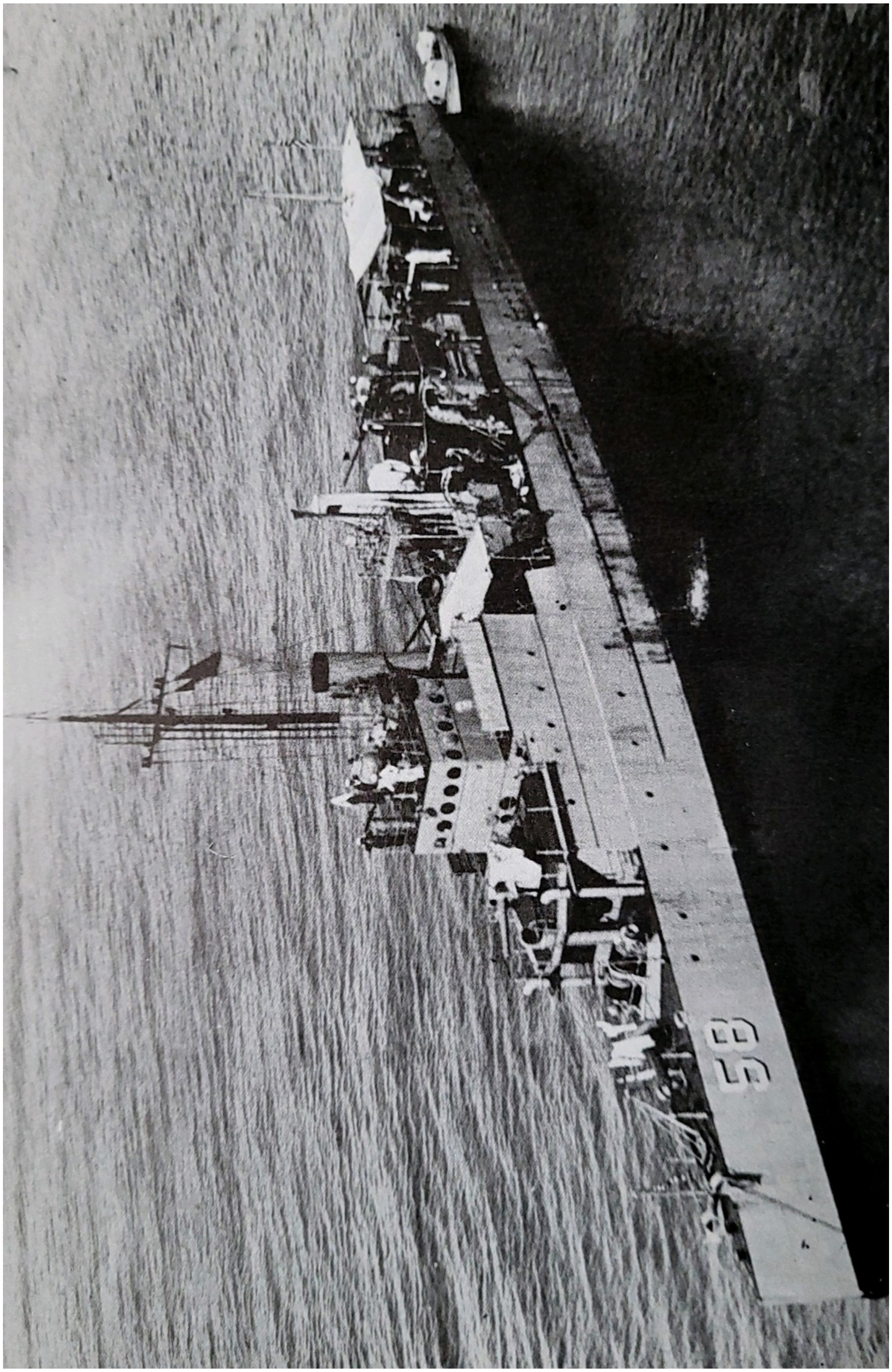


Figure 5. Eagle 58 setting sail in 1925 (Friedman 1987:39).

sixtieth Eagle boat was commissioned on 15 October 1919, just short of one year after the initial projected deadline for the project (Hounshell 1985:198).

Military usage of Eagle boats was scarce. With the threat of submarines no longer present, the Navy found itself lacking situations in which the big submarine hunters could be effective. In a 2 January 1919 hearing with the Committee on Naval Affairs for the House of Representatives, Rear Admiral David W. Taylor suggested that Eagle boats could play the part of shallow water gunboats in the West Indies, Central and South America, China, and the Philippines, noting that the larger vessels could perform gunboat service in the Philippines more efficiently than the SC-1 class submarine chasers already stationed there (House Committee on Naval Affairs 1919:121). Three were deployed (along with twelve heavily armed SC-1 submarine chasers) to perform gunboat and communications services in the defense of U.S. troops stationed in Archangel, Russia in the March of 1919 (Woofenden 2006:124). In February of 1921, three more were deployed as aircraft tenders for a seaplane-led survey of the Hawaiian Islands. In what would become the longest journey accomplished by aircraft up to that point, the presence of the Eagle boats gave the seaplanes long range capabilities they did not independently possess as well as allowing for the planes to handle repairs without needing to return to base (Carriel 1921:127-129). The journey also demonstrated the ways in which improvements in radio technology made effective communication between naval and aerial military assets possible regardless of visual contact with each other, a development that would prove quite useful in the Second World War. Generally speaking, however, the Eagle boats failed to live up to the excitement that initially surrounded their production. They developed a negative reputation regarding their seaworthiness and half of the Eagle boats produced were decommissioned by

1924 (Hounshell 1985:200). Only eight of the original sixty made it to the Second World War, where they were only deployed in continental waters.

Second World War Submarine Chasers

During the interwar years, U.S. policy was shaped by War Plan Orange, a series of Joint Army-Navy Board plans intended to deal with the threat of Japanese expansion in the Pacific (Morton 1959:221-222). The role of submarine chasers, now described as patrol craft or PCs, in this hypothetical war was to serve in much the same role that had once been projected for Eagle boats, combining the most useful qualities of the SC-1 and the Eagle boat in a design versatile enough to release larger destroyers to join the main naval fleet in offensive combat operations (Friedman 1987:48-49). They were also considered valuable to the island-hopping strategy planned for a war in the Pacific, as their shallow draft and maneuverability could allow them to be used as troop transports and close support vessels during landing operations. Initial plans for antisubmarine warfare operations in the Atlantic looked to the production of updated SC-1 class submarine chasers. However, the Type VIIC U-boat, soon to become the workhorse of the Kriegsmarine, was twice the length of the 110-foot submarine chaser, could outrun it on the surface, typically carried 14 torpedoes, an 88 millimeter(mm) deck cannon, and a 20-mm anti-aircraft gun, and could carry anti-ship mines (Stern 1991:18; Offley 2011:111). The U.S. Navy continued to look to the larger designs for salvation.

After the U.S. declaration of war following the Japanese attack on Pearl Harbor in December of 1941, the Germans quickly shifted their focus to the U.S. Atlantic coastline for U-boat driven operations known as Operation Drumbeat. Hunting primarily off natural maritime chokepoints in what would soon be designated as the Eastern Sea Frontier (ESF) by the U.S. Navy, this new unrestricted submarine warfare campaign sank 171 ships between mid-January and mid-June 1942 (Warnock 1993:8). The U-boats operated with almost no fear of retribution from the U.S. Navy, as the elderly Eastern Sea Frontier (ESF) Fleet had failed to produce the new ships needed to replace the vessels transferred to the Pacific theater in the wake of the attack on Pearl Harbor. The ESF Fleet, tasked with suppressing these new and more formidable U-boats, consisted of eight Eagle boats, eighteen 110-foot subchasers, eleven gunboats, five river gunboats, and converted leisure yachts of varying capability, supported from the air by four blimps and six Army bombers (Riesenberg Jr. 1966:118; Veigele 1998:27). Even with the frequency of attacks in the early months of Operation Drumbeat, this collection of vessels did not even make contact with a German submarine.

The vacuum in patrolling abilities created by the transfer of so many fighting vessels was initially filled by aircraft, with all available Army and Navy airplanes as well as the Civilian Air Patrol being used to patrol for U-boats and rescue survivors of sunken merchant shipping (King 1966:155-156). U.S. Marine Corps Air Station Cherry Point, located in southeastern North Carolina, became a particularly important base for U.S. Navy and U.S. Army Air Force observation and scouting squadrons in early 1942 as they attempted to stop the heavy rate of sinkings in the corridor between the Virginia Capes and Charleston, South Carolina (Offley 2014:4-5). These teams of scout and observer craft were followed up in mid-May 1942 by the arrival of U.S. Army Air Force light bomber squadrons as well. However, these land-based forces were accustomed to the strategic bombing doctrine of the Army and had neither the equipment nor the personnel to effectively do the specialized work of airborne antisubmarine warfare (Warnock 1993:4). The observation and scouting forces did not have the weaponry to attack submarines and the light bomber squadrons were not accurate enough yet to effectively subdue the U-Boat force off the East Coast of the U.S. with the ESF Fleet as it stood. Additional naval vessels were needed in short order to continue filling the void.

The patrol craft planned as part of War Plan Orange arrived in the Atlantic shortly after the start of Operation Drumbeat. During the design phases of the late 1930s, the General Board lobbied for two 215-ton, twin-screw subchaser prototypes, one steam powered and flush decked and the other diesel powered with a raised forecastle deck (Veigele 1998:28). The vessels were modeled after the destroyer U.S.S. *Mahan*, with a forecastle to provide freeboard for dryness and achieve the highest volume on the lowest hull weight (Friedman 1987: 53). The new subchaser was expected to have a top speed of 22.5 knots and was equipped with twin rudders slightly larger than those of earlier destroyers to improve maneuverability. PC-451, the diesel-powered raised forecastle design, was a 165-foot vessel with a top speed of 21.8 knots and won the initial government contract (Figure 6). However, it was rejected by the U.S. Navy Bureau of Ships (BuShips) because it was considered too tight spatially to accommodate more modifications and crew (Friedman 1987:59). BuShips preferred PC-452, an easily modified flush decked vessel that could carry the number of anti-aircraft weapons desired to have the ideal fighting capabilities for the multipurpose usage described in War Plan Orange. PC-452 also incorporated an innovative steam engine that designers projected would make the vessel ten knots faster and more maneuverable than its diesel-powered competition (Veigele 1998:28). Unfortunately for U.S. Naval planners, the steam engines consumed so much water that the evaporators installed onboard could not make up for the deficit, and the engines were determined to be impractical onboard small combatant warships due to the difficulty of mass producing them. As a compromise BuShips recommended installation of the PC-451 class's diesel engines in a PC-452 hull. This vessel, the PC-461 class, would become the eventual winner of the competition (Figure 7).

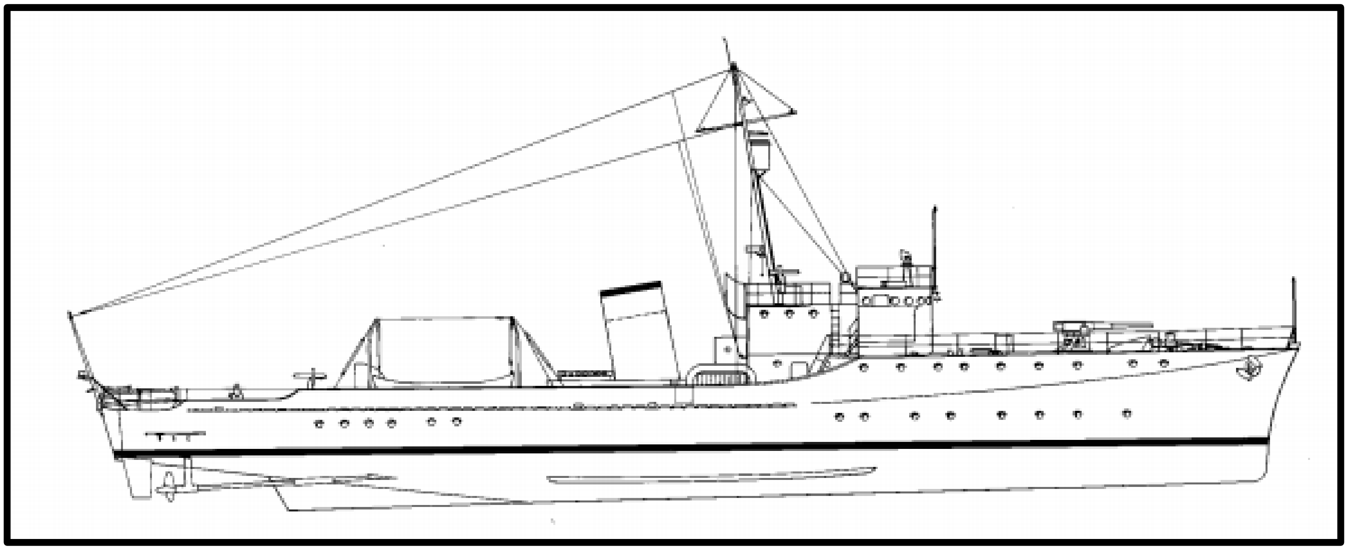
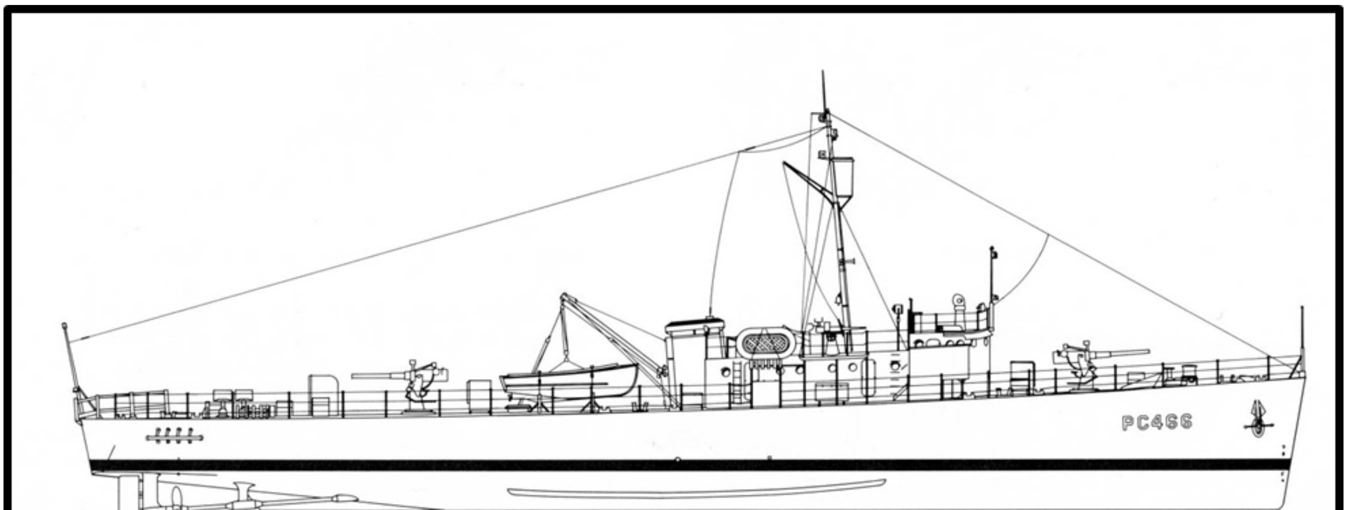


Figure 6. PC-451 as constructed in August 1940 (Friedman 1987:60)



PC 466. (A. D. Baker III)

While PC-461 was not considered as seaworthy as PC-451 due to its flush deck, the additional space onboard allowed the PC-461 class subchaser to surpass the Type VIIC U-boat in combat effectiveness. The subchaser was armed with four twin 20-mm guns, depth charges, and the new Mousetrap rocket launchers (Friedman 1987:68). The Mousetrap was particularly valuable to the effectiveness of small combatant warships because it was lighter and more accurate than both K-guns and the Hedgehog depth charge launchers being used by heavier Allied vessels (U.S. Rocket Ordnance 1946:15-17). While depth charge throwers were certainly improving, the Mousetrap's rocket propelled explosives increased both the number of direct hits on enemy submarines in both theaters of the war and the likelihood that surfaced submarines would surrender rather than trying to fight their way out of encounters with the physically smaller subchasers. Even when U-boats stood and fought, the maneuverability and sturdiness of the subchaser allowed it to engage in ramming tactics that neutralized their surface firepower (Veigele 1998:37). The PC-461's peak tank and keel were so solid that a direct hit on a submarine would collapse the U-boat's conning tower or tear open the pressure hull while still allowing the subchaser to remain afloat and functional.

The addition of the adaptable and sturdy PC-461 submarine chasers to the Battle of the Atlantic had a sobering effect on the pace of U-boat attacks. Though armed well enough to stand and fight with U-Boats, their greatest contribution was in the escorting of convoys. After the initial six months of carnage in 1942, Vice Admiral Adolphus Andrews initiated coastal convoys to protect merchant shipping from U-Boat attacks (King 1966:156). PC-461 class submarine chasers operated on the edges of these convoys, using their specialized submarine hunting capabilities to deter German U-Boat captains from attacking and subdue them when they did (Veigele 1998:153). As the U-Boats were pushed south out of the ESF convoys and their 173-

foot escorts continued to deter them, eventually reaching as far south as the upper waters of South America. After the overall subdual of U-Boats in the Battle of the Atlantic, the adaptability of the new submarine chasers allowed them to serve in multiple roles in both the European and Pacific theaters, operating as escort vessels, troop transports, navigation and control vessels, and gunships in among other roles.

Conclusion

When unrestricted submarine warfare galvanized the U.S. to join the First World War, a special type of naval vessel was born. Filling the need for an invisible battle with an unseen foe, the SC-1 class submarine chaser helped hasten the end of unrestricted submarine warfare and demonstrated the value of shallow drafted patrol craft capable of operating in multifaceted ways within the 20th century theater of war. While Eagle boats were deployed in small numbers and failed to make the impact SC-1 class vessels did, the attempt at mass producing a larger, more flexible submarine chaser capable of filling in for destroyers informed the design and production techniques for the next generation of submarine chasers in a very important way. The PC-461 class submarine chaser, while a bit less seaworthy than preferred, perfected the ratio of desirable characteristics to production efficiency in a vessel fast enough, strong enough, and sturdy enough to hold serve with U-boats and eventually help dictate the terms of the battle raging off the coast of the U.S..

When paired with the antisubmarine warfare efforts of other branches of the U.S. military and other Allied nations overall, the submarine chaser represented a collective response to a shocking change in naval conduct. Germany’s willingness to attack communal spaces rather than specific military targets had reverberating effects on not just the naval strategy that led to the creation of the submarine chaser, but the people living and operating in the communal spaces where those attacks took place. The development of the submarine chaser is indicative of development among societies on both sides of the Atlantic, and by default becomes a case study in how those developments came about.

CHAPTER THREE: TECHNOLOGICAL MOMENTUM AND CULTURAL CORES IN THE SCOPE OF U.S. SUBMARINE CHASER DEVELOPMENT

Introduction

A first assessment of the broad picture of submarine warfare and antisubmarine countermeasures suggested a Charles Darwin-like, natural selection approach to the theory supporting this research. However, treating the submarine chasers and their U-boat opposition as evolving life forms with characteristics that reflected adaptation to a changing environment did not account for the impact of the most significant contributors to that evolution: the people, both military and civilian, of Germany and the U.S.

This chapter will discuss origins of two theoretical systems, the theory of technological momentum and the theory of cultural cores, and implement them as a lens through which to view U.S. submarine chaser development. Application of these theories to the historical record will aid in the assessment of the digital models for impactful changes in their development

Technological Momentum and Cultural Cores

The theory of technological momentum derives from the research of Thomas P. Hughes on hydrogenation in post-World War I Germany. In that research, he argued that the contractual alliance between I.G. Farben, a German chemical firm, and Adolf Hitler's Nazi Party was the result of technological momentum carrying a vulnerable company into the arms of extremists (Hughes 1969:131-132). Hughes felt that the momentum of the chemical production was stimulated in its infantile phases by the excellent scientific research of engineers, chemists, and managers from the I.G. Farben firm, but the crash of the German economy after the First World War left the firm with few prospects and a technological skillset begging to be applied. The momentum of that mature technology then carried the company towards a relationship with the power giving them the most likely chance of continuing its development, the Nazi Party. Historians almost immediately challenged Hughes' theory of technological momentum by arguing that it was for all intents and purposes synonymous with the already existing theory of technological determinism (Smith and Marx 1994:101).

Technological determinism is the belief that new technologies are the primary cause of major social and historical changes at the macrosocial level of social structure and can subtly influence social and psychological changes at the microsocial level through the regular use of particular kinds of tools (Oxford Reference n.d.). Supporters of the theory perceive technology as autonomous and neutral and believe that it is an inevitable force that will lead to positive or negative consequences. In countering arguments about his mimicry of technological determinism, Thomas P. Hughes defined technological determinism more simply as the belief that technical forces determine social and cultural changes (Hughes 1994:102). He then addressed the opposite perspective, social construction, and briefly defined it as the belief that social and cultural forces determine technical change. His defense of the theory of technological momentum combined these two concepts with the introduction of time as a factor. Hughes felt that in its infantile stages, technology is controlled and shaped by the environment in which it is created, while mature technology controls and shapes the environment around it.

In a book titled *Atrocity, Deviance, and Submarine Warfare: Norms and Practices During the World Wars* (2013), Nachman Ben-Yehuda used his own theoretical system to challenge perspectives on the intersection of technology and culture in a nuanced way as well. Ben-Yehuda defines cultural cores as symbolic structures that influence the way we perceive, interpret, and act in the social environments in which we live (Ben-Yehuda 2013:9). The concept, rooted in nineteenth century French sociologist Émile Durkheim's theories on “collective conscience,” argues that cultural cores are deep-rooted belief systems surrounded by symbolic-moral universes in which the core belief is reflected through symbolic representations such as words, images, and ideas. The boundaries of symbolic-moral universes are where battles between conflicting beliefs occur, with their feedback affecting the cores of each. According to Ben-Yehuda, the heart of the cultural core and its surrounding symbolic-moral universe is made up of three elements: unconventional behavior that can escalate to deviance and crime, collective memories that are often accompanied by cultural traumas, and myths (Ben-Yehuda 2013:17). These three elements form the foundations of symbolic change, stabilization, and rejection of symbolic change within cultures.

According to the *Encyclopedia of Criminology and Criminal Justice*, an act must go against norms, values, or laws that are set in place to prevent that behavior in order to be considered deviant (Robertson 2014). It does not necessarily have to be threatening nor criminal and can receive either a positive or a negative response. A negatively deviant act can harm others while a positively deviant act can be beneficial to society. Nachman Ben-Yehuda notes that the primary factors for what is or is not defined as deviance depends on morality and power (Ben-Yehuda 2013:19). The definition of morality varies based on the society and frequently changes with new circumstances, while power determines the construction of moral systems and how to enforce them. Simply put, this means that deviants are those who lack the power to define moral standards and thus prevent themselves from being labeled as deviants.

Collective memory is defined as a form of memory shared by a group and of central importance to the social identity of the group’s members (Roediger and Abel 2015:359). Events in collective memory are often characterized by a simple narrative structure that emphasizes the beginning, turning, and end points of a scenario. It is based on a single, biased perception of historical events that aids in the creation of a cultural identity in the present. One of the primary contributors to collective memory is mythology, the third factor in Nachman Ben-Yehuda's cultural core model. In his description of mythology, he coins the use of the term *interpretative truth*, defined as a truth that is based on combining facts in different and creative ways (Ben-Yehuda 2013:38). Though it is biased and contains some untruths, interpretative truth uses fact as a building block to create a credible narrative. Regarding myth overall, Ben-Yehuda notes that it is a portrayal of a sequence of "events" (real or imaginary) distinguished from a regular historical account by the following factors:

1. An attitude of sacredness
2. A high degree of symbolization
3. A dimension of morality, that of an instructive lesson
4. A frequent demand for action from the listener (real or symbolic), either immediately or in the future
5. A conscious "choice" of specific events and a disregard of others, distinctly different from the historical context
6. A simple narrative in which the moral world is painted simplistically in terms of "good" and "bad," sometimes even in short slogans
7. An impressive site with an impressive environment attached to the mythical tale (Ben-Yehuda 2013:39-40)

According to Ben-Yehuda, national myths are processed by individuals through "master frames," which produce criteria for and teach individuals what to pay attention to, what to ignore, and how to combine one's knowledge into a systematic, consistent, and coherent worldview (Ben-Yehuda 2018:40). These myths are intended to stir the emotions of the peoples' collective memory of certain events, which in turn results in social reactions to those topics. They are especially important in times of conflict, when it is necessary to galvanize the people, and thus restructure the cultural core, towards a common cause.

Nachman Ben-Yehuda applied his theory of cultural cores most intensely to a subject of serious relevance to this study: the submarine. In his concluding discussions, he argued that the cultural cores of most major powers began a transition away from a system of morality based around sparing the innocents to naval strategy of total war with the introduction of Alfred Thayer Mahan's theories on naval warfare as deviant behaviors (Ben-Yehuda 2013:225). In an essay titled "Commerce Destroying and Blockade" (1890), Mahan encouraged commerce destroying, the attacking of an enemy nation's merchant shipping in an effort to incapacitate that nation, and argued that the inevitable suffering that method of warfare would cause to the people of that nation was completely legitimate because it accomplished the broad aim of weakening that enemy nation enough to win a war (Mahan and Westcott 1918:92-93). Nachman Ben-Yehuda noted the influence of this strategy on naval planners and the deviance it normalized in the societies that chose to participate in it. The introduction of the submarine to the naval landscape during the First World War only changed the mechanism for the implementation of Mahan's strategy of commerce destroying and blockading, as the British, U.S., and former Confederate States all used one or both strategies with varying effects prior to the implementation of effective submarine warfare (Mahan and Westcott 1918:91, 94-95). However, this changing of the mechanism, from surface vessels which presented the opportunity to defend oneself or surrender, to the unrestricted warfare strategies of submarines created another deviant condition in which battles between the symbolic-moral universes of Germany and the Allies took place. In the end, Nachman Ben-Yehuda concluded that the three elements composing a cultural core, deviance, collective memory, and myth, were all altered at a global level by the introduction of the submarine to the naval landscape (Ben-Yehuda 2013:254).

