ABSTRACT

HULL PRESERVATION: PRESERVATION METHODS AND MANAGEMENT OF THE BATTLESHIP NORTH CAROLINA MEMORIAL, WILMINGTON, NORTH CAROLINA

By

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Director: Dr. Nathan Richards

PROGRAM IN MARITIME STUDIES, DEPARTMENT OF HISTORY

The USS *North Carolina* (BB-55)*,* was the most decorated battleship in the United States Navy during World War II. During its service, the USS *North Carolina* participated in every major action in the Pacific receiving fifteen battle stars. The ship was decommissioned in 1947 after only six years of service. It was then stricken from the Naval Vessel register in 1960 and was set to be sold for scrap. However, the residents of North Carolina, including thousands of school children, saved the ship from being scrapped and raised enough money to have it towed down the Cape Fear River to Wilmington, NC. It now serves as a memorial to the veterans of North Carolina who served in World War II.

After sitting in its berth for decades, the ship began to experience hull deterioration. A project to repair the worst section of the hull (the starboard bow) finally took place in 2011. Now, several other sections need repair. Today, caretakers of USS *North Carolina* have recently finished installing a permanent cofferdam around the vessel. Repairs to several sections of the ship's hull are currently underway.

Utilizing archaeological and cultural resource management approaches, this thesis will discuss the preservation issues that steel-hulled battleship museums face, focusing on the USS *North Carolina*, as well as the methods for restoring and maintaining the hulls of these ships. It

will also analyze methods used to solve these preservation issues, which will allow for better preparation when dealing with similar issues that may arise in more recently converted battleship museums. This thesis will also seek to understand the relationship that battleship museums play in preserving cultural heritage.

HULL PRESERVATION: PRESERVATION METHODS AND MANAGEMENT OF THE BATTLESHIP NORTH CAROLINA MEMORIAL WILMINGTON, NORTH CAROLINA

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DEDICATION

This thesis is dedicated to the men and women who have served aboard the USS *North Carolina* both as a naval vessel and a museum ship. Their dedication to the protection of the nation during World II and preservation of the USS *North Carolina* since then have impacted the lives of myself and many others by allowing the stories and memories of great men and women to be shared with past and future generations.

ACKNOWLEDGEMENTS

I would like to think my family for their constant love and support. The continual encouragement provided by my beautiful wife, Jacqueline, and amazing parents kept me always inching closer to the completion of this project. Likewise, I would never have been able to complete this project without the guidance received from my advisor Dr. Nathan Richards. Your belief in this project, as well as the encouragement and occasional much needed tough love you provided were instrumental in me reaching this point. Additionally, I would like to think everyone who helped me during the editing process: my sister (Rachel Rittenhouse), Joel Cook, Ryan Miranda, and Aleck Tan. Your constructive criticisms and advice were invaluable to me. I would also like to think my committee members, Dr. Lynn Harris and Dr. Christopher Oakley for taking the time to read and edit this paper as well. Finally, I would like to think the people who made this thesis possible at the Battleship North Carolina Memorial. Thank you to Chris Vargo for taking the time to meet with me and discuss the current project back when this thesis was just an idea. Thank you to Mary Ames Booker for opening the ship's archives and allowing me access to the information that made much of my research possible. Lastly, I would like to thank Ken Rittenmeyer for sharing his work and knowledge of the ship with me during my visits.

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CHAPTER ONE: INTRODUCTION

The battleship was one of the most powerful assets a navy could own for several decades in the late 19th and early 20th centuries. Many naval aficionados believed the battleship would be the key to winning naval engagements in World War II by slugging it out with other battleships for supremacy. However, the invention of the aircraft carrier vastly changed the way naval warfare was waged and became the key to victory at sea. Instead of serving as the focal point of the fleet, battleships were instead used in the roles of anti-aircraft defense and shore bombardment (Hone 2013:56-58).

Following the war, battleships remained symbols of power and influence, especially to the public. This public perception led to the push for many of these battleships to be saved from scrapping and converted into museums and memorials. The USS *North Carolina* (BB-55) was one of the first World War II-era battleships to be converted into a museum. Today, the USS *North Carolina* rests in a berth along the Cape Fear River in Wilmington North Carolina shown in Figures 1-2. The ship serves as both a museum and a memorial to the men and women who fought in all branches of the military during World War II.

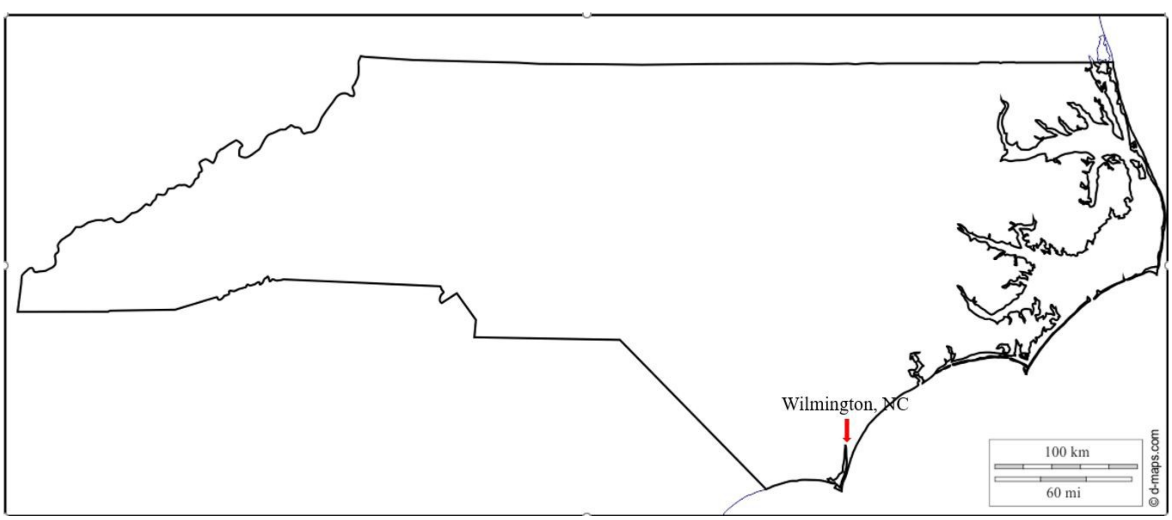


Figure 1. Map showing location of Wilmington, NC. (Image by Author 2020)

Figure 2. Map showing location of Battleship North Carolina Memorial. (Image from Google Maps 2020)

The Battleship *North Carolina* Memorial is managed by the USS North Carolina Battleship Commission, which was established in 1960 by the state of North Carolina to "provide an organization whose charter was to oversee the administration and operation of the USS North Carolina as a permanent memorial and exhibit for the State's World War II veterans" (Battleship North Carolina 2018b). The Battleship *North Carolina* Memorial was intended to serve as a memorial not only to the sailors who served on it during the war, but to all North Carolina veterans of World War II. That makes the importance of the ship as a monument farther reaching than just past sailors, their families, and those interested in the ship's history. Instead, the ship holds significance to anyone who has interest in World War II and the impact it had on the state of North Carolina. Therefore, understanding the best ways to preserve the structural integrity of the ship is of the utmost importance.

Furthermore, the popularity of World War II-era museum ships, particularly battleships, warrants seeking a better understanding of the issues surrounding hull preservation and the best solutions to these issues. Though the USS *Texas* was converted in 1948 and the USS *Alabama* and USS *North Carolina* in the mid-1960s, several other battleships from World War II were not converted into museums until the late-1990s and early 2000s (Table 1; and Texas Parks & Wildlife 2018; USS Alabama Battleship Memorial Park 2018; Battleship North Carolina 2018b). The newer ship museums underwent more recent upkeep and repair as they were in active duty more recently than the older battleship museums. This means they will begin to experience similar preservation issues that the older ships are currently struggling with.

Battleship Museum	Location	Year Converted to Museum
Texas	La Porte, Texas	1948
North Carolina	Wilmington, North Carolina	1961
Alabama	Mobile, Alabama	1964
*Massachusetts**	Fall River, Massachusetts	1965
Missouri	Honolulu, Hawaii	1999
Wisconsin	Norfolk, Virginia	2000
New Jersey	Camden, New Jersey	2001
Iowa	Los Angeles, California	2012

Table 1. List of Battleship Museums. (Mohl 2016). *recommissioned in 1980s and used as a parts cache for restoring other *Iowa*-class battleships to service.

Research Questions

This thesis examined the past actions, and present and future challenges of USS *North Carolina*'s preservation through examining records and decision making for the ship, but also by looking at other case studies of preservation actions to consider their application to the preservation of the battleship *North Carolina* and other battleship museums. This thesis analyzed methods used to solve these preservation issues, which will allow for better preparation when dealing with similar issues that arise in more recently converted battleship museums. The thesis sought to understand the relationship that battleship museums play in preserving cultural heritage. The following research questions were proposed to understand and analyze this information properly:

1) What preservation strategies have been used to preserve the Battleship *North Carolina*, and how do those strategies impact the future integrity of the vessel?
2) How can the hull preservation strategies of the Battleship *North Carolina* be used to impact and improve other battleship museum's preservation strategies?
3) How have hull preservation strategies improved or impeded the public outreach abilities of the Battleship *North Carolina?*

Ship museums are at risk of corrosion and preservation issues due to a variety of factors. These range from environmental factors to cultural and economic factors. The ability to understand these issues and how to manage resources used to combat them is essential to the longevity of ship museums moving forward. A primary technique employed during this study was to use historical data to create a 3D model to identify and assess degrees of deterioration risk along the hull of USS *North Carolina.* Creating this model opens potential opportunities to apply its basic formula to other ship museums in the future.

Modeling

The main goal of this project was to examine the past preservation strategies that have been applied to USS *North Carolina* and predict how these changes will affect the future integrity of the vessel. This was done through a series of different models using the McNeel's *Rhinoceros* software. Multiple models were developed to show the different areas where *North*

Carolina has received repairs or other preservative actions using color-coding. ECU graduate, William Sassorossi used a similar method in his thesis, *Defending the East Coast: Adapting and Converting Commercial Ships for Military Use* (2015), where he color-coded areas of adaptation commercial ships had military equipment installed on them (as seen in Figure 3). This required historical and archival research to discover the specifications of repairs, upgrades, and preservation actions applied to USS *North Carolina.* These models were then interpreted to understand how the preservation strategies have affected the state of the vessel over time, which in turn allowed for future areas of possible degradation to be identified. This potentially will allow for similar models to be extrapolated onto other battleship museums to allow managers of those vessels to determine areas of future issues and allow them to make more informed preservation decisions.

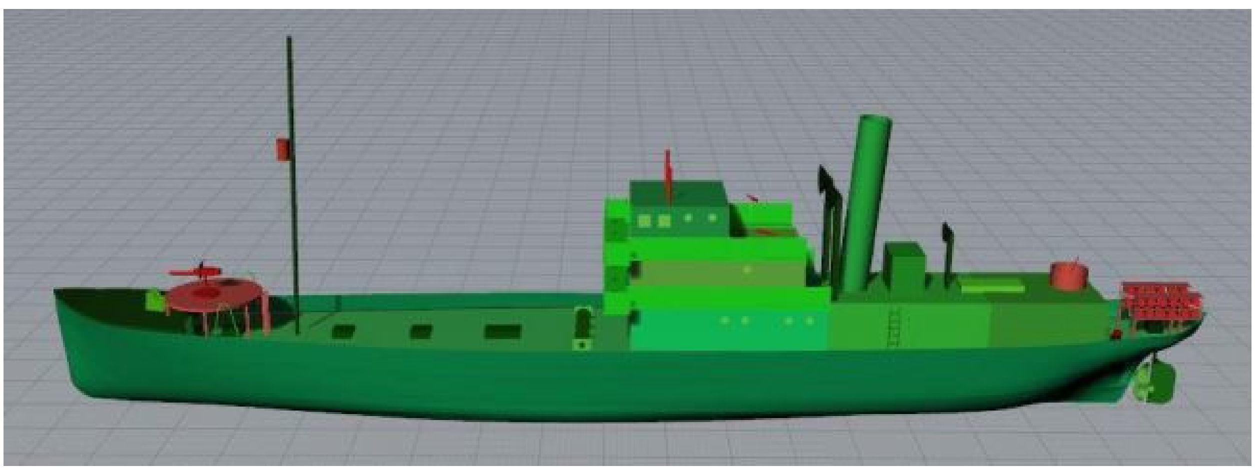


Figure 3. Example of using color-coded models to display changes on a ship (Sassorossi 2015: 145)

Limitations

As will be outlined in this thesis, preservation of USS *North Carolina* will always be a work in progress. Periodically, major investments will culminate in actions that have significant ramifications for future site preservation. One of these is the ongoing work to cofferdam the battleship's hull. As a current action, gauging the success of the current cofferdam project cannot be fully considered. With the cofferdam and the SECU memorial walkway complete, replacement of portions of the steel hull, starting with the bow, are now underway. However, by viewing the results of similar projects like the USS *Alabama* and the 2011 repairs of the starboard bow of the USS *North Carolina,* the limited results of the current project can be estimated.

Another limitation of this project is the inability to collect samples for corrosion analysis. Consequently, the author must rely upon photographic evidence and reports from these projects instead. Visual inspection and photographs taken by the author of corrosion on the ship's hull as well as the progress of the current project were included as evidence as well. However, this thesis relied mainly on textual evidence due to the difficulty of acquiring physical evidence.

Structure

This study is a culmination of collecting historical information and considering theories of historic preservation and cultural tourism. This information was then applied to create 3D model to analyze the risk zones of USS *North Carolina*'s hull. Chapter One serves as an introduction to the study by outlining the project's primary objective and outlining the structure. Chapter Two provides the historical background of the ship so that context is provided to understand how the ship came to be in its current state of preservation. This information includes the pre-design history, design and construction, active duty, and post war history of USS *North Carolina.* Chapter Three examines theories and common practices connected management practices for museum ship preservation. USS *North* Carolina served as both an active warship and a museum ship during its career. This required researching both preservation and upkeep strategies taken on active warships during World War II and theories of preservation, cultural resource management, and tourism.

Chapter Four discusses the methodology used during this study. This project implemented both extensive historical research as well as 3D modeling. The research focused on historical data regarding USS *North Carolina* as well as analysis of theories regarding active warship maintenance and museum ship preservation, historic preservation, and cultural tourism. The 3D modeling program, *Rhinoceros 6.0* (Rhino), was used to create a digital model for visualization of the state of preservation the ship was at during different stages of its career. The 3D model served as a crucial tool for analyzing past and present preservation issues on USS *North Carolina.* Chapter Five presents a detailed discussion of events and actions that effected the preservation of the ship in chronological order. This information was broken into sections discussing the ship's time in active duty where it underwent maintenance, suffered torpedo damage, and was placed in the mothball fleet. This section was followed by a discussion of the preservation issues and actions USS *North Carolina* was subjected to as a museum ship. Chapter Six presents an analysis of the information collected and discussed in the Chapters 2-5. The analysis was completed by taking the historical data collected and creating a 3D model that used color coding to depict varying degrees of risk for preservation issues and activities. Finally, Chapter Seven provides concluding statements on this study.

CHAPTER TWO: HISTORY OF USS *NORTH CAROLINA*

The state of a ship's preservation is due to a combination of factors. In order to understand the state of USS *North Carolina*'s preservation, it is essential to provide historical context that allows for a better understanding of preservation management issues and decisions. *North Carolina* was the first American battleship built in over two decades, and several years of studies were put into the design of the ship (Blee 2005:6). Since its construction, the ship served in World War II, was place d in the Inactive Reserve Fleet and mothballed, and has been converted into a museum ship and memorial. This chapter outlines the pre-war events that affected the design of USS *North Carolina*, the design and construction of the ship, and the transition from active warship to museum ship.

Battle between Wars: Naval Arms Limitations

In 1919, the ink had barely begun to dry on the Treaty of Versailles, the treaty that ended one of the most devastating wars in human history, but the victors were already preparing for the next conflict. Although World War I was over, the fire of a great naval arms race had already been ignited. The United States, Britain and Japan were the three main nations involved in the struggle for naval supremacy early on. Although severely limited by the Treaty of Versailles, many in Germany's high command structure pushed to rebuild Germany's greatness through its navy. This sentiment was especially strong within the ranks of German submariners. For the next decade, these three powers and other nations, including a resurging Germany, would try and fail to restrain the growing power struggle fueled by naval armament and technological advances (Rose 2007a:4-6, 44-48).

The United States had amassed a large merchant marine fleet in the nineteen months that it participated in World War I, but it was not completed until the war ended. This meant that the United States had a modern fleet of ships to challenge Britain, a country economically exhausted from the financial burdens conflict, for naval supremacy in the Atlantic (Rose 2007:4). On top of a vast merchant marine, the United States seemed to have no intentions of ending its capital-ship program started in 1916, which "had the stated aim of overtaking the Royal Navy in numbers with the largest battleships that could transit the Panama Canal—a fleet second to none" (Sandler 2004:114). In October of 1918, less than a year before the Treaty of Versailles was signed, Woodrow Wilson agreed to resume work on the 1916 program, as well as supporting a duplicate program, which would bring the total of planned capital-ships to twenty battleships and twelve battle cruisers (O'Connel 1991:234). The United States began construction on the *South Dakota* Class, which would have displaced 40,000 tons and been armed with 16-inch guns, in 1920, well after World War I had come to a close This massive and rapid expansion of naval power presented a very serious potential threat to the Royal Navy.

Britain, unwilling to risk relinquishing the naval superiority that had allowed it to thrive as a maritime empire also began drawing up plans to construct eight new battleships that would be mounted with 18-inch guns. Not only was the growing American naval power a threat to Britain, but so was the idea of 'Freedom of the Seas" presented in Woodrow Wilson's Fourteen Points (O'Connel 1991:233-234). The politicians and tacticians in Britain realized that "without a superior fleet Britain would no longer count as a great power," but they also realized that after depleting the nation's treasuries trying to out-build Germany before 1914 and win World War I they were in no position to engage themselves in a naval race of any kind (Rose 2007:7).

In the Pacific, Japan found itself in a prime position to assert national dominance over the Western Pacific at the end of World War I. It had escaped the worst of the bloodshed and been granted strategically significant possessions in the Mariana and Marshall Islands thanks to the Treaty of Versailles. These island chains outflanked the American outpost located in the Philippines and were located far too close to Hawaii for American comfort (O'Connel 1991:244). Japan's rise to dominance ensured that they would be the chief rival of the United States for control of the Pacific. This rivalry began to fester in the early 20th century when Theodore Roosevelt audaciously sent the Great White Fleet on a voyage around the world to display American naval power in order to ascertain political strength on an international scale. The Great White Fleet's voyage included a stop in Tokyo Bay that was intended to quell any ambitions the Japanese might have had in expanding its interests towards the United States possessions in the Pacific (Rose 2007:143-148).

The rivalry between the United States and Japan was only intensified by the fact that the Japanese boasted the third largest navy in the world, which was highly trained and thoroughly modernized. The rapid expansion and continued post-war buildup of the American Navy under Woodrow Wilson was highly concerning to the Japanese, and while most nations saw the buildup aimed towards Europe, Japan felt the dangers of the American naval buildup was aimed directly at them (O'Connel 1991:244-245). In response to Wilson's 1919 shipbuilding plan, Japan restarted its 8:8:8 program, of which the first ships produced were the *Nagato* class, the first fully Japanese designed battleships (Whitley 1998:200-203). Japan's dedication to naval armament was evident in the nation's budget went tripled naval expenditures from $85 million in 1917 to $245 million in 1921 (O'Connel 1991:245). The intensity of the naval armament race between the United States, Britain, and Japan was rapidly reaching a boiling point that would lead to conflict if compromises were not made.

Compromise came from talks among the victors of World War I in Washington D.C. from November 1921- February 1922. After months of debates and bargaining, diplomats came to an agreement that would shrink the large fleets that had been created during pre-World War I and World War I buildups to manageable proportions, as well as encouraging modification of existing ships over building new vessels. The main terms of the Washington Naval Treaty created a ten year "holiday" on building capital ships, limited the displacement of battleships to 35,000 tons, limited the gun caliber to 16-inch guns, and created a 5:5:3 ratio of capital ships for the United States, Britain, and Japan respectively (Rose 2007:29-30). The treaty also called for the scrapping of several older outdated capital ships by each country to reach the required ratios. Other terms that the Washington Naval Treaty covered included limiting aircraft carriers to 27,000 tons and required that submarines not displace more than 10,000 tons (O'Connel 1991:270-271; Rose 2007:30-31).

Design and Construction

The Washington Naval Treaty was reaffirmed and modified in the London Naval of 1930 (Rose 2007:53-55). However, behind the scenes the Imperial Japanese Navy was not adhering to the limitations and the German Navy was orchestrating a resurgence in its depleted fleet. This caused the naval arms race to begin again and forced the United States to begin contemplating building new battleships within the limits of these naval treaties (Rose 2007:41-50; Whitley 1998:289-290). Design ideas for what would become the *North Carolina* class began in 1933 and the process produced seventy-seven variations between 1935 and 1937 before a final design was agreed upon by the Navy's General Board (Blee 2005:2-3; Friedman 1985:243-269; Garzke

1995:32). The final design for USS *North Carolina* (BB-55) displaced 42,279 tons (35,000 standard displacement) and when fully loaded measured in at 44,800 tons (Whitley 1998:290-291).

The hull and decks of the ship were designed with varying degrees of thickness dependent on structural strength and minimizing the weight of the ship to decrease displacement in order to meet the restrictions set by the Washington and London naval treaties. The steel plating that made up the hull of the ship had varying thicknesses. The bow of the ship was built with .5-inch plating whereas the rest of the ship's hull consisted of plating ranging from .625-inch to .75-inch plating (Hotz 2010). The main armor belt was 12-inches thick amidships and was inclined at 15°. The armor belt was backed by .75-inch thick Special Treatment Steel (STS) (Friedman 1985:274). STS was a higher quality steel material that was typically used as "splinter armor" after replacing nickel steel (Friedman 1985:71). The outer edges of the main armor belt were reduced to 6 inches. The armor belt was designed to protrude 6.5 feet above the maximum draft of the ship as well as the same distance below the minimum draft. This prevented the ship from being entirely expose by effects of a single torpedo (Friedman 1985:266). The main deck of the ship 1.375-inches thick with 1.25-inch thick teak planking on top of it. The second deck was a combination of 3.6-inch armor that was fused to 1.4-inch STS plates. The third and final armored deck was .62-inch STS and was known as the "splinter deck" (Friedman 1985: 274-278). Underwater protection was further supplied by the torpedo-protection bulkheads. This system consisted of five compartments divided into torpedo bulkheads. The outermost and innermost layers remained void, while the three inner bulkheads were filled with liquid (usually oil or seawater), which is depicted in Figure 4 (Battleship *North Carolina* Memorial Archives 2016).

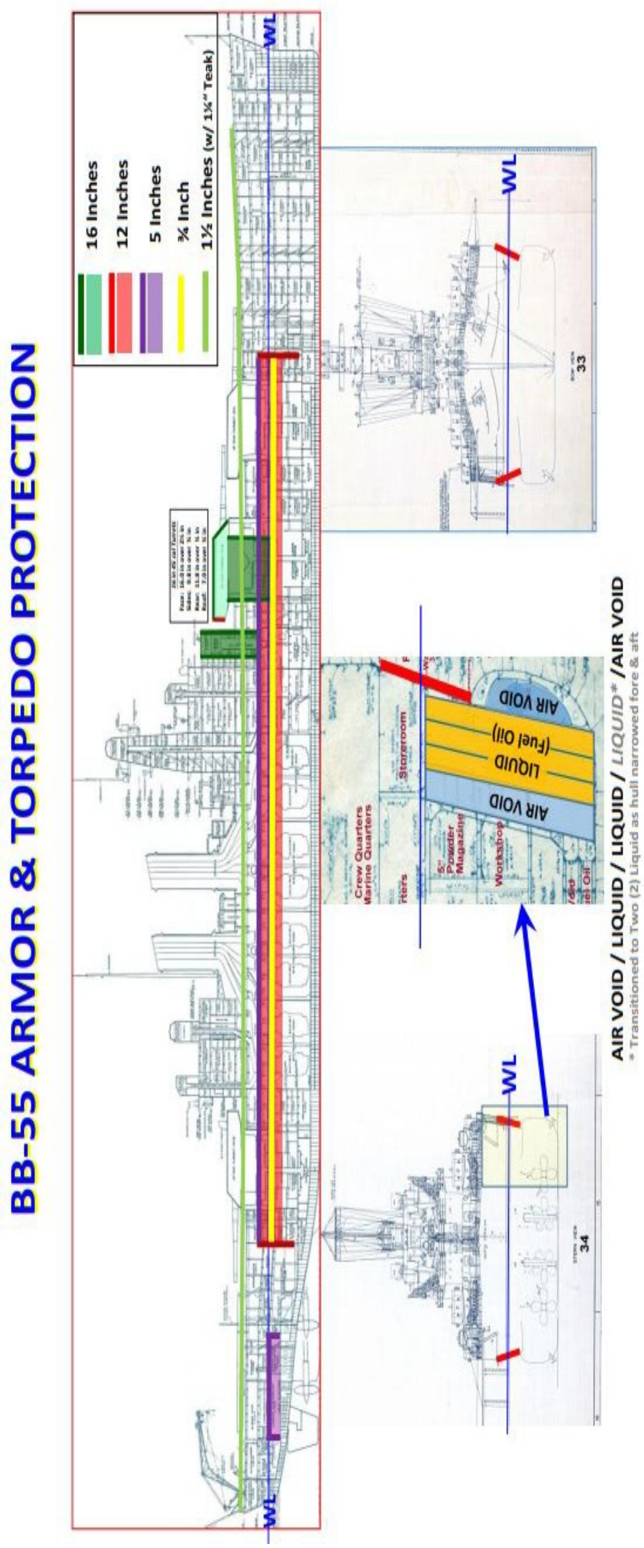


Figure 4. Armor Protection Schematic of USS North Carolina. (Battleship North Carolina Memorial Archives 2016).

While the design was mostly determined by the limitations of the Washington Naval Treaty, designers of the *North Carolina* class were able to introduce many radical improvements over the designs of the ship's predecessors. These design improvements included modifications such as a sweeping flush deck that was unbroken from bow to stern and a castle-like superstructure instead of tripods and cage masts. They also featured rotating armored mounts for secondary guns instead of casemate style guns featured on older battleships. The ship had four propellers, with the inboard propellers mounted on twin skegs, and two rudders positioned ten feet from the center line behind the inboard propellers. The ship's four engine rooms were arranged one behind another and were separated by watertight bulkheads to limit flooding and damage cause by mines or torpedoes (Blee 2005:3-4). Final modifications to the design were made after construction had already begun on USS *North Carolina* and included substituting 16-inch guns instead of the original 14-inch guns, as well as modifying the power plant to produce 121,000shp instead of the original 115,000shp needed to produce 27 knots (Whitely 1998:291-292).

The *North Carolina* class was authorized to be built by an act of Congress passed on 3 June 1936 (Friedman 1985:270). At this point, the United States Navy had not constructed a new battleship in sixteen years, and the first completed since 1923 when *West Virginia* was completed (Musicant 1986:4; Blee 2005:6). The two sister ships of the *North Carolina* class, USS *North Carolina* and USS *Washington*, were so much larger than any other ship built by the United States at the time that the building ways at the New York and Philadelphia Navy Yards had to be extended and strengthened before construction could begin. The keel of the USS *North Carolina* was finally laid on Navy Day, 27 October 1937, at the New York Navy Yard in Brooklyn, New York (Garzke 1995:35). Initially significant mudding was suggested for the construction of the ship in order to save weight and improve efficiency. However, due to technical complications that would affect speed of construction, cost, and shipyard procedures, only 30% of the ship was welded and the rest was riveted (Garzke 1995:35).

USS *North Carolina* was the first of ten fast battleships that would join the United States Navy during World War II (Battleship North Carolina 2018). By the time the ship was launched on 13 June 1940, Germany had already captured Paris four days earlier and Japan had invaded China. The launching ceremony included a speech by Clyde R. Hoey, the governor of North Carolina, while his daughter, Isabel Hoey, christened the ship with over 54,000 spectators watching (Blee 2005:31-33). The ship suffered minor damage during its launching but was quickly ready for its fitting out which took approximately ten months. "Fitting out" is the stage of construction after the hull structure is complete, where thousands of tons of machinery and armament are installed. On 9 April 1941, USS *North Carolina* was commissioned, which signified that the United States Navy was willing to accept responsibility for the ship as a member of its active fleet. The commissioning "received international news coverage because the vessel was already widely acclaimed as the most powerful warship in the world" (Blee 2005:36).

Figure 5.USS *North Carolina* at sea. Photo from https://visitpearlharbor.org/americas-decorated-ship-world-war-ii/

Active Duty

Once a ship is commissioned, it goes through a period of tests and training, known as a "shakedown," in order to assess and improve the battle-readiness of the ship and its crew. Unfortunately for USS *North Carolina,* pictured in Figure 5, it had a serious issue with vibration problems, which lengthened the duration of its shakedown. The vibration problems required the ship to continuously return to New York Navy Yard for adjustments, and the constant trips in and out of the harbor earned USS *North Carolina* the nickname "Showboat" (Blee 2005:23-29). USS *North Carolina* continued training for several months, until 7 December 1941, the date of the Japanese attack on Pearl Harbor. The training for the ship was immediately accelerated, and it received orders to join the Pacific Fleet for duty on 28 May 1942. USS *North Carolina* departed Hampton Roads, Virginia on 1 June 1942 traveling with Task Force 37, bound for the west coast (Battleship *North Carolina* Memorial Archives 2004:1). *North* Carolina passed through the Panama Canal on 10 June 1942 on its way to join Task Force 18 with the carrier *Wasp* (CV-7) (Whitley 1998: 293).

The ship arrived in Pearl Harbor on 11 June 1942 and immediately sailed to Tonga-Tabu Island, where it practiced shore landings and supported operations around the Fiji Islands. Following completion of training operations, USS *North Carolina* joined Task Forces 11, 16, and 18 and sailed towards the Solomon Islands, where it served as a support unit for the carriers attached to each task force (Battleship *North Carolina* Memorial Archives 2004:1). The battleship was one of the most powerful assets a navy could have owned for several decades in the late 19^{th} and early 20^{th} centuries, and many naval aficionados believed the battleship would be the key to winning naval engagements in World War II by slugging it out with other battleships for supremacy (GlobalSecurity 2011; Hone 2013:56). However, the invention of the aircraft carrier vastly changed the way naval warfare was waged and became the key to victory at sea. USS *North Carolina* demonstrated how important the new role of battleships was almost immediately. During the first battle *USS North Carolina* played an active role in on 24 August 1942, the ship avoided several dive bomber attacks while shooting down seven planes and assisting in downing almost seven more (Blee 2005:80). The withering fire the ship filled the sky with was crucial in the defense of the fleet's aircraft carrier. While the ship suffered no structural damage, it did lose its first crewman to enemy strafing during the attacks (Battleship *North Carolina* Memorial Archives 2004:1).

Torpedo Damage

On 15 September 1942, USS *North Carolina* suffered the worst damage it would take during the war: a torpedo hit on the port side abreast of turret number 1 that was fired by a Japanese submarine (Battleship *North Carolina* Memorial Archives 1947:1). The torpedo attack was among the deadliest and luckiest executed by a submarine to occur during World War II. The Japanese submarine I-19 fired a salvo of six torpedoes aimed at the carrier *Wasp,* of Task Force 18, connecting with its target on three out of the six torpedoes. The three torpedoes that missed continued to slice through the water towards Task Force 17, which USS *North Carolina* was a part of. The ships of Task Force 17 were located approximately 12,000 yards away from Task Force 18. One of the torpedoes never struck a target, but of the two remaining torpedoes, one struck the destroyer *O'Brien* (DD-415) and the other USS *North Carolina.* USS *North Carolina* was the only ship of the three hit by the torpedoes fired by I-19 that did not sink. *Wasp* was abandoned that night, and sunk by the American destroyer *Lansdowne* to avoid it being attacked by an approaching Japanese surface fleet, and *O'Brien* sank on 13 October 1942 after receiving temporary repairs and sailing for San Francisco (Battleship *North Carolina* Memorial Archives 1947:3-5; Blee 2005: 82-91).

After suffering the torpedo hit at 14:52, USS *North Carolina* was able to remain in formation until 20:00 that night due to excellent damage control by its crew. The ship lost five men during the attack: one washed overboard and four killed from the results of the torpedo detonation (Battleship *North Carolina* Memorial Archives 1947:4). At 20:00 USS *North Carolina* was directed to proceed to Nukualofa, Tonga-Tabu for repairs. There, the repair ship *Vestal* conducted several repair jobs including: removing protruding lips of shell plating, installing a cofferdam to pump water out of the damaged area for the removal of the four bodies of the sailors killed in the attack and the repair of pipe lines and bulkhead boundaries. The repairs also included shoring additional bulkheads adjacent to the flooded areas. These repairs were completed on 21 September 1942, and the ship then proceeded to Pearl Harbor Navy Yard for permanent repairs (Battleship *North Carolina* Memorial Archives 1947:4). USS *North Carolina* spent time in Pearl Harbor receiving repairs to the torpedo damage as well as upgraded anti-aircraft guns from 30 September-17 November 1942 (Blee 2005:94).

Remaining War History

After this visit to Pearl Harbor, USS *North Carolina* spent the rest of the war in continued support of carriers in almost all fleet operations. The ship returned to Pearl Harbor three times: once in April 1943 for minor overhaul, a second time in June 1944, and a third time in May 1945 for repairs following the battle for Okinawa. It also spent several months at the Naval Shipyard in Bremerton, Washington for another overhaul from July-October 1944 (Battleship *North Carolina* Memorial Archives 2004: 2-4). These repairs and overhauls helped the ship continue to improve its effectiveness as a powerful anti-aircraft unit protecting the invaluable aircraft carriers of the fleet. USS *North Carolina* also participated in several shore bombardments throughout the island-hopping campaign in the Pacific.

Throughout the three years that USS *North Carolina* served in the Pacific, it bombarded enemy territories nine times. It participated in close to fifty engagements, during which it shot down twenty-four planes as well as sinking a Japanese freighter. USS *North Carolina*'s performance during the war earned the ship fifteen battle stars, the most of any battleship during World War II (LoProto 2017). As the first fast battleship, USS *North Carolina* had to learn to deal with challenges associated with wartime duties and different situations faced during war (Blee 2005:142). While USS *North Carolina* performed its duties excellently, due to the building of larger, more modern battleships designed after the end of the United States adherence to limitations set by the Washington Naval Treaty, it would not take long after World War II ended for the ship to see an end to its fighting days.

Battleship Retirement to Museum Life

The ship eventually returned to the United States in October of 1945 and was given a hero's welcome. It sailed into Boston on 17 October 1945 and received a message from President Harry S. Truman stating, "No vessel of America's World War II battleship fleet served as long in combat or with greater distinction than USS NORTH CAROLINA, from Guadalcanal to Tokyo Bay. The whole nation is proud of her" (Blee 2005:144). However, after the war ended, a period of disarmament began, which led to a decreased need for active battleships. Instead, USS *North Carolina* was instead used for other activities. USS *North Carolina* was used by Naval Academy midshipmen for training cruises in the Caribbean twice during the summer of 1946. The ship returned to New York Navy Yard in October 1946 to be prepared for inactivation (Blee 2005:145). It was decommissioned on 27 June 1947 and placed in the Inactive Reserve Fleet, also known as the “mothball fleet” (Mooney 1961:109-110). USS *North Carolina* sat in the Inactive Reserve Fleet in Bayonne, New Jersey until it was struck from the Navy List in June 1960.

After the ship was struck from the Navy List, it was intended to be scrapped, but when the citizens of North Carolina heard about this, they started a fundraising campaign to save the ship and have it brought to Wilmington, North Carolina where it remains today (Battleship North Carolina 2018). The idea was first proposed by two residents of Wilmington, James S. Craig, Jr. and Hugh Morton. With the help of the Governor of North Carolina, Luther Hodges, and several others, a plan to save the ship was put into motion. Thousands of citizens and school children donated a total amount of $330,000 dollars to have the ship brought to Wilmington, North Carolina as well as prepare a proper berth to store the ship. In September 1961, the ship was towed from its berth in Bayonne, New Jersey to the Cape Fear River. On 2 October 1961, USS *North Carolina* arrived in Wilmington and was moored in its current location across the river from downtown Wilmington (Blee 2005:145).

After spending twenty years in Wilmington, USS *North Carolina* was nominated to the National Register of Historic Places on 23 July 1981. This designated the ship as a historically significant site under several criteria. It met criteria A due to its participation in the Pacific theater during World War II, as well as being associated with the lives of over 2,000 crew members and all American service members in World War II. USS *North Carolina* met criteria C since it was the first modern battleship built by the United States after World War I (National Archives 1981:5).

Management Structure

The Battleship *North Carolina* Memorial is managed by a small crew. These positions include the Executive Director, an Assistant director in charge of operations and maintenance, a comptroller, a Director of Retail Sales, a Curator, a Museum Services Director, a Promotions Director, and other members involved with Living History and day to day activities on the *N*orth Carolina (Battleship North Carolina, 2018). All these positions are essential to the operation of the Battleship *North Carolina* Memorial, but the positions most related to the preservation and management of the ship are the Executive Director, Assistant Director, and Curator.