Adaptation of Technological Momentum and Cultural Cores

Thomas P. Hughes's theory of technological momentum and Nachman Ben-Yehuda's theory of cultural cores have points at which they converge as well as areas in which divergence is apparent. Both theories operate under the assumption that technology and culture intersect in ways that affect each other and neither theorist believes that technology is neutral. However, the ways in which that non-neutrality is defined differ significantly. In assessing the impact of the mature technology created by the I.G. Farben firm, Hughes pointed to the significant financial and time investments in chemicals technology and lack of investment from public sources as the generators of momentum in accepting government contracts from the newly established Nazi government of 1933 (Hughes 1994:109-110). From Hughes's perspective, mature technology that arrives too late to be of use for the social circumstances that created it becomes "a solution looking for a problem" (Hughes 1994:110). Nachman Ben-Yehuda's cultural cores theory would counter Hughes's insistence on the need of a solution to find a problem by challenging the need to find a problem at all. Rather than applying a sense of autonomy to the technology once it reached a mature stage, the theory of cultural cores operates on the assumption that technology is worthless without being incorporated into the human consciousness, rationalized, and put to practical use (Ben-Yehuda 2013:12). Applied to the I.G. Farben firm, the theory of cultural cores would classify the development of beneficial chemicals technology as deviance that colored the collective memory of the society (in this case, specifically the leadership of I.G. Farben) with the memory of developing the technology as the beginning, the end of the war as the middle, and the yearning desire to apply this technology as the end of said memory. Wielding the power to classify the positive or negative impact of this technology, I.G. Farben chose to classify any use of the technology as positive deviance. The mythology of the company, built on the interpretative truth that not applying such impressive technology would be an unacceptable waste, subsequently altered the symbolic-moral universe and cultural cores of I.G. Farben to allow for complicity with a fascist dictatorship.

With the similarities and differences between the theory of technological momentum and the theory of cultural cores in mind, the theoretical approach used for this research operates from a balance of the two. Two general tenets underpin this assessment of submarine chaser development in the First and Second World Wars:

1. Technology has infantile and mature phases during which it can influence societies or be influenced by societies.
2. Cultural cores and their symbolic-moral universes are where momentum most shows up as a factor.

Organizing theoretical concepts in this way challenges certain characteristics of both original theoretical concepts. The first tenet gives technology even more fluidity than does Thomas P. Hughes, allowing it to be influential or influenced regardless of its phase of maturity, while the second acknowledges the systematic organization of Nachman Ben-Yehuda's theory of cultural cores while applying Hughes' belief in momentum to the emotions of the people utilizing technology rather than the technology itself. To simplify the application of these tenets they will be described respectively as *technological deviance* and *cultural momentum.*

Technological Deviance and Cultural Momentum Applied

In a Reichstag debate occurring on 6 December 1897, German Foreign Secretary Bernhard von Bülow declared "We wish to throw no one into the shade, but we also want our own place in the sun" (Bülow 1897:2). Bülow's words, directed at a representative within the Reichstag, were the opening phase of the *Weltpolitik*, or world politics, mentality Imperial Germany would apply to its internal development and external interactions. This policy was not necessarily unexpected. One of the key components of Germany's imperialism was the mythical belief that Germans of all classes were a "chosen people" (Snyder 1935:17). Though he was unaware of it at the time, Adolf Stoecker, a clergyman serving as Germany's strongest proponent in the nationalistic fervor sweeping the young nation, listed the features of Germany's cultural core within his speeches. He emphasized the "industrious, honest, loyal, pious, and altogether richly endowed" nature of German people and noted that every German felt a sense of duty that paired with diligence, ability, and indefatigableness to create a wholly unique culture of superior people (Snyder 1935:17-19). Stoecker also believed in a national soul synonymic with the collective conscience theories of his French contemporary, Émile Durkheim, but took this belief a step further by emphasizing another myth: the need for purity in the German race to maintain the purity of collective conscience. While the German people did not buy wholeheartedly into Adolf Stoecker's Christian-Socialism, the nationalism he promoted was a common theme among Germany's great leaders.

Otto von Bismarck set the tone for the relationship between the beliefs of Germany's cultural core and the way that played out in its symbolic moral universe in 1862, when he declared before the Prussian Parliament, predecessor to the German Reichstag, that "it is not by speeches and majority resolutions that the great questions of the time are decided…but by iron and blood" (Bismarck 1862). However, Bismarck's declaration was that of a defensive minded nationalist. During his time as Chancellor of the German Empire from 1871 to 1890, Bismarck maintained the idea of *Realpolitik,* avoiding overseas projection of power in favor of a more pragmatic, homebound approach. This approach was highly effective, with the unification of Germany, defeats of major land powers Austria and France in rapidly conducted wars, and twenty years of stability in Europe (Barkin 2021). The ascendancy of Wilhelm II to the German throne resulted in the dismissal of Bismarck and the introduction of the *Weltpolitik,* resulting in a distinct change in the symbolic-moral universe surrounding Germany's cultural core. Bismarck had given Germany the stability and power it needed to act on Kaiser Wilhelm's desire to use that power and the cultural beliefs undergirding it for expansion. This cultural momentum would become especially apparent in the branch of the German military Kaiser Wilhelm most desperately wanted to project power, the Imperial German Navy.

In the late 1890s the Imperial Naval Office, led by Admiral Alfred von Tirpitz in the role of secretary, whittled away at the power of the civilian-led Reichstag in influencing naval decision making. Just after his appointment in 1897, Admiral Tirpitz and his naval colleagues set about codifying the navy's finances through the "Iron Budget", a law that mandated the size of the fleet and automatic replacement of warships after fixed periods of time and created the legal precedent of *Flottengesetz* or "fleet law" to contend with any other disputes from their civilian rivals (Bönker 2012:177-180). In a nation that already placed priority on the opinions of military leadership over those of civilian officials, this codified victory by the Imperial German Navy further widened the gap. As mentioned in the previous chapter, Admiral Tirpitz's consolidation of naval power did not mean that he was prepared to pour resources into the development of submarines, which he perceived as useless without the ability to make overseas voyages (Tirpitz 1919:138). However, the traditional historical narrative does show that the Imperial German Navy under Tirpitz, as well as the navies of other powerful nations, were considering the youthful and as yet unproven submarine as a future weapon of war. Aware that they desired to use it but not confident in the weapon as it stood, the Imperial German Torpedo Inspectorate continued to look for ways to develop it into the weapon they wanted by consulting with outside entities on torpedo technology and continually testing submarine prototypes until they achieved the performance qualities they desired (Rössler 1975:19-21). The influence of the infantile submarine on the Imperial German Navy and the Imperial German Navy's alterations to the submarine both serve as prime examples of technological deviance. The maturity or immaturity of technology was irrelevant to it both impacting and being impacted by the Imperial German Navy.

The ways in which submarine technology was deployed by Imperial Germany demonstrated the impact of cultural momentum. The first action that inspired the deployment of the U-boat, Great Britain's blockading of Germany at the outbreak of the First World War, stimulated indignation and rage throughout Germany. Chancellor Theobald von Bethmann-Hollweg described it as "a refinement of cruelty nothing less than diabolic" while Admiral Reinhard Scheer bitterly noted that Great Britain acknowledged negotiated limitations on blockading "with the mental reservation, however, of disregarding them at pleasure" (Hollweg 1920:158; Scheer 1920:xiii). However, Admiral Alfred von Tirpitz blamed the blockade and the loss of the war on the hubris of German diplomacy, noting that "it was a common fundamental failing of our policy to use up piecemeal the great but insufficient reputation of power which Bismarck left us" (Tirpitz 1919:190). Germany's cultural core was organized on the belief that the nation and its people were superior and that the nation had the right to enact its *Weltpolitik* on the world. When other symbolic-moral universes, in this case that of the equally hegemonic Great Britain, clashed with Germany's cultural core driven decision to join the First World War, the cultural momentum of the Germans played an important factor in their response. Their belief in their place as a superior people was completely at odds with Great Britain entering German waters and dictating German survival. With their cultural momentum already roaring towards expansionism and the U-boat already available as a mature technology, it was an inevitability that the stealth weapon would be put to use.

Cultural momentum also affected the U.S. in the buildup to the First World War. The development of American exceptionalism as the root of their cultural core began before the U.S. was even a country. In 1765, John Adams, future president, wrote that he would "always consider the settlement of America with Reverence and Wonder – as the Opening of a grand scene and Design in Providence, for the Illumination of the Ignorant and the Emancipation of the slavish Part of Mankind all over the Earth" (Adams 1765). Adams was not alone in this sentiment. The leadership of the British Colonies endorsed Adams's belief in the U.S. as a particularly unique and independent country with their signing of the Declaration of Independence in 1776. Key among the ideas put forth in the document was the belief that American citizens were cosmically endowed with the unalienable right to "Life, Liberty, and the pursuit of Happiness" (United States 1776). These beliefs served as a symbolic-moral universe around the U.S. cultural core beliefs in their exceptionalism and uniqueness. They also shifted the actions of the young nation from those of a defensive mindset in the 18th century to a colonizing, yet paternal mindset in the 19th century.

Where Germany wished to enact imperial rule in conquered territories, draining them wholesale of their resources for the good of the German state, the U.S. approached its expansion with the same intent but outwardly projected the mythical idea that assimilation of conquered peoples was to their benefit. The term “Manifest Destiny” was coined by John O’Sullivan in an 1845 journal article titled “Annexation,” in which he spelled out the “God-given” right of the U.S. to expand its borders and annex other nations and peoples into those borders (O’Sullivan 1845). This thought process directly contributed to the U.S. wars of the 19th century: the Mexican War for expansion into Texas, the Civil War for the redefining of life and liberty, the Indian Wars to capture territory and advance the “illumination” of Native Americans, and the Spanish-American War for the continued colonial ambitions of the rising world power. In fact, the U.S. naval campaign in the Philippines during the Spanish-American War was the first instance where U.S. and German symbolic-moral universes had the potential to collide and from the perspective of Admiral Tirpitz, the place where U.S. distaste for Germany began (Tirpitz 1919:185). An assumed truth in the idea of Manifest Destiny and the forced assimilation accompanying it was the superiority of white Protestant Americans over all other people, an eerily similar belief system to that being preached by Adolf Stoecker in Imperial Germany at roughly the same time. This belief made the pursuit of expansion, whether “Iron and Blood” or “Manifest Destiny” driven, easy, no matter how brutal the cost of that conquest might be. In conflicts with more disadvantaged opponents like the Apache or Sioux Native Americans, this meant genocide. But for the U.S. to face a rising global power like Germany, the expenditure of large amounts of resources and lives would need justification capable of stimulating cultural momentum. Germany would provide just that in the deep waters of the Atlantic Ocean.

When the First World War began, the U.S.' cultural core both prevented it from openly joining the conflict and encouraged furtive support of Great Britain's goals within it. The U.S. held isolationism, a stance born from a speech by President James Monroe in the early 19th century, as an important tenet of their cultural core. In a speech to Congress on 2 December 1823, President Monroe noted that the U.S. did not participate in the wars of European powers and should not do so long as those wars did not affect U.S. territory (Monroe 1823). The U.S. generally followed President Monroe's advice throughout the rest of the 19th century and into the start of the 20th, with President Woodrow Wilson winning re-election in 1916 on the campaign slogan "He Kept Us Out of War." However, Wilson began to backtrack on that campaign slogan even before he secured his second term. In a speech titled "The End of Isolation", given just three days before the 7 November 1916 general election, Wilson declared that the financial and economic influence of the U.S. on world affairs had ended any hopes of isolationism (Wilson 1918:164-165). Assessing the U.S. interaction with Europe based on Wilson's parameters, the isolationist tenet of the U.S. cultural core had been shattered long before his speech. When the First World War began, the U.S. began financing loans to the Allied Powers that totaled over eight billion dollars (Rolt-Wheeler 1920:372). By the end of the war, that number had reached over ten billion dollars. This strong financial support of the Allied war effort from the neutral U.S. was undoubtedly what Admiral Alfred von Tirpitz was referring to when he threatened to make neutral countries shiver with dread for aiding Germany's enemies. The technological deviance of the submarine would finally impact the U.S. directly when the Imperial German Navy made good on that threat just a few months later with the sinking of *Lusitania*.

President Wilson and Secretary of State William Jennings Bryan responded to the attack six days later with a joint message in which they outlined the number of U.S. citizens killed thus far in U-boat attacks, reiterated their beliefs on the freedom of the seas, and encouraged Imperial Germany to apologize and pay reparations (Wilson 1915). Most noteworthy in the message was the assertion that U.S. citizens had an inalienable right to travel on merchant ships regardless of their nationality, including those flying the flags of belligerent nations. This demand again revisited the staunch U.S. cultural core belief in life, liberty, and the pursuit of happiness. It also placed Imperial Germany in a situation which would require either the continued challenging of the U.S. cultural core or the betrayal of its own cultural core via the suspension of unrestricted submarine warfare. On 19 April 1916, President Wilson issued an ultimatum on unrestricted submarine warfare and threatened to cut diplomatic ties, causing the Germans to indeed betray their cultural core through an indefinite suspension of the practice (Wilson and Shaw 1924:268). In other words, the cultural momentum of U.S. indignance towards the unrestricted submarine warfare campaign overpowered the momentum of the German belief in *Weltpolitik*.

However, the force of U.S. cultural momentum was not yet strong enough to subdue Germany's ambitions permanently. The Imperial German government and military leaders collectively agreed to renew the unrestricted submarine warfare campaign at a meeting held in Pless on 9 January 1917, gambling that Great Britain would be defeated before the U.S. could have a significant impact on the war (Manson 2000:6-11). This decision became a counterpunch to the U.S.'s earlier challenge. The nation so invested in neutrality and maritime liberties was forced to choose between the two to protect itself from being enveloped by the cultural momentum of Imperial Germany's *Weltpolitik.* President Woodrow Wilson stated as much in his 2 April 1917 request to Congress for a declaration of war, advising Congress to "formally accept the status of belligerent which has thus been thrust upon it" (Wilson and Leonard 1918:36). The U.S. core belief in neutrality was eliminated by the presence of the U-boat and Imperial Germany's willingness to use it to enact its beliefs.

As demonstrated by the deployment of the U.S. Navy and its SC-1 class submarine chasers in the European theater less than a year after the U.S. declaration of war, German decision-makers were incorrect in their assumption that the U.S. would not be able to impact the war in a substantial way. U.S. destroyers began arriving in British waters almost immediately after the declaration of war, reducing the strain on a British destroyer contingent stretched thin between escorting convoys and patrolling for submarines (Leighton 1920:18). The arrival of the SC-1 class submarine chasers at the beginning of 1918 allowed for the release of even more destroyers to perform convoy escort duty. As the convoy system began to take effect, the U-boats lost their edge in the battle for control of the seas. U-boats of the First World War tended to operate as individuals rather than in teams, and the strong destroyer escorts accompanying convoys prevented independent submarines from attacking the merchant ships with any regularity (Messimer 2001:149). The reduction of U-boat effectiveness in attacking merchant shipping was one way in which the SC-1 class submarine chasers became a representation of technological deviance and cultural momentum themselves. Though the SC-1 ships were in their infantile stage, their presence and its positive impact on convoying served as a negatively deviant technological change for the Imperial German Navy and a physical manifestation of U.S. cultural core beliefs once again pushing back against those of Imperial Germany. Though it did not have an impact on the First World War, the Eagle boat and its plan to combine the strengths of the destroyer and SC-1 class submarine chaser was a physical manifestation of that as well.

The Second World War brought about a similar conflict of ideals manifested through technology. Nazi Germany and its leader, Adolf Hitler, vacillated between perceiving the U.S. to be a weak and degenerate power and an economically and politically aggressive nation that challenged Germany's rightful place in world affairs (Manson 1990:85-86). More often than not, however, it was the weak and degenerate perception that won out. The core of this mindset, the Nazi Party's racially motivated belief in the supremacy of German people over all others, was little different than the cultural core belief of their First World War predecessors. Adolf Hitler's *Mein Kampf*, an autobiographical and political publication, defined his belief in a "Master Race" of Aryan people with the right to use other, lesser peoples in any way they deemed fit (Office of U.S. Chief of Counsel for Prosecution of Axis Criminality 1947:10). This belief was the most essential part of Nazi Germany's cultural core and informed all facets of the political and military maneuvers conducted before and during the Second World War. In the Kriegsmarine, it meant an immediate willingness to implement unrestricted submarine warfare. Grand Admiral Karl Döenitz, a U-boat veteran of the First World War, deployed the U-boats of the Second World War using the *rudeltaktik,* or pack tactic, specifically to confuse and overcome the well-defended convoys he first experienced during the earlier war (James, Zaforteza, and Muffett 2019:205). Using U-boats in this way indicated a maturation in the application of the technology, a new form of technological deviance stemming from a mature U-boat, and the Allies struggled to contain it in the early years of the war.

In the U.S., entry into the Second World War took a similar pattern to that of the First. The cultural core belief in neutrality regained momentum in the late 1930s as U.S. citizens became disillusioned with the post-war impact of Wilsonian politics and Congress passed several neutrality acts in an effort to make that core belief ironclad (Manson 1990:54-55). However, another surprise attack, the 7 December 1941 attack on Pearl Harbor by Imperial Japan triggered a declaration of war from the U.S. the following day and declarations of war on the U.S. by Germany and Italy just a few days after that (Roosevelt and Geselbracht 1988:5-8). The U.S. cultural core belief in neutrality once again competed with and lost to the cultural momentum of belligerent nations with beliefs based in their own superiority. Operation Drumbeat pressed the advantage even further as Admiral Döenitz's U-boat wolfpacks took a devastating toll on unprotected merchant shipping in the ESF (Warnock 1993:8).

The arrival of the PC-461 class submarine chaser in the Atlantic theater in 1942 served as a manifestation of U.S. cultural core beliefs in much the same way its predecessors did in the First World War. The initiation of a conflict in the Pacific theater put a strain on destroyers that the PC-461s were able to alleviate, and the combination of SC-1 and destroyer characteristics made them a viable option in aiding the growth of the convoy system as it attempted to counter the rudeltaktik of the U-boats (Friedman 1987:48-49; Veigele 1998:153). This again represented the submarine chaser playing a technologically deviant role in a World War, with the PC-461s of the second conflict demonstrating a maturation of submarine chaser technology and its impact on the U-boats and thus the cultural momentum of Nazi Germany.

Conclusion

Thomas P. Hughes' theory of technological momentum and Nachman Ben-Yehuda's theory of cultural cores offered the initial theoretical framework to assess the impacts on submarine chasers in the First and Second World Wars. Finding each theory to lack elements necessary for an accurate evaluation, they were synthesized into the concepts of *technological deviance* and *cultural momentum.* Technological deviance was defined as the idea that technology has the ability to influence a culture regardless of its phase of maturity and was demonstrated through the infantile impact of the U-boat on the U.S. and the submarine chaser on the U-boat. Cultural momentum was defined by retaining the idea of cultural cores and the conflicts that influence them but adding momentum as a characteristic capable of influencing how those conflicts are resolved. This was demonstrated through the conflict between German *Weltpolitik* and U.S. freedom of the seas in the First World War, and Hitler's "Master Race" theories and U.S. neutrality in the Second World War. In the following chapters, the theories of *technological deviance* and *cultural momentum* will provide the framework for a more intensive assessment of the influences on submarine chaser development.

CHAPTER FOUR: DIGITIZING THE SUBCHASERS

Introduction

The methodology for addressing the questions put forth about subchaser development has three components: historical and archival research, site visits to vessels associated with the Second Battle of the Atlantic, and three-dimensional (3D) computer modeling of subchasers reflective of adaptation over time. The World Wars are arguably the two most heavily documented events in world history, and the fight against unrestricted submarine warfare often took center stage. As a result, both Battles of the Atlantic and the vessels that took part in them have been heavily eulogized, and East Carolina University's Joyner Library has an extensive collection of resources on both submarine and antisubmarine warfare during the World Wars. Site visits to period vessels located in Baltimore, Maryland and Fayetteville, North Carolina provided visual perspective on the armament and strategic objectives of both the Germans and Americans in the Battles of the Atlantic and aided in the process of 3D modeling the three subchaser types selected for comparative analysis of vessel designs from the First World War, Interwar Years, and Second World War.

Historical Research

The first book selected for the historical research process was Bernard Edwards's *Dönitz and the Wolfpacks* (1996), an overview of the second Battle of the Atlantic with a focus on the civilian crews that were often the primary targets of unrestricted submarine warfare. It offered a specific perspective on submarine warfare and encouraged the pursuit of historical resources that assessed the impact of submarine warfare over time. Michael Gunton's *Submarines at War* (2003), which discussed the development of the submarine both as a weapon of war and a phenomenon to the human psyche, provided such a historical perspective. It was followed up by

The U-boat: The Evolution and Technical History of German Submarines (1975), a massive and comprehensive history of the German submarine written by Eberhard Rössler. Though Rössler's book did address the political motivations behind the development of the German submarine, it focused heavily on the mechanical background of the vessels. In contrast, Admiral Alfred von Tirpitz's *My Memoirs* (1919) allowed for an understanding of the origins of the U-boat from the perspective of the political and military figures financing the inventors who mastered the technology. Admiral Tirpitz built his naval career, which spanned from 1869 to 1916, off his work in early German submarine development, even participating in the first negotiations for the purchase of long-range torpedoes. His perspective on the First World War and the ramping up of submarine usage was useful in understanding the initial planning phase of the first Battle of the Atlantic and the Allied reaction to it. This book was cross referenced with Patrick J. Kelly's *Tirpitz and the Imperial German Navy* (2011) to ensure any potential biases in Alfred von Tirpitz's work, written after his removal from the German Navy and the defeat of Germany in the First World War, were eliminated in this work's presentation of German submarine development.

Teddy Suhren's self-titled memoir, *Teddy Suhren, Ace of Aces: Memoirs of a U-Boat Rebel* (2006), provided a personal perspective on the German U-boat strategy in the second Battle of the Atlantic from the eyes of one of its executors. At several points during the memoir, Suhren mentioned the work of both subchasers and aircraft in both proactively and reactively protecting Allied convoys from his attacks. There was an especially valuable section in which Suhren discussed his vision for the future of submarine warfare with Adolf Hitler and he was privy to the development of newer submarines designed specifically to outperform the threat of subchasers and air power. Suhren's memoir was followed up by a book written from the U.S.

perspective, historian Ed Offley's *Turning the Tide: How a Small Band of Allied sailors defeated the U-boats and won the Battle of the Atlantic* (2011). Though it did not focus on subchasers specifically, the book had a heavy emphasis on the convoy system in general and excellent information on the contributions of aircraft operations to the Second Battle of the Atlantic. His follow up, *The Burning Shore: How Hitler's U-boats brought World War II to America* (2014), focused on the East Coast of the U.S. and specifically on the exploits of German U-boat U-701, but still provided excellent information on the American reaction to U-boat warfare and the development of aerial antisubmarine warfare during the Second World War. Further investigation of air power in the World Wars led to the discovery of John J. Abbatiello's *Anti-Submarine Warfare in World War I: British Naval Aviation and the Defeat of the U-Boats* (2006), which addressed the initial developments in coastal naval aviation and its impact on the First Battle of the Atlantic. Though, as mentioned in the title, it focused primarily on British naval aviation, it paired well with Chris Dubbs's *America's U-Boats: Terror Trophies of World War I* (2014) to provide a broad picture of the Allied interest in aircraft as antisubmarine weapons. Dubbs's book devoted a significant number of pages to the use of captured U-boats to settle the conflict between U.S. Army Air Corps General William "Billy" Mitchell and Secretary of the Navy Josephus Daniels over the practicality of air power in naval operations.

Regarding submarine chasers specifically, the first book consulted about the topic was perhaps the most invaluable source of this entire study. Norman Friedman's *United States Small Combatants, Including PT-Boats, Subchasers, and the Brown-Water Navy*: *An Illustrated Design History* (1987) began with the origins of First World War-era subchasers, tracing their political development back to the Wilson Administration's desire to build a strong coastal defense and their stylistic lineage back to Franklin Delano Roosevelt's ideas about repurposing civilian motor yachts (Friedman 1987:19-21). Friedman then detailed the progression of political, economic, and military influences on the development of subchaser designs during the Interwar Years. His deep knowledge of subchaser development led directly to the selection of the SC-1, PE-1 (Eagle Boat), and PC-461 subchaser designs as the ideal vessels to recreate via 3D computer models for this study, and his inclusion of mechanical drawings of each vessel was a useful aid in the reconstruction process. Friedman's knowledge of SC-1 class submarine chasers was supplemented by Todd A. Woofenden's *Hunters of the Steel Sharks: The Submarine Chasers of World War I* (2006), which provided valuable information on the deployment of SC-1 class submarine chasers in the First World War. Woofenden's website *subchaser.org* also proved invaluable, as it provided the leads to several primary sources on the hunting techniques and mechanical development of the 110-foot vessels. Sources for the PE-1 class submarine chaser proved more elusive, but manuals such as *The Machinery Installation, Operation, and Care of Eagle Boats* (1924) offered insight on the performance characteristics of the vessel while First World War era congressional hearings from the House Committee on Naval Affairs and contemporary journal articles from the U.S. Naval Institute offered insight both on the logistics of construction and political decision-making. William J. Veigele's *PC Patrol Craft of World War II: A History of the Ships and Their Crews* (1998) focused specifically on PC-461 class subchasers and contained a section of firsthand accounts from their crews, which added important perspective to the understanding of antisubmarine warfare strategy on a ship-by-ship basis. It also contained an extensive appendix of drawings that proved indispensable in the 3D modeling of the PC-461 class subchaser.

The theoretical components of this study still relied on works focused generally on the First and Second World Wars. The theoretical concepts from Nachman Ben-Yehuda's *Atrocity,* *Deviance and Submarine Warfare: Norms and Practices during the World Wars* (2013) were discovered accidentally while evaluating the book for its potential value to the historical research process. Émile Durkheim's *The Division of Labor in Society* (1933) was also evaluated to gain a better understanding of the theoretical lineage behind the theory of cultural cores. Thomas P. Hughes's theory of technological momentum was first perceived while reading *Does Technology Drive History?: The Dilemma of Technological Determinism* (1994) and followed up by his original work on the theory, *Technological Momentum in History: Hydrogenation in Germany 1989-1933* (1969). Other sources consulted for their potential impact on the theoretical components of this study were John H. Lienhard's *How Invention Begins: Echoes of Old Voices in the Rise of New Machines* (2006), Samuel Lilley's *Men, Machines, and History: The Story of Tools and Machines in Relation to Social Progress* (1965), and Daniel Lloyd Spencer's *Technology Gap in Perspective: Strategy of International Technology Transfer* (1970), though they had little impact on the final outcome of the project.

Technical Research

To reconstruct the subchasers considered by this study, it was necessary to conduct technical research to find ship plans for each of the three vessel types. Initial research began with East Carolina University's Joyner Library Special Collections. The Barbour Boat Works, Inc. Records (1943-1998), contain ship plans for both civilian and military contracts given to Barbour Boat Works, a ship construction company founded in New Bern, North Carolina by Herbert William Barbour in 1932 (Daugherty 2008). Among those plans are numerous types of patrol craft, including ship plans for an SC-450 class subchaser. The SC-450 class subchaser followed the same ship lines as its predecessor, the SC-1, differing only in propulsion, armament, and sonar technology (Friedman 1987:58). This meant that ship lines for the SC-450 could potentially be used to project the hull shape of the SC-1 and other sources used to fill in the correct accoutrements. Upon visiting the archives, however, it was determined that the plans were far too large and unwieldy to digitize without skewing the lines and thus incorrectly scaling the 3D model. Fortunately, a search of the National Archives' "*The Unwritten Record,"* a blog created by the staff of the National Archives' Special Media Archives Services Division to share topics of interest to the staffers, revealed a full set of digitized SC-1 plans (Figure 8) (Mulligan 2016). Plans for the second vessel modeled in this study, the PE-1 class subchaser known more commonly as the Eagle Boat, were digitized and easily available through the Benson Ford Research Center, a subsidiary of the Henry Ford Museum of American Innovation (Figure 9).

The greatest challenge in the technical research process was finding reliable PC-461 class subchaser ship lines. The first attempt used a set of plans titled *Sub Chaser U.S.S. PC-461* (n.d.) from David C. Marlowe of Largo, Florida (Figure 10). While the lines from this model appeared to be accurate to the naked eye, slight imperfections in the sketch resulted in issues with the mesh points upon lofting the lines in *Rhinoceros 3D*. These issues resulted in the software either not being able to produce the hull shape at all or producing a hull shape with bulges and twists throughout. The ship lines from similar drawing by Edward Wiswesser of Mt. Penn, Pennsylvania projected in a similar fashion in the modeling software. These challenges led to the eventual acquisition of copies of the original BuShips PC-461 ship lines from "The Floating Drydock," an online store that specializes in producing ship plans for modelers but also carries some direct copies of BuShips plans (Figure 11). These plans were digitized and imported into *Rhinoceros 3D*. The details of deck equipment and rigging for the PC-461 class subchaser were sourced from the appendix of William J. Veigele's *PC Patrol Craft of World War II: A History of the Ships and Their Crews* (1998). The outboard profile plans, titled *Sub Chaser (PC): Plan* *for Modeling a PC Patrol Craft of the PC 461 Class* (1987) were drawn by John B. Tombaugh, while the more detailed sketches following it were drawn by Robert K. Baldwin during his time as a sailor on board the PC-543 (Figures 12, 13).

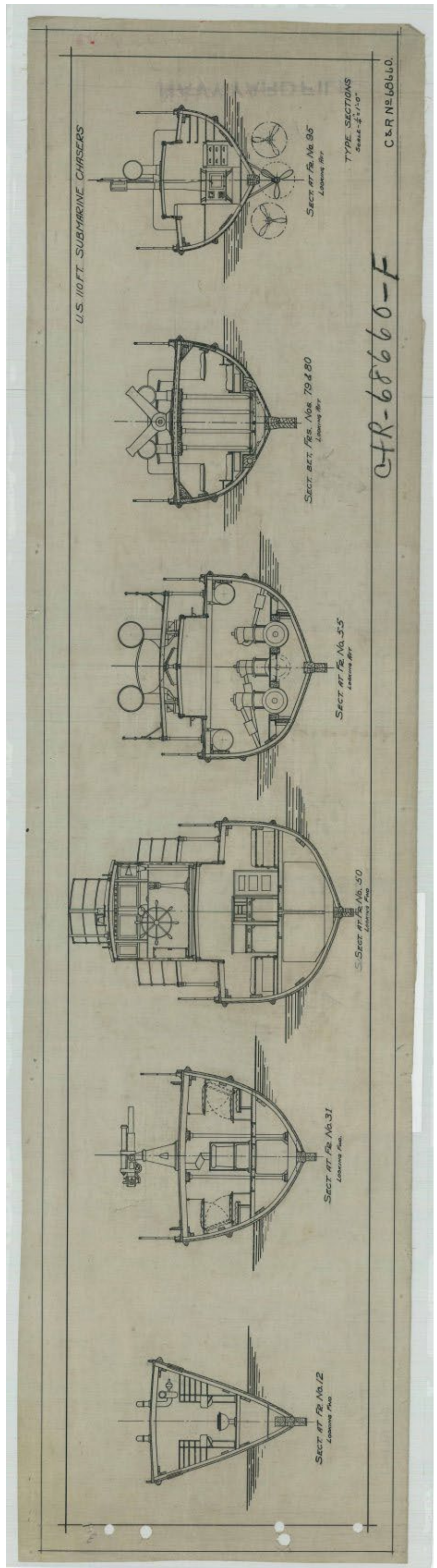


Figure 8. *U.S. 110 Ft. Submarine Chaser Booklet General Plans: Type Sections* (D.J. Maxson, 1918).

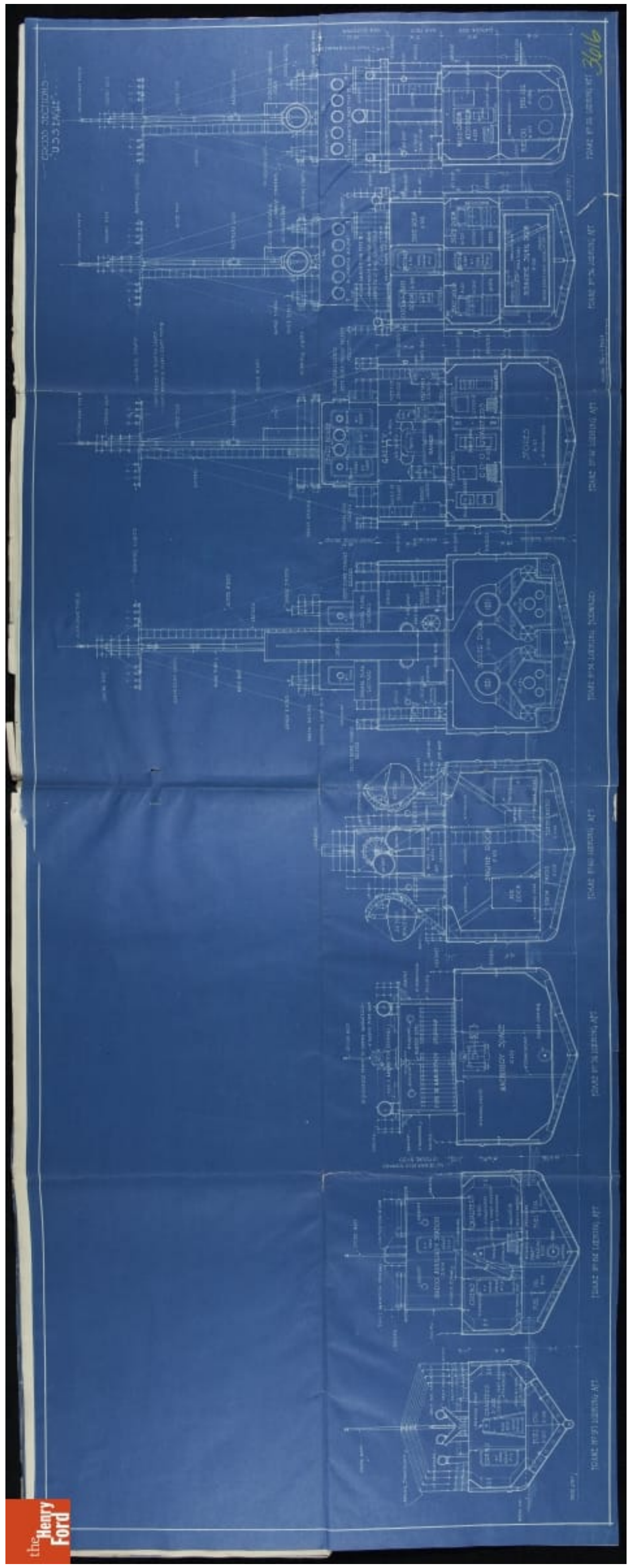


Figure 9. Ford Motor Company “Eagle Boat” Blueprints (Ford Motor Company 1918:8)

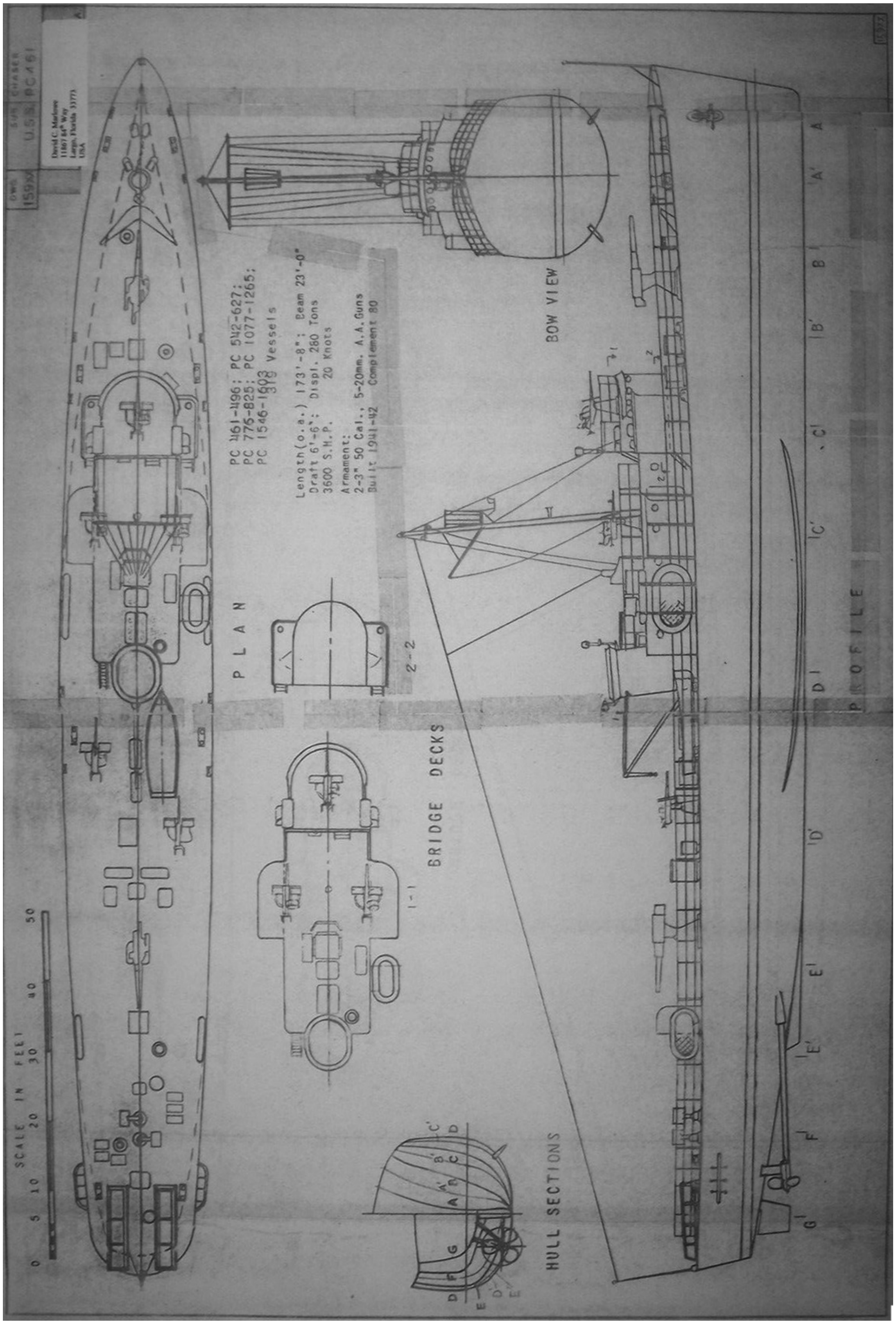


Figure 10. *Sub Chaser U.S.S. PC-461* plans (Marlowe n.d.).

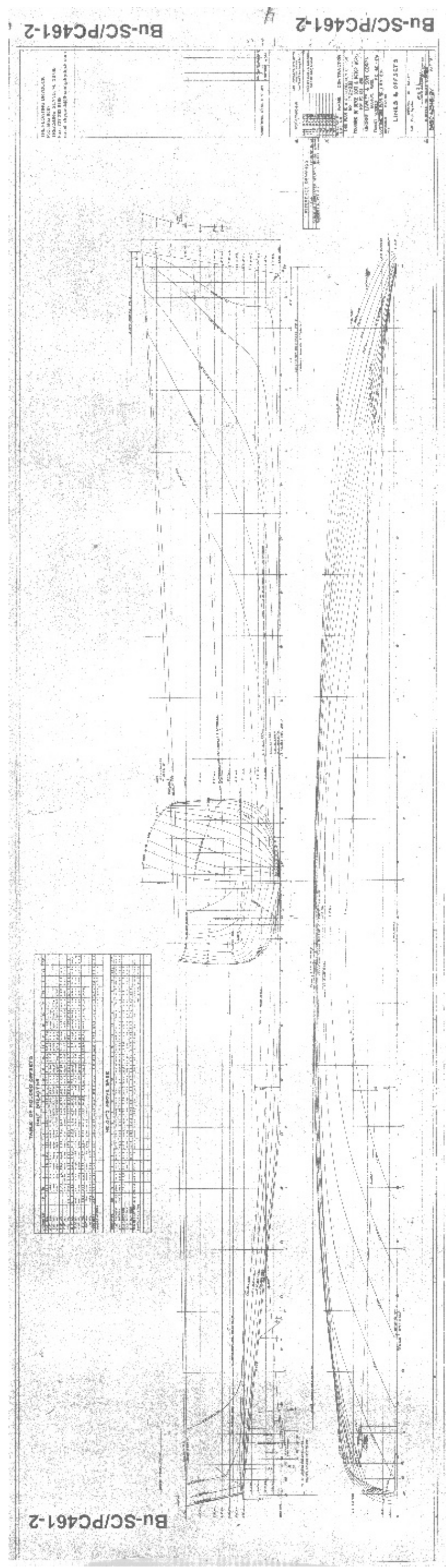


Figure 11. *Bu-SC/PC461-2* (George Lawley and Son Corporation 1941)

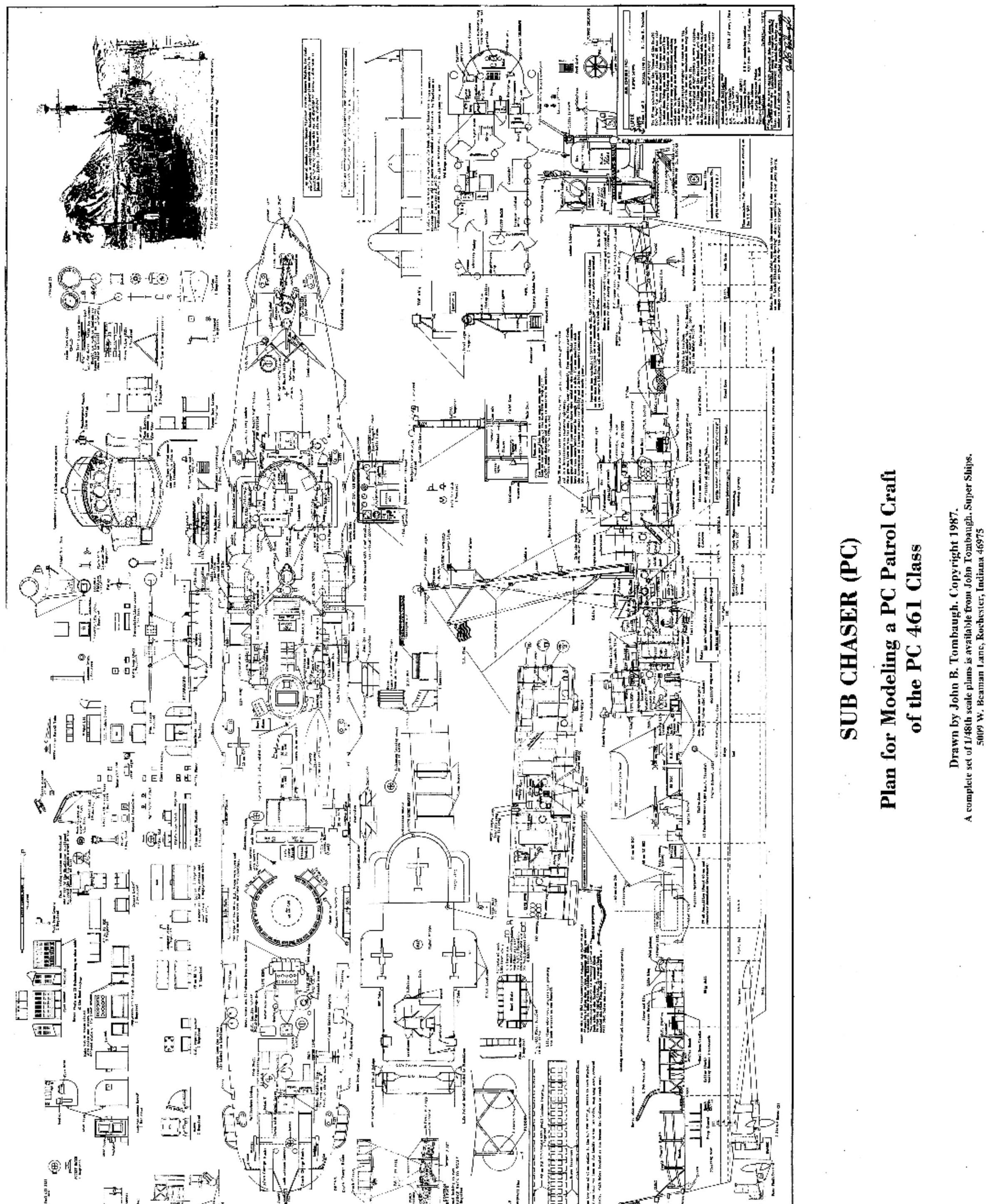


Figure 12. *Sub Chaser (PC) Plan for Modeling a PC Patrol Craft of the PC 461 Class* (John R. Tombaugh 1987).

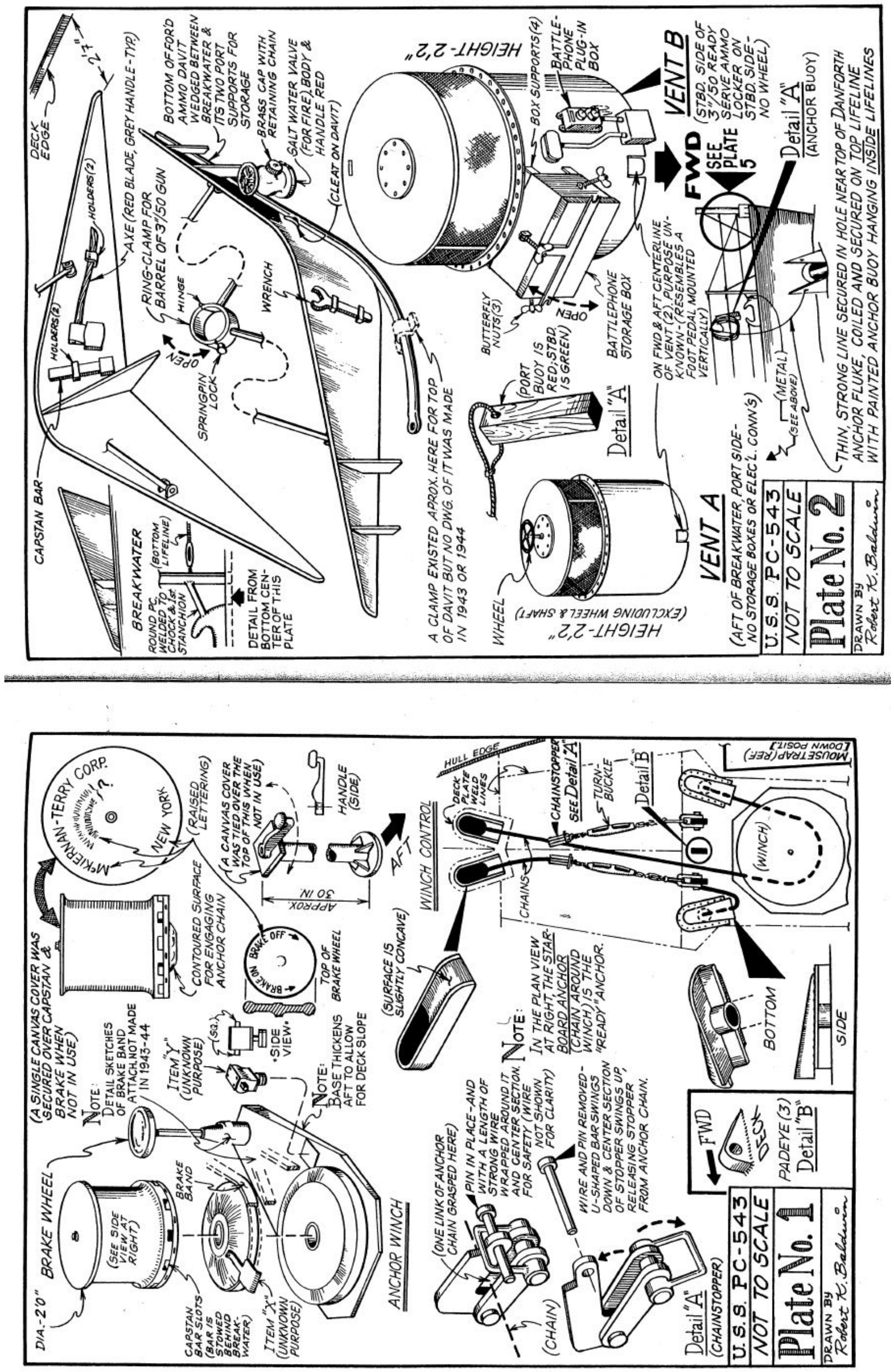


Figure 13. *Plates 1 and 2 of U.S.S. PC-543 Sketches* (Robert K. Baldwin in Veigele 1998:301-302).

Site Visits

To gain more information on the physical appearance of submarines and subchasers in the broader picture of the Battles of the Atlantic, several site visits were made to vessels associated with the conflicts. The first, part of the Historic Ships in Baltimore collection, was United States Coast Guard cutter (U.S.C.G.C.) *Taney* (Figure 14). Commissioned in 1936 at Philadelphia Navy Yard, the 327-foot vessel is the lone survivor of the 1941 attack on Pearl Harbor and now serves as a museum ship in Baltimore's Inner Harbor (Taylor 2009:34). The significance of the vessel in the scope of this study is its service as an antisubmarine escort in the Pacific Ocean and Mediterranean Sea, where it protected convoys from Japanese and German submarines, respectively. Though the vessel in its current state is significantly different from its Second World War rendition, having been updated for two successive wars and eventual Coast Guard service, it still carries physical markers and stylistic characteristics relevant to the reconstruction process of the subchasers discussed in this thesis, particularly the PC-461 class. Its depth charge launchers and Hedgehog rocket launchers have long since been removed, but the former locations of the weapons systems are clearly defined by the plate metal used to cover them. Gaining a firsthand understanding of the placement and clearances needed for U.S.C.G.C. *Taney*'s antisubmarine weaponry made identifying these same weapons locations on later visits to a PC-461 class subchaser much easier. USCGC *Taney* also carried a similar length to beam ratio to the SC-1 and PC-461 class subchasers (7.9:1 length to beam, 7.8:1 length to beam, and 7.5:1 length to beam, respectively) and the same flush-decked construction style. Stylistically, this represented a consistent pattern in desired antisubmarine patrol craft characteristics among American designers and the ability to physically feel the slope of the deck made error corrections much easier during the modeling process.

Figure 14. USCGS *Taney* in Baltimore Inner Harbor (Jeffrey Katz in Meehan 2018)

The next vessel visited, also a member of Historic Ships in Baltimore, helped develop a better understanding the operational capabilities of a Second World War submarine and touched on theoretical concepts discussed in this study. The U.S.S. *Torsk*, a Tench-class submarine launched by the U.S. Navy in 1944, served in the Pacific theater and sank the last combatant ship of the Second World War (Taylor 2011:34-36) (Figure 15). At approximately 311 feet, the U.S.S. *Torsk* was comparable in size to the largest of the Type VII U-boats discussed previously, no doubt the result of U.S. studies of German submarine technology during the First World War (Dubbs 2014:63). Of all the anecdotes mentioned during the visit U.S.S. *Torsk,* one in particular made an impact on this study. While operating off the coast of Japan, the submarine came across a target of opportunity. After firing a spread of torpedoes that missed the large freighter it was pursuing, *Torsk* found itself suddenly on the defensive against the two Japanese frigates protecting the noncombatant vessel (Taylor 2011:37). In a matter of ten minutes, the U.S.

submarine sent both warships to the bottom and continued on its tour of the Japanese coast. The idea that it could destroy two fairly large warships in a matter of minutes, leaving approximately 900 sailors to die in the process, placed the theoretical concepts of Nachman Ben-Yehuda into a tangible package. Though outside the scope of this Battles of the Atlantic focused study, U.S.S. *Torsk'*s actions in the Pacific helped the influence of the submarine on the symbolic-moral universes of the world powers make sense. The concept of "brother seaman," previously discussed in regard to the work of Bernard Edwards, was not a consideration for the crew of U.S.S. *Torsk.* In much the same way Germany's indiscriminate killing affected the U.S. position on joining both World Wars in the first place, the same behavior on the part of the Japanese likely affected U.S. core beliefs enough to result in the behavior of the U.S.S. *Torsk*.