The current Executive Director of the Battleship North Carolina is a retired United States Navy captain named Terry Bragg (Battleship North Carolina 2018). Bragg took over as the Executive Director in March of 2009, when he replaced his predecessor Capt. David Scheu, who had served in the Executive Director position for seventeen years (Steelman 2009). Bragg served in the United States Navy for thirty years. During that time, Bragg commanded a destroyer squadron and a guided missile frigate. This experience has prepared him for how to deal with maintaining and keeping the ship in proper condition. While in the Navy, Bragg earned a master's degree in financial management. This turned out to be very beneficial in preparing him to manage a self-supporting institution like the Battleship *North Carolina* Memorial.

Subordinate to the Executive Director is the Assistant Director, Chris Vargo. Vargo's responsibilities include managing the day to day operations of the ship and supervising preservation and restoration of the ship and the artifacts stored within it. Before joining the crew of the Battleship *North Carolina* Memorial, Chris Vargo served in the Coast Guard as the chief of the Inspections Division at the U.S. Coast Guard's Sector North Carolina. His duties in that position required him to make sure that a variety of vessels and waterfront facilities complied with safety regulations. During his service with the Coast Guard, Vargo inspected over 900 foreign vessels a year, inspecting ships that had both hazardous and explosive cargo (StarNews Online 2012). Vargo's experience has made him a veteran of analyzing a ship and identifying areas that are in poor condition.

Another important member of the crew related to conserving and managing the Battleship *North Carolina* Memorial is the Curator, Mary Ames Booker. Booker oversees preservation the numerous artifacts stored aboard the Battleship *North Carolina.* These artifacts include numerous letters, photos, other documents, and uniforms. While the Assistant Director oversees preserving the largest artifact, the battleship, the curator oversees the huge number of smaller artifacts within the museum. The Battleship *North Carolina* Memorial also launched its digital archive in 2013, which contains over 26,000 records (Thompson 2017).

The USS *North Carolina* Battleship Commission is the organization that was created to oversee the administration and operation of the USS *North Carolina.* It was given its charter in 1960 by the State of North Carolina. The general statutes for the Battleship Commission require the Battleship *North Carolina* Memorial to be an enterprise activity. This means that it must generate its own revenue in order to cover the cost of its administration and operation. The Battleship *North Carolina* Memorial does not receive any funds for its administration or operation from any level of government sources. This requires the Battleship *North Carolina* Memorial to rely on admissions, Ship's Store sales, donations, and investments to fund itself. The members of the USS *North Carolina* Commission are chosen by the Governor of the State of North Carolina. The Secretary of Cultural Resources and the Secretary of Commerce are automatically chosen as voting ex- officio members, and the Secretary of Cultural Resources also serves as the Commission Secretary (Battleship North Carolina 2018).

<u>Preservation Projects</u>

USS *North Carolina* has undergone several instances of repair and modifications throughout its career. As an active battleship, it underwent repairs or took on new equipment at Navy yards during and after World War II. It stopped in Pearl Harbor six separate times to receive different alterations or repairs: October 1942, March and April 1943, May 1944, and May and June 1945. These stops ranged from "strip ship" changes that prepared the vessel for wartime duties, to repairs from torpedo damage that the ship suffered in action (Battleship North Carolina 2018)

The USS *North Carolina* first arrived in Wilmington, North Carolina on 2 October 1961 (Battleship North Carolina 2018). The ship had not been placed in drydock for repairs since 1953 and received no repairs to its hull until a 2011 project that repaired a portion of the starboard bow. The project was paid for with funds that were raised during Operation Ship Shape in 1998. The project was executed by the Taylor Brothers Marine Construction company, which built a portable cofferdam that allowed workers to repair portions of the starboard hull identified as having the most significant need for repair as seen in Figure 6 (The North Carolina Department of Cultural Resources 2011). The project was started in May of 2011 and finished in late November of that year. Once the project was complete, the cofferdam was removed. It managed to stay under the projected budget of $2.1 million.

Figure 6. Portable Cofferdam being fitted to USS *North Carolina* during 2011 starboard bow repairs. Photo from http://www.jmsnet.com/projects/battleship-uss-north-carolina/

Currently, the USS *North Carolina* is amid a much larger scale restoration of the ship's hull. The current project consists of two stages:

1. building a permanent cofferdam that surrounds the entire ship as well as a memorial walkway that will allow visitors to walk around the ship
2. repairing the port bow and starboard and port sections of the stern.

The project is estimated to cost a total of $13.5 million. The cofferdam construction will cost $7 million, while the steel hull repairs are estimated to cost $6.5 million (North Carolina Department of Cultural Resources 2015). Both the cofferdam and memorial walkway, which is funded by State Employees' Credit Union and modeled in Figure 7, are being constructed by Orion Marine Group (Battleship North Carolina 2018). Once the cofferdam is built, it will allow workers to drain the water from around the ship and access the portions of the ship that need repairs. The memorial walkway will allow visitors to walk all the way around the ship and the presence of the cofferdam will not affect the ability of visitors to access the ship itself, which will operate on its normal schedule during the entire project.

Figure 7. Drawing of USS North Carolina cofferdam and SECU Memorial walkway. Photo from https://www.coastalreview.org/2015/05/uss-north-carolina-wwii-history-and-bird-trail/

The USS *North Carolina* is not the first ship museum to use a permanent cofferdam as a strategy for hull repairs on the ship. The USS *Alabama*, located in Mobile, also used this method in 2001 as part of a $15 million project that included moving the submarine USS Drum permanently out of the water onto a land base (USS *Alabama* Memorial 2017b). The success of the USS *Alabama* cofferdam project was crucial in deciding to use this approach on the USS *North Carolina* instead of attempting to dredge the ship out of its berth and tow it to Norfolk or Charleston for dry-docking and repairs. The latter option not only would have taken several months, in which the ship would not have been available to visitors, but it would have also required the dismantling of the masts, which are too tall to fit under bridges along the Cape Fear River that were not installed until after the USS *North Carolina* arrived in Wilmington.

Conclusion

USS *North Carolina* currently rests in a berth along the Cape Fear River in Wilmington, North Carolina settled in the mud. It stands as a monument to the veterans of the state of North Carolina who lost their lives in World War II and as a symbol of the naval might of the United States Navy during World War II. The journey the ship took to get from its construction as a warship to its conversion to a museum ship played a crucial role in impacting the preservation of the ship to this point. This chapter outlined the pre-World War II events that impacted the design of USS *North Carolina* and the design and construction of the ship. It also provided insight into the active duty of USS *North Carolina* during World War II, during which it suffered a torpedo hit, which required replacing a portion of the hull along the starboard bow, as well as describing the ship's transition from an active warship into a museum ship and memorial.

Damage from a torpedo hit and other minor damage suffered during the war required repairs that replaced a large section of the hull along the port bow with newer metal, which deteriorated less quickly than portions of the original hull. A lack of maintenance once the ship was converted into a museum allowed several small holes to rust through the hull of the ship, which led to a major repair project on the starboard bow in 2011 as well as the current permanent cofferdam and hull repair project that is in progress. The preservation issues created from these circumstances and the subsequent solutions to them are excellent cases for analyzing how effective such practices are when preserving the hull of World War II battleships.

CHAPTER THREE: WARSHIP AND SHIP MUSEUM PRESERVATION PRACTICES AND THEORIES

Introduction

The ability to assess the results of preservation management decisions on USS *North Carolina* requires an understanding that preservative action plans and management practices are guided by theories of preservation, cultural resource management, and tourism. However, there is not a single theory that encompasses all aspects of preserving a historic vessel. USS *North Carolina* began its career as an active warship and was managed according to theories and practices focused on the upkeep of an active warship. In 1961, it transitioned from active warship to museum ship, which required the theories guiding its management practices to transition as well. In 1990 the Secretary of the Interior published *Standards for Historic Vessel Preservation Projects*, which has served as a set of guidelines for ship museums since its publication. In the case of USS *North Carolina*, the preservation management actions taken as an active warship and during the first thirty years it was a museum ship did not have the luxury of these guidelines. This chapter will first explore common practices used in active warship maintenance, focusing on painting and cathodic protection. It will then move on to discuss historic vessel preservation practices with a focus on types of berths, protective coatings, cathodic protection, and maintenance schedules. Examining the differences between warship maintenance and historic vessel preservation is important, because each method potentially poses different issues. The tension between maintaining for use and maintaining for preservation of historic material is mirrored by the tension between cultural tourism (use) and historic preservation (preserving).

Therefore, the chapter will conclude by discussing cultural tourism and historic preservation theories that have relevance to historic vessel preservation.

Active Warship Maintenance Theory

Maintaining an active warship was and is a task that requires constant attention to the requirements for keeping the ship in good condition. The high number of sailors moving about on a ship's decks and the dirt and wear that accrues from constant use required continual cleaning. Washing the decks was a part of everyday life that sailors engaged in. Just as the decks were constantly subjected to weather and wear and tear, the hull of the ship was continuously at the mercy of the environment. The constant battering of the elements on the hull was one of the biggest issues a warship had to deal with. If the hull did not receive proper maintenance, it was liable to rust or lose structural integrity, this could manifest in leaks or weakened patches in the armor belt along the ship's waterline, an area where the ship was most at risk from oxidation processes (Herrera et al. 1993:254). The two main methods for maintaining a ship's hull are painting and cathodic protection.

Painting

The issue with a ship made of steel is that "when not covered by paint or other impervious material, [it]) is peculiarly susceptible to both chemical and electrolytic action and…together with the rapidity with which corrosion may take place under favorable conditions, make its prevention a matter of vital importance" (Marine Engineering & Shipping Age 1924:134). The proper protection of a ship's hull was considered incredibly important by the Navy, and this can be seen by the fact that they included "Painting and the Preparation of Surfaces Therefor" in the first section of the book which deals with "Subjects All Enlisted Men Should Know" (United States Naval Institute 1943:xi). Painting was the primary method used to protect warships from rust, and this required continual maintenance. *The Bluejackets Manual 11th ed*. states that "Keeping a warship in first-class condition means a constant battle against rust, and the only effective protection against rust is good paint properly applied to metal surfaces that have been carefully prepared for painting" (United States Naval Institute 1943:254). The same volume also discusses what paints are made of and how to properly apply paint in this chapter, but the type of paint that it focuses on the most is bottom paint. The section of the ship most vulnerable to rusting is from the waterline down, therefore these are the most important areas to protect with painting. The bottom paint of a ship was applied in two different layers: an anticorrosive bottom paint and an antifouling bottom paint. The anticorrosive bottom paint was applied directly to the steel hull of a ship, and its purpose was to prevent rust and corrosion of the plating. The Mare Island Naval Shipyard was responsible for creating a cold plastic anti-fouling paint from 1940-1941 that extended required dry-docking periods from 6-9 months to almost 18 months (Morrs 2002a). The antifouling bottom paint was applied over the anticorrosive layer and was intended to prevent fouling or marine growth along the bottom of the ship. Antifouling bottom paint typically included oxides of copper and mercury as their ingredients (United States Naval Institute 1943:257). The United States Navy developed their "battleship gray" paint in 1910. It was formulated to be lighter than the previous lead paint the navy had used to this point, salt-water proof, and it contained no toxic materials. The paint was composed of "40 percent of blanc fixe (precipitated barium sulphate), 60 percent zinc oxide and sufficient bone black or other black to give the desired shade of gray. The vehicle was 85 percent linseed oil and 15 percent of drier and thinner, the thinner always being of the hydro-carbon petroleum type" (Rock 1931:582).

Painting is the most effective way to prevent rust on a ship, however, if the surface is not properly prepared before the paint is applied, it will be of little value. Paint requires a clean foundation to be applied to, and "If loose old paint, rust, dirt, dust, moisture, or grease exist on the surface, they will prevent the new paint from entering the surface pores" (United States Naval Institute 1943:259). The *Bluejackets' Manual* insisted that surfaces be cleaned immaculately before painting surfaces. Rust was the biggest concern, since it was known to spread under paint if a rust spot was not removed before applying a new coat. This would cause the new paint to flake off and allow more rust to develop and spread along the ship. Sailors were instructed to use a painter's torch and apply heat to a rust spot to remove it effectively (United States Naval Institute 1943:260).

<u>Cathodic Protection</u>

Protective coatings, such as paint, are the most efficient method for protecting steel structures from corrosion, but "cathodic protection, often in conjunction with protective coatings, is also used to protect immersed parts of bare steel surfaces (including coating damaged areas) from corrosion" (American Bureau of Shipping 2017:1). Cathodic protection traces its origin back to 1823 when Sir Humphry Davy discovered a method for protecting copper sheathing against corrosion from seawater by using sacrificial iron anodes (Denison 1947:295; Roberge 2020). Cathodic protection is an electrochemical method that is used to prevent corrosion on submerged metallic structures (Department of Defense [DoD] 2003:1-1). The basic corrosion process that cathodic protection fights against consist of four major components: cathode, anode, electrolyte, and metallic connection. The cathode is where reduction reactions occur, the anode is where corrosion occurs due to oxidation reactions, the electrolyte is the location where ions flow and in the case of ships would be the water surrounding a vessel, and the metallic path consist of any conductor that allows electrons to flow from the anode to the cathode (DoD 2003:2-1 - 2-2). Cathodic protection systems control corrosion by relocating oxidation reactions and making the protected structure a cathode in the corrosion cell (DoD 2003:2-25). There are two basic ways to create a cathodic protection system: galvanic cathodic protection (GCP) and impressed current cathodic protection (ICCP).

Galvanic cathodic protection systems, or sacrificial anode systems, electrically attach a metal with different corrosion potential to the surface of the metal that is trying to be preserved as seen in Figure 8. The sacrificial metal, commonly zinc, magnesium, and aluminum when used on iron and steel surfaces, has a more negative voltage, which makes it the anode in the corrosion cell and causes it to corrode instead of the protected surface (DoD 2003:2-28, 2004:8). Even though the anode is consumed by the process, it is typically designed and installed in a manner that makes it easy to replace every ten to fifteen years, which is the common lifespan for sacrificial anodes (DoD 2004:8). Sacrificial anode cathodic protection systems are very simple, with the simplest form consisting of an anode made from an active metal being attached directly to the structure where it will be exposed to the same environment as the structure it is protecting. This is the most common system used in the protection of ships (DoD 2003:2-28). GCP systems, while simple, are so effective that when properly installed and maintained "the structure being protected is essentially immune to corrosive attack and its lifetime is limited by other factors" (DoD 2004:8).

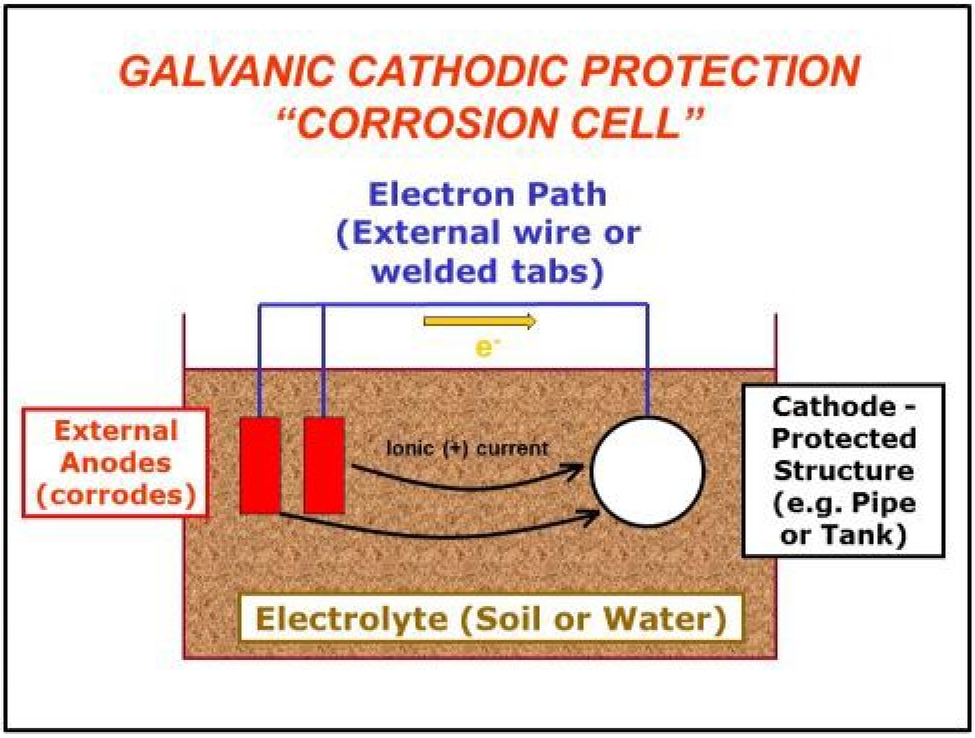


Figure 8. Diagram of Galvanic Cathodic Protection (Image from DoD 2004).

Impressed current cathodic protection systems, shown in Figure 9, essentially work the same way as GCP systems do by supplying a current for protection of a metal surface. In ICCP however, a direct electrical current is supplied to create potential difference between the anode and the surface of the protected structure (DoD 2004:10). The material for anodes in an ICCP system differ from a GCP system because they need to have the capability to pass current into the environment without being consumed at a high rate. The two most used materials for this are graphite and high silicon cast iron, but other materials such as magnetite and platinum have also been used (DoD 2004:10). Just like in GCP systems, a properly designed ICCP system will effectively prevent corrosion on the structure it is installed to protect (DoD 2004:10).

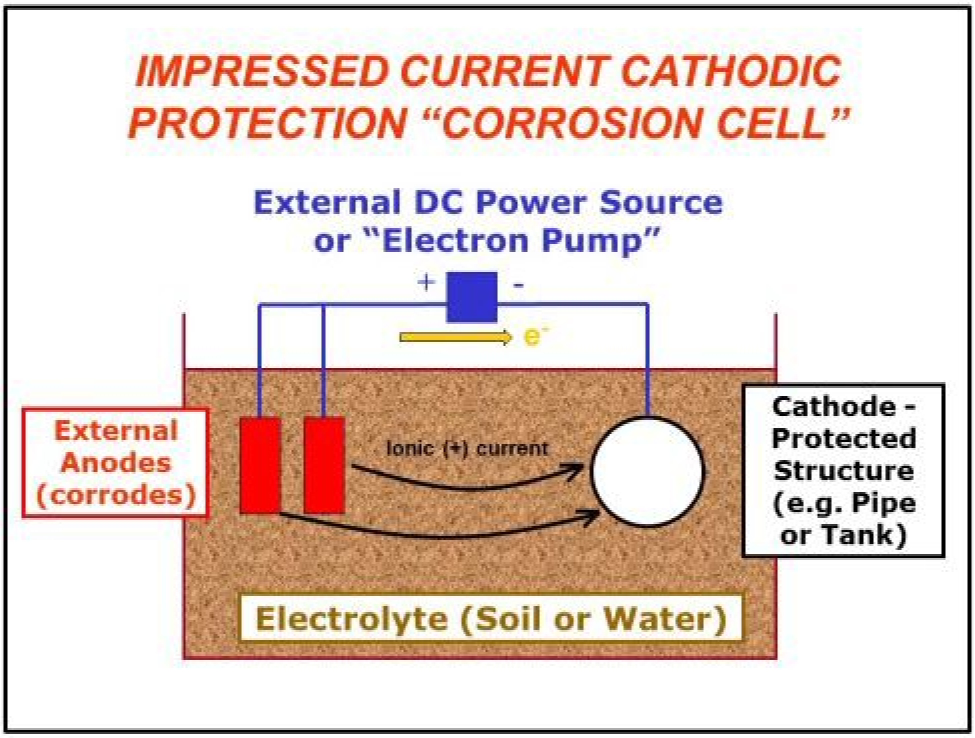


Figure 9. Diagram of Impressed Current Cathodic Protection (Image from DoD 2004).

Cathodic protection systems are and have been an important element in maintaining active warships for over a century. Whether a GCP system, an ICCP system, or both are used, both systems can reduce the life cycle costs by indefinitely sustaining a utility's lifetime (DoD 2003:1-2). The ability to prevent a ship's hull from corroding allows it to stay in action for a longer duration of time before dry docking for repairs and maintenance are needed.

The maintenance of an active warship was essential for keeping it in peak fighting shape and out on the open seas for the longest duration possible. Applying paint and protective coatings was one of the primary methods for preventing rust and corrosion but required continual maintenance. Cathodic protection systems were another prominent method used to prevent corrosion on ships' hulls, and these systems required less frequent periods of maintenance to keep performing. While both methods were the most common and highly effective, it is also true that parts of a vessel had to be replaced due to factors such as corrosion, getting worn out, or being considered out of date. While these replacements usually did not affect the hull of a ship, replacements were made to the hull when a ship took damage, such as the torpedo damage USS *North Carolina* took.

Museum Ship Maintenance Theory

Museum ships, just like active warships, require a great deal of attention to keep them in good condition and to prevent corrosion. These ships do not have the constant presence of a large crew moving around and wearing down the decks, but depending on visitation numbers, large amounts of tourists walking the decks can have a similar effect on the wear and tear of a vessel. Museum ships are also subject to weather and the environment in which they are berthed. The most important aspect of a museum ship to protect is the hull, because if the hull becomes compromised, the structural integrity of the entire ship is put at risk. Charles Gordon, the chief engineer and director of facilities for the USS *Midway* Museum stresses the importance of the hull on a ship museum stating, " 'Protecting the hull is the crux of my existence,'… Without an intact hull, 'none of us would have a job'" (Dougall 2013:21). There are several different types of hulls and each type requires different methods of preservation. Research into theories and best practices for maintaining museum ships indicates that there are four main areas to focus on: type of berth, paint, cathodic protection, and maintenance schedule.

<u>Type of Berth</u>

The methods of preservation vary based on the type of hull and the way a ship is berthed. There are for basic types of berthing: high and dry, fully afloat, aground, and embedded in ground or above ground. Museum ships berthed high and dry are berthed out of the water without any liquid ballasts present as well, such as the submarine USS *Drum,* which was removed from the water completely and placed on a land base (Morss 2007; USS Alabama Battleship Memorial Park 2017b). A ship that is berthed fully afloat will be subject to partial or complete grounding in low water conditions, and a ship that is berthed aground, which has partial liquid ballast to keep the ship aground under normal conditions will float during high water conditions (Morrs 2007). In the case of USS *North Carolina*, the ship is steel-hulled and berthed aground, which means that the ship is not floating but is settled into the mud in its berth. The way a ship is berthed affects the areas and ways that corrosion attacks a ship as well as the methods for preventing these types of corrosion.

Museum ships berthed aground are subject to normal corrosion but must also deal with many other corrosion factors. In an article exclusively discussing ship museums berthed embedded in the ground, Strafford Morss discusses how these ship museums "are attacked simultaneously 24/7 in at least five directions:" wind-water line corrosion, external galvanic corrosion, erosive effect of mud/sand rubbing the hull plate thin, internal galvanic corrosion, and structural degradation from anaerobic bacteria (Morss 2002b). These ships face more structural strain due to resting on the bottom surface. They also deal with more external corrosion since they are held in place, because this allows the waterline of a ship to fluctuate with the rise and fall of water levels since the ship no longer floats. Cathodic protection systems are unable to provide protection to the waterline of the ship due to fluctuating waterline (Morss 2007). It should be noted that in the case of USS *North Carolina,* the permanent cofferdam that has been constructed around it should help regulate the waterline level. USS *Alabama* is the best case of a battleship berthed aground using a permanent cofferdam to reduce corrosion, since it initially experienced severe hull leakage and oil releases due to its original mooring system which lacked the cofferdam (Morrs 2002b). Museum ships berthed aground also suffer from physical erosion such as mud or sand constantly rubbing against the hull it meets and eroding protective coatings away over time. The presence of internal liquids, such as those needed to flood ballast tanks to keep the ship on the bottom, creates an internal corrosion factor that must be considered as well (Morss 2007).

USS *Texas* serves as an excellent case study for the issues a ship that was berthed both aground and afloat faces. In its initial years as a museum ship, USS *Texas* was run hard aground in a dredged berth that was hydrofilled to twelve feet. Several of the ship's tanks were flooded to serve as ballast and keep it grounded (Moss 1993:3). While under the care of the Battleship *Texas* Commission, a lack of funding prevented major maintenance programs for the ship, however in the late 1960s, the deteriorating wooden deck was removed and replaced with a concrete deck. Finally, in 1983, due to its inoperable financial state, the Battleship *Texas* Commission relinquished ownership of USS *Texas* to the Texas Parks and Wildlife Department. The ship had received no bottom maintenance in the thirty-five years since arriving in San Jacinto and very little bottom inspection. More than ten of the ships bottom tanks were flooded from exterior hull penetrations, severe interior deterioration was also present, and the steel deck underneath the concrete deck replacement was dangerously corroded as well (Moss 1993:3).

Following extensive fundraising efforts, a donation from U.S. Congress through appropriations to the U.S. Navy, and substantial funding by the Texas Parks and Wildlife Department, extensive shipyard restorations began at Todd Shipyard, Galveston in December 1988. This project included replacing 350,000 pounds of steel on the hull and main deck, which required 40,000 rivets that were seal-welded on the underwater hull. A high-tech epoxy (anti-corrosive) coating was also applied to the underwater hull as well. After these repairs, additional interior repairs, and replacement of the concrete deck with a historic period wooden deck, USS

Texas returned to San Jacinto over thirteen months later (Moss 1993:3, 37-38). Instead of being berthed aground, which was the main cause of lacking bottom hull maintenance, USS *Texas* was given a permanent mooring system afloat. This was preferred since it allowed for easier access to inspections and repairs of the bottom. However, due to constant surges of water into the berth of USS *Texas* and a small maintenance crew, the traditional system of lines and winches was not practical, so the ship was attached to four monopiles by seven-foot collars along its starboard side (Moss 1993:45). Overall, the 1988 restoration of USS *Texas* cost over $6.9 million in repairs and over $5 million for berth redevelopment and wooden deck replacement (Moss 1993:61).

<u>Paint</u>

For the preservation of a historic vessel, painting is one of the best ways to prevent corrosion. *The Secretary of the Interior's Standards for Historic Vessel Preservation Projects with Guidelines for Applying the Standards* (SHVP) recommends "Applying appropriate paint or other coating systems to metals or alloys after stabilization or cleaning" (DOI 1990:40). SHVP includes "Failing to reapply protective coating systems to metals or alloys that require them after stabilization or cleaning, so that accelerated corrosion occurs" and "Failing to ensure that all surfaces, whether wood or metal, receive proper preparation before application of coatings" in its list of not recommended guidelines (DOI 1990:40). While a cathodic protection system is effective for protecting portions of the ship that are constantly underwater, it is unable to provide any protection to the most vulnerable part of the ship, the wind/water line. This area of the ship is best protected with a layer of anti-fouling and anti-corrosive paint. These coatings are often expensive to apply, but the initial cost is comparatively small when compared to other resources and the issues that arise if not applied properly (Morss 2002c). USS *Alabama* is an excellent example of the importance of proper painting for museum ships. USS *Alabama* was a *South*

Dakota class battleship that was commissioned in August 1942. It served in both the Atlantic and Pacific theaters during World War II, but was decommission in 1947 after the war ended in. The ship remained in reserve at the Puget Sound Navy Yard in Washington until it was struck from the Naval Vessel Register and set to be scrapped in June 1962 (Naval History and Heritage Command 2019). Like both the USS *Texas* and USS *North Carolina*, a statewide campaign to bring the ship to its namesake state began, and $800,000 of the $1,000,000 were raised to have the ship towed from Washington, and the rest was loaned to the Battleship Alabama Commission to be repaid once it opened to the public. The ship arrived in its berth in mid-September 1964, and once it was placed in its berth, it underwent four months of sandblasting, priming, and painting to prepare the ship for public visitation (USS Alabama Battleship Memorial Park 2017a). The fact that the last thing the ship went through before beginning its career as a museum ship was a long period of proper paint removal and repainting demonstrates the importance of protective coatings in museum ships. These concepts are directly aligned with the same topic discussed in *The Blue Jackets' Manual*, which emphasizes the importance of properly painting and preparing to paint surfaces for prevention of corrosion.

Cathodic Protection

Methods for preserving steel-hulled museum ships vary depending on several factors, but there are some methods that tend to be universal. One prominent method used for protecting a ship from corrosion is an impressed current cathodic protection system or a galvanic cathodic protection system. One article in the HNSA handbook states that "Impressed current cathodic protection should be mandatory" and NAVSEA now requires an ICCP system to be installed on new donation ships (Morss 2002b, 2002c). SHVP also encourages using "renewing or installing hull zincs" and "Designing an active or passive cathodic system to compensate" for the stray electric currents that may be in waters surrounding a historic vessel (DoI 1990:65). Whether using a GCP system, an ICCP system, or a combination of both, installing a cathodic protection system on a museum ship is essential.

Cathodic protection systems have a variety of benefits and limitations that must be taken into consideration when installing them on museum ships. As mentioned in the previous section about museum ship painting, cathodic protection systems are unable to fully protect the wind/water line of a ship. They are unable to protect a surface from physical erosion, nor can they improve the condition of a structure. Annual inspections and maintenance of cathodic protective systems, because it takes less than half a volt of difference to determine whether a system is effective or not (Morrs 2002b). Monitoring a cathodic protection system's performance can be done by measuring the structure's potential, measuring the supplied current, or both methods when possible. Scheduled maintenance can include inspections and adjustment of equipment, while unscheduled maintenance can include troubleshooting and repairing faulty equipment identified from inspections (DoD 2003:1-2).

Maintenance Schedule

The method that encompasses all preservation practices for museum ships is having a well-planned maintenance schedule. In the SHVP's definition of preservation, it emphasizes the need for a maintenance schedule stating that preservation is, "the act or process of applying measures to sustain the existing form, integrity and material of a vessel. It may include initial stabilization work, where necessary, as well as ongoing maintenance" (DoI 1990:4). This definition largely encompasses the acts of protection and stabilization which are also defined by SHVP, and it asserts that "good historic preservation practice demands that the preservationist adhere to one basic precept in all work undertaken: to retain and preserve to the greatest extent possible the historic form and fabric of the vessel" (DoI 1990:10). The document also acknowledges that the process of preservation never ends and requires regular and thorough inspections as well as cyclic maintenance such as refinishing or repainting sections of the ship (DoI 1990:11). A good maintenance schedule ensures that cathodic protection systems and that protective coatings are functioning properly. Ensuring that all systems designed to protect a vessel from deterioration is the best method for sustaining the structural integrity of a historic vessel.

Two cases that demonstrate the importance of having a well-planned maintenance schedule are *Texas* and USS *Olympia.* In 2012, USS *Texas* again saw the effects of the difficulties in maintaining a historic vessel come to fruition in the form of two flooding events. From June 9-22, thirteen tanks and fifteen compartments flooded due to a leak in the vessel's hull. The leak was located and patched and dewatered during this period. However, on June 23, a leak starting in the blister caused hull failure and over 5,000 tons of water leaked into the ship causing an eight foot draft decrease in the stern and four foot draft increase at the bow as well as a six degree list to the starboard side (Smith and Davis 2012). Ninety-five patches were needed to repair leaks in the hull, and the listing of the ship due to flooding also damaged the ship's mooring system. In total, over $2 million were needed to repair the ship from these flooding events (Smith and Davis 2012). These major flooding events, and subsequent continual minor flooding events proved that the current program of patching leaks is no longer viable. As of today, USS *Texas* is awaiting a $35 million restoration project that has been approved and funded as well as a new location for its berth which is still being decided upon (Bramlett 2019). The inability of USS *Texas* to maintain its protective systems at a high level allowed the aging hull to deteriorate and cause major leaks and flooding in the vessel. These events show how important it is to not just identifying a problem and fix the results of the problem, but also to identify what can be done to prevent similar problems in the future.

USS *Olympia* was commissioned on 5 February 1895, having served in the Spanish American War and World War I, where it brought home the body of the Unknown Soldier. The ship was placed in a reserve status and received its first dry-docking in twenty-three years in 1944 and was officially stricken from the Naval Register on 2 January 1957 (Evans 2016). USS *Olympia* received additional repairs and preparations to be safe for public viewing following this, and then it was provided a berth at Municipal Pier 9 North in Philadelphia, PA. Unfortunately, the river traffic and tides caused the ship to continually part its mooring lines berth, which led to it being moved to Pier 4 South. In January 1996, USS *Olympia* was moved into the newly constructed Penn's Landing and Independence Seaport Museum assumed care for the ship as well as the submarine *Becuna* (SS-319) (Evans 2016).

Lack of funding prevented adequate preservation efforts on USS *Olympia*. The inability to dry-dock the ship led to profuse hull corrosion. Additionally, the Douglas Fir on the ship's weather decks was deteriorating, which led to many leaks. Some preservation efforts were made, such as reducing asbestos in public access areas, installing a waterproof membrane on the weather decks, and restoring the original skylight and scuttle on the after main deck (Evans 2016). In March 2003, a fire broke out on the ship causing damage to a small area below decks. 2003 estimates put the cost of fully restoring USS *Olympia* at over $30 million. In 2011, Independence Seaport investigated transferring ownership of USS *Olympia*, however no organization was able to provide a viable long-term solution. Instead, extensive fundraising was begun to raise the necessary $10 million needed for hull repairs (NewsBank 2014). Continual hull maintenance and minor repairs have been conducted due to grants from the National

Maritime Heritage Grant Program and other grant programs (Allen 2015). Like USS *Texas* and USS *North Carolina,* USS *Olympia* received very little maintenance in the first few decades after it transitioned into a museum ship. The lack of maintenance such as dry docking or repainting for a ship berthed afloat allowed the hull to deteriorate. A proper maintenance schedule that included scheduled dry docking would have helped to reduce deterioration and in return would have reduced the need for costly major repairs. Investing initial funds into developing protective systems for a ship's hull, such as protective coatings and cathodic protective systems, and creating a detailed maintenance system to provide for maintaining these systems and identifying other issues will likely save museum ships a great deal of money in future repair costs.

Cultural Tourism and Historic Preservation Theories

While most of the aspects to theories related to cultural tourism and historic preservation do not deal specifically with historic vessels, there are portions of these theories that contribute to guiding practices of historic vessel management. One of the major issues between historic vessel preservation and tourism is understanding the effect that tourism has on a cultural heritage asset, such as USS *North Carolina.* In an essay in the book, *Cultural Tourism and Sustainable Local Development* (2010)*,* Harry Coccossis claims that:

> The wear and tear on monuments by visitors (physical impacts), noise, pollution and waste (environmental impacts), congestion, rising costs of services, land-use change and competition (economic effects), and the commercialisation of culture, loss of tradition and other (socio-cultural) effects are often quoted as evidence of negative impacts from tourism (Coccossis 2010:49).

He goes on to argue that the negative impacts tourism has on a destination might also have negative feedback effects on the tourism activity itself, which creates a destructive cycle for the cultural heritage asset (Coccossis 2010:50). The physical impacts that tourists can have on a ship are the most pertinent subject discussed in this chapter. Physical deterioration from tourism manifests itself due to a variety of factors: a lack of resources to deal with deterioration, a lack of methods to monitor risk of damages or loss to an asset, and a lack of methods for preventing the acceleration of natural processes of destruction (McKercher and du Cros 2002:61). McKercher and du Cros also discuss the negative consequences of a poor relationship between cultural tourism and cultural management, claiming that high visitation without signaling can result in tourists defining experiences themselves and "a bored tourist can sometimes be a destructive or disrespectful tourist" (du Cros and McKercher 2007:25). The inability to generate revenue through tourism or lack of tourism prevents cultural heritage sites from generating the funds necessary for often expensive preservation strategies. The need to generate funding from tourism often prevents sites from shutting down for maintenance or monitoring at risk areas, since closing a site prevents it from generating these funds. These impacts can be exasperated by the unethical actions of tourism operators who encourage or permit inappropriate uses of cultural assets, which often lead to the destruction of these assets (McKercher and du Cros 2002:23). While there are several negative impacts that tourism can have on preservation, McKercher and du Cros also point out that the "appropriate presentation of assets can assist the tourists' understanding of the need for conservation and retention of important cultural heritage assets in general", and that "revenue from tourism can be reinvested in documentation, planning, and management of heritage assets" (McKercher and du Cros 2002: 61-62).

Building Life Cycles or Life-Cycle Analysis (LCA) is one of the most relevant historic preservation theories relating to historic vessels. This theory breaks buildings down into building elements, which are then divided into four categories: structure, building envelope, interior elements, and systems. These categories are used to create a working list that separates building components based of their lifestyle (Tyler et al. 2009:304). Structural elements are intended to be constructed for survivability and should be built to last a long time. Regarding a historic vessel, the interior beams, bulkheads, and frames create the structure element. These create the backbone and support for the entire vessel and are built out of durable materials out of necessity. LCA claims that "when survivability is achieved, almost unlimited durability is achieved at the same time" (Tyler et al. 2009:305). The building envelope consist of outer materials used to cover the interior and structure of a building. These elements are exposed to weathering, thus periodic renewal is impossible to avoid. Periodic renewal refers to tasks ranging from simple maintenance, like painting, to partial replacement (Tyler et al. 2009:305). The building envelope of a historic vessel would include the hull, deck, superstructure, and other elements not located below decks. The hull is subject to both weathering and a continually changing waterline, while the rest of the ship's building envelope is exposed to traditional weathering. Interior elements and systems are supported and protected by a buildings structure and building envelope, which makes controlling the interior environment for preservation much easier. Life-Cycle Analysis can allow preservation management teams to understand and prioritize maintenance and preservation projects for historic vessels.