Juxtaposed against the stealthy lethality of the American submarine was the highly visible S.S. *John W. Brown* (Figure 16). The massive vessel, located just outside Baltimore at a mooring surrounded by commercial cargo vessels, is one of two operational Liberty ships remaining in the world and serves as a museum ship for the public (Aceto 2008:24). 2,710 Liberty ships, mass-produced emergency cargo vessels, were constructed from 1941 to 1945, and at 441 feet in length and 57 feet in beam were easily adaptable vessels that served as troop transports, tankers, aircraft transports, depot ships, and other naval auxiliaries (Tucker 2011:464-465). However, these incredibly versatile ships were incredibly slow, powered by steam engines that produced a maximum speed of 11 knots. This made them vulnerable to attacks from enemy submarines, and *John W. Brown* undoubtedly would have encountered German U-boats as it served in the Atlantic theater, sailing between Italy, North Africa, and Southern France (Aceto 2008:26). However, the cargo vessel and its comrades were able to survive these encounters through the use of the convoy system, often supported by PC-461 class subchasers and the occasional Eagle Boat. Touring this vessel and gaining an understanding of its vulnerabilities within the convoy system made the focus on specific characteristics in second generation submarine chasers more understandable. Visual aids inside the museum and explanations from the crew also helped increase comprehension of the execution of a convoy journey in a way that likely would have been unattainable based purely on literature sources.

Figure 15. *U.S.S. Torsk* in Baltimore Inner Harbor (Photo by Author 2019).

Figure 16. S.S. *John W. Brown* from starboard side (M. Kelly 2012)

The final visited site was U.S.S. *PC-1084,* a PC-461 class vessel laid down on 7 September 1942 at George Lawley and Sons of Neponset, Massachusetts and commissioned on 31 August 1943 (Williams 2018). The vessel escorted convoys along the Atlantic coast of the U.S. until its deactivation on 19 August 1946. It was sold to Robert Minges of the Pepsi-Cola Minges family at a California salvage sale in 1946, towed from California to Breece's Landing in Fayetteville, North Carolina and used as a floating dock for private yachts owned by wealthy Fayetteville native Oscar Breece and his associates. According to Fayetteville city historian Bruce Daws it remained floating for quite some time before tampering by salvage hunters in search of copper punched a hole in the stern of the vessel (Pers. Comm. Bruce Daws, 12/20/18). As a result, the subchaser quickly filled with river water and silt, shifting into the listing position in which it now rests (Figure 17).

Figure 17. U.S.S. *PC-1084* in its current location, Breece's Landing, Fayetteville, N.C. (File photo/The Fayetteville Observer)

After applying for and obtaining a non-disturbance archaeological research permit (Permit Number 19CFR658) through the North Carolina Office of State Archaeology, four separate trips were taken to Fayetteville to visit the remains of U.S.S. *PC-1084.* The first, in the spring of 2019, was a scouting trip to determine the feasibility of the vessel as an archaeological site for an advanced field school through East Carolina University's Program in Maritime Studies. At the time of this visit the ship was almost completely submerged, with just the starboard side of the main deck edging out above the river water. Though the water was murky and the footing somewhat dangerous, it was still easy to identify and visually scale gun placements, superstructure, and other identifiers that had long since been removed from the ship. The final three trips occurred when the vessel was almost completely exposed, with the Cape Fear River just four inches above its all-time low. After a second scouting trip, two follow up days of photogrammetry work were conducted both on foot and from kayaks. Outside of the bow section, leaning tenuously at a 45-degree angle and concealing a potentially deadly pool of quicksand, the entire ship was recorded at a distance of no further than a few feet from the camera lens (Figure 18). Jagged holes left from the aforementioned work of amateur salvage operations served as crawl spaces that provided opportunities to examine the remains of the network of wiring and piping that made the subchaser operable.

The photogrammetric modeling intended to be the main focus of the final two visits to U.S.S. *PC-1084* was not successful. However, the attempts provided opportunities to physically identify and handle many of the objects modeled at later stages of this project. Having the opportunity to scour over intact prop guards or stand in the center of the giant circle clearly marking the former location of the ship's 40-mm gun made the 3D modeling process move at a much smoother pace. Even when the diagrams used in the modeling process were a bit congested and difficult to read, personal experiences on *PC-1084* clarified much of the confusion.

Figure 18. Bow section of U.S.S. *PC-1084* (Photo by author 2019).

Ship Modeling

The 3D modeling process began by uploading the previously mentioned BuShips plans for the PC-461 class vessel, the first constructed, into *Rhinoceros 3D* 6.0 modeling software from McNeel and Associates. The ship lines were traced from the ship plans into specific, colored coded layers in order to make the numerous lines more navigable and give a basic outline of the ship's hull (Figure 19). Once this process was completed, the Loft tool was used to create a solid hull shape. Because of the number of lines and the slight human errors in the curvature of the lines, the initial hull shape was contorted and incorrect. To correct this issue, the number of control points, or points along each lofted line, was increased within the Loft calculations to get the hull shape shown in Figure 20.

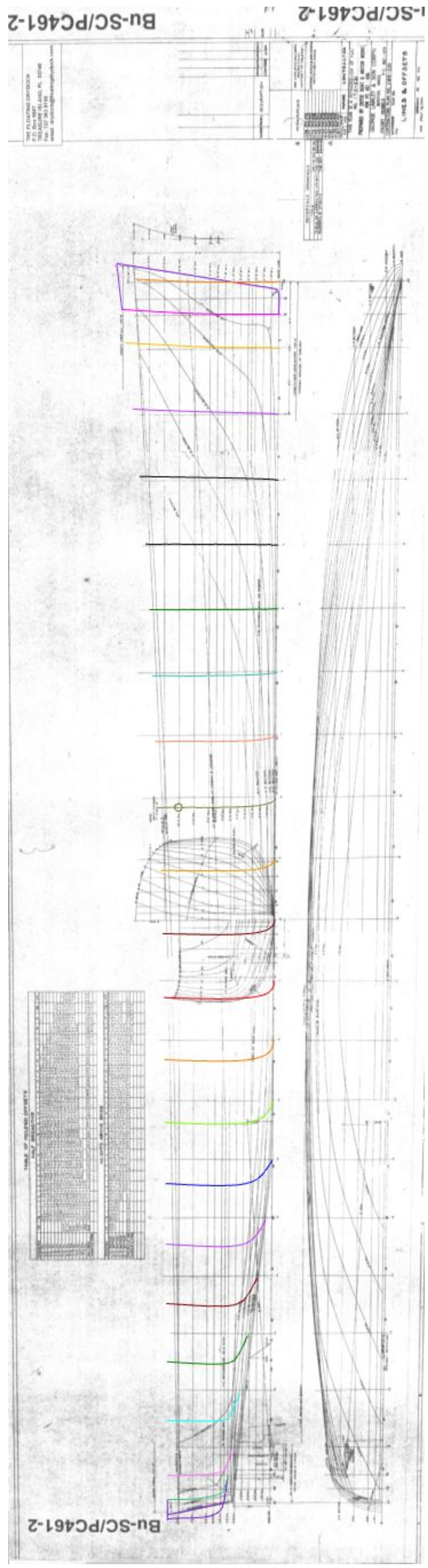


Figure 19. BuShips Plan with drawn ship lines (Image by author 2020)

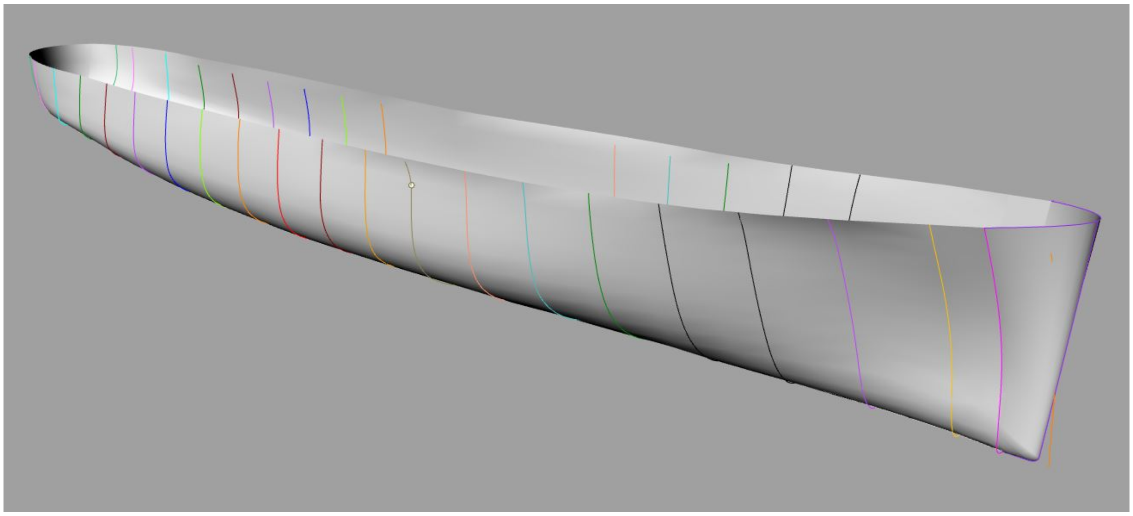


Figure 20. Hull with drawn ship lines in *Rhinoceros 3D* (Image by author 2020).

With the hull shape established, the main deck was created by selecting the top edge of the hull along the starboard side and using the Extrude tool to drag a surface horizontally over to the port side (Figure 21). The additional material left over from this process was erased using the Trim tool, and the main deck was placed into a layer of its own to allow for easier navigation throughout the construction process. Next, the John R. Tombaugh plan and profile views were scaled and overlaid onto the hull in order to allow for easy tracing of the deck equipment and superstructure, and Robert K. Baldwin's sketches were referenced to perfect close up details (Figure 22). Certain items were pulled from 3dwarehouse.sketchup.com, a repository for 3D models maintained by Trimble, with the depth charge launchers, 20-mm cannons, and 40-mm Bofors gun borrowed from Phil Andrawis's *PT-Boat Royal Navy #46* model (2016), the doors and railing from Nikos D.'s *WW2 US American Navy USS BB New York Battleship WWII* (2018), and the *US Navy Searchlight 17 inch* (2016) from Battery519IDA used to represent the searchlight located on the PC-461 class subchaser's smokestack (Figures 23, 24). To import these items into the model, they were downloaded from 3dwarehouse.sketchup.com using Trimble's SketchUp software and then converted into *Rhinoceros 3D* files. These files were then imported into the PC-461 project and scaled using the Tombaugh drawings. The end result of this was a complete late war PC-461 class submarine chaser (Figure 25).

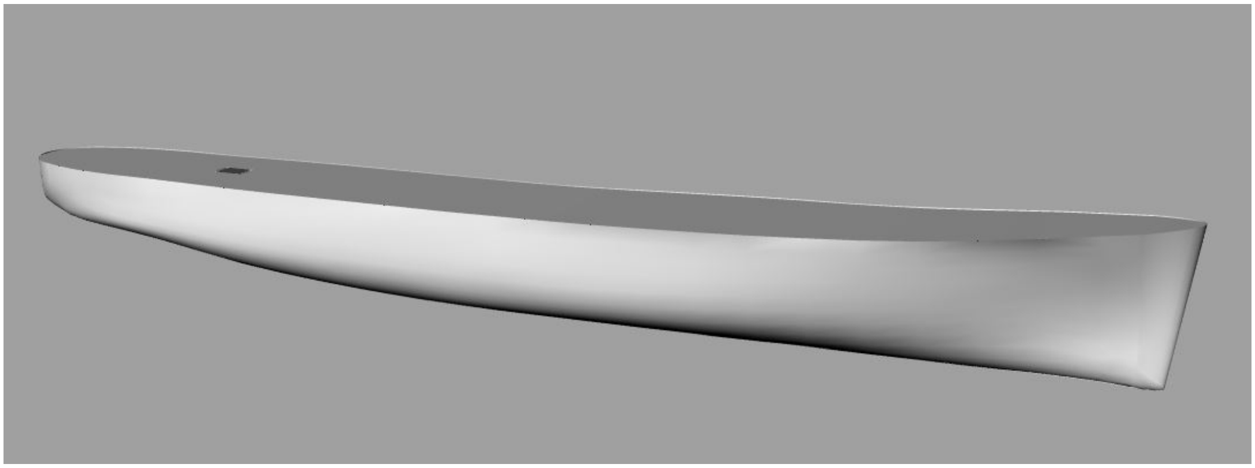


Figure 21. Main deck of PC-461 class model (Image by author 2021)

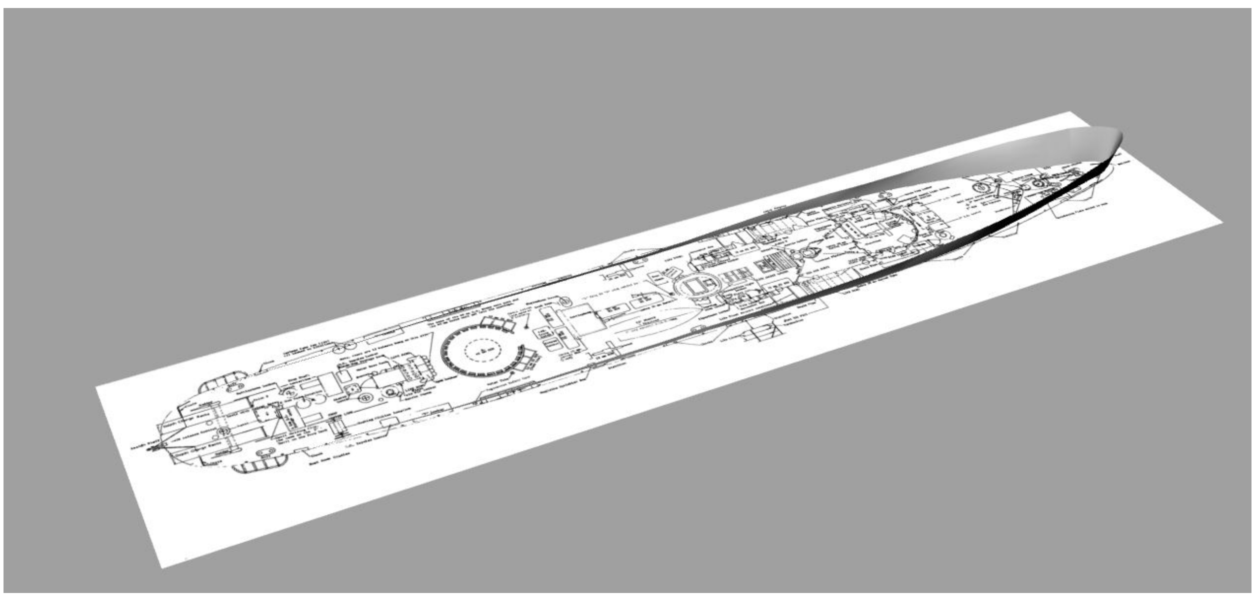


Figure 22. Tombaugh overlay on hull (Image by author 2021)

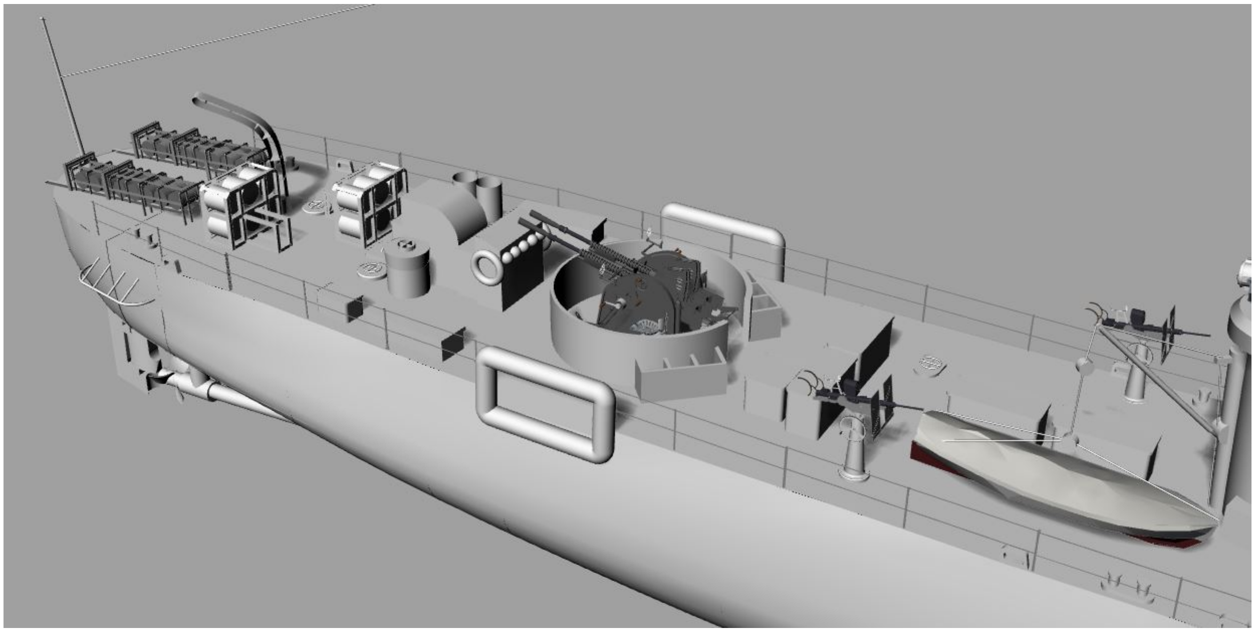


Figure 23. Depth charge racks, 20-mm cannons, and 40-mm Bofors gun (Image by author 2021).

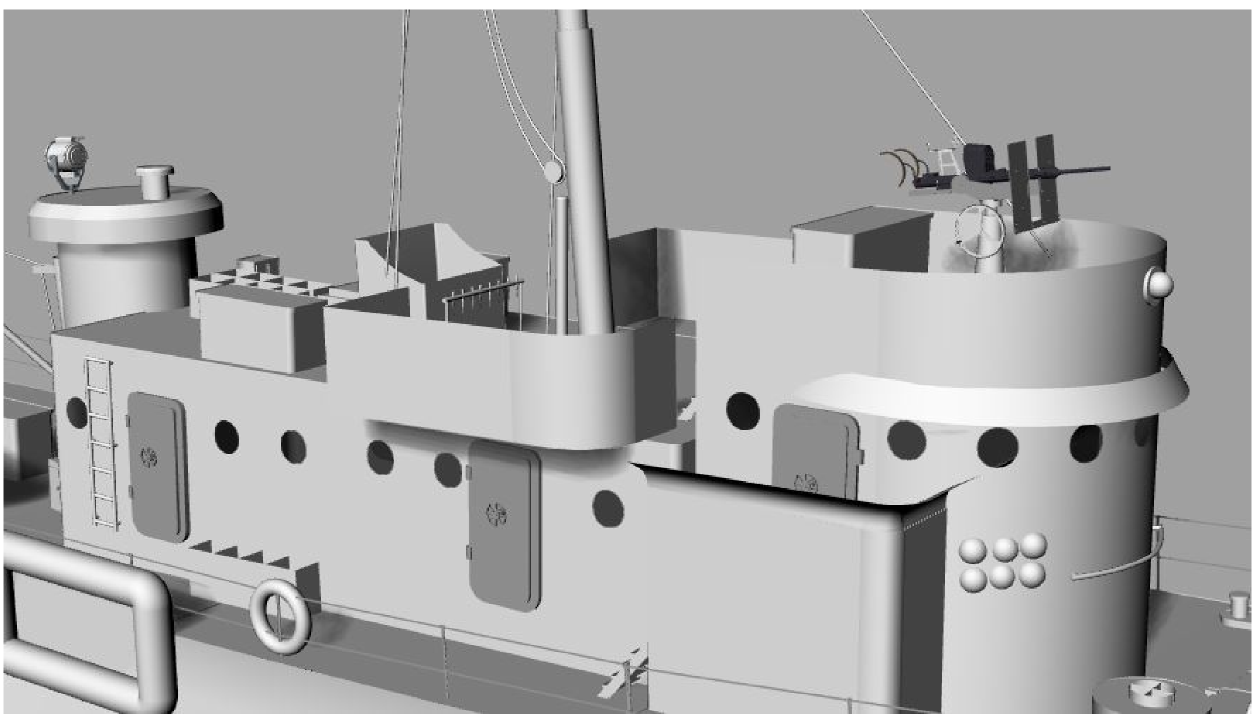


Figure 24. Doors, railing, and searchlight (Image by author 2021).

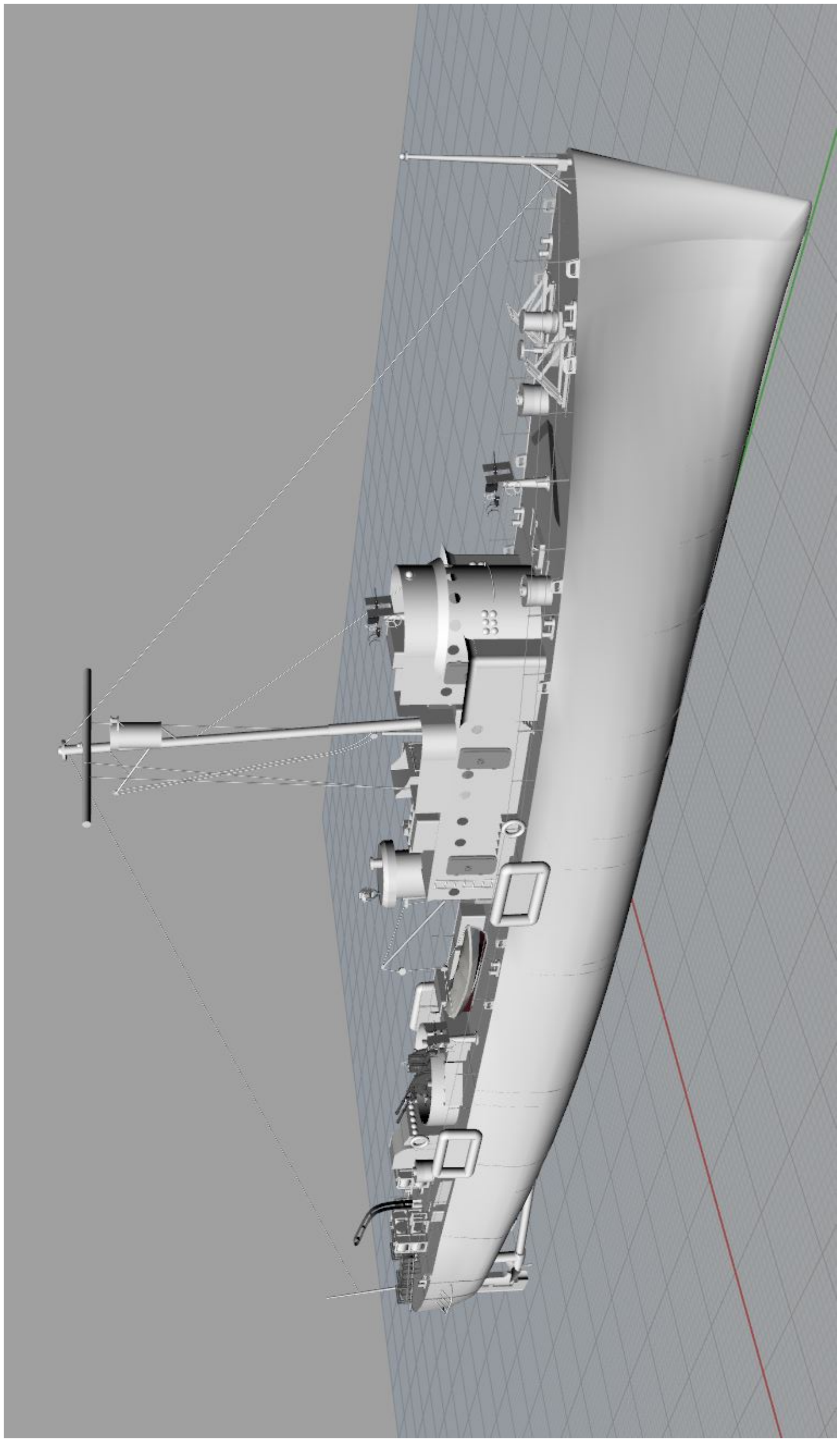


Figure 25. *Rhinoceros 3D* model of PC-461 class submarine chaser (Image by author 2020).

The same process was used to reconstruct the PE-1 Eagle Boat. Slight complications arose in the reconstruction process due to damage to the original copies of the inboard plan digitized by the Benson Ford Research Center. However, the outboard profile, plan views, and cross sections were undamaged and simple to work from. Each of the cross sections was labeled with a number corresponding with the location of that section of hull along the length of the ship. To make sense of this, the cross-section plans were cut into individual files and lined up with their corresponding numbers on the profile view plans (Figure 11). This organization and the blocky nature of the vessel made tracing the lines and lofting the hull a much simpler process than that of the PC-461 class vessel. The most difficult part of reconstructing the Eagle Boat were the small details incorporated into its design.

Because it was constructed just after the turn of the 20th century, the vessel still held many of the characteristics typically found on earlier 19th century vessels. The age of the ship plans caused severe pixilation when trying to look closely at these details, resulting in several challenging and lengthy miniature construction projects. For example, the armament onboard the Eagle boat was created by hand, rather than borrowing from other pre-existing 3D models, and each cylindrical portion of the gun had to be sketched and connected by hand (Figure 26). Other characteristics such as the overhead cover for the depth charge racks and the racks themselves had to be created by hand using various drawn polygons (Figure 27). These small details extended the reconstruction process for the PE-1 by many hours. Throughout this process, Norman Friedman's *United States Small Combatants, Including PT-Boats, Subchasers, and the Brown-Water Navy*: *An Illustrated Design History* (1987) was useful in clearing up confusion. His detailed explanations clarified specifics about the vessel and allowed for its completion (Figure 28).