Conclusion

Preservation management of historic vessels requires a balance between historic preservation, cultural resource management, and tourism. The historic vessel must be preserved and protected due to the historical importance that society deemed it had, but it also must also be available for tourism to be displayed to that society, otherwise, it is a waste of money preserving a historically important vessel that people are unable to appreciate. This chapter discussed common practices used in maintaining both active warships and museum ships, in order to compare the two and understand the effects these methods can have on a vessel if not done properly, and also to look for underlying theories that can be extracted from these practices due to a lack of an overarching theory for historic vessel preservation. It also discussed theories in historic preservation and cultural tourism for the purpose of exploring the tension between the principals of preservation in historic preservation and use in cultural tourism regarding historic vessel. Finding a way to balance the need for both is key to successful preservation management of a historic vessel.

CHAPTER FOUR: RESEARCHING AND REBUILDING USS *NORTH CAROLINA*

Introduction

To accurately understand and represent the state of USS *North Carolina*'s preservation, a multifaceted methodology was implemented. This project plan incorporated extensive historical research and analysis of theories regarding active warship maintenance and museum ship preservation, historic preservation, and tourism. Additionally, a digital model of the ship was created, using the three-dimensional modeling program *Rhinoceros 6.0* (Rhino), to help visualize and assess the state and progression of preservation issues that USS *North Carolina* has experienced. The use of Rhino models was critical for the final analysis of this project. Essentially, this project consisted of a combination of historical research and 3-D modeling to analyze past and present preservation issues of USS *North Carolina*, and to determine best practices for museum ships in similar environments moving forward. Initially a literature review of the research phase will be provided, which will detail resources used and the way they were applied. It will focus on the four main topics of research: USS *North Carolina* history, active warship maintenance, museum ship management practices, and historic preservation and cultural tourism. This will be followed by a detailed discussion of the modeling process that will discuss the building methods and issues faced in the modeling phase. The chapter will end with a brief discussion on how the Rhino model results were interpreted in preface to a larger discussion on this subject in following chapters.

Literature Review

The initial task of this project was to gather information on four topics: USS *North Carolina*'s history, active warship maintenance, museum ship management practices, and historic preservation and tourism. Dividing these topics into individual objectives created a more focused and efficient approach for research. The research relating to the history of USS *North Carolina*, included pre-WWII naval history, active duty history of USS *North Carolina*, and the ship's history after being converted to a museum. Research relating to active warship maintenance investigated methods of upkeep and preservation used on active duty warships to see how those actions could have affected that state of preservation on USS *North Carolina.* Museum ship management practices were also explored in order to understand common practices used. These common practices were then analyzed for effectiveness and compared to the practices undertaken by those in charge of USS *North Carolina.* Finally, historic preservation and tourism theories were explored so that they could be examined in relation to museum ship management practices and compared to see if these management practices were lacking in any areas or not. A combination of primary sources and secondary sources were explored to retrieve the necessary information on these subjects. This section describes the historical research phase in the order it occurred, which begins with information about the history of USS *North Carolina.*

<u>USS *North Carolina* History</u>

The initial topic of research was focused on gathering information about the history of USS *North Carolina*. This included research into pre-World War II naval strategy and history that would help understand the reasoning behind the design of the ship. Research into USS *North Carolina*'s time as an active duty warship composed a significant portion of this phase as well. The research on this topic concluded with studying the literature written about the battleship's time as a museum ship.

Literature written about the pre-World War II period of both the United States and international naval history was the first topic that was studied in relation to USS *North*

Carolina's history. It was imperative to develop an understanding of this time period because the policies and ideologies of that era shaped the design of the first battleship the United States had built in over sixteen years. Most of the literature from this portion of research consisted of secondary sources retrieved from East Carolina University's Joyner Library. An excellent general overview of international policies and ideologies regarding naval power were provided by Lisle A. Rose in *Power at Sea Volume I: The Age of Navalism 1890-1918* and *Power at Sea Volume II: The Breaking Storm 1919-1945* (Rose 2007a, 2007b). These two volumes discuss the effects World War I and the shipbuilding programs started late into that war had on creating a naval arms race leading up to World War II. They also discussed the inter-war attempts at limiting this arms race with treaties such as the Washington Naval Treaty and the London Naval Treaty of 1930, discussed fully in the history chapter. Another source that provided a more focused presentation of information regarding the United States Navy and its obsession with battleships was *Sacred Vessels: The Cult of the Battleship and the Rise of the U.S. Navy* by Robert O'Connel (1991). This book provided a more detailed account of the Washington Naval Treaty and focused intently on the rivalry that developed between the Japanese and American navies leading up to World War II.

Once a foundational understanding of pre-World War II naval history had been established, research focused on the design and construction of USS *North Carolina* ensued. Again, a great deal of sources on this topic were retrieved from Joyner Library. Most of these sources consisted of dictionaries written about battleships or naval ships, in general (Friedman 1985; Mooney 1991; Garzke 1996: Whitley 1998; Sandler 2004). These sources provided information on both the design of USS *North Carolina* as well as a general overview of the ship's active duty history. Ascertaining information such as the thickness of each deck in addition to armor and hull thickness were crucial bits of information that would assist in analyzing the preservation of the ship. Ben Blee's monograph *Battleship North Carolina* provided a source that was much more focused than the large dictionaries, which only provided general overviews. Blee included a similar amount of detail about the overall design specifications of the ship but went much more detail when discussing the design and construction process, which required seventy-seven designs before a final design was agreed upon. Additional research into this topic was retrieved from a January 2019 visit to the Battleship North Carolina Memorial Archives. This visit provided access to the ships design plans as well as other historical documents that augmented data on the specifications of the battleship (Battleship *North Carolina* Memorial Archives 1947, 2004, 2011).

The research related to the active duty history of USS *North Carolina* was retrieved from largely the same sources as those used to ascertain information relating to its design and construction. The multiple ship dictionaries provided a general overview of the campaigns the ship participated in, Ben Blee's monograph provided slightly more details related to this era of the ship as well as a detailed account of the torpedo damage the ship suffered in September 1942. The visit to the Battleship North Carolina Memorial Archives also provided more information about the ship's active duty history. This included a damage report from the September 1942 torpedo incident and general write ups of the ship's operational history. A large portion of the data collected from the archive visit was retrieved from digital folders that were not inserted or stored in a traditional archival system. This required the author to create a system of labeling the folders and subfolders to adequately cite each utilized source.

The final portion of research into USS *North Carolina*'s history involved reviewing literature relating to its time as a museum ship. *Battleship North Carolina* by Ben Blee provides the most information in a published monograph about the ship's time post-operational warship duty. The website for the USS *North Carolina,* http://www.battleshipnc.com/, also served as a strong source for discovering information regarding the ship's time as a museum ship. Additional information regarding USS *North Carolina* as a museum ship was retrieved from newspapers and press releases relating to projects the ship is undertaking (North Carolina Department of Cultural Resources 2001a, 2011b, 2015; Hotz 2010; StarNews 2012; Thompson 2017; Battleship North Carolina 2018a).

Active Warship Maintenance

Researching the practices and theories behind maintaining an active duty warship was important, so that when analyzing the state of USS *North Carolina*'s preservation, past actions and how they adhered to standard practices could be included. Information gathered on this topic was pulled from a heavy number of primary sources that were supplemented with secondary sources. A review of literature on this topic resulted in findings that showed there were two major categories involved with the maintenance of an active warship's hull: painting and cathodic protection.

The first line of defense an active warship has against corrosion is its paint. Research into the different types of protective coatings, their common ingredients, and application methods were the principle focus of this subject. Most of the information found related to this topic came from *The Bluejackets Manual 11th ed.* (United States Naval Institute 1943). This manual for United States Navy sailors details every aspect of life in the navy that new sailors would need to know, including procedures for painting and the proper techniques for removal and reapplication of paint. *The Bluejackets Manual* also provided information about the different types of coatings such as anticorrosive and antifouling bottom paints. Secondary sources uncovered supplemental information about the development of new types of paint, as well as the ingredients commonly used in the different paints (Marine Engineering & Shipping Age 1924; Rock 1931; Morrs 2002a).

The other prominent method for preventing corrosion on active warships was the use of cathodic protection systems. A large section of the information was gathered from documents published by DoD, describing the design of cathodic protection and the operation and maintenance of these systems (DoD 2003, 2004). These documents covered the differences between the two main types of cathodic protection systems discussed in the theory chapter: GCP and ICCP systems. Additional information regarding the effectiveness of the types of cathodic protection systems as well as issues and other general information related to cathodic protection systems were retrieved from articles in the Historic Naval Ships Association (HNSA) handbook as well as other journal articles and are discussed more in-depth in relation to museum ship maintenance.

Museum Ship Management Practices

The next phase of research focused on information relating to management practices for museum ships and the theories that govern those practices. Studying this topic was essential, because most preservation issues that ships converted to museum ships face occur during this period. The prevalence of preservation issues an active warship ship converted to a museum ship faces is due to a variety of factors, such as the lack of funds or a sizeable labor force required to execute the level of maintenance a large vessel requires. To fully understand the state of preservation USS *North Carolina* is currently in required obtaining knowledge on common practices undertaken to preserve museum ships. This knowledge allowed comparisons to be drawn between common practices and the practices taken by the caretakers of USS *North*

Carolina, which allowed for a more complete analysis to be undertaken. Studying the literature on this topic revealed four categories that were essential components to the management practices for museum ships: the type of berth in which a museum ship is placed, the paint and protective coatings used on a museum ship, the type of cathodic protection implemented, and a museum ship's maintenance schedule.

In what type of berth will the ship be stored? This is one of the first decisions managers of a new museum ship must make before the museum ship even arrives. The type of berth in which a museum ship is placed determines what methods of preservation can and should be used on it. Much of the information on the different types of berths museum ships can be housed in came from articles written by Strafford Morss in *HNSA Operations Handbook* (Morss 2002b, 2007). This information discussed the four major types of berths: high and dry, fully afloat, aground, and embedded in ground or above ground (Morss 2007). Once an understanding of the types of berths was achieved, researching the berth type USS *North Carolina* is in (embedded in the ground) as well as how other museum ships from a similar period were berthed became the primary focus. The two main ships that were studied were USS *Texas* and USS *Alabama.* USS *Texas* provided a case study of a ship with similar berthing to USS *North Carolina* and the resulting issues, while USS *Alabama* provided a case study of the effects a permanent cofferdam has on the preservation of a ship (Moss 1993; Morss 2002b; USS Alabama Battleship Memorial Park 2017b).

The next two categories of museum ship maintenance researched were painting and protective coatings and cathodic protection. The research into this topic focused on literature such as *The Secretary of the Interior's Standards for Historic Vessel Preservation Projects with Guidelines for Applying the Standards* (SHVP) and *HNSA Operations Handbook* with supplemental information drawn from a case study of USS *Alabama* (DOI 1990; Morss 2002c). SHVP provided information that emphasizes the importance of protective coatings and having them applied appropriately (DOI 1990:40). Articles from *HNSA Operations Handbook* provided information about different types of coatings and their effectiveness, as well as discussing the areas on a ship that are most important to protect with protective coatings (Morss 2002c). SHVP also included a discussion on the topic of the benefits of using an active or passive cathodic protection system on historic vessels (DOI 1990:65). Articles from *HNSA Operations Handbook* further discussed the capabilities and limitations in a cathodic protection systems ability to protect a historic vessel (Morss 2002b, 2002c).

The final category of this topic that required research was the maintenance schedule around which museum ships function. Ultimately, the actions of the initial three categories fall under this category. Most research on this topic looked at case studies of USS *Olympia* and USS *Texas* and the negative effects that lacking a well-planned maintenance schedule had on these vessels (Smith and Davis 2012; NewsBank 2014; Allen 2015; Evans 2016; Bramlett 2019). This research showed how a well-planned maintenance system keeps all other preservation actions functioning at a high level and thus prevent corrosion.

Historic Preservation and Cultural Tourism

The final stage of reviewing literature involved research into the principal theories of historic preservation and cultural tourism relating to museum ship preservation. This portion of the research was undertaken to obtain a better understanding of how common management practices for museum ships align with theories of historic preservation and tourism, since a museum ship serves as both a historic object and a tourist attraction. It was important to gain an understanding of how tourism can affect cultural heritage assets and how the two ideologies can work together for the best outcome. The literature that was studied for this topic consisted of books that provided a general overview of the concepts of cultural tourism, historic preservation, and the relationship between the two (McKercher and du Cros 2002; du Cros and McKercher 2007; Tyler et al. 2009; Coccossis 2010). Cultural tourism literature that was examined largely discussed the impacts, both physical and financial, that tourism has on cultural heritage assets. Research into historic preservation provided a theory known as Building Life Cycles or Life Cycle Analysis (LCA) that has a pertinent relationship to historic vessels (Tyler et al. 2009). This theory provided a foundation for which to assess the priority of what portions of a ship should be preserved first and what sections of a ship are at a higher risk of deterioration than others. Once research was completed on this topic, the literature review phase of the project was complete, and the modeling phase was ready to begin.

3-D Modeling (Rhinoceros 6.0)

3-D models of historic ships provide tools for archaeologists and historians when pursuing research on this topic. 3-D models not only provide a visual aid to researchers but contain immense amounts of historical data that have a great deal of potential for analytical purposes. By recreating the construction process, the modeler can examine the reasoning behind building an object, which often helps reveal techniques and processes used by the original builders (Fox 2015:93). The process for creating the 3-D model of the USS *North Carolina* was executed in several stages that will be discussed in this section.

The modeling process began with the collection of Booklet of General Plans for U.S.S. *North Carolina* prepared at the Navy Yard, New York in September 1944 (BuShips 1944a). As mentioned earlier, these plans were gathered from the archives of the Battleship North Carolina Memorial in January 2019. Once collected, these plans were uploaded into the 3-D modeling program *Rhino,* discussed earlier. These plans served as a guide for tracing the lines of the ship and creating an accurate model based off the plans.

Initially, the profile plan was uploaded into *Rhino*, and then twenty-five cross section frames that ranged from frame 1 to frame 174 were inserted into their appropriate place on the profile plan of USS *North Carolina* (Figure 10). These cross sections were taken from BuShips September 1941 Cross Section Diagram of U.S.S. *North Carolina* (BuShips 1944b). Ideally, having the lines drawing for USS *North Carolina* would have been the most accurate method for creating the correct hull curvature, however the lack of said plan required the use of individual cross section at different frames that were traced to provide the ship's lines. Once placed in its proper location along the profile plan, each cross-section diagram was traced from the keel to the main deck along the starboard side of the vessel (Figure 11). The cross-section diagrams were all oriented looking forward down the ship. Some of the cross sections did not line up exactly with the profile drawing, and once all were completed, some of the lines required extensions to meet where the deck line should have been. It should be noted that these plans may not have been as accurate as an actual plan with the lines drawing would have been, and this fact along with potential user error likely contributed to slight inaccuracies where the main deck and hull come together.

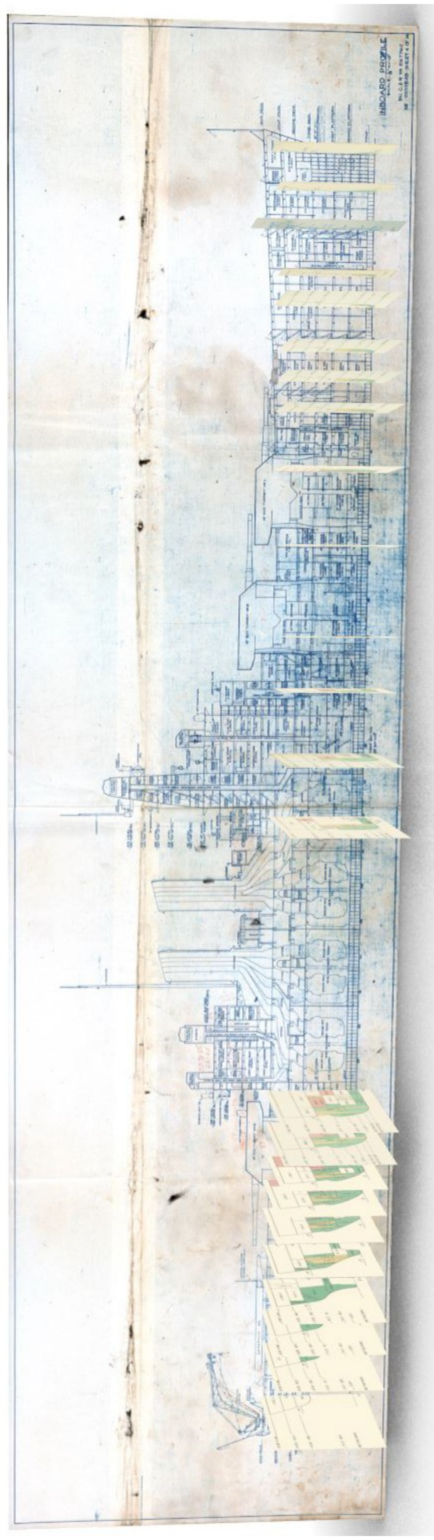


Figure 10.Profile plan with cross section plans inserted in appropriate locations. (Image by Author 2020).