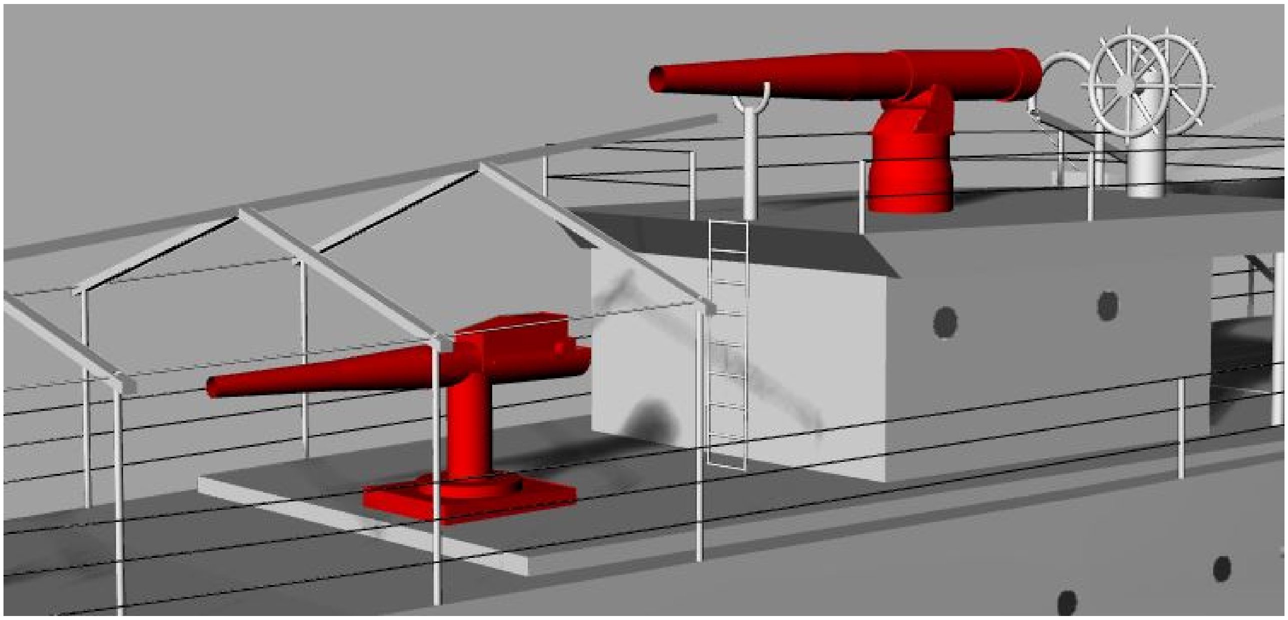


Figure 26. Deck guns color-coded red (Image by author 2021).

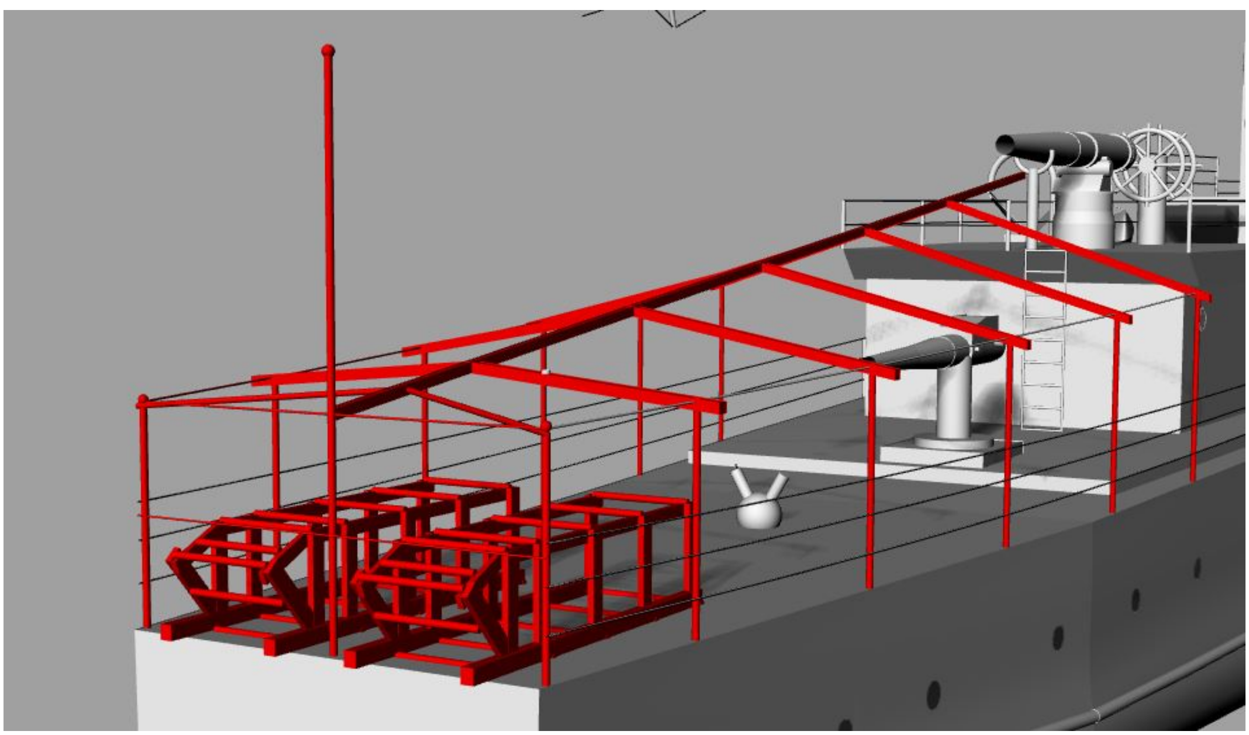


Figure 27. Deck cover and depth charges color-coded red (Image by author 2021).

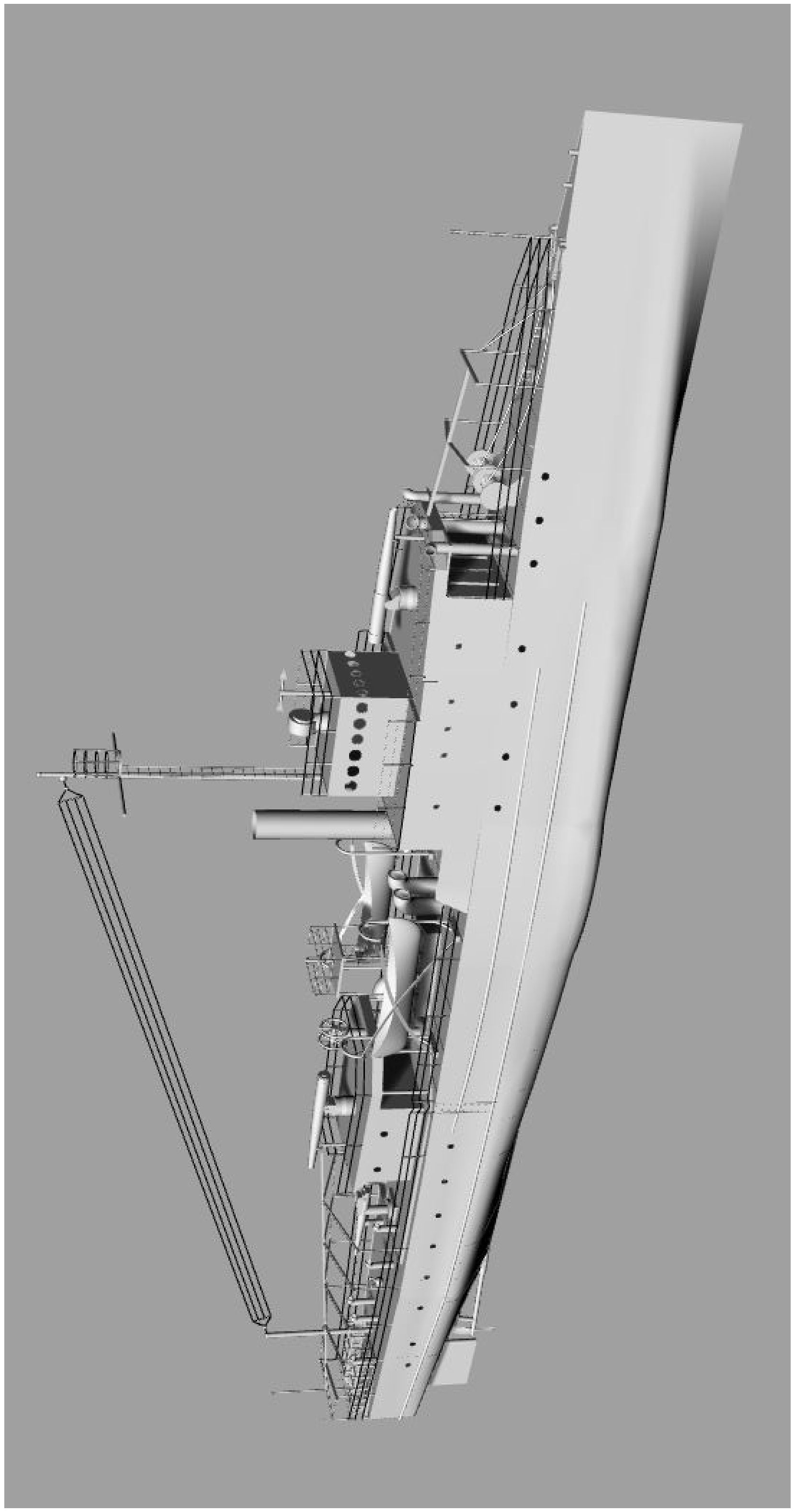


Figure 28. *Rhinoceros 3D* model of PE-1 class submarine chaser (Image by author 2021).

The final ship model, the SC-1 class subchaser, was not a matter of construction but rather one of verification. A completed 3D model was discovered on the 3D model website CadNav and borrowed for the purposes of this project, but only after it was verified as accurate based on the previously discussed General Plans from the Bureau of Construction and Repair. The model appeared proportionally to be a perfect construction of an SC-1 class vessel but the scale for it was incorrect, with the "Distance tool" in *Rhinoceros 3D* measuring it out at approximately 1,200 feet rather than the correct 110 feet it was supposed to be. This would be problematic in the comparative analysis of this vessel with the other generations of subchasers and required correction. This was accomplished by clicking the View tab in the upper left-hand corner of *Rhinoceros 3D* and then clicking on grid options. First, the units for the SC-1 class subchaser model were changed from centimeters to feet to reflect the pattern for the other two models. Next, the grid was adjusted to match those of the Eagle Boat and PC-461 class subchaser by using a split screen monitor to verify that the grid line count, minor grid line spacing, and major grid line spacing were identical for all of the models. Once the grid adjustments were complete, a 110-foot line was drawn on the grid and the SC-1 model scaled up to the correct length using the Scale 3D tool. The beam and depth of the model were measured and determined to be proportionally correct based on the General Plans specifications, completing the process of evaluating and preparing the SC-1 subchaser model (Figure 29).

The completed models served two purposes in this study. In the results chapter, they allowed for the highlighting of characteristics discussed in the historical research and the visual identification of potential strengths and weaknesses in each class of vessel. New technological advancements such as detection equipment or armament were highlighted with specific colors to make visualization and identification less complicated. In the analysis chapter, the models were

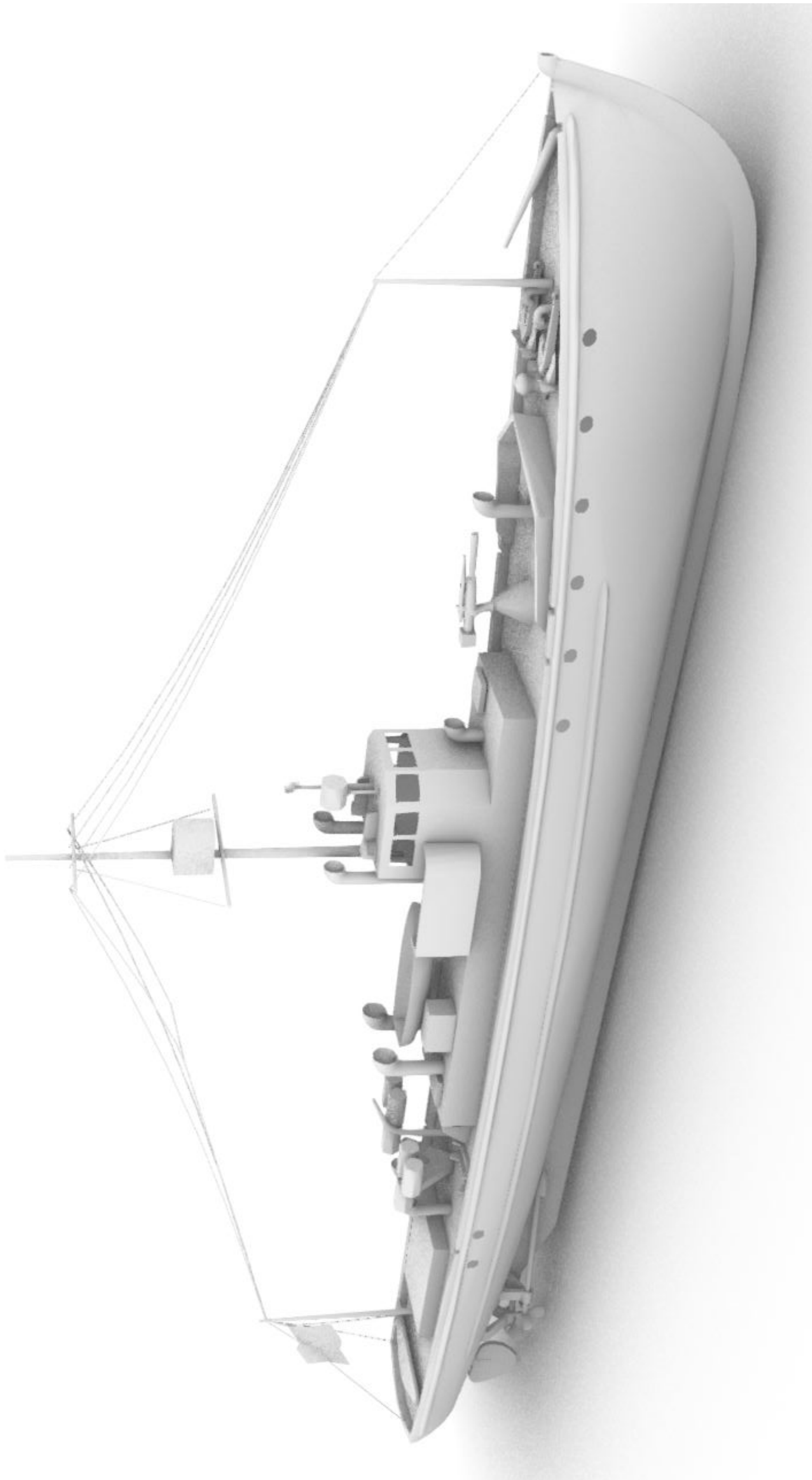


Figure 29. *Rhinoceros 3D* model of SC-1 class submarine chaser (Image by author 2021).

used to compare and contrast characteristics between the different types of submarine chasers and between the submarine chasers and the submarines they were designed to pursue.

Conclusion

This chapter examined the process of identifying, researching, and developing submarine chaser models from the First World War, Interwar Years, and Second World War with the intent of examining change over time. The models created through this process provide the tools for use in comparative analysis to determine the consistencies and adaptations resultant from intermingled interactions with national beliefs, enemy weapons modifications, and concurrent aircraft development.

CHAPTER FIVE: U.S. SUBCHASER DESIGN AND DEVELOPMENT (1919-1944): A DESCRIPTION OF THE SC-1, PE-1, AND PC-461 DESIGNS

Introduction

This chapter will illustrate changes in US submarine chaser design from 1917 to 1944. The key components in illustrating these changes are the 3D models, which will be used in conjunction with historical images and documentation to discuss in detail the purpose and design characteristics of three generations of submarine chasers. To achieve this objective, characteristics of each submarine chaser will first be categorically enumerated. Each section will then conclude with an assessment of those characteristics and their success in achieving the specific goals put forth for each vessel. Characteristics that fit completely into the objectives for the vessel will be coded green, objects that have a balance of beneficial and detrimental characteristics will be coded yellow, and completely detrimental characteristics will be coded red. By labeling the successful and unsuccessful characteristics of each vessel in this way, influences on future construction can be readily showed.

The SC-1 Class Submarine Chaser (1917-1919)

Almost immediately after the outbreak of hostilities along the Western Front, U.S. citizens and politicians alike began to discuss preparedness measures for dealing with a potential conflict with Imperial Germany. By 1916, the U.S. Navy was vetting options for a small, sturdy patrol craft to protect commerce along the U.S. coastline from German U-boat incursions. The first option available for this purpose was an 80-foot motor launch commissioned by the British Royal Navy from Elco in the spring of 1915 (Messimer 2001:124). Though the boats were extremely versatile and maneuverable, the British Royal Navy found them to be entirely too small to serve as antisubmarine patrol craft (Treadwell 2000:6). The General Board of the U.S.

Navy took British recommendations into consideration, beginning design work for a vessel larger and sturdier than the Elco motor launch in February of 1917. The General Board's request for an inexpensive and sturdy wooden boat with excellent seakeeping ability resulted in the SC-1 class submarine chaser, a 110-foot vessel intended to serve as a supplement to the destroyers already patrolling off the U.S. coastline (Friedman 1987:26-27).

The hull design of the SC-1 was primarily the work of master yacht builder, Albert Loring Swasey. Having already figured out that these new vessels would operate far out to sea, where extreme speed over short distances was less useful than sustained moderate speed, Swasey opted for stability by flaring the forward section of the vessel and designing a rounded, roughly symmetrical bilge form to meet a following sea or a head sea (Friedman 1987:30). He also cut away the forefoot of the keel as much as possible to allow for better maneuvering in a following sea. The C&R's Preliminary Design division took Swasey's design as the basis for the SC-1 but made significant changes to the hull. Due to a shortage of steel, Preliminary Design opted for yellow pine or oak for the keel and yellow pine for the planking (Robinson 1917:186-187) (Figure 30). The length was increased to 110 feet to account for the speed from the two engines expected to power it, and the stern was changed to have a rise of floor aft to aid the vessel in rough conditions and following seas (Friedman 1987:30-31). To account for the increase in hull length, six of the seven bulkheads were made of steel to stiffen it, with the after peak bulkhead made of wood on the theory that it would be more watertight than a steel bulkhead. The ship's keel and deadwood were thought to be too heavy, with the keel adding 10 percent resistance at the SC-1's top speed, but both were retained to prevent rolling and to allow for a stable gun platform.

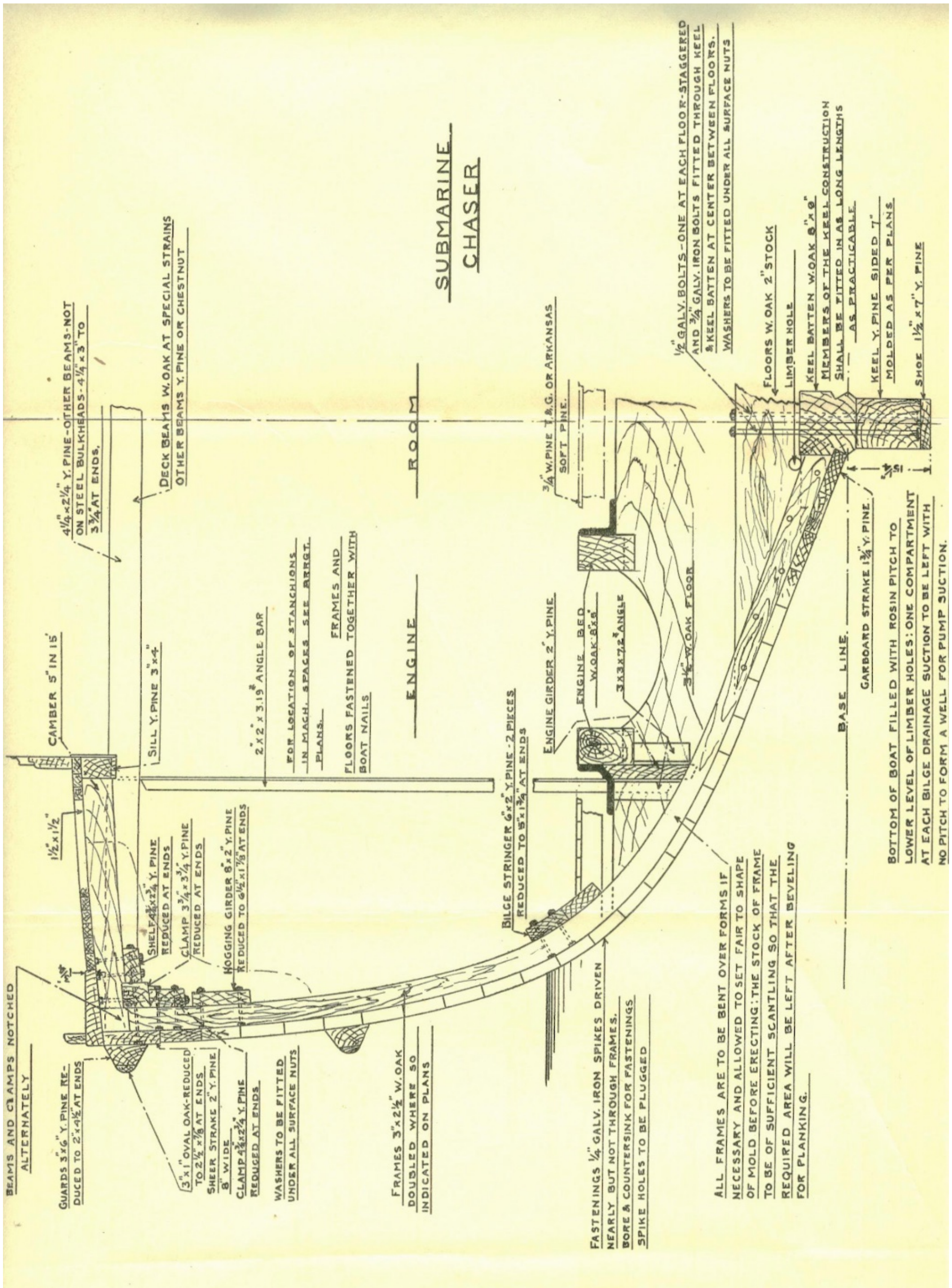


Figure 30. Detailed cross-section of SC-1 class submarine chaser construction (R.H.M. Robinson 1917:187).

The propulsion system of the SC-1 class submarine chaser consisted of three 220-bhp gasoline engines sourced from the Standard Motor Company (Figure 31). The engines were already in use in Elco boats and were considered “slow-speed” engines, not meant for explosive speed, but rather sustained speed in all types of weather (Sutphen 1917:151). They were substituted for the two 300-bhp engines called for in the SC-1 design because they were already readily available, resulting in a triple screw propulsion design rather than the initial twin screw the designers planned for. With a range of 900 nautical miles at 10 knots on 2400 gallons of gasoline, the SC-1 class subchaser was typically expected to run out at sea for no more than two weeks and had a projected top speed of 16.85 knots on three engines, 14.35 knots on two engines, or 9.4 knots on one (Friedman 1987:31-32). Each SC-1 was equipped with battery powered compressed air starters which allowed for the operation of the engines with just compressed air, using multiple sets of cams meant for running ahead and running astern to use the air inlet valves, exhaust valves, and ignitors (Bureau of Steam Engineering 1917:11-13). The vessels also had an auxiliary two-cylinder gasoline powered engine that generated electricity and backup compressed air, but the poor ventilation caused by having four engines in a small, cramped engine room caused fire hazards serious enough that the Navy Bureau of Engineering issued Circular Letter D-2 in July 1919 advising sailors on the issue (Woofenden 2006:22-23).

The primary device used for hunting submarines via the SC-1 and all other patrol craft during the First World War was the hydrophone. SC-1 subchasers were equipped with the C-tube and either the SC-tube or the K-tube (Messimer 2001:126). The SC-tube was a variation of the C-tube design that was built into the hull of an SC-1 class vessel via a water-tight mounting assembly that allowed the device to be extended beneath the hull when hunting submarines and

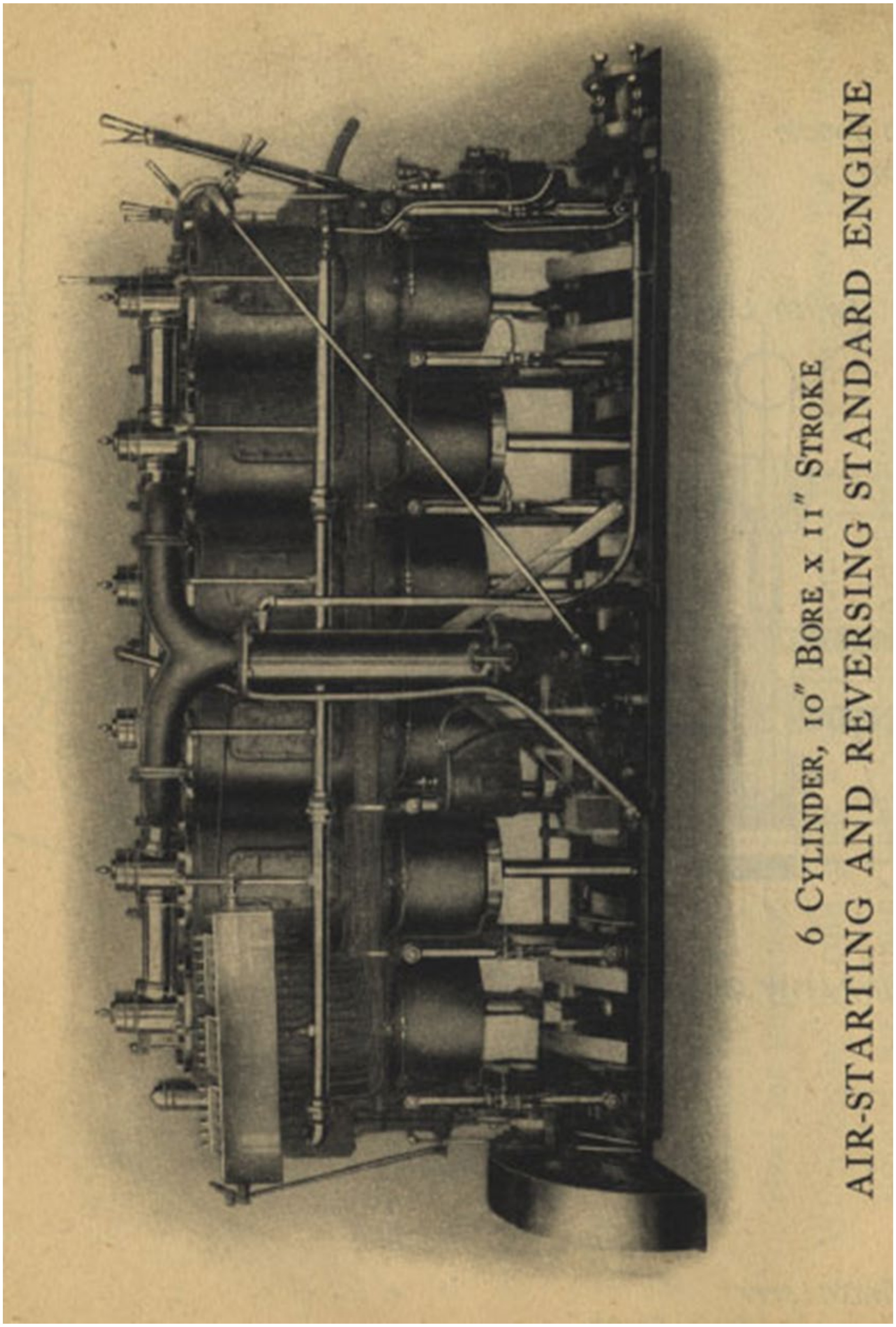


Figure 31. 6 Cylinder, 10" Bore x 11" Stroke Air-Starting and Reversing Standard Engine (Bureau of Steam Engineering 1917).