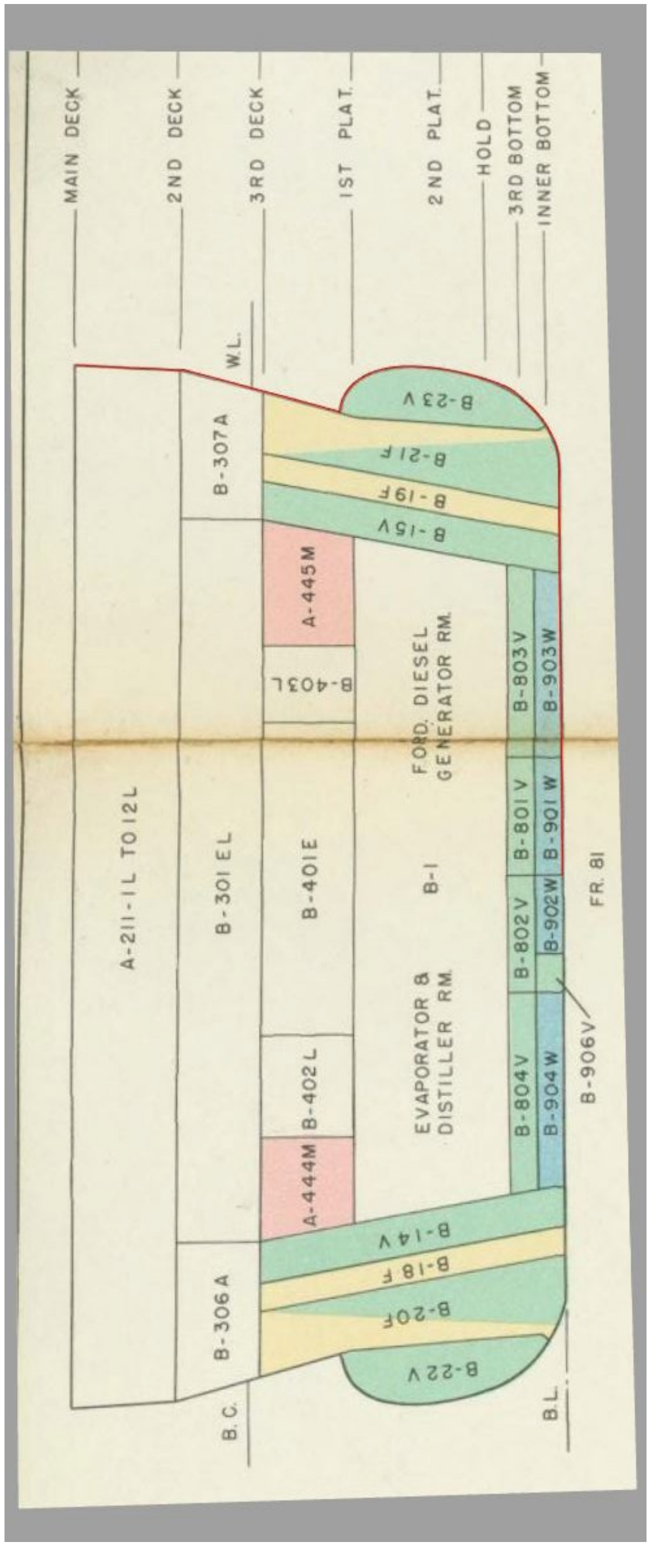


Figure 11. Line tracing of cross section diagrams to create ship's lines. (Image by Author 2020).

Once all the cross-section lines were drawn, the starboard half of the ship's hull was created in Rhino. This was done by selecting all the completed lines traced from the cross-section drawings and using the loft function (Figure 12). However, due to the complex lines along the ship's hull as well as the uniquely shaped bow and stern of the ship, the initial attempt to create the hull out of a single loft was unsuccessful. Much of the issue with creating a clean loft centered on the USS *North Carolina*'s twin skeg design. Overcoming this obstacle required using a combination of the loft and sweep functions in different sections of the ship. In total, eight separate sections were individually rendered using either a tight loft or a sweep and then combined using the join function (Figure 13). With the starboard side of the hull rendered, the mirror function was used to duplicate the rendered starboard hull across the y-axis creating the hull for the port side. This was then joined to the starboard hull, which created the completed hull (Figure 14).

The completion of the hull as close to historical accuracy as possible was the starting point for the rest of the model. However, by using the hull as the foundation for building the rest of the model, it created a disadvantage that limited the accuracy of the rest of the model. The rest of the model had to conform to the shape of the hull regardless of whether the blueprints did or did not align perfectly with the created hull. This mainly affected lower decks, particularly the void spaces running longitudinally close to the outer hull that served as part of the ships protection system. Although this limitation existed, it did not affect most of the components of the model needed for analysis.

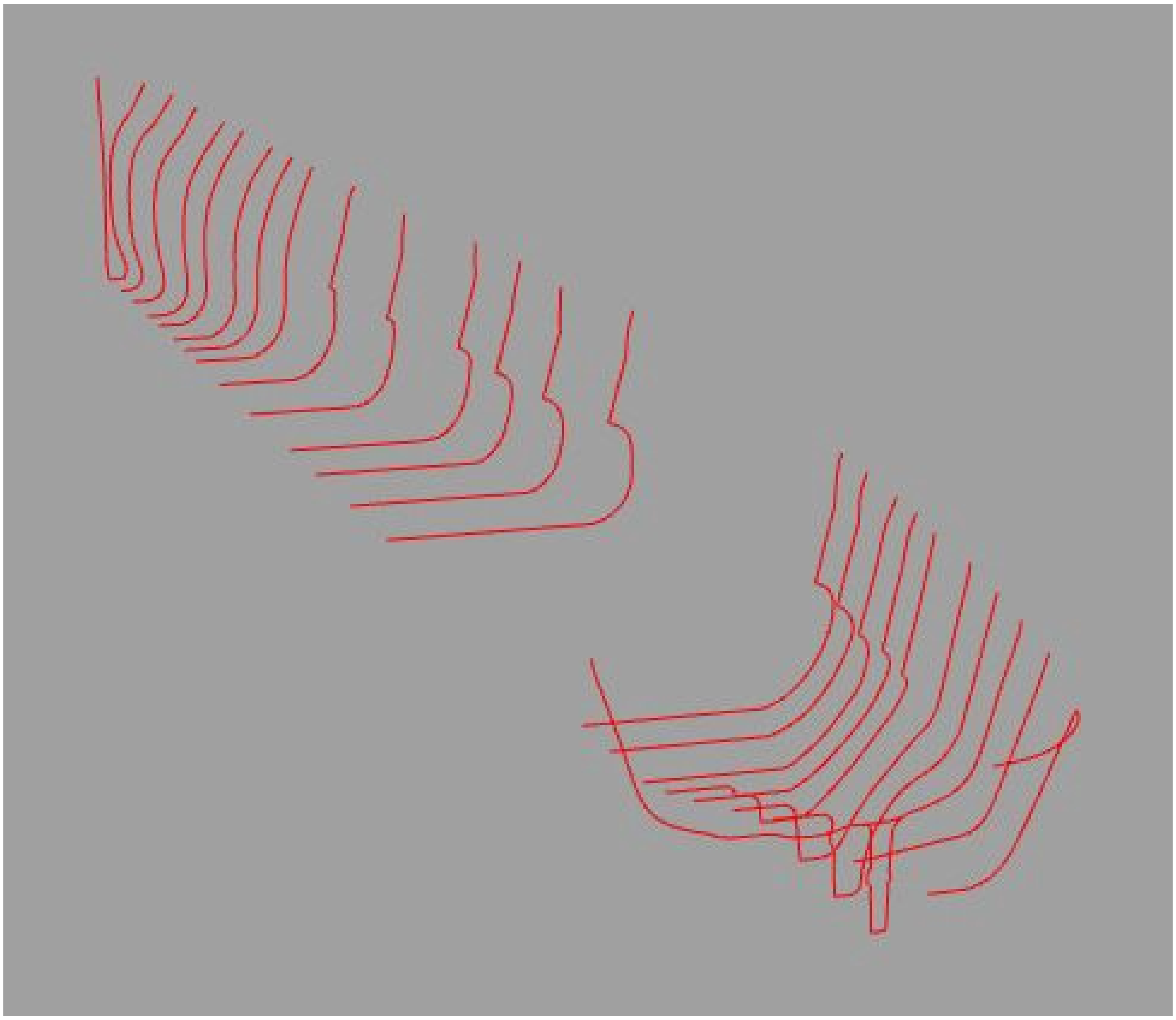


Figure 12. Isometric view of final lines (half breadths) representation of USS *North Carolina* hull (Image by Author 2020).

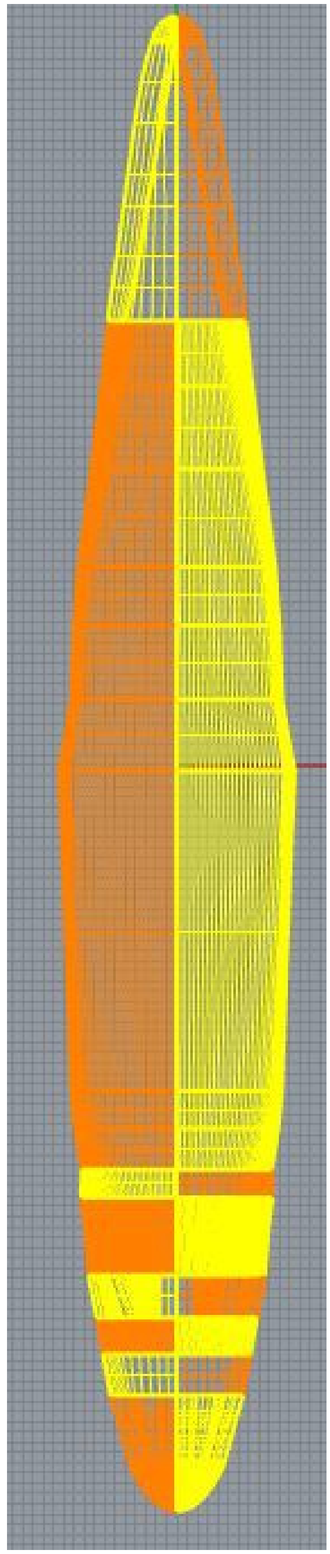


Figure 13. Plan view with highlighted areas depicting the individual sections lofted to create a completed hull. (Image by Author 2020).

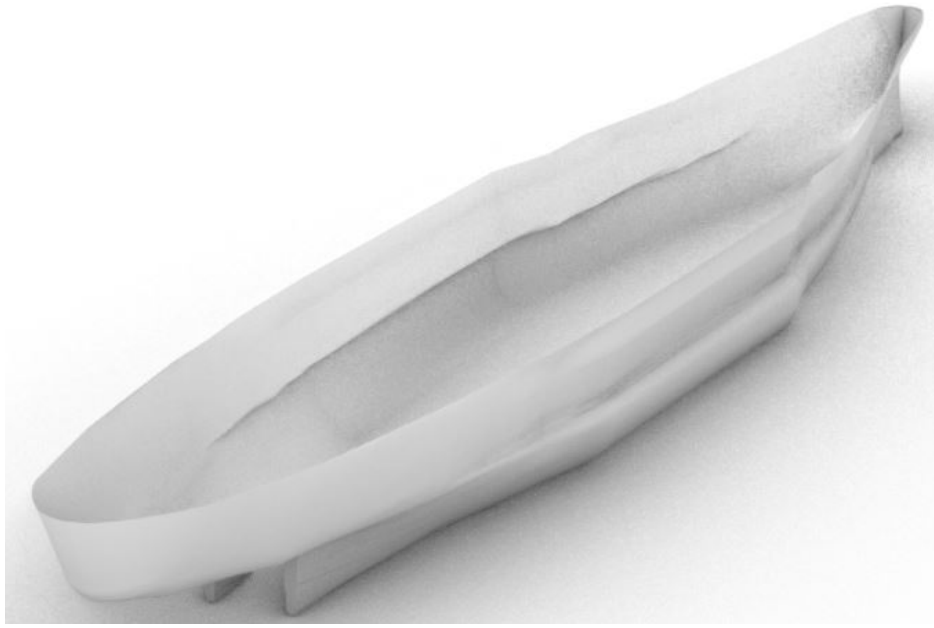


Figure 14. Rendered hull after combining individual sections and mirroring. (Image by Author 2020).

The next phase of building the model consisted of creating the main deck and the six decks below the main deck: the half deck, second deck, third deck, first platform, second platform, and hold (Figure 15). Each of these decks were created by tracing the deck line along the inboard profile plan of each deck and then extruding each line out into a rectangular surface. The hull was then used as a trimming tool to remove any excess surface outside of the ship's hull, which gave each deck its shape. Due to the complications of joining the separate hull sections together, a clean trim could not be achieved. This required trimming each deck in segments as well and joining them together to create the complete deck. The only deck that did not use this technique was the main deck, which required tracing the outline of the hull at the main deck line, extruding that curve into a surface, and finally using the extruded surface to trim the main deck surface.

2020).

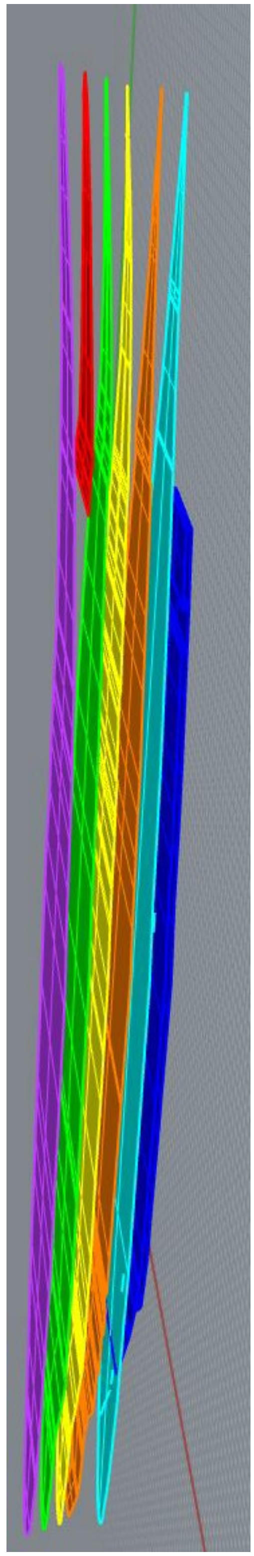


Figure 15. Shaded view depicting each of the decks below the main deck. (Image by Author 2020).

Once each of the lower decks were completed, the bulkheads and longitudinal lines of each deck were the next components to be added. The bulkheads were created by tracing the major bulkhead lines visible on the Inboard Profile schematic of USS *North Carolina*. After all the bulkhead lines were traced out, they were extruded into surfaces and trimmed using the hull of the ship as a cutting tool (Figure 16). Once the bulkheads were complete, the longitudinal lines depicted by each deck's blueprints were traced out deck by deck. Once all the lines on an individual deck were traced out, they were extruded vertically and trimmed using the deck they represented and the deck above them as trimming tools (Figure 17).

The next phase of model construction, once the structure of the ship from the main deck down had been completed, was building the super structure. This task was completed by tracing out the deck lines of each level of the superstructure deck from the main deck up. First the main deck's lines were traced and extruded up to the level of the deck above it, the superstructure deck. This included tracing out two of the main turrets as well as four of the 5-inch batteries. This process was replicated on the remaining superstructure decks up to the 3rd level above the superstructure deck on the aft portion of the ship and the top of chart and pilot house on the forward portion of the ship. Creating the rest of the forward portion of the superstructure above the pilot house required tracing the structure of the remaining portion of the tower and extruding it out. Once the tower was created, the outer balconies wrapped around it were created and lined up with the profile of the ship. Finally, the smokestacks were traced and extruded up to align with the blueprint and the superstructure of the ship was largely complete (Figure 18). The only other component of the model remaining that was created by the author was the rudder and propeller shafts.

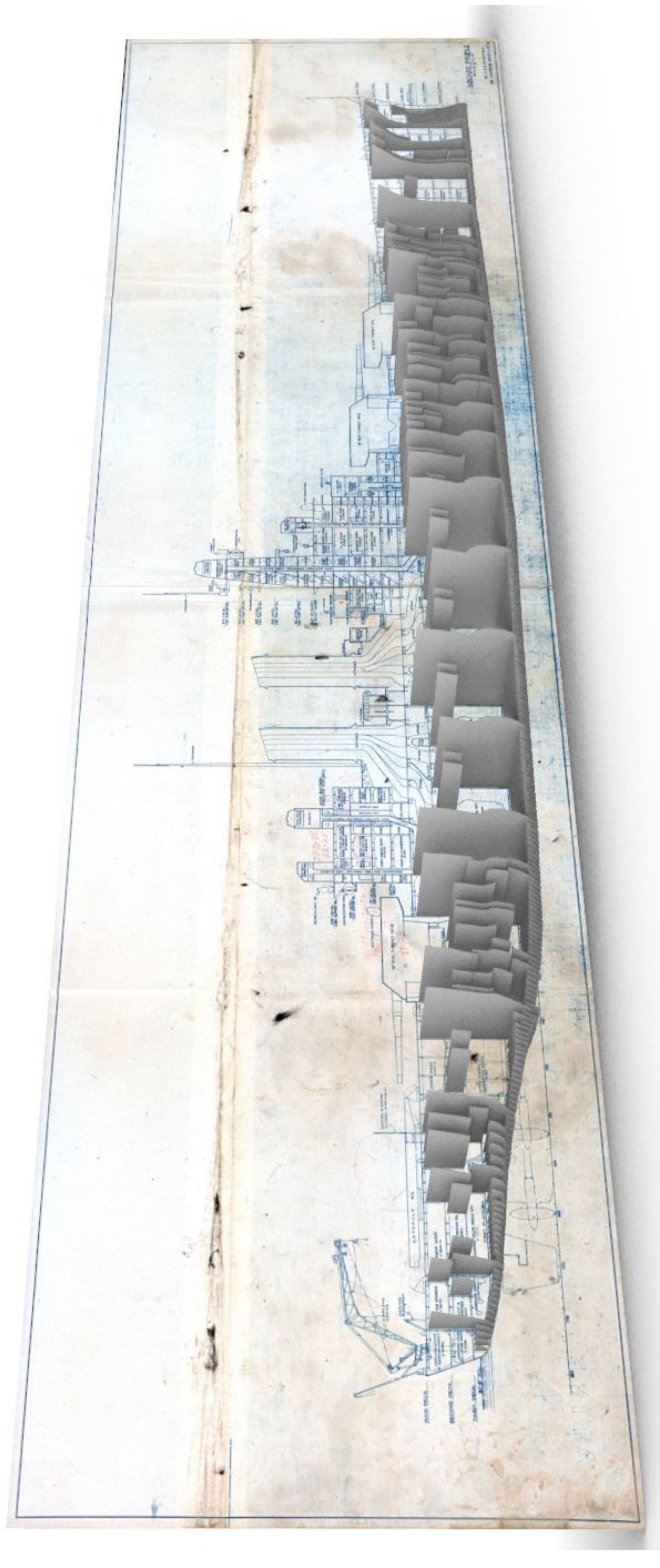


Figure 16. Bulkheads lined up with Inboard Profile plan. (Image by Author 2020).

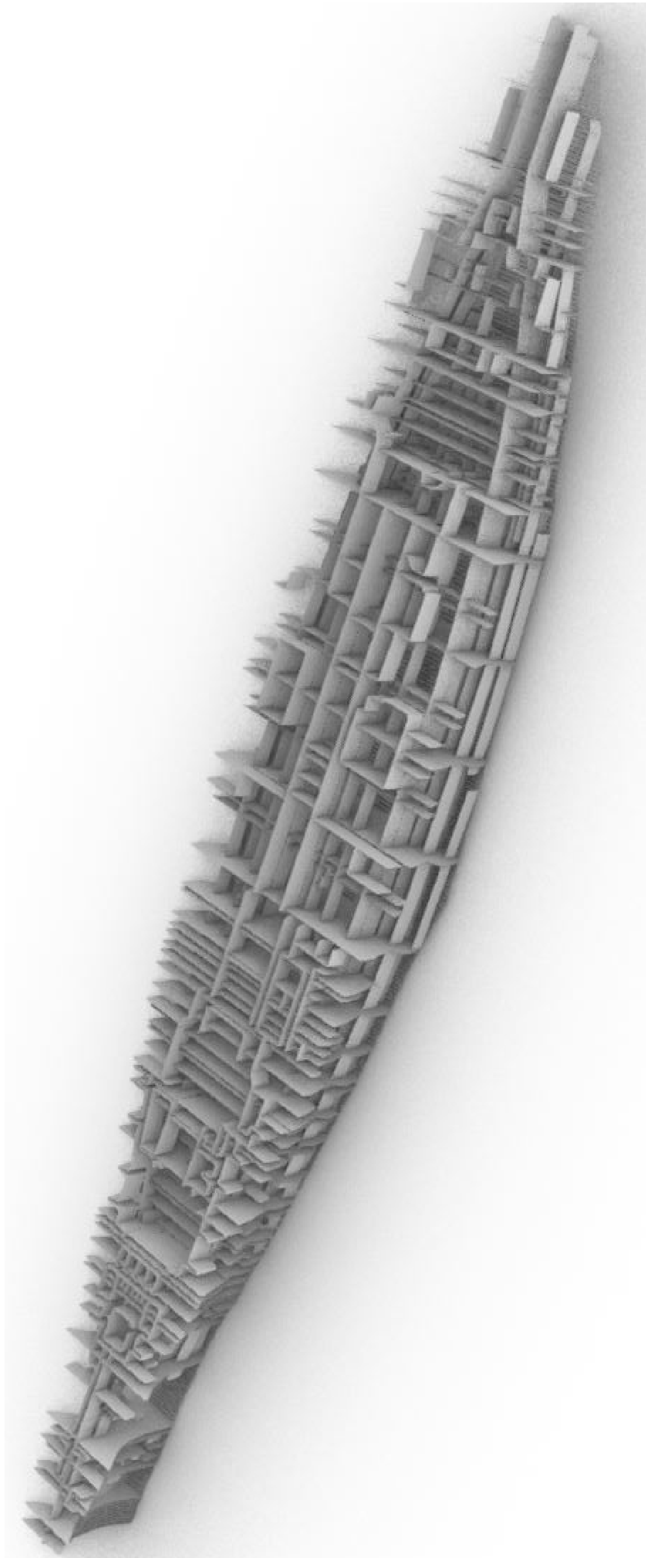


Figure 17. Rendering of bulkheads and longitudinal structures of USS *North Carolina*. (Image by Author 2020).

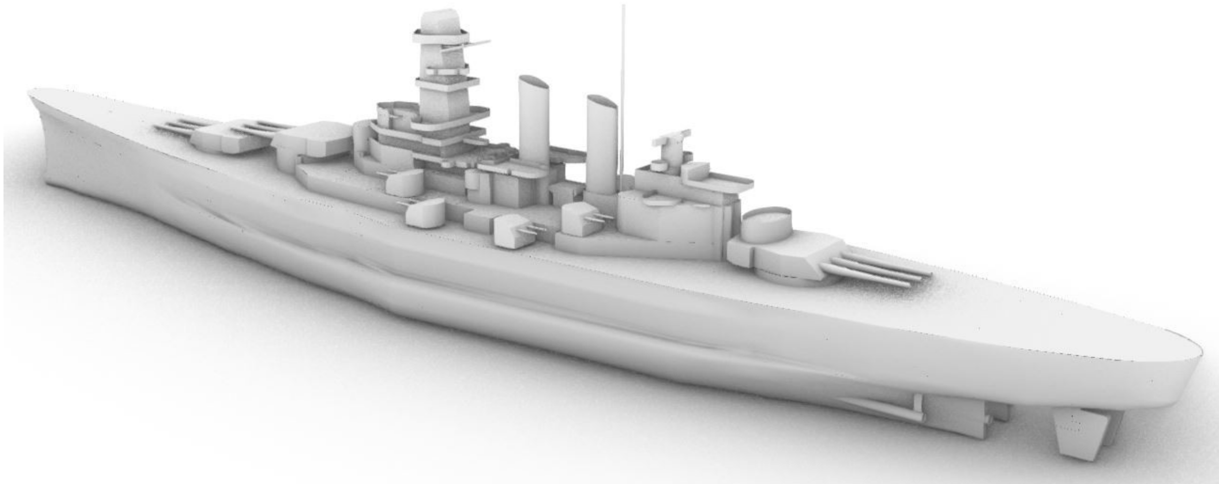


Figure 18. Rendering of USS *North Carolina* hull and superstructure. (Image by Author 2020).

To complete the model, it was more economical to import parts of the ship that would have been more time consuming as well as more technically difficult to create. These included the catapults and two Vought OS2U Kingfisher float planes, the 1.1 in. quad anti-aircraft guns, the .50-cal machine guns, two secondary battery directors, four propellers, and the anchor chains on the bow. These components were imported from two files located on the website https://3dwarehouse.sketchup.com/. The Kingfisher float planes and their catapults were taken from the model "Air raid Pearl Harbor. This is no drill." which was uploaded by the user Rootin' T. The spotlight was imported from the model "US Navy Searchlight 17 inch" and uploaded by the user Battery519IDA. All the remaining components were imported from a model on 3DWarehouse of the USS New York uploaded by Nikos D. Additionally, a texture resembling water was inserted to depict the model at sea. These additions completed the model of the USS *North Carolina* as depicted by its ship plans dating September 1944 (Figure 19 & 20).

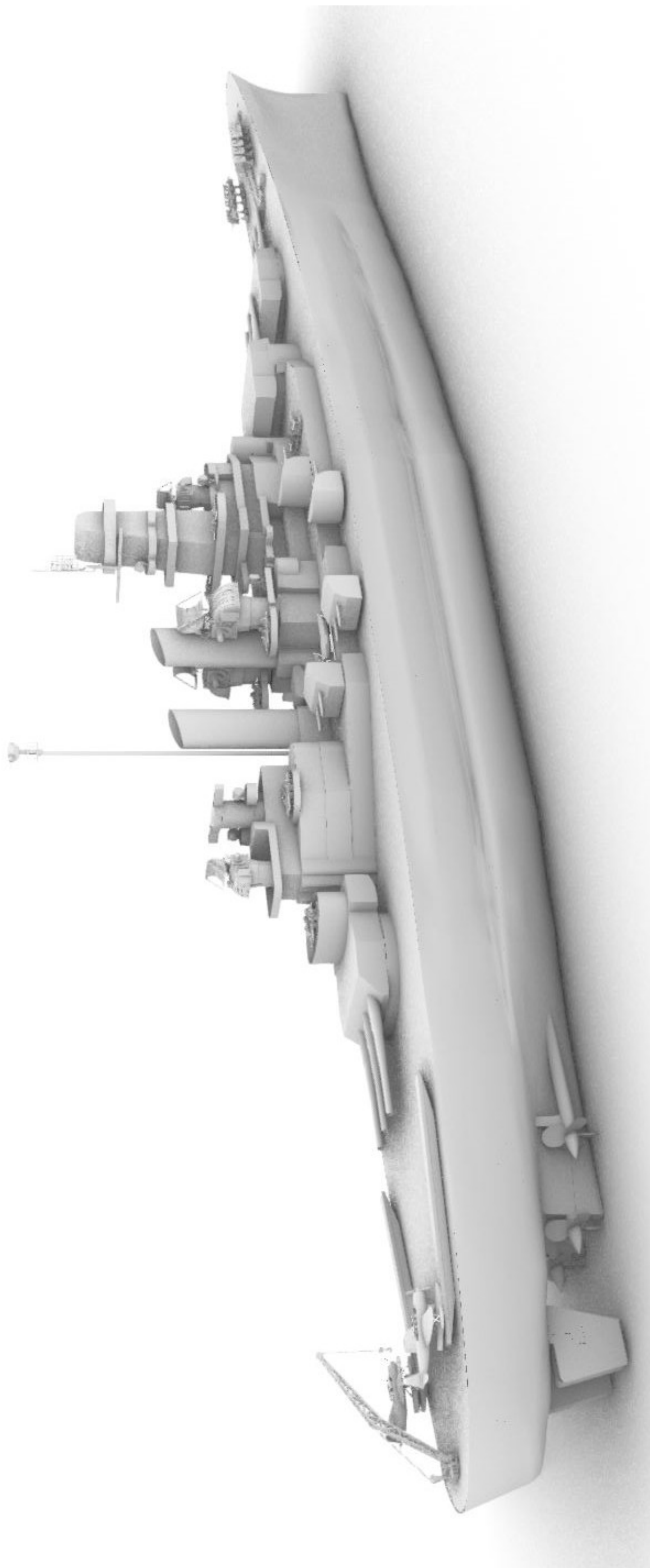


Figure 19. Fully rendered model of USS *North Carolina*. (Image by Author 2020).

Figure 20. Model depicting USS *North Carolina* at sea. (Image by Author 2020)

With the model of the USS *North Carolina* complete, two additional models depicting alterations to the ship were required. The first additional model created was a model that depicted the ship in its permanent berth without a cofferdam. The other model that was constructed depicted the USS *North Carolina* in its permanent berth with the newly constructed permanent cofferdam around it. Images from these models will be discussed more in depth in the following chapters. Both models, along with the additional model were required to provide accurate analysis on the past and future circumstances that did and may affect its current and future preservation.

Conclusion

This project was complex and required multiple stages of work to complete. The methodology chapter discussed the different stages of this project in the order that they happened. The literature review covered topics about USS *North Carolina*'s history, active warship maintenance, museum ship management practices, and historic preservation and cultural tourism. Once a complete review of these topics was discussed, a detailed explanation of the 3-D modeling process, which used Rhinoceros 6.0, was provided. The following chapters will discuss the results of the research and modeling process as well as providing an analysis of what these results mean for USS *North Carolina*'s future.

CHAPTER FIVE: PRESERVATION ACTIVITIES ON USS *NORTH CAROLINA*

Introduction

The current state of preservation that USS *North Carolina* exists in is due to a combination of effects and actions that it has endured throughout its life. This chapter will provide a detailed account of these actions. First, the effects the ship endured from its time as an active warship will be discussed. These will include the maintenance it underwent, the torpedo damage it suffered in 1942, and its time spent mothballed after inactivation. Once the details of this era have been provided, the preservative actions USS *North Carolina* was subjected to as a museum ship will be examined. These will consist of the initial berthing process and preservation activities from 1962-2010, the portable cofferdam project, and the permanent cofferdam project. Wartime activities culminated in actions that must be taken into consideration today because they have impacted what can or should be preserved. These activities dictate what changes would impact the vessel's historical significance and sometimes serve as preservation hurdles. The actions and effects discussed in this chapter will be analyzed in the following chapter.

1United States Naval Vessel Era

USS *North Carolina* was a member of the United States Navy from its commissioning on 9 April 1941 until it was struck from the Navy List in June 1960. From 1941 to 1947 the ship served in World War II and spent time as a training vessel for the Naval Academy, before it was decommissioned and placed in the Inactive Reserve Fleet on 27 June 1947 (Mooney 1961:109-110). During its time as a member of the United States Navy, USS *North Carolina* was subject to a variety of actions that affected its state of preservation. These actions will be broken down into three categories: maintenance activities conducted on the ship, the torpedo damage it suffered, and its time spent “mothballed” in the Inactive Reserve Fleet.

Maintenance Activities Aboard USS *North Carolina* in WWII

An active warship required continuous maintenance to keep it in peak fighting shape during wartime. This maintenance can be broken down into two main categories: daily maintenance tasks and dry dock/shipyard maintenance. Each of these topics will be discussed in accordance to their known occurrences aboard USS *North Carolina.*

The multitude of tasks required to prevent corrosion aboard vessels required the effort of every one of the thousands of sailors that served aboard United States Navy vessels during World War II. The contingent of the crew responsible for conducting these maintenance tasks would have been the enlisted sailors. Daily maintenance tasks such as removing rust, repainting, and scrubbing the decks were part of keeping a ship in fighting shape, and the enlisted soldiers guide to serving in the navy, *The Blue Jackets Manual*, included sections detailing how to complete each of these tasks (United States Naval Institute 1943: 254-260). USS *North Carolina*’s company of sailors ranged from 1,500 at the time of her commissioning to approximately 2,339 in late 1945. Of the 1945 number, 2,195 of the sailors aboard USS *North Carolina* were enlisted (Blee 2005:39-40). As discussed in the theory chapter, painting was the most effective way to prevent corrosion onboard the ship. Continual inspection for signs of rust were carried out, and removal of the rust followed by repainting was one of the tasks that enlisted sailors continually were assigned. A typical day at work according to the ship’s “plan of the day” included two periods of conducting “ship’s work”, one at 0800 and the second at 1300. “Ships work” referred to any routine work that was in progress. This could include “cleaning, painting, repairing equipment or machinery, swabbing the decks, cleaning gun barrels, lubricating machinery, schooling those eligible for promotion, etc."(Figure 21) (Blee 2005:56).

Figure 21. Workers painting French destroyer *Le Triomphant* in 1940. (Image courtesy of Imperial War Museums).

To understand the scope of work required for maintenance aboard USS *North Carolina*, it is important to understand the surface area that the crew was responsible for maintaining. USS *North Carolina* is 728 feet long (714 feet at the waterline), has a beam of 108 feet and four inches, and is roughly 50 feet from keel up to the main deck (Whitley 1998:289). Only the draft of the ship (31.5 ft per the contract design) was ever provided in research, so the total height (49 ft) from keel to main deck was acquired using the scale model created in *Rhinoceros* (Garzke

1995:34). The ship has six decks from the main deck down to the hold as well as a half deck at the bow between the main and second deck. Using a basic square footage calculation, 6(728x108), the decks of the ship cover a surface roughly 474,744 ft^2. The actual square footage of the decks is slightly smaller due to the narrowing of the ship as its moves from the center bow and aft, but this number provides an idea of just how much area had to be maintained aboard the ship. Likewise, providing a rough estimate of the square footage of the ship's hull depicts the quantity of work required to keep the ship afloat. Each side of the ship, port and starboard, consists of a surface area roughly 50 feet tall and 728 feet long, while the bottom of the ship would have a rough surface area 728 feet long and 108 feet wide. The port and starboard side of the vessel each have a surface area of 36,400 ft^2 (Figure 22) for a combined total of 72,800 ft^2, while the bottom of the ship has a surface area of 78,624 ft^2 (Figure 23). The total surface area of the outside of USS *North Carolina*'s hull is roughly 151,424 ft^2, and if doubled to depict the inside surface area of the hull adds up to 302,848 ft^2.

While naval warships underwent daily maintenance for minor issues, they also periodically required more complex maintenance, repairs, and overhaul that had to take place in a shipyard. Throughout World War II, USS *North Carolina* sailed into a shipyard for some sort of repairs or maintenance five times. Four times the ship was required to return to Pearl Harbor and once it sailed all the way to Puget Sound Navy Yard. The first time the ship was forced to return to Pearl Harbor was in September 1942 after sustaining torpedo damage. After waiting over a week for a dry dock large enough to accommodate the ship, it only took twenty-one days in drydock for USS *North Carolina* to rejoin the fleet in the Pacific (Blee 2005:92-93). The ship's next visit to Pearl Harbor came in March of 1943 due to vibration issues in the ships number two propeller shaft (Figure 24). This required drydocking to allow for repairs, but also included the installation of new search and fire control radar on the ship (Whitley 1998:294; Blee 2005:96).

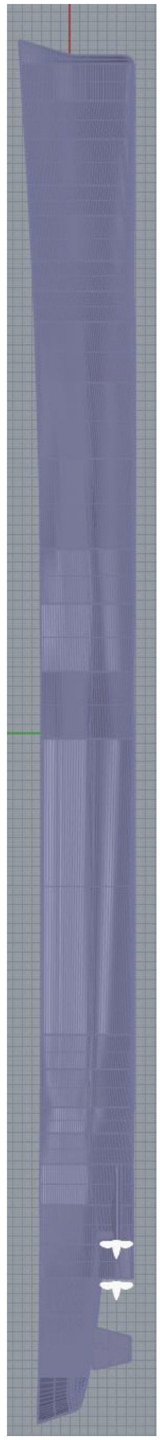


Figure 22. Profile view of USS *North Carolina* hull equal to 36,400 ft^2. (Image by Author 2020)

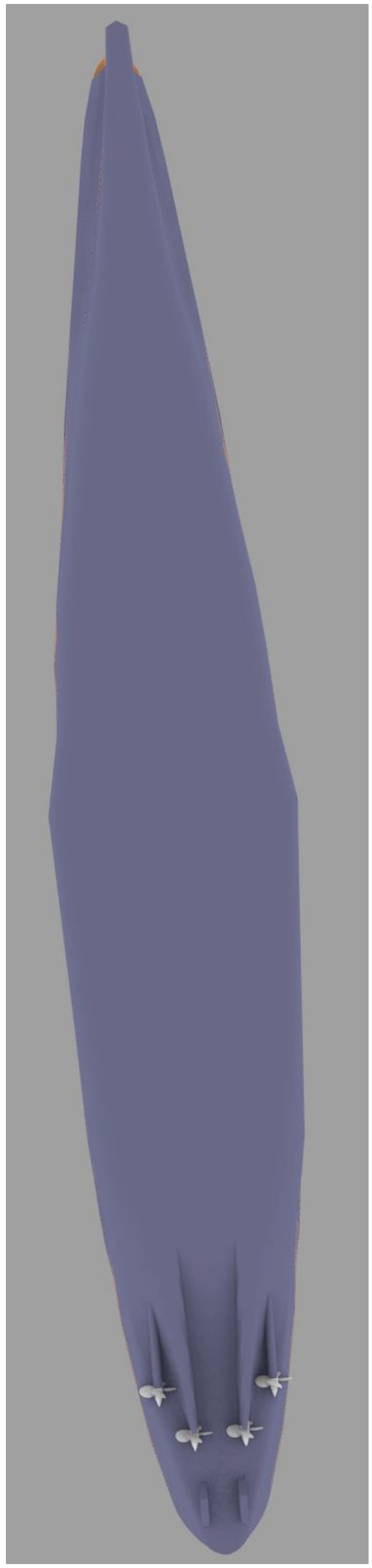


Figure 23. Bottom view of hull equal to 78,624 ft^2 (Image by Author 2020)