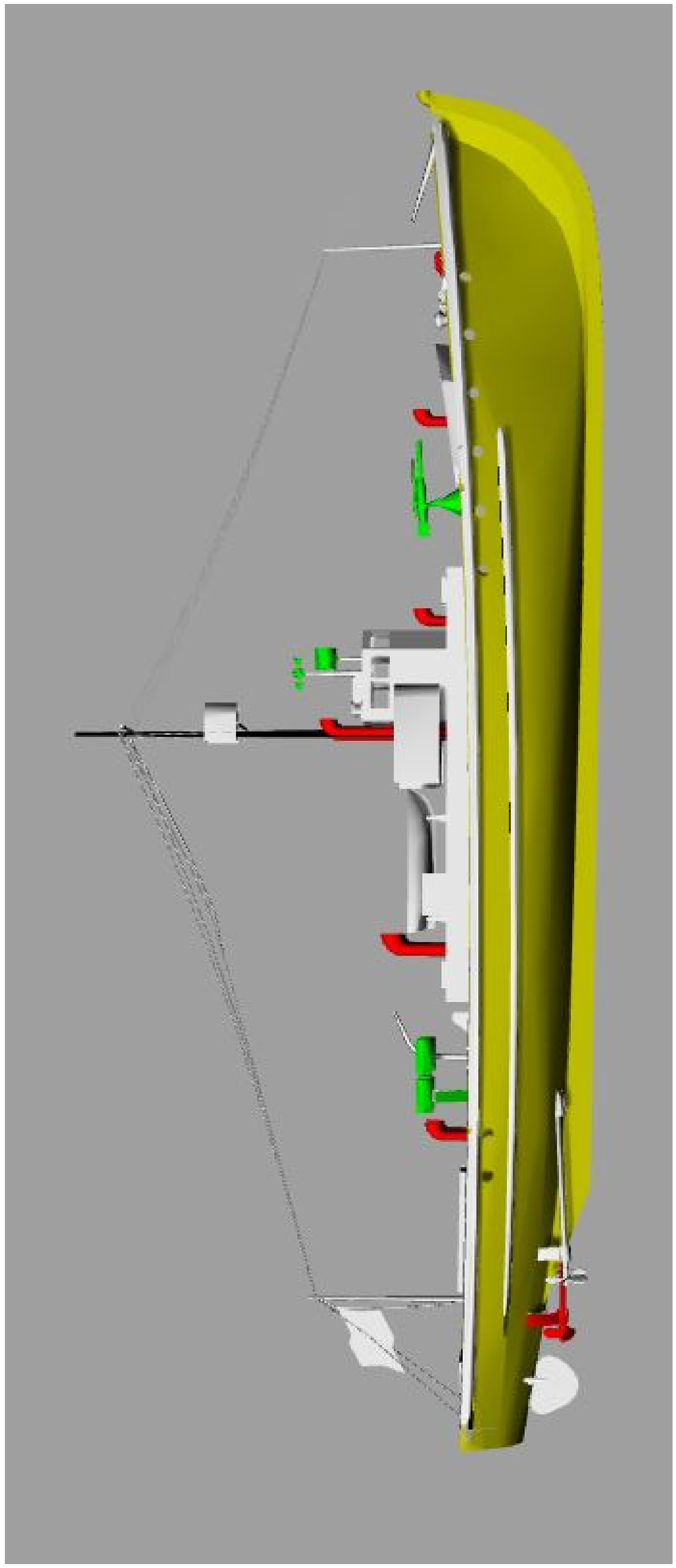
retracted up against it when not in use (Woofenden 2006:37). The device was shaped like an inverted T, with rubber bulbs on the ends of the horizontal sections and the vertical portion of the device connected to a stethoscope in the listening room of the ship. The same set up was used onboard US submarines, with the T extended above the vessel rather than below. The SC-tube could be rotated using a hand wheel, and a graduated dial showed the direction of the tubes in relation to the boat, allowing the direction of a sound to be determined using a magnetic compass. A different U.S. hydrophone design, the K-tube, consisted of a brass pipe construction, equilateral triangle with three carbon microphones, one wooden or hollow metal float, and twelve smaller floats (Messimer 2001:118). Electrical cables connected the K-tube to a shipboard control console, which allowed the operator to listen through earphones and tune in on the sounds using an indicator dial. The K-tube could be suspended at depth of 40 feet, which eliminated excess sound and allowed the device to operate at a reported acoustic range of 30 miles (Friedman 1987:20). If hydrophones failed to work, the SC-1 was also equipped with the trailing wire. Developed by the British early in the war, the trailing wire consisted of a phosphor-bronze reel of wire attached to a weight, consisting of either an insulated length of chain or a wooden triangle, and dragged across the ocean floor (Woofenden 2006:43). The wire and chain trailed behind the vessel, with the weight of the chain keeping the sensitive wire on the seafloor. If the wire contacted the metallic hull of a submerged vessel, an electric buzzer would ring in the pilot house to notify the crew of the contact.

The armament of the SC-1 shifted over time. The original armament consisted of one 3-inch, non-recoiling Davis gun and two machine guns (Friedman 1987:32). The Davis gun was multipurpose, capable of high angle fire for anti-aircraft warfare, but also armed with high explosive rounds for surface combat and flat nose, non-ricochet depth rounds for antisubmarine warfare (Messimer 2001:125). The machine guns were typically Lewis light machine guns with a weight of just 28 pounds, nearly half that of the typical medium machine gun during the First World War, and a rate of fire of 500 to 600 rounds per minute (Hogg and Batchelor 1976:27). The SC-1 also carried eighteen Mark II 300-pound depth charges (Woofenden 2006:55-56). Initially, twelve were carried in launching racks on the stern and the remainder in ready racks, but the introduction of the Y-gun into naval combat quickly changed the SC-1's armament once again. The U.S. built Y-gun was able to fire depth charges at a range of up to 80 yards over the port and starboard sides of a vessel (Messimer 2001:160). The Y-gun's moniker came from its two barrels, joined to the breech at a 90-degree angle, and the depth charges used in the weapon were modified with bolted on plungers used to mount the explosives on the device (Millholland 1936: 48). The two depth charges were then fired simultaneously. In December of 1917, the U.S. Navy began substituting the Y-gun for the Davis gun on SC-1 subchasers, eventually outfitting the majority with this new technology.

The SC-1 subchaser (Figure 32) was considered a production success that still left the U.S. wanting more. The small size and wooden construction of the SC-1 made it easy to produce and combined with the deployment of detection technology onboard the vessels to give the U.S. its first glimpse of the potential in offensive anti-submarine warfare (Woofenden 2006:178). However, the SC-1 was severely underwhelming in adhering to the seakeeping ability initially emphasized as an integral characteristic. Part of the lack of seaworthiness in deeper waters could most certainly be attributed to the small size of the SC-1, but lack of tight weight control played a significant part as well. By the end of the war the vessels were averaging a weight of 75 tons, nearly nine tons more than their projected weight of 66.5 tons and were almost certainly slower and less seaworthy as a result (Friedman 1987:33). Upon reviewing the SC-1 building program during the buildup to the Second World War, President Franklin D. Roosevelt determined the lack of weight control to be one of the most significant issues with the program and demanded extremely strict controls on future patrol vessels. Furthermore, the most significant contributors to the weight increase, the third engine and third screw turbine, did little to aid the SC-1's performance. The third engine increased the subchaser's speed by less than two knots while lowering the center of gravity by almost a foot, and there was at least one documented case of a crew removing the third engine with no real loss in top speed (Messimer 2001:125, Friedman 1987: 31). Additional weight issues from the heavy wooden keel were counteracted by its benefit in aiding the stability of the gun platforms. As mentioned in Chapter 2, SC-1 submarine chasers found great success in operating as close shore bombardment vessels and were later outfitted to serve specifically in that role.

The use of gasoline as the primary fuel source was another problematic characteristic for the SC-1, as gas fires and explosions happened frequently enough to cause the circulation of a letter regarding the handling of gasoline onboard (U.S. Navy Department 1919). Numerous sailors onboard SC-1 class submarine chasers were killed, and several vessels lost when gasoline vapors accumulated in the confined spaces of the engine rooms (Woofenden 2006:23). While the vessels did have ventilation systems, they were powered by the auxiliary systems and not often in use when the main engines were running. With the potential for fires in mind, the wooden hull of the vessel carried some detrimental consequences should a fire break out. While the SC-1 was capable of achieving the goals set out for it, certain characteristics of its construction would need to be resolved to achieve true success.

Figure 32. Model of SC-1 Class submarine chaser (Image by author 2021).



The PE-1 Submarine Chaser/Eagle-class Submarine Chaser (1919-1924)

While the SC-1 could be appreciated for its seaworthiness in all but the roughest of conditions, there was speculation among the members of U.S. Navy leadership that the U-boats could be defeated by 1918 if a larger vessel capable of matching the all-weather capabilities of the U-boat were available for deployment. C&R proposed a vessel intended to pair with a destroyer to hunt submerged submarines and a design based around listening gear and an armament primarily made up of depth charges, but the General Board rejected this design. Instead, they preferred a vessel capable of independent offensive and defensive action with seaworthiness allowing it to work the deep water into which the smaller SC-1 class subchasers were pushing the German submarine fleet (Friedman 1987:37).

With established shipbuilding facilities already engaged in the production of destroyers, larger warships, and merchant shipping, the design of the PE-1 needed to be simplified so that less experienced shipyards could complete construction (United States Naval History Division 1976:744). The first adaptation for efficiency was the flush deck design of the vessel. The framing and plating were intended to eliminate almost all curvature, with straight plates making up the bilge to keel and bilge to sheer sections of the vessel, and the transom flat both to allow for depth charges to be dropped directly off the stern and for ease of construction (Figure 33). While it was recognized that the straight sides and extremely narrow bow would cause wetness forward, adjustments to the design to correct this were dismissed when it was determined that they would cause additional complications in construction. A draft of six and a half feet was chosen to help the vessel hold its course in rough weather, and the frames were spaced only 21 inches apart and stresses were kept to 6 tons or less to reduce hull distortion in pounding seas (Friedman 1987:38-39). Additionally, the metacentric height of the vessel was reduced

Figure 33. Progress on Prototype Eagle Patrol Boat (Ford Motor Company 1918).

from 18 inches to 12 inches to compensate for design changes and weight increases at later stages of construction.

Though the Bureau of Construction and Repair intended to use diesel engines in the PE-1, Henry Ford suggested steam turbines instead (Gardiner 1985:132). The engine of the vessel was a Poole high-speed turbine, considered to be a compact and efficient design for the 2500 shaft horsepower it could produce (Navy Department of Engineering 1924:1) (Figure 9). The engine was driven by two boilers of the express type, designed by the Bureau of Engineering. These boilers were oil fired, which required regular inspections for oil leaks and other issues prior to their use if they were idle for an extended period of time (Navy Department of Engineering 1924:47). The warming up process for these engines took no less than 15 minutes, which could put them at a disadvantage when compared to engines propelled by other types of fuel sources including the diesel engines of enemy submarines. The boilers also required regular cleaning and could foul up if not well maintained. The projected range for the PE-1 at a cruising speed of 10 knots was 3,500 nautical miles and projected top speed was reduced from 21 to 18 knots in another attempt at simplifying production (Friedman 1987:43).

The PE-1 was initially equipped with the same detection capabilities as the SC-1, carrying C-tube and K-tube hydrophones. To use these devices, it had a unique electrical system powered by storage batteries which allowed for the operation of the detection equipment and the running of auxiliary lights during the hunting process (Friedman 1987:41). Unfortunately, a common complaint from Eagle boat crews was that electrical appliances had continual trouble with the ball bearings of governors on their generators wearing out (Navy Department of Engineering 1924:65). On vessels in which this was the case the equipment used in detecting enemy submarines would be rendered unusable, making the purpose of the PE-1 much more difficult to achieve. The size of the vessel would almost certainly provide an advantage for watchmen onboard, and it was also equipped with a 24-inch searchlight for nighttime operations (Figure 10). However, the delay in production meant that the PE-1 was never used in the role it was designed for during the First World War. It took the advent of the Second World War and the renewed U-boat campaign for the few remaining PE-1 vessels to participate in antisubmarine warfare operations, using new sonar capabilities instead of the old First World War hydrophones (Cianflone 1973).

Designed to be able to stand up to a surfaced U-boat, the PE-1 was initially armed with two Mark 9 4-inch single purpose guns, one .50 caliber machine gun, and a depth charge rack with nine 300-pound charges (Gardiner 1985:132). Later in their development the Eagle boats would be armed with Y-guns, but these armament changes mattered little due to their late arrival in the First World War. The eight PE-1 submarine chasers that survived up to the Second World War were modified to reflect the newer weapons technology of the conflict. PE-19, PE-27, and PE-48 were rearmed with one 3-inch dual purpose gun, one Hedgehog depth charge launcher, two .50 caliber machine guns, and two four charge depth-charge tracks (Friedman 1987:43-44).

Though it was intended to be a multifaceted submarine chaser capable of holding its own both in combat and in the roughest of weather conditions, the PE-1 never truly lived up to that billing. The design was rushed due to the U-boat problem and the U.S.'s late entry into the conflict, and the General Board even went so far as to admit that the design would not have been adopted had the time constraints and threat from submarines not been so severe (Gardiner 1985:132). The ship could not accept much modification at all, with the postwar calculations of the dissatisfied Preliminary Design and General Board indicating that it would require double the shaft horsepower, an increase of 25 feet in length, and increased machinery to reach their preferred top speed of 24 knots (Friedman 1987:44). The increased weight in machinery would in turn require heavier scantlings and thus a more conventional, curved hull, which completely nullified the logic of Henry Ford's straight lined, mass production plan. Furthermore, the workmanship produced by the River Rouge plant was poor, proving that the expenses saved on working with less experienced boat builders were not actually expenses saved in the long run (Hounshell 1985:195).

The electric arc welding used to hold the frames to the hull of the PE-1 was so bad that the superintending constructor requested that the Ford workers do little to no welding on the water-tight and oil-tight bulkheads as a safety precaution (Hounshell 1985:181). Unaware that scaffolding was used to get the proper angles for bolting plates in shipbuilding, Ford placed his workers on ladders with short-handled wrenches which prevented them from being able to tighten the bolts enough to ensure proper seals. The lack of experience also led to metal shavings being trapped between the plates, making proper sealing essentially impossible. The first seven PE-1 submarine chasers to launch reported water and oil leaks almost as soon as they began their trial runs (Hounshell 1985:183). Falling in line with the reports from the documents, the reconstructed 3D model demonstrated clear points of weakness on five of the ship's 114 frame. At frames number 26, 46, 60, 82, and 97, all places where the natural bend of a ship's hull would conflict with the rushed workmanship of an assembly line, the 3D model clearly demonstrated a poor fit in the plating (Figure 34). Though sources do not specifically note where leaks occurred in the early vessels, it is very likely that these were problematic points. Furthermore, specifically between frames 46 and 60, the 3D model demonstrated a slight imperfection in the fitting at the bilge that would have been corrected with reinforcement and riveting during the actual construction of the vessel.

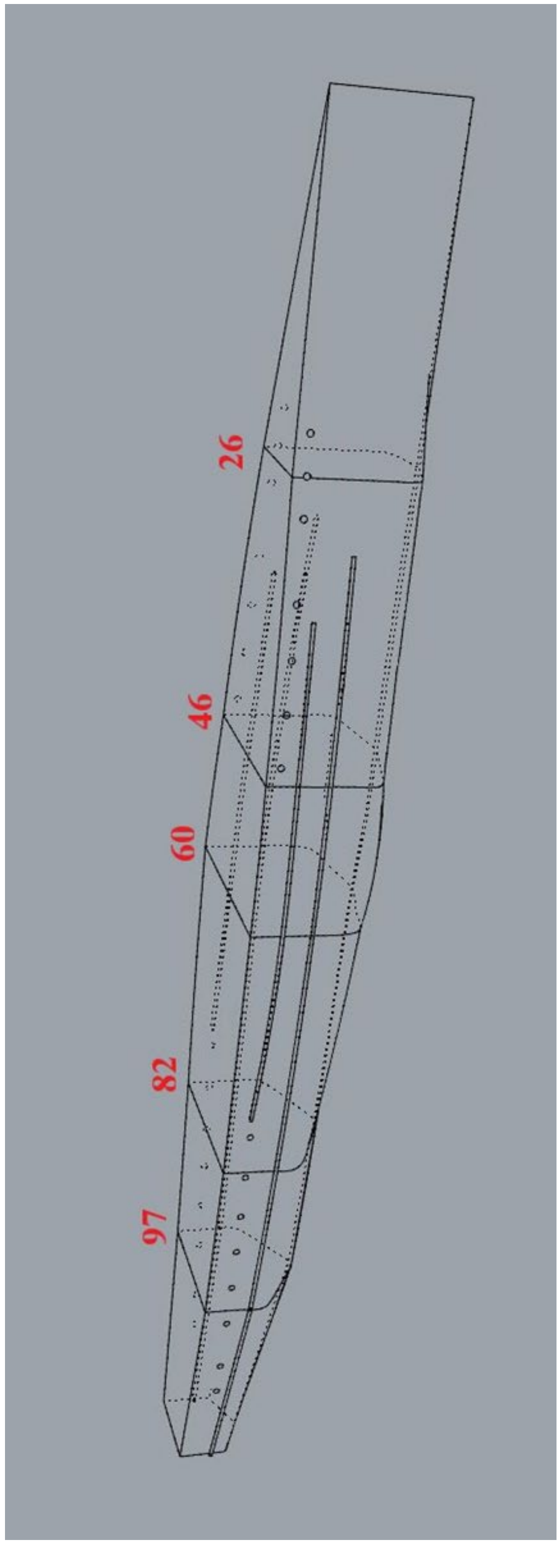


Figure 34. Technical image of PE-1 hull with weak points identified (Image by author 2020).

However, this is not a natural flow of the ship's hull and it is likely that the strategy of plating above and below the bilge would have created an opportunity for that section to bulge out and leak over time as rough sea conditions took their toll on the PE-1's hull.

The elimination of curvature plagued the PE-1 class subchaser in other ways as well. The height of the vessels paired with the downsizing in metacentric height and flat stern to cause an excessive heel of 20 degrees when turning (Friedman 1987:43). The downsizing of the metacentric height, specifically, resulted in a center of gravity so high above the center of the underwater body that the rudder on the vessel would have to be impossibly long for its center of pressure to properly counteract the heel. In other words, the vessel was top heavy. The weight of the upper works paired with the lack of typical curvature affected its seaworthiness during sharp turns and in rough seas. These issues are reflected in the 3D model, where the nature of the program has the effect of a virtual drydock through which one can view and analyze the entirety of the vessel rather than just the components visible above the waterline. In Figure 35, a view of the PE-1 class subchaser with the hull removed but upper works still visible, the weight and instability issues with the vessel become abundantly clear.

Just to the fore of the smokestack on the lowest level of the deck are two fuel tanks, marked with red circles, that span the entirety of the midships section. The weight of these tanks, paired with the weight of the various components in the forecastle, were likely the source of the high center of gravity leading and heeling of the vessel. Though the engines just aft of the smokestack (marked by blue circles) would contribute to the weight differential and fuel tanks in the stern section and help balance out the vessel, it is clear that even without accounting for the anchors and deck equipment not shown in the bow section that

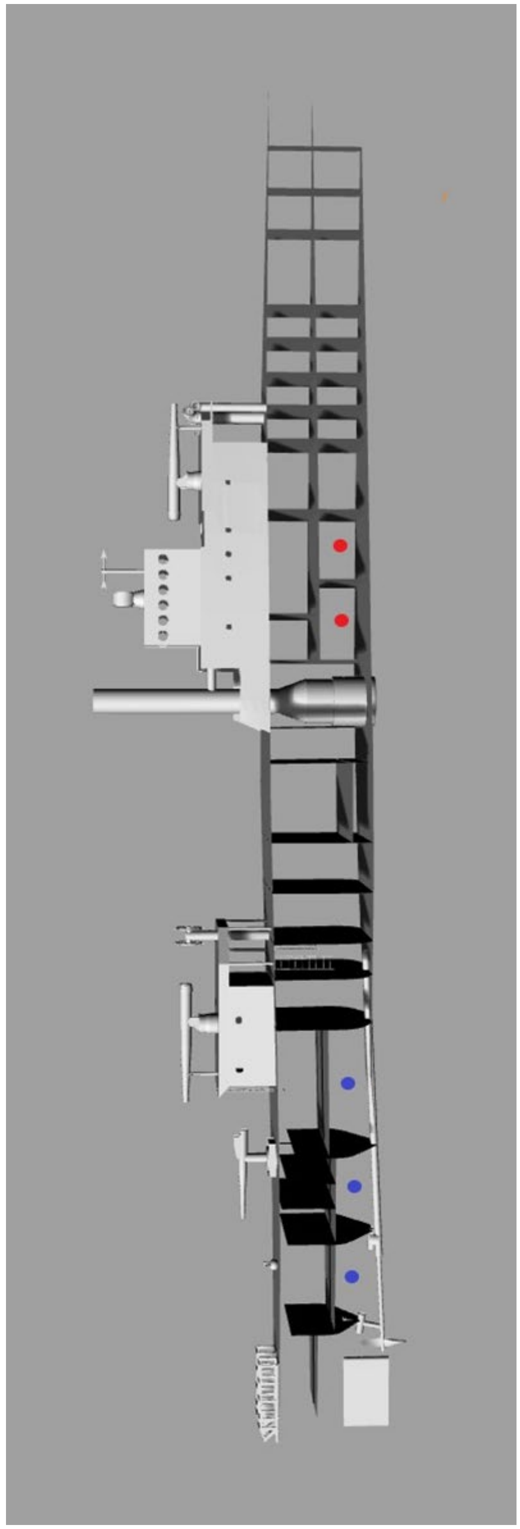


Figure 35. Starboard view of PE-1 inboard with fuel tanks (red) and engines (blue) identified (Image by author 2020).

the weight distribution would drive the bow of the vessel slightly downward into the water and affect the sharpness of the heel on turns. As mentioned previously, the rudder's center of pressure was too far below the vessel's center of gravity to help the situation. The complete model (Figure 36) illustrates these issues, as the weapons and after deck would help slightly with driving the rudder down but not enough to counter the forward lean caused by the forward accoutrements.

Though the PE-1 class subchaser was intended to be an improvement on the SC-1 class, both in size and formidability, flaws in its design and construction led to it having little if any impact on the First World War. It successfully achieved the size requirements and speed of construction desired by the General Board, as well as retaining the heavy armament and detection capabilities necessary for a submarine chaser to operate independently of other vessels. However, the issues with the hull design and weight distribution in the PE-1 and the inability to counter those issues with expedient solutions sank the program. The first vessel was commissioned on 30 October 1918, just twelve days before the Armistice, and the original 100 Eagle boats requested was cut down to 60, with the final vessel being delivered on 15 October 1919 (Friedman 1987:43). By 1924, 30 of those 60 were laid up and 22 assigned to the naval reserve, with just eight remaining by the time the U.S. entered the Second World War in 1941. Unlike the SC-1, there was no attempt to revive production of the Eagle boats for the second conflict, but the size, speed, and armament goals intended for them never left the mind of the General Board.

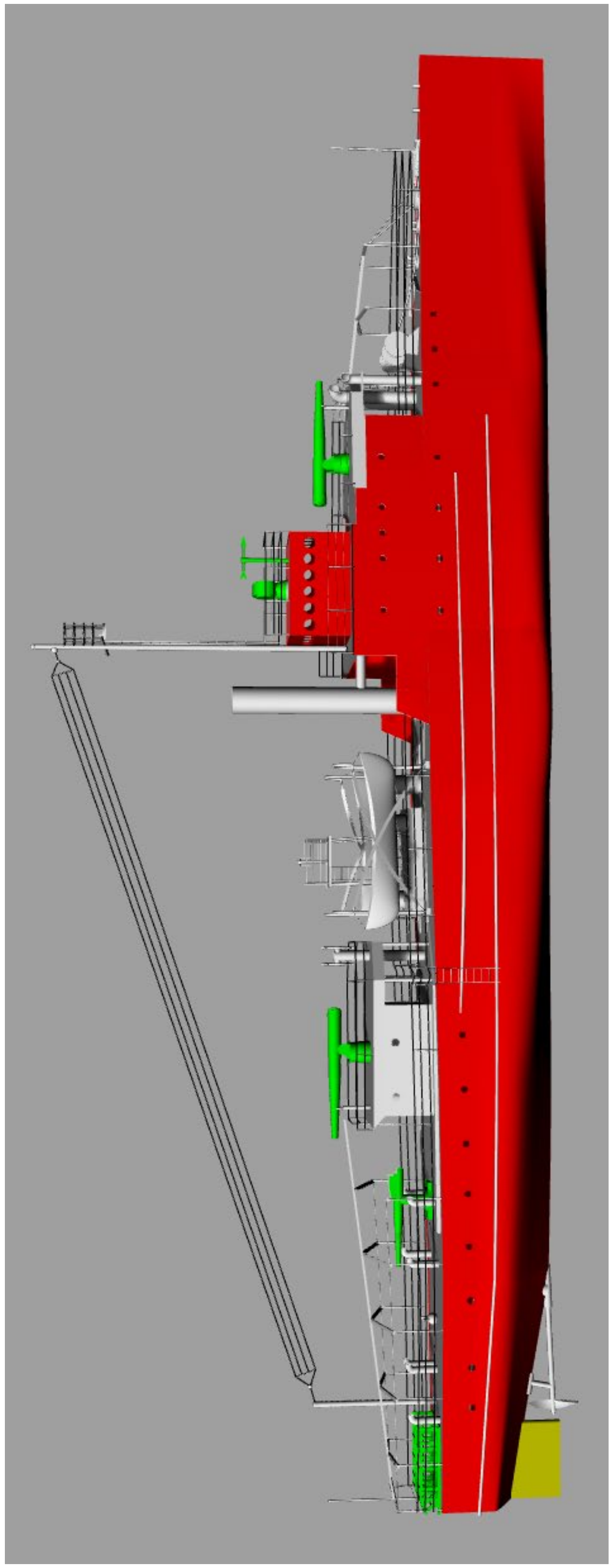


Figure 36. PE-1 class submarine chaser model (Image by author 2021).

The PC-461 Class Submarine Chaser (1942-1945)

As previously mentioned, the SC-1 class subchaser design was reintroduced at the advent of the Second World War, though with some modifications. The three 220-bhp gasoline engines were replaced by either two 500-bhp or two 1200-bhp engines depending on the period in which they were produced (Gardiner 1980:153). However, the U.S. Navy was concerned with the SC-1 class vessels, noting that the latest U-boats would be both faster and more heavily armed than the SCs and thus had no reason to fear them. The General Board announced a design competition to vet options for a larger, more formidable submarine chaser comparable in size to the older PE-1 class Eagle boats.

The PC-451, the favored vessel in the competition, had a raised forecastle and the curvature of the SC-1 in a larger hull. However, the tight spacing of the PC-451 limited modification and crew sizes in a way that was unacceptable to the General Board. Instead, they favored the PC-452. Though it was flush decked, its lines followed those of the SC-1 far more closely and increased its seaworthiness while also allowing it to be modified. After determining that the propulsion system for the PC-452 could not be produced at high enough rates the newly minted Bureau of Ships, a merger of the Bureau of Construction and Repair and Bureau of Engineering, decided to complete another merger by joining the PC-452 hull with the PC-451's propulsion system to produce the PC-461 class submarine chaser in 1942 (Gardiner 1980:153).

As demonstrated by the 3D model, PC-461 class vessels, though flush decked, followed a more natural hull shape reminiscent of the SC-1 class (Figure 37, 38). The chief complaint about the hull, documented by the Chief of Naval Operations naval districts division, pointed out that it was too light and too poorly constructed, making its seaworthiness questionable and its projected top speed subpar (Friedman 1987:64).

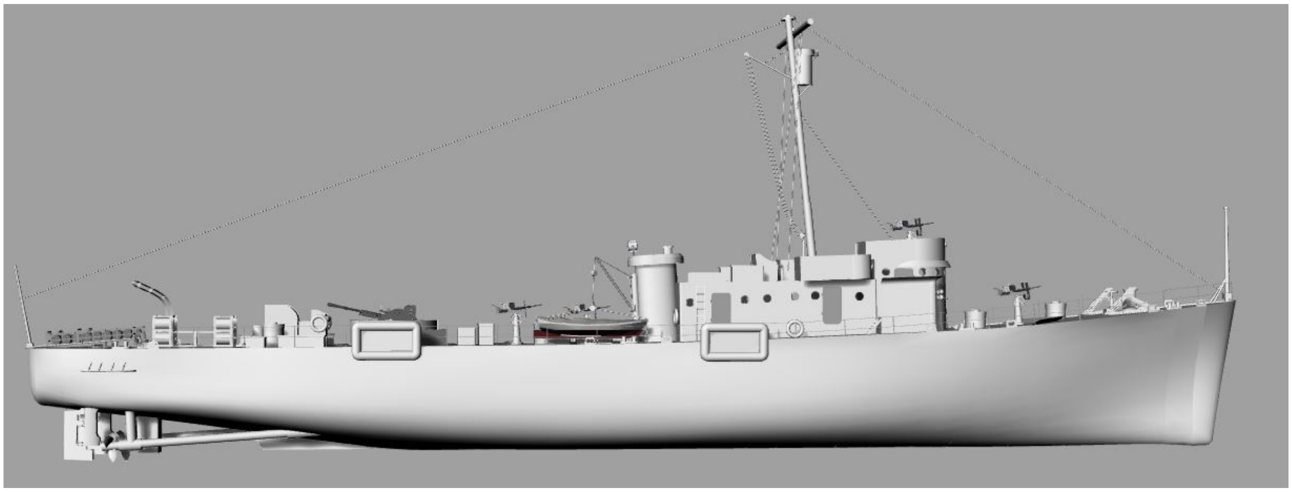


Figure 37. Starboard view of PC-461 class submarine chaser (Image by author 2021).

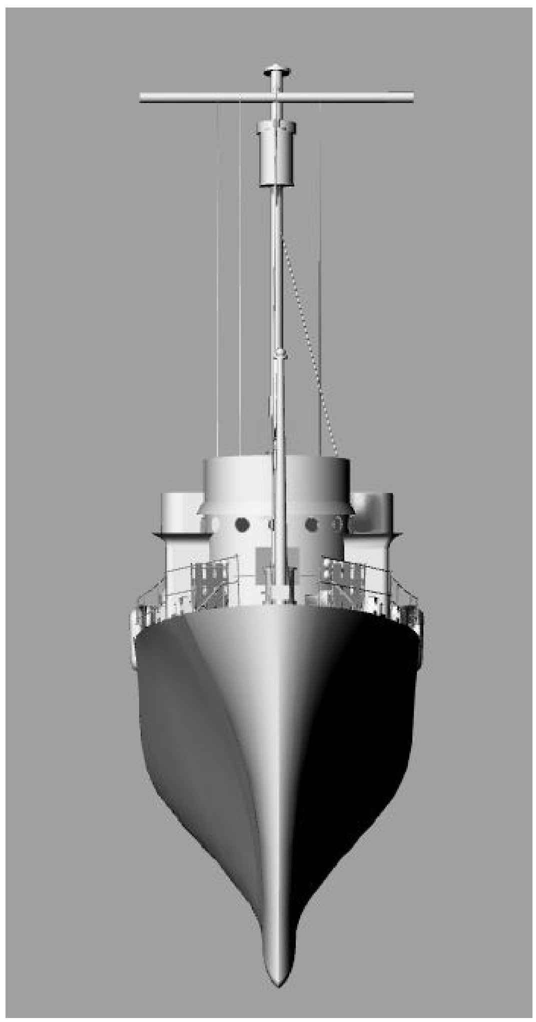


Figure 38. Frontal view of PC-461 class submarine chaser (Image by author 2021).

However, the Bureau of Ships, namely Captain E.C. Cochran argued that the lighter construction of the new submarine chaser mimicked that of the lightly constructed destroyers already in production and would hold up against the rough seas of the North Atlantic. While this was true, the quality of life onboard a PC-461 class submarine chaser was poor. Seasickness was extremely common, and the vessels rolled and pitched so severely at times that disgruntled PC sailors had a running joke about deserving a 50/50 split of flight pay and submarine pay (Veigele 1998:123-125). The PC-461 would maintain a reputation for rough handling in heavy seas throughout the course of the Second World War but, to its credit, not a single vessel was lost due to sea conditions.

The PC-461 class submarine chaser was powered by two 1000-bhp diesel engines and twin screws, with a top trial speed of 20.4 knots (Gardiner 1980:153). The trial speed was two knots below initial predictions but was expected to increase with the adjustment of the mufflers to reduce back pressure. The vessel's effective range was 3,000 nautical miles at a 12-knot cruising speed and, as mentioned previously, it could operate safely (though uncomfortably) in extremely rough sea conditions. The propulsion system for the PC-461s proved to be their greatest developmental concern, as the need for lightweight diesel engines put them into direct conflict with other small combatant vessels such as submarines, minesweepers, and seaplane tenders (Friedman 1987:66). There was a temporary period in late 1941 where the General Board considered canceling the PC-461 and producing larger numbers of the updated SC-110s, but a last-minute increase in engine availability allowed the building program to continue.

The detection equipment plans for the PC-461 were different than those for its predecessors, as both radar and sonar were becoming more viable options than the lower frequency hydrophones of the First World War. Sonar, used to detect objects by emitting sound waves towards the sea bottom and measuring their return after being reflected to “map” the seafloor, was particularly important to the new submarine chasers. First tested on U.S. submarines, the QC-JK sonar, a combination of two sonar systems, became the standard detection system onboard PC-461 submarine chasers. The passive, or listening JK, sonar found and classified targets while the active QC sonar worked in a single ping mode to determine the range and bearing of targets (Weir 1991:74). A U-boat sitting on the bottom would be detected during the mapping process and could either be attacked by the identifying subchaser or by one of the other members of the patrol group. The new system was also useful for station keeping in convoys when rough sea conditions eliminated the ability to maintain visual contact with other ships within the group (Veigele 1998:121).

The armament of PC-461 submarine chasers changed rapidly over time and varied from ship to ship, as certain groups of the vessels were re-designated for different duties. The initial battery consisted of two 3-inch dual purpose guns, two light machine guns, and twenty-two depth charges split between the ready racks and the two depth charge racks at the stern of the ship (Friedman 1987:66). As weapons technology continued to develop, U.S. naval doctrine called for all .50 caliber machine guns to be replaced by 20mm Oerlikon cannons whenever possible (Figure 39). The Oerlikon was a German weapon designed in the last days of the First World War which eventually ended up in production for the Allies (Garas 2019). Onboard naval vessels, the cannon’s pedestal was bolted to the deck with a pedestal head that rotated horizontally and a handwheel that allowed the barrel elevation to be raised or lowered about 15 inches (Lambert and Ross 1990:228). In October 1942, a temporary shortage of 3-inch guns led to the replacement of the PC-461’s after 3-inch guns with unpowered 40mm antiaircraft guns, a change that became permanent after a short time (Friedman 1987:68).

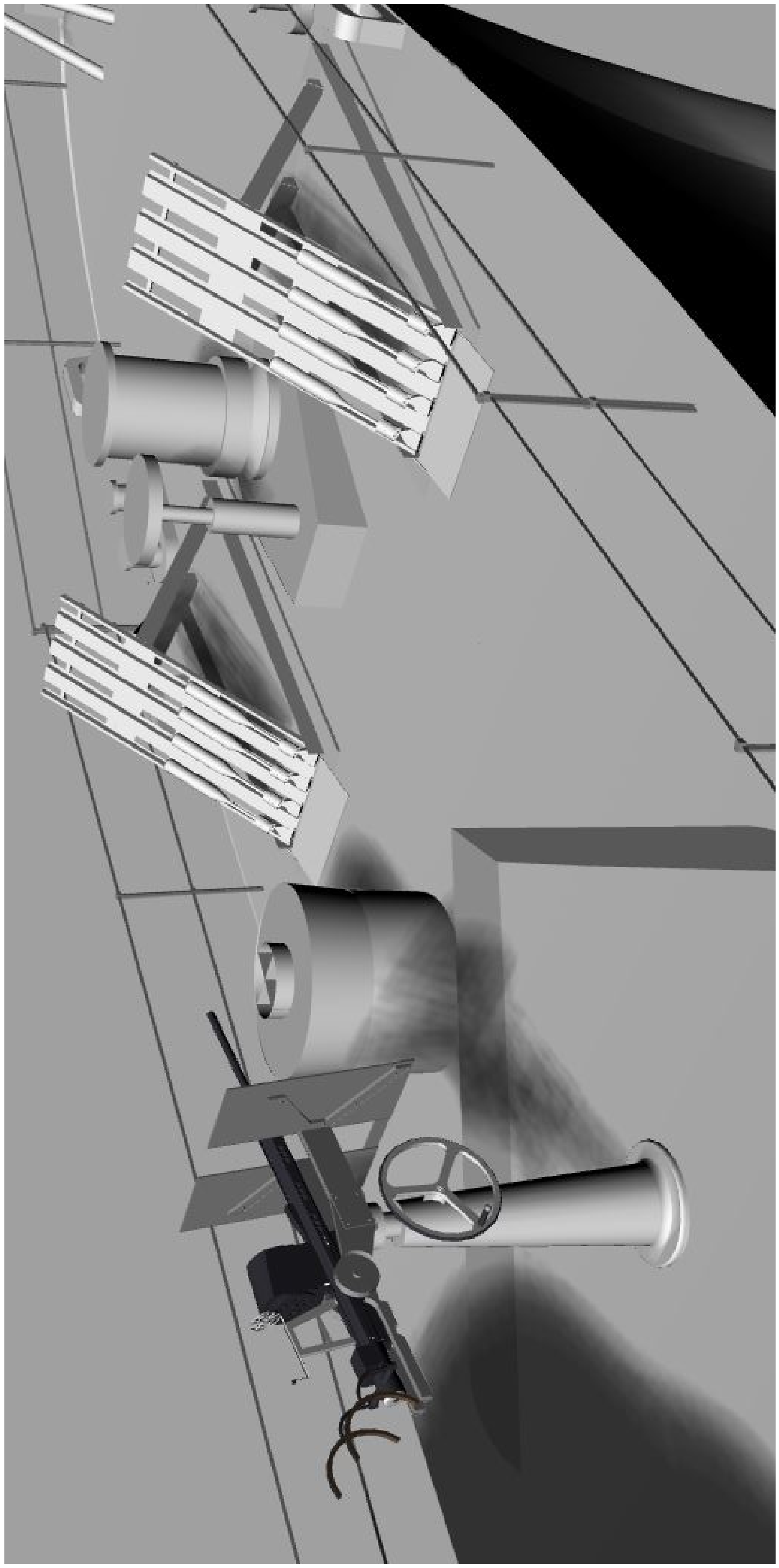


Figure 39. Oerlikon (left) and Mousetrap Rocket (right) launchers onboard PC-461 class submarine chaser model (Image by author).

The next weapon introduced to the PC-461's arsenal was the Mousetrap rocket launcher. This antisubmarine weapon had four rails linked by a boxed frame that was bolted to the deck of the ship (Lambert and Ross 1990:232). The rails could be raised by an electrical connection when in use and the four rockets on the rails could be fired out in front of the vessel, lessening the detection to attack time for antisubmarine patrol craft significantly. The Mousetrap was also a much smaller weapon than its British cousin, the Hedgehog, meaning that it could be included in the PC-461's arsenal in *addition* to the other weaponry onboard rather than requiring a substitution and potential degradation of firepower.

Overall, the PC-461 (Figure 40) was considered a success in patrol craft production during the Second World War. It was not a perfect patrol craft by any means, but it was the closest the naval design bureaus came to accomplishing their desired objectives for a patrol craft in either of the World Wars. Though a bit rough in heavier seas, the vessel was seaworthy without being overly manufactured, and the size and spacing of the vessel allowed for it to be easily modified as new detection equipment and weaponry were deployed in the antisubmarine warfare effort. The design was also extremely versatile, with dozens of the vessels being converted into motor gunboats, amphibious control boats, and even experimental sonar ships (Friedman 1987:69). However, in its specific duty as an antisubmarine patrol craft, it became a less necessary option as the antisubmarine campaign shifted into even deeper waters and other methods of patrol became more viable options (Gardiner 1980:152). While hundreds of PC-461 submarine chasers served during the course of the Second World War, they were quickly phased out for a new generation of patrol craft.

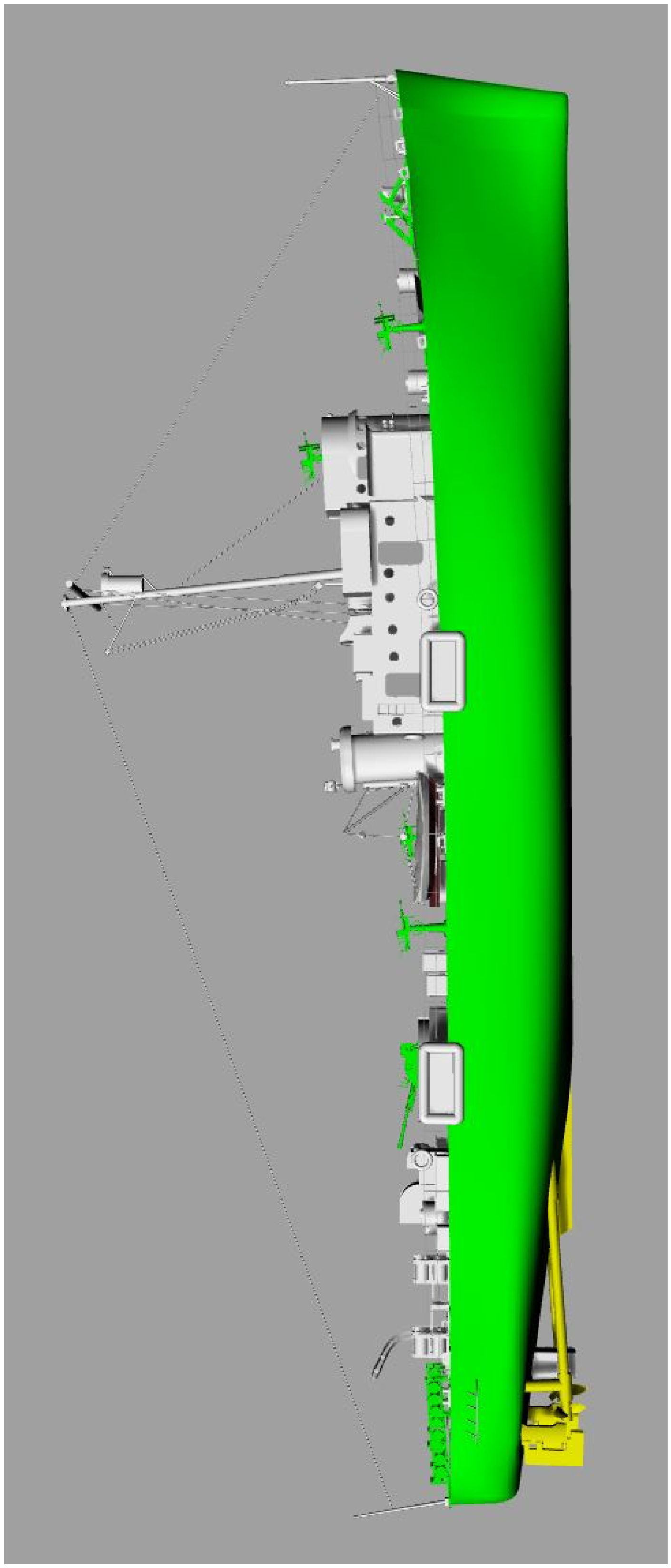


Figure 40. PC-461 class submarine chaser model (Image from author 2021).

Conclusion

In this chapter, 3D models were used in conjunction with historical information to explore the design and construction of the three generations of submarine chasers highlighted by this thesis. Characteristics were evaluated for their benefits or lack thereof to determine their value and influence in the development of successive submarine chasers; these were color-coded based on their positive, neutral, or negative influence. The following chapter will combine this research with theoretical and historical concepts to address the thesis questions associated with this project.

CHAPTER SIX: ANALYSIS OF INFLUENCES ON SUBMARINE CHASER DESIGN AND DEVELOPMENT

Introduction

This study was created with the intention of determining the most impactful factors in the development of submarine chasers during the First and Second World Wars. To achieve this goal, historical research into the origins of both submarines and submarine chasers was conducted along with three-dimensional construction of SC-1, PE-1, and PC-461 submarine chaser designs using Rhinoceros 6.0. The reconstructed models provided tangible examples of the vessel classes to assess due to the absence of any safely accessible archaeological remains. They also allowed for the side-by-side examination of submarine chaser archetypes spanning a twenty-five-year timeline. This chapter will use the theoretical framework established in Chapter 2 and the assessments of the submarine chasers from Chapter 4 to evaluate the ways in which various factors in the process of submarine chaser development affected the vessels. By determining the common influences among the SC-1, PE-1, and PC-461 submarine chasers, this chapter will resolve the questions posed at the beginning of this study.

Mirroring the U-boats

The first indication that the U.S. might be threatened by German unrestricted submarine warfare was the peaceful arrival of *Deutschland* in Baltimore, Maryland on 9 July 1916 (Dubbs 2014:16-17). The vessel was the Imperial German Navy's first attempt at a cargo U-boat, a large, unarmed submarine designed to circumvent the impenetrable British blockade by carrying economic goods underneath it and onward to neutral ports, namely those of the U.S.. Banking on stealth over speed, these cargo U-boats were the largest built to that point, maintaining the 213-foot length of the most recent combat submarines but increasing the beam from 21 feet to 29 feet and more than doubling the displacement (Gardiner 1985:177, 180). The cargo U-boat experiment proved to be a successful one, as *Deutschland* delivered 163 tons of concentrated dye, worth 1.4 million dollars in 1916, to Baltimore and returned unscathed to Germany with a collective 782 tons of raw goods worth well over 20 million dollars (Rössler 1981:67). On 7 October 1916, a Type UB-II submarine, *U-53,* was escorted into Newport, Rhode Island, where Captain Hans Rose requested an audience with U.S. Navy Rear Admiral Austin Knight to deliver a letter intended for the German ambassador, Johann Heinrich von Bernstorff (Dubbs 2014:27-29). Its arrival in U.S. waters was a source of excitement for U.S. citizens and extreme discomfort for U.S. political and military leaders. Speculation from the media about potential peace talks being the subject of the delivered letter were rapidly put to rest when *U-53* sank half a dozen merchant ships just outside of neutral U.S. waters the day after its departure, with U.S. warships standing by to rescue survivors as the Germans methodically went about their business (Sims 1920:464; Dubbs 2014:30). The newly discovered range of U-boats, paired with Germany's resumption of unrestricted submarine warfare in February 1917, simply hastened the pace of a wave of cultural momentum already sweeping across the U.S.. Prior to the U.S. entry into the First World War, fictional books about German invasions of the unprepared U.S. fueled the fears of civilian and military figures alike, with authors such as John Bernard Walker devoting entire chapters to the deployment of U-boats as the spearhead of these potential invasions (Dubbs 2014:46, Walker 1915:66). The SC-1 class submarine chaser reflected that cultural momentum racing to meet the technological deviance of the German submarines.

In designing the SC-1 submarine chasers specifically in response to the technological deviance of German U-boats, it was a given that the capabilities of enemy submarines would be reflected in their design. Submarines prioritized speed, armament, range, and stealth as keys to waging successful unrestricted submarine warfare campaigns, and the new submarine chasers needed to match them in those characteristics to have any chance at blunting their stranglehold on the Atlantic Ocean (Table 2).

Table 2. SC-1 and First World War-era U-boat comparison.

	SC-1 class submarine chaser	First World War U-boat
Max. Speed	16.85 knots	16.8 knots (*U81)*
Max. Armament	1917: 6-inch gun, 2 machine guns, 10 depth charges 1918: 3-inch Poole gun, 2 machine guns, Y-gun	10 torpedoes, 105 mm gun (Type UB-III)
Max. Range	1000 nautical miles (nm)	11,220 nm (*U81)*
Max. Detection/Stealth capabilities	K-tube: 30 nm range	Submerged (still): 24 hours Submerged (moving): 55 nm range (Type UB-III)

As Table 2 demonstrates, regardless of the U-boat in question, their maximum capabilities all face viable counterbalances in the SC-1 class submarine chaser. The maximum speed of the submarine chaser matches that of *U81* and the armament outgunned even the most heavily armed submarine in a one-on-one conflict. With submarine chasers often operating in trios, the firepower differential leans even more in their favor. The physical size of the 110-foot SC-1 meant that it could stay out at sea longer than its contemporaries, mirroring the long deployment capabilities of its quarry in a way that smaller patrolling vessels like the Elco boats could not. While U-boats had longer ranges overall, they left their home bases deep in German territory as self-contained, independently operating vessels. The distance between them and a hunting location could amount to thousands of miles, while the submarine chasers were designed to consistently rotate through specific areas and return to their home bases regularly. The detection equipment onboard paired with the rapid starting and stopping ability of the SC-1's propulsion system to eliminate the advantages the U-boats enjoyed when concealed underwater. As better detection equipment became available, it was incorporated to increase those advantages to an even greater degree. Perhaps the most significant indicator of the submarine's impact on the submarine chaser was the incorporation of depth charges as the primary munition in its arsenal. Prior to the arrival of submarine chasers in European waters, the most effective way to attack a submarine was to bait it into targeting an armed merchant ship and hope that the merchant ship could elude the torpedoes long enough to either ram it or sink it with artillery fire (Messimer 2001:73). This method of combat still adhered to cultural core beliefs based in freedom of the seas and standing face-to-face fights with opponents. There was a sense of gamesmanship reminiscent of an earlier century. In 1917, aboard U.S. vessels, U.S.-made depth charges changed that.

While they were not the first depth charges to be deployed against submarines, Mark II depth charges eliminated the premature explosions of their predecessors and increased the depth at which they could be triggered to explode (U.S. Bureau of Ordnance 1920:99-100). On SC-1 class submarine chasers, these depth charges were fitted onto metal racks at the stern of the vessel and released into the sea upon the detection of a suspected enemy submarine (Woofenden

2006:87). These depth charges, paired with the silent hunting techniques made possible by the use of hydrophones and stoppable combustion engines, demonstrated a mimicry of the stealth techniques deployed by the very submarines SC-1 subchasers were out to hunt. In developing a submarine chaser to deal with the technological deviance of submarines and its effrontery, the U.S. tacitly allowed the cultural momentum of German submarine warfare to shift its own cultural core towards a more ruthless, ungentlemanly style of naval combat. That Detachment Two, operating as part of a barrage line that restricted freedom of the seas in that area completely, gained the most fame out of all the SC-1 submarine chaser detachments while enacting the behaviors that brought the U.S. into the conflict in the first place is just further evidence of this shift. In facing down the technological deviance of the submarine, the SC-1 class submarine chaser became a form of deviant technology itself.

The influence of the SC-1 submarine chaser, and through it the impact of the submarine, materialized in the PE-1 class submarine chaser as well. The purpose for constructing the Eagle boats was the cost-effective production of a vessel capable of bridging the technological gaps between the SC-1 class submarine chasers and the destroyers that often served as lead vessels on their patrols (Crowell and Wilson 1921:469). The U.S. Navy General Board settled on the PE-1 as the option that encapsulated their vision for maturing the deviant technology of the SC-1 submarine chaser in a larger, more efficiently produced form (see Table 3).

Table 3. PE-1 and First World War-era U-boats comparison

	PE-1 Class submarine chaser	First World War U-boat
Max. Speed	18 knots	16.8 knots (*U81)*
Max. Armament	1919: 2 4-inch guns, 1 .50 caliber machine gun, 10 depth charges (Y-gun added soon after initial armament)	10 torpedoes, 105 mm gun (Type UB-III)
Max. Range	3500 nm	11,220 nm (*U81)*
Max. Detection/Stealth capabilities	K-tube: 30 nm range	Submerged (still): 24 hours Submerged (moving): 55 nm range (UB-III)

Even with the significant flaws discussed in the previous chapter, Eagle boats still demonstrated characteristics indicative of a desire to compete with and outperform the German U-boat fleet. Though the vessel was larger and more heavily built than the SC-1, it was still two knots faster than the fastest German submarine and far more heavily armed. Had they been deployed in a wartime environment, the range of Eagle boats would have allowed them to stay out to sea far longer than their smaller contemporaries, thus keeping enemy submarines submerged and incapable of attacking merchant shipping for greater expanses of time. The much heavier armament of the PE-1 class submarine chaser and the pursuit of the same rapid start and stop capabilities and speed of the SC-1 class vessels also solidified the U.S. acceptance of submarine-like ruthlessness in antisubmarine warfare. But more than any of these characteristics, the most crystalline indicator of the U-boat's influence on the PE-1 design was the use of Henry Ford's assembly line methods to rapidly produce them.

Germany's U-boat fleet was exacting a fearsome toll on Allied shipping by April of 1917, and even with the additional U.S. vessels arriving in Europe, continued to sink merchant shipping at an unbearable rate. For every fifteen destroyers deployed in antisubmarine warfare tactics one submarine was destroyed while the number increased to a ration of ninety-eight to one for patrol vessels deployed in the same manner (Messimer 2001:140). With Eagle boats designed to bridge the gap between the two classes, one can assume that the ratio for Eagle boats deployed to U-boats destroyed would be approximately fifty-seven to one. By 1917, at least 17 Type UB-I, 30 Type UB-II, and 84 Type UB-III submarines were operating in the European theater, with other submarine types not accounted for. Based on the 131 Type UB submarines alone, the number of Eagle boats needed to subdue them would be well into the thousands if submarine production was no longer happening in Germany. This, unfortunately, was not the case. Even at the end of the First World War, Allied representatives found German naval yards with U-boats still under construction (Dubbs 2014:62). The need for numbers to defeat them demonstrated a different type of technological deviance from the German submarines. With no clear end to the war in sight, in early 1918 the number of U-boats available for deployment forced the U.S. to look to mass production in defeating them. By foregoing the smooth lines and craftsmanship of the SC-1 in favor of a utilitarian design that prioritized quantity more than quality, the submarine lent yet another cultural and technological influence to the submarine chaser program.

Like its predecessors, the PC-461 was defined as a vessel intended for antisubmarine warfare operations by the U.S. Navy Department (Veigele 1998:36). It was designed to stay out to sea like the submarines it pursued, and its engines maintained the rapid starting and stopping ability of its predecessors and a higher top speed than the Type VII submarines it faced in the Atlantic theater. The detection equipment was the best of its day and continued to improve as sonar technology evolved. The armament of PC-461 class submarine chasers also evolved over the course of the war with an eye towards defeating surfaced submarines in one-on-one combat. However, PC-793 captain William Veigele noted that these efforts were unsuccessful and that most PC-461 commanders viewed ramming U-boats as a safer option than engaging them in a gun battle (Veigele 1998:36-37). But that was not all the PC-461 was capable of.

War Plan Orange represented another cultural shift for the U.S.. Rather than developing a submarine chaser to neutralize threats in the Atlantic, the increased aggression from the Japanese in the Pacific dictated a globetrotting patrol vessel capable of operating in many different roles. This design shift was informed by the late war technological deviance of the SC-1 and the postwar technological deviance of the Eagle boat, with the submarine playing a secondary role rather than a primary one. The deployment of heavily armed SC-1s and Eagle boats to Archangel, Russia and the Philippines was both the most mature stage of technological deviance for submarine chasers and the most infantile stage for a new vessel that looked to blend the characteristics of submarine chasers, destroyers, and gunboats into one body. The body type and lines were informed by those of the smoother SC-1, while the heavy armament, size, and mass production techniques drew their influence from the lessons learned with the Eagle boats (Figure 41). By capitalizing the best characteristics of the SC-1 class and PE-1 class submarine chaser in one unified body, the cultural momentum of the U.S. paired with the lessons learned from the technological deviance of First World War submarine chasers to produce a completely new form of small combatant vessel.

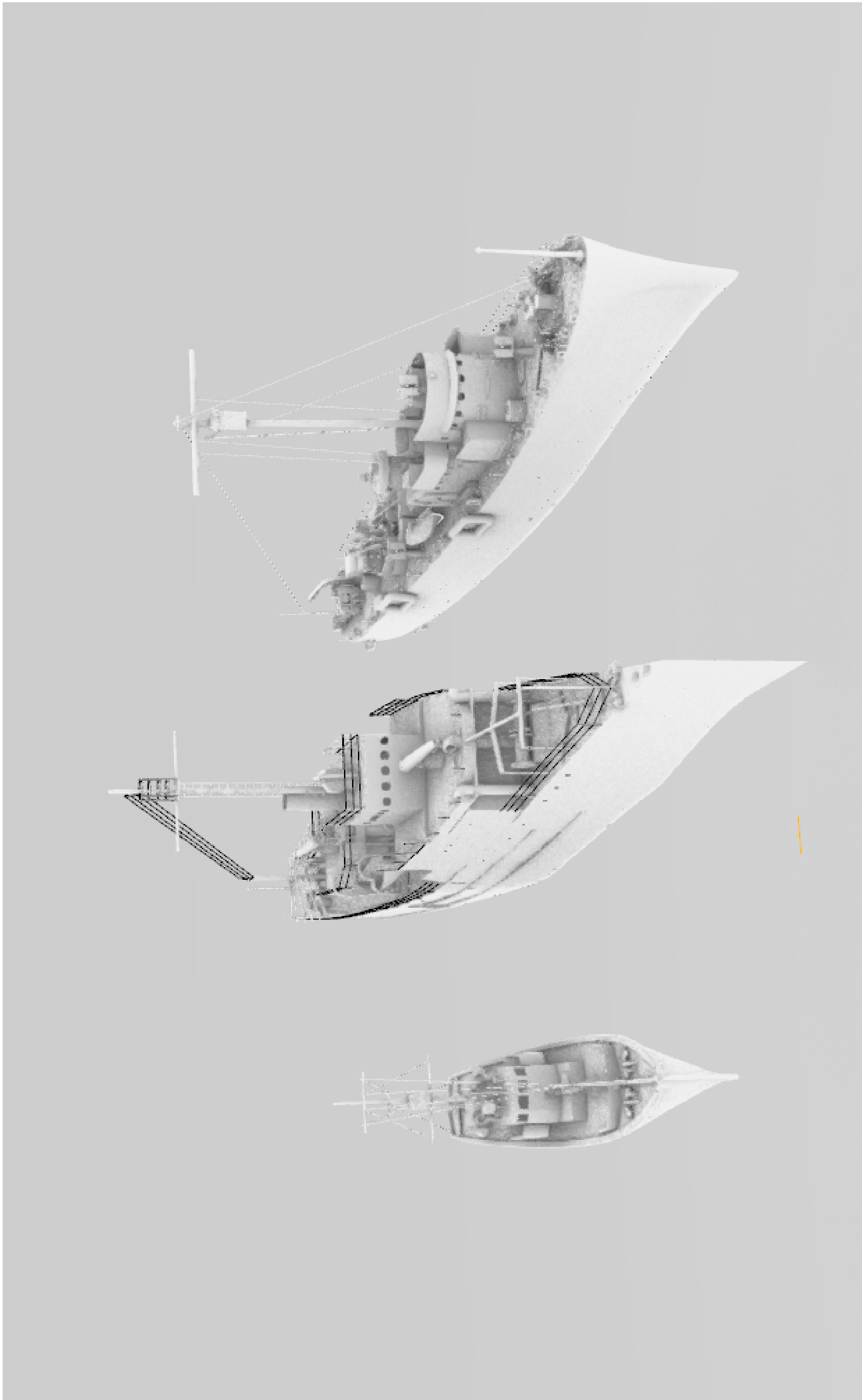


Figure 41. Side-by-side comparison of submarine chasers (Image from author 2021).

Maneuvers on Land and Sea

That the submarine chaser came to exist as a weapon of war was the result of a chain of political maneuvers occurring in places far removed from the waters of the Atlantic Ocean. Both the German and American naval authorities had issues with the interference of civilian leadership in naval affairs. This rivalry between the military and civilian leadership of both countries would resurface repeatedly in the build up to and carrying out of many naval tasks during both World Wars. As mentioned in Chapter 2, the cultural momentum of the *Weltpolitik* played a significant role in Germany's willingness to use the submarine in an unrestricted fashion. When Theobald von Bethmann-Hollweg took over the Chancellery of Germany in 1909, he did so with the cultural momentum of the nation already against him. The odds grew even worse with the breakout of the First World War. In 1916, the Reichstag passed a resolution stating that the Chancellor would be guided by the opinions of the Supreme Command, made up of General Erich Ludendorff and Field Marshal Paul von Hindenburg, regarding unrestricted submarine warfare (Manson 1990:8). Bethmann-Hollweg was strongly opposed to unrestricted submarine warfare due to his desire to maintain peace with the U.S. Though he may have worded it differently, he understood that unrestricted submarine warfare was a war initiating violation of the neutral nation's cultural core and that its entry would ensure a German defeat. But military and naval officials, chafing at the fact that the Imperial German Navy had been stuck at anchor for the duration of the war, undermined him and convinced the Imperial German government to unleash the U-boat on January 9, 1917 (Manson 1990:10-11).

The first indication that political maneuvering in the U.S. would impact submarine chasers was an article from the *New York Times*, dated 3 September 1915, announcing the organization of a national naval reserve by Acting Secretary of the Navy Franklin Delano

Roosevelt (United States Naval Institute 1915:1651). Though it may have seemed a logical and believable maneuver to the public, Roosevelt's announcement was in fact a bold and intentional lie. Nearly as soon as the First World War began, President Woodrow Wilson took a strong stance in favor of U.S. neutrality. In a speech given on 18 August 1914, he stated that:

> The effect of the war upon the U.S. will depend on what American citizens say and do. Every man who really loves America will act and speak in the true spirit of neutrality, which is the spirit of impartiality and fairness and friendliness to all concerned (Scott 1918:66-67).

The speech continued with Wilson noting that the fate of the nation would be decided by what those in the U.S. did and said in public meetings, newspapers, and other communal places. Like every president since James Monroe, Woodrow Wilson considered the Atlantic Ocean to be a buffer between the U.S. and the affairs of the European powers. Franklin Roosevelt did not. His "preparedness" stance was echoed by many within the U.S., and Roosevelt took advantage of the power given to him by a temporary absence from Secretary of the Navy Josephus Daniels to publicly announce a definitive military action that neither his superior nor the civilian leadership had agreed to (Friedman 1987:21). The reporting of Roosevelt's unsanctioned announcement in the *New York Times*, one of the most well-read newspapers in the U.S. then and today, meant that Secretary Daniels could not refute it without making both the military and civilian leadership look incompetent. Instead, he altered the plan, requesting that the General Board design a specialized patrol vessel rather to substitute for the assortment of civilian vessels Roosevelt suggested. The program that created the SC-1 submarine chaser was influenced heavily by the cultural momentum created by the individual actions of Franklin Roosevelt.

The political influences on the Eagle boat came from the Navy Department as well, though they differed from those of the SC-1 in extremely significant ways. While the building program was a direct response to the German deployment of submarines, just as Franklin Roosevelt's preparedness strategy was for the SC-1, the influence of civilians on the program cannot be underestimated. Rather than the U.S. Navy pushing for the inclusion of Ford's assembly line in the process of constructing the next submarine chaser class, the impetus came from the opposite direction. Secretary Daniels himself was a newspaperman who earned his appointment to the Secretary of the Navy though his political support of Woodrow Wilson (Encyclopedia of World Biography 1998). The Naval Consulting Board, a body of civilian inventors and scientists created by Josephus Daniels to keep him aware of technological novelties potentially useful to the war effort, was made up primarily of individuals who also lacked any experience with naval affairs (Daniels 1922:17). The name "Eagle boat", and the media campaign that followed, were derived from a *Washington Post* article written by Henry Ford's assistant, Ernest G. Liebold, to convince Congress of the necessity of the building the PE-1 class submarine chaser (Hounshell 1985:183-184).

While shifts in the U.S. cultural core beliefs regarding the conduct of naval warfare and the technological deviance of U-boat production were key influences, this collection of inexperienced people played their part in affecting the technical proficiency of the Eagle boat when it deployed. Assumptions Henry Ford and his engineering team made about the ease of construction in naval engineering made them reluctant to accept help from naval professionals when it was offered, and Charles C. West, the superintending constructor and an employee of the Manitowoc Shipbuilding Company, filed several formal complaints about the quality of work on the Eagle boats in which he noted pronounced resistance to his suggestions and those of other naval construction experts (Hounshell 1985:193-195). This resistance showed up in the maturity level of Eagle boat technology. Where the SC-1 submarine chaser was solidly capable of performing the job for which it was designed, the Eagle boat struggled with basic operational requirements like leaks and stability when turning. While the finished product still performed a level of technological deviance in influencing design and construction characteristics in the PC-461, it did so at an infantile level unrepresentative of the knowledge gained from three years of institutional knowledge regarding antisubmarine warfare.

The planning for Second World War submarine chasers was politically influenced by the same source as its SC-1 predecessor. After Japan's invasion of China in 1937, Franklin D. Roosevelt, then the President of the United States but still as adamant about preparedness as he was in the First World War, initiated a U.S. Navy-led construction program for an updated steel version of the SC-1 class submarine chaser (Friedman 1987:48). At around the same time, Admiral A.J. Hepburn made a proposal for the revitalization of a junior destroyer program similar to that of the PE-1 to augment the lack of destroyers available for deployment. As these two programs began, Roosevelt found himself maneuvering around the revived U.S. cultural core belief in isolationism. Though Nazi Germany posed a serious threat to France and Great Britain, with the U.S. no doubt next on their list of enemies to slay, the president found himself negotiating feverishly with Congress to repeal the embargo on arms trading for a revised neutrality act passed in 1938 (Manson 1990:68-69). The President couched his argument in the same terms as his First World War predecessor, arguing that an arms embargo would favor aggressor nations in a way that went against the definition of true neutrality.

The attack on Pearl Harbor served as the catalyst for shifting the nation's cultural momentum in Roosevelt's favor. A meeting of Allied civilian and military leaders, known as the

Arcadia Conference, occurred in Washington D.C. from 22 December 1941 to 14 January 1942 and informed the decision-making regarding naval preparations for the U.S. entry into the war (Veigele 1998:21). The conference concluded with an agreement to fight a holding war against Japan while resources were focused toward loosening Nazi Germany's chokehold on Great Britain. This agreement served as a source of cultural momentum for the PC-461 program, as it automatically implied the need for the very tasks for which the PC-461 was suited. Roosevelt also completed another significant contribution to the PC-461 program through his specific targeting of the U.S. Navy's various design teams as the nucleus of the patrol boat's design. Rather than looking to the Eagle boat as the primary example for the PC-461 design, he referenced the First World War SC-1 program and by default its Navy-led construction in his suggestions to the U.S. Navy Preliminary Board (Friedman 1987:48). This subtle maneuver ensured that the mistakes of the Eagle boat would not be repeated. While the patrol boats were mass produced, the projects were completed under the strict supervision of the General Board and with the assistance of shipbuilding firms rather than unrelated manufacturing entities. The end result was a patrol boat that was proficient and mature in its technological development.

Friends On High

While airborne observation existed prior to the start of the First World War, the airplane as a weapon capable of adding a third dimension to the battlefield truly blossomed in the conflict. This ability translated to naval warfare as well. The first U.S. naval aviation squadrons arrived in France in 1917 and participated in a myriad of operations, including 43 attacks (six successful) on enemy submarines and convoy escort duty in which no craft protected by U.S. naval aviators was ever successfully attacked by a U-boat (Daniels 1922:228-229). However, their impact on the development and deployment SC-1 submarine chasers was minimal because that was all it could possibly be. While airplanes did sometimes spot submarines and notify SC-1 hunting teams about them, the best long-range aircraft in the U.S. arsenal had an effective flying range of just over 500 miles, which made the general operations of the longer winded submarine chasers a more common patrolling strategy (United States Congress House Committee on Naval Affairs 1919:xlvii; Woofenden 2006:48). Just as submarines were operating from an infantile phase of technological deviance, so too were airplanes. Furthermore, SC-1 submarine chasers could use their detection equipment to operate at night, whereas aircraft lost any element of usefulness with the setting of the sun. Perhaps most significant in the disconnect between the two patrolling technologies, however, was the inability to communicate effectively. While both aircraft and submarine chasers carried wireless radio devices, SC-1 class submarine chasers and their lead ships still communicated primarily through the use of flag hoists (Chambers 1920:15). The process was one from an antiquated age and prevented aircraft from working efficiently with submarine chasers in the rapidly changing environment of antisubmarine warfare.

The PE-1, with its longer range and independent operations, no doubt would have faced the same issues in collaborating with airplanes in antisubmarine warfare operations had it been deployed in large numbers during the First World War. However, the postwar usage of the vessel also offered a look into just how symbiotic the relationship between aircraft and submarine chasers could be. As mentioned in Chapter 1, in February of 1921, U.S. Navy seaplanes 43 and 44 completed the longest journey achieved by aircraft up to that point due to the presence of three Eagle boats serving as aircraft tenders (Carriel 1921:127). The radio technology used to complete the voyage served as a form of technological deviance that matured both aircraft and submarine chaser technology dramatically. Rather than having to operate through synthesized patrols scheduled without changing conditions in mind, the success of this venture demonstrated the potential for submarines and aircraft to work efficiently in dynamic situations. PE-1 class submarine chasers would not be leading the way in either aircraft transportation and support or future antisubmarine warfare operations, but this journey to survey Hawaii set a precedent for what was possible in the next conflict.

The first attack on a submarine occurred on 5 September 1939, when a British Anson plane belonging to No. 233 Squadron sighted and attacked a submarine off the coast of Scotland using 100-pound bombs (Price 2004:39). The bombs skipped off the surface of the water and detonated in midair, puncturing holes in the fuel tanks of the attacking aircraft and forcing it to land at sea. The crew of the airplane found their dinghy unpunctured and were rescued shortly after while HMS *Seahorse* survived the friendly fire attack with only hull damage sustained from hitting the bottom while trying to escape. In U.S. waters, the initial level of success was no better. A flurry of U-boat attacks along the East Coast in the early months of 1942 forced the organization of patrol squadrons along the coastline to provide an air umbrella, but the aircrews were ineffective due to flaws in doctrine, poor equipment, and poor training (Offley 2014:ix). In just six months of retooling, these squadrons would pair with other forms of antisubmarine warfare to turn the tide of the Second Battle of the Atlantic permanently. A significant portion of that success was attributed to the presence of "hunter-killer" groups with aircraft overlooking the Atlantic battlescape as the "hunters" and surface vessels as the "killers". This combination of air and sea antisubmarine warfare led to the destruction of 40% of the German U-boat fleet by March of 1943 and the admission of German Admiral Karl Dönitz that the Battle of the Atlantic was essentially over (Veigele 1998:154). But even the success of this collaboration was not indicative of the aerial impact on submarine chaser design and development.

Another examination of the side-by-side comparison of the three submarine chasers featured in this study confirms that the fixation on speed, armament, range, and detection capabilities never slowed because of the arrival of other vehicle-driven technologies in the theater of antisubmarine warfare (Table 4).

Table 4. Side-by-side Comparison of Submarine Chaser Capabilities

	SC-1	**PE-1**	**PC-461**
Speed	16.85 knots	18 knots	20.4 knots
Armament	1917: 6-inch gun, 2 machine guns, 10 depth charges 1918: 3-inch Poole gun, 2 machine guns, Y-gun	1919: 2 4-inch guns, 1 .50 caliber machine gun, 10 depth charges (Y-gun added soon after initial armament)	1942: 2 3-inch guns, 2 light machine guns, 22 depth charges 1945: 4 Oerlikon 20-mm guns, one Bofors 40-mm gun, 22 depth charges, two Mousetrap rocket launchers
Range	1000 nm	3500 nm	3000 nm
Detection	K-tube: 30 nm range	K-tube: 30 nm range	QC-JK Sonar: 300 nm range

Even with the growth of aircraft as military expedients happening during the development of submarine chasers and at times alongside submarine chasers, aircraft never influenced the strategic objectives for which the submarine chasers were outfitted. Whether aircraft were present or not, the objective for submarine chasers was to grow bigger, faster, and more deadly via the impact of technological deviance from submarines and the cultural momentum of antisubmarine warfare. While aircraft did aid in achieving the final objective of suppressing German unrestricted submarine warfare, they did so as an ally rather than a projector of power.

Conclusion

The influences on the design and development of the submarine chaser during the First and Second World Wars were numerous and complex. In this chapter, those influences were analyzed to determine just how significant their impacts were on the overall growth of the submarine chaser from the 110-foot SC-1 class to the 173-foot PC-461. First among the influences assessed was the German U-boat, the vessel type the SC-1 was designed to pursue. This was followed by an evaluation of the political influences, both military and civilian, and how the cultural momentum of U.S. and German societies played its part in speeding the growth and characteristics of the submarine chasers. Finally, the impact of aircraft on the development of the submarine chaser was discussed to determine whether the rapid growth of air power led to the elimination of certain design characteristics in the vessels they supported against the submarines.

CHAPTER SEVEN: CONCLUSIONS

The arrival of the German U-boat on the naval landscape served as a direct challenge to the cultural beliefs of the United States. One of the most significant factors in responding to this challenge was the submarine chaser, an offensive-minded small combatant vessel intended to hunt submarines and end the threat of unrestricted submarine warfare. This study was initiated with the intention of determining the greatest influences on the design and development of submarine chasers as they and those who sailed on them doggedly pursued that goal throughout two World Wars.

To achieve this goal three specific submarine chaser types, the SC-1, PE-1, and PC-461 class vessels, were selected as samples most representative of the overall footprint of submarine chaser technology. Historical research was conducted on the origins of the three vessels and a theoretical framework was laid for assessing the factors most likely to impact their growth. Four research questions were proposed to further guide this project and three-dimensional models of each submarine chaser class were created using *Rhinoceros 3D,* with the intent of using the models as digital archaeological sites to evaluate them for technological successes and failures. These technological successes and failures were then used to draw conclusions about areas of greatest need throughout the timeline of submarine chaser construction and to analyze the greatest impacts on submarine chaser design.

The first research question asked how the capabilities of enemy vessels affected submarine chaser design. This can be answered by referring to Chapter 6 of this study. The submarine was the reason for the submarine chaser. Without Imperial Germany's introduction of the U-boat and unrestricted submarine warfare in the First World War, the SC-1 class submarine chaser may never have been produced. However, once the SC-1 was utilized in the First World

War, it became a technologically deviant impact on submarine chasers. U.S. Naval officials recognized that the SC-1 was a versatile military craft, just as capable of conducting shore bombardments and escorting destroyers as it was hunting submarines. From the point of that realization to the conclusion of the Second World War, the submarine chaser itself had a greater impact on submarine chaser development than did the submarine. In the PE-1 class, officials sought to eliminate the need for a “mothership” to support the smaller SC-1 class while maintaining the versatility and effectiveness the small vessels brought to the antisubmarine warfare effort. In the failure of that project were sown the seeds for the successful and versatile PC-461 class, which combined the best characteristics of its predecessors into a brand-new type of small combatant vessel.

The second question related to the ways in which the opinions of political and military officials affected the development of submarine chasers, and the answer is intertwined with the first. The actions that led from the SC-1 class to the PC-461 class were dictated by the perspectives of sailors from varied environments and cultural backgrounds, and how they responded to the cultural momentum of other nations and their varied and interesting leaders. The SC-1 class submarine chaser reflected not just the response to the technologically deviant behavior of German U-boats but a reflection of cultural momentum echoing across the political landscape. To deploy such a vessel with stealth technology and devastating attacking strategies demonstrated a politically motivated shift in the cultural cores of the U.S., but the momentum of that shift was driven most aggressively by Assistant Secretary of the Navy Franklin Delano Roosevelt and his “preparedness” theory. In the PE-1 class submarine chaser the technological deviance of longer ranged submarines forced the development of a larger vessel, but the cultural momentum of uninformed and unreceptive civilian entities resulted in an underdeveloped, yet still influential, technology. The PC-461 class patrol craft was the result of a synthesis of the two previous renditions' flaws, combining the hunting characteristics of the SC-1 submarine chaser with the long ranged, multifaceted uses of the Eagle boat. This synthesis was not a coincidence, but rather the effect of subtle diplomatic maneuvering from President Franklin D. Roosevelt to ensure that the proper decision-makers were responsible for producing the patrol craft. For every technological aspect of the submarine chasers, a human being with political desires was behind the decision.

The next research question examined the role that air power played during the Second World War in eliminating the need for equipment and construction practices necessary during the First World War. In air power, submarine chasers received a boost to their momentum without being affected by the technological deviance of the airborne vehicles. Because of differences in technological advancement and timing, it was always in the best interest of those pushing the submarine chaser as an independently operative vessel to continue doing so. Early returns on aircraft deployment demonstrated that the submarine chaser could outperform them in the duty for which it was named, while later collaborations took time and patience to synchronize into an effective fighting machine. Without the advantage of foresight, those developing the submarine chaser could only continue to do what appeared to be best for the success of antisubmarine warfare at the time, which happened to be continuing to push submarine chasers to be as self-sufficient as the craft they pursued.

The final question of this study considered the significance of the influences on the development of submarine chasers during the First and Second World Wars. This question is rather odd upon reflection. No one singular influence could possibly have stood out as the most significant influence on the development of a subject operating in an environment as vast as the

Atlantic Ocean during the two World Wars. Submarines, of course, were the most impactful element in the genesis of submarine chasers but the political maneuvering of military and civilian officials, all with strong beliefs on what was best for the fate of merchant and military ships alike, played a massive role in driving that creation forward. Submarine chasers themselves also played off of each other to develop and grow. In the PC-461 class vessel lie the legacies of both the SC-1 and the PE-1, demonstrating that they too were just as influential as enemy submarines and political actions. In essence, the submarine, the submarine chaser, and the cultures behind both all took their opportunities to drive forward that growth. Whether it was the technological deviance of the submarine or the cultural momentum of an outraged U.S. citizenry, each played a role in influencing the design and development of the submarine chaser in the First and Second World Wars.

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