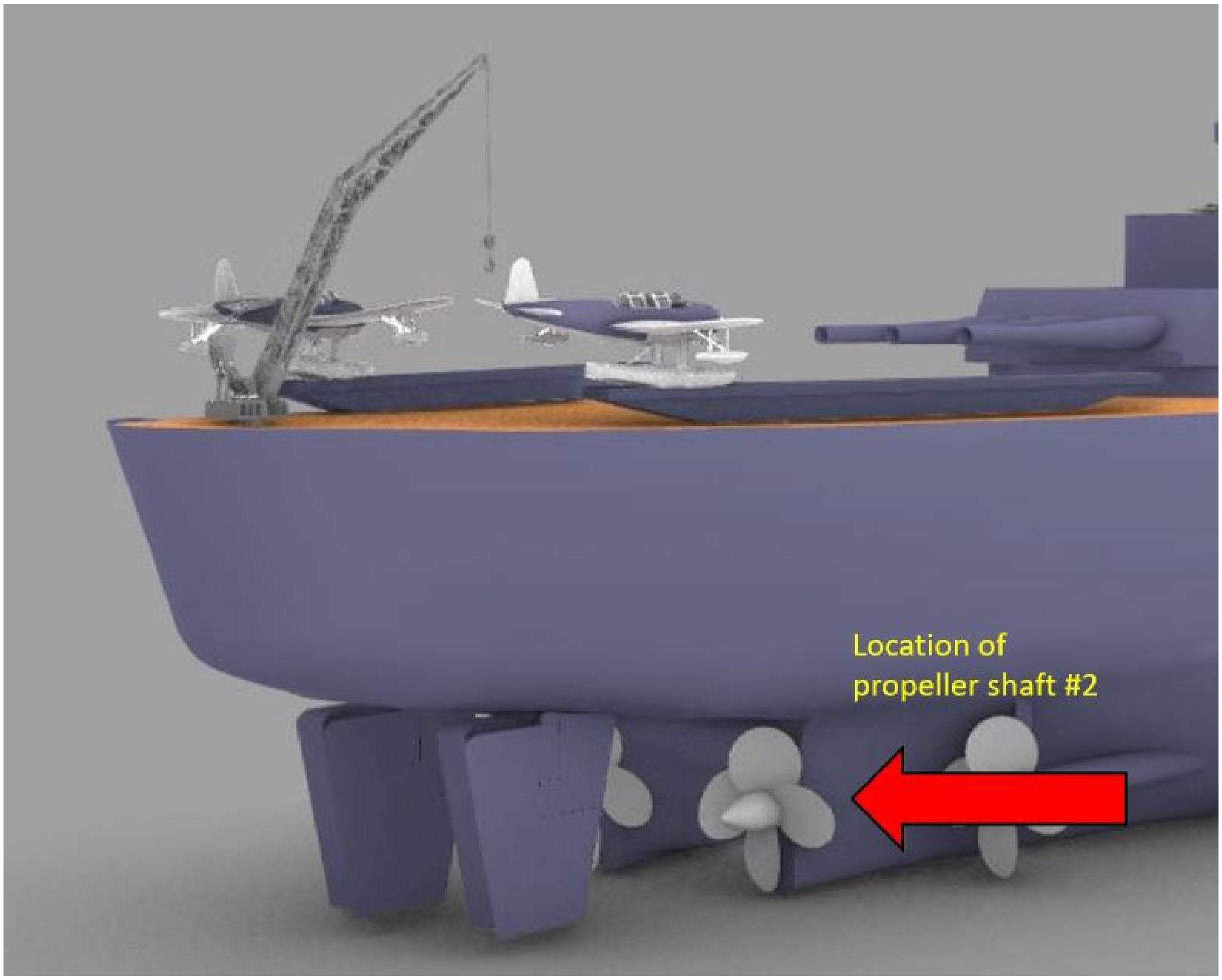


Figure 24. Image depicting location of propeller shaft #2 (Image by Author 2020)

Another return to Pearl Harbor happened in May 1944 because the ship needed repairs to its rudder (Blee 2005:106). The next visit to a shipyard USS *North Carolina* had required a slightly farther voyage to Puget Sound Navy Yard in Washington. This visit occurred from July to September 1944 and consisted of a "long needed shipyard overhaul" (Blee 2005:113). According to the current *Maintenance Policy for Navy Ships* 2019, overhaul is defined as the "accomplishment of maintenance and modernization" (Chief of Naval Operations 2019:C-7). USS *North Carolina* visited Pearl Harbor one more time for repairs in May 1945 before the war ended. The final visit to a shipyard USS *North Carolina* made as an active warship brought it back to its place of birth, New York Navy Yard, for inactivation. This visit was the last instance of major maintenance the ship received at a shipyard before being placed in the Reserve Fleet at Bayonne, New Jersey (Blee 2005:145).

15 September 1942 Torpedo Incident

The only major damage that USS *North Carolina* suffered from the enemy occurred on 15 September 1942 at 1452 when the ship was struck by a torpedo fired by a Japanese submarine. As mentioned in the Chapter 2, the torpedo barrage fired by the Japanese submarine, *I-19*, was the most devastating ever fired, with five of the six torpedoes hitting American vessels and two of the three vessels hit ultimately sinking (Whitley 1998:293-294). The torpedo struck USS *North Carolina* on its port bow close to frames 45 and 46 and approximately 20 feet below the ships water line. The dimensions of the hole created by the explosion measured 32 feet in length from fore to aft, and 18 feet in width (depth) shown in Figure 25-26 (Navy Department 1949:7). Initial inspection and repairs were made by the repair ship USS *Vestal* at Tonga-Tabu. These inspections revealed the size of the hole as well as serious indentations in the hull from frame 42 to frame 53 that extended from the first platform down to halfway between the second platform and hold (Navy Department 1949:7). USS *Vestal* then removed protruding lips of shell plating from around the hole by underwater cutting and then a cofferdam was placed around the hole to allow for repairs to bulkhead boundaries and shoring of bulkheads adjacent to the flooded areas of the ship (Navy Department 1949:5). These repairs were completed on 21 September 1942 and USS *North Carolina* then sailed to Pearl Harbor for permanent repairs as shown in Figure 1. While a detailed record of all repairs was not discovered during the research phase, they would have included welding a large panel of steel that covered the hole left by the torpedo damage. A portion of this panel, where the welding could be seen was shown to the author during a visit to the Battleship North Carolina Memorial on 18 January 2019.

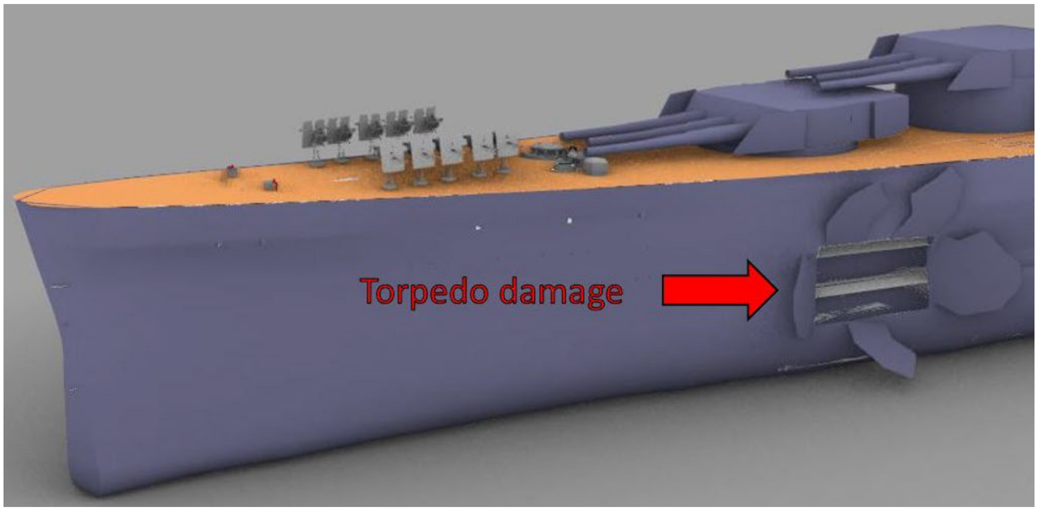


Figure 25. Model depiction of torpedo damage. Image by Author 2020.

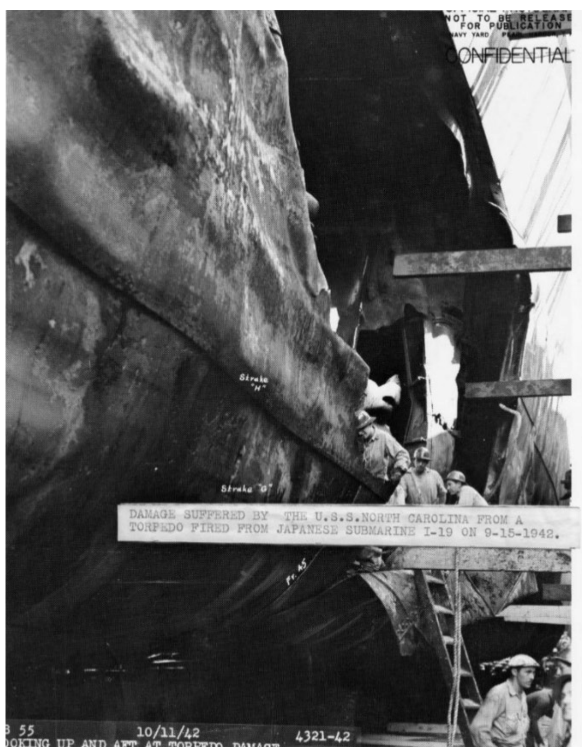


Figure 26. Image depicting torpedo damage taken at Pearl Harbor Navy Yard 10/11/1942.

(Image from Battleship North Carolina Memorial Archives)

Mothballing of USS *North Carolina*

USS *North Carolina* was decommissioned on 27 June 1947 and placed in the Reserve Fleet at Bayonne, New Jersey (Blee 2005:145). The decommissioning and inactivation of a ship was a process often referred to as "mothballing." A ship was inactivated and placed in the Reserve Fleet when it was no longer needed in the navy at the current time. After World War II ended, the excess of ships that had been rapidly built to fight in a large war had to be reduced. While some ships were scrapped after the war, many ships were inactivated but kept in reserve in case the need would arise for them to be used again. A ship that was mothballed could be prepared for action much quicker than a new ship of the same type could be built. Ships were kept in a state of readiness in the Reserve Fleet, because the assumption was that if a vessel was needed it will be due to a national emergency and time will be of the essence (Bureau of Ships 1956:89). Several of the steps for inactivating a ship directly affect the preservation of the hull of a ship, and these steps will be discussed in this section in accordance with "Chapter 9- Readiness and Care of Vessels in Inactive Status" from *Bureau of Ships Manual* (1957).

The first step before being decommissioned was a yard overhaul for inactivation. USS *North Carolina* returned to New York Navy Yard, the same yard that was responsible for building it, for its inactivation overhaul. The purpose of the yard overhaul was to accomplish any urgent repairs or preservation work that could not be completed by the ship's crew. The types of repairs scheduled during a yard overhaul were those deemed too complex or uneconomical to complete once the ship was inactivated and could include repairs to the propulsion system and repairs required to insure water tightness of the hull and above-water structure (Bureau of Ships 1956:2). These repairs were broken down into three categories: emergency, urgent, and desirable. Emergency repairs were repairs that were considered "essential to the security of the vessel or were required to prevent excessive deterioration of the vessel" (Bureau of Ships 1956:3). Urgent repairs were defined as mandatory for the vessel to depart the base where it was berthed for a shakedown cruise, and desirable repairs were those which would make the vessel more efficient if time for activating the vessel was not pressing (Bureau of Ships 1956:3).

Once the yard overhaul was carried out, the ship would ready for the rest of the inactivation process to be completed. As much of the machinery, boilers, piping, and electrical apparatus as possible were left completely assembled. This was to expedite the reactivation process if necessary (Bureau of Ships 1956:3). The entire interior of the ship was to be dehumidified, especially the steam propulsion plant. Additionally, voids, double bottoms, and blisters were also dehumidified if possible (Bureau of Ships 1956:33). Below decks, any corrodible surface not protected by paint or dehumidification were to be coated with a thin-film rust-preventative compound, and special means were to be applied to preserve the underwater hull and weather decks (Bureau of Ships 1956:4). The thin-film rust-preventative compound was not used on the hull or areas above deck, because paint was proven to be a superior preservative and was to be used on surfaces exposed to the weather (Bureau of Ships 1956:20). While these were general instructions for preserving an inactive ship in the Reserve Fleet, there were more detailed instructions for preservation of the hull.

To preserve an underwater steel hull, such as that of USS *North Carolina*, the following steps were taken. The underwater hull and boot topping area were painted in accordance with Section S19-1 General Specifications for Building Vessels of the United States Navy. This included applying a hot plastic or cold plastic paint system to the underwater body of a vessel in the Reserve Fleet, except for submarines, which had a vinyl paint system applied (Bureau of Ships 1956:26). The boot-topping area of a vessel was preserved with four coats of Formula 146 paint, which was a black, cold plastic antifouling paint (Bureau of Ships 1956:26; Navy Department 1957:154). The boot topping is the area of a ship's hull between the light line (average waterline of a ship when it is not loaded) and the load water line (average waterline of a ship when loaded) (Figure 27). Additionally, $1^{1/4}$-inch high-purity hull zincs were installed in accordance with the Bureau of Ships Instruction 9190.4 and special precautions were supposed to be taken to prevent painting over the installed zincs. Ships in the Reserve Fleet were also required to have the hull cleaned by sandblasting and then repainted any time it was drydocked for periodic preservation. Dry docking periods were determined by factors such as the five to six-year period of effectiveness of the paint film (Bureau of Ships 1956:26-27). USS *North Carolina* received dry dock repairs once while in the Reserve Fleet, in 1953 (NC Department of Cultural Resources 2015:3). Finally, all leaks, regardless if they were major or minor, were required to be stopped (Bureau of Ships 1956:27).

All portions of the hull above water, as well as the decks and upper works, required thorough preservation while in inactive status as well. Any rust spots were required to be cleaned and touched up with two coats of red lead primer, formula 116 paint. If the rust spot was located on the edge of a plate, lighting holes, or weld lines, a third coat of primer was to be added (Bureau of Ships 1956:27). On vertical surfaces, such as the hull above water, two coats of haze gray paint, formula 5-H (MIL-P-15130) were applied. Horizontal surfaces were painted with two coats of gray deck paint, formula 20 (JAN-P-699) (Bureau of Ships 1956:27). Before applying any additional paint to needed areas, loose scale and rust were removed with a wire brush to make sure the new coat adheres properly, and rust did not spread underneath it. USS *North Carolina* would have been subjected to these standards during its time in the Reserve Fleet.

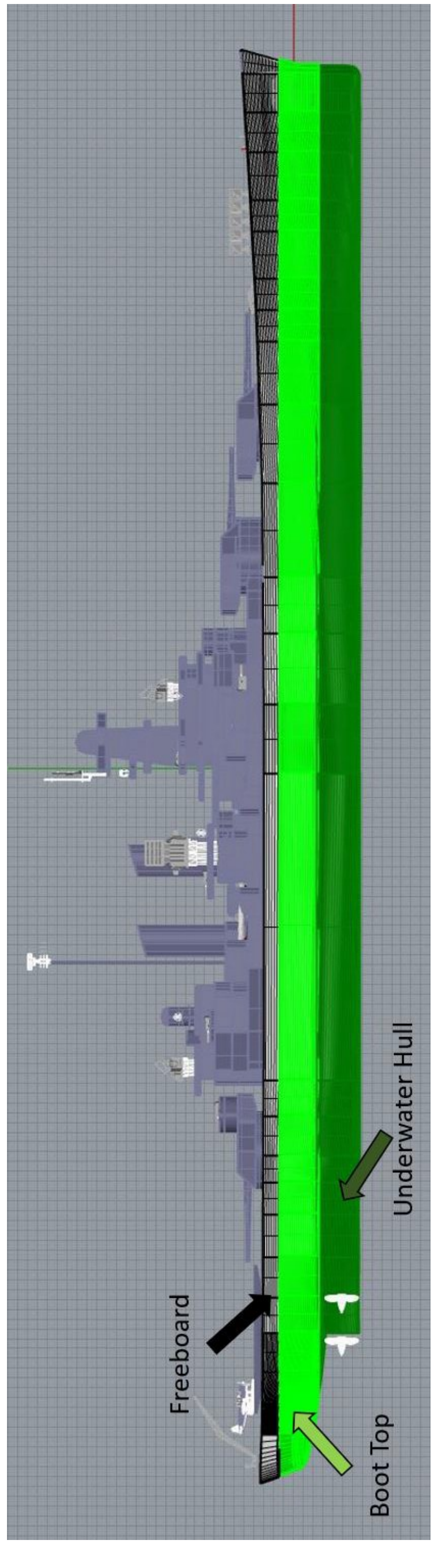


Figure 27. Image depicting Boot topping area and underwater hull on USS *North Carolina.*

Image by Author 2020

Museum Ship Era

USS *North Carolina* remained in the Reserve Fleet for the next fourteen years before it was intended to be sold for scrap. However, when the Navy announced this decision, the state of North Carolina came together and raised the funds to have the ship saved. After raising $330,000 to have the ship towed from Bayonne, New Jersey to Wilmington, North Carolina, USS *North Carolina* began its trip in September 1961 and arrived at its current berth on 2 October 1961 (Blee 2005:145). This section discusses the initial transition to museum ship and preservation activities USS *North Carolina* underwent, the 2011 portable cofferdam project, and the current permanent cofferdam project.

Initial Transition to Museum Ship and Preservation Activities 1961- 2010

The USS *North Carolina* was transferred to the state of North Carolina through the Navy's Ship Donation Program, which was overseen by the Naval Sea Systems Command (NAVSEA). The program was created in 1948 and given authority through Title 10, U.S. Code Section 8676 to transfer select, historically significant vessels to any state, Commonwealth, possession, or municipal corporation for use as a public museum or memorial in the United States (United States Congress 2019: 10 USC 8676). The Ship Donation Program currently requires a three-phase application process before approving the transfer of a naval vessel to another entity, but prior to 2009, NAVSEA required the entire application to be submitted at one time (NAVSEA 2009a:1). The $300,000 that the state of North Carolina raised was not to buy the ship from the navy, but to pay for the costs of physically transferring the ship to its new location. The *Ship Donation Program Manual* (2009) states that the applicant is "solely responsible to obtain, repair, and maintain the vessel at its own expense, in a condition satisfactory to the Secretary of the Navy" (NAVSEA 2009b:6). The total cost of bringing USS

North Carolina to Wilmington was $100,000 to prepare the berth for the ship, $100,000 to condition the ship for display, and $50,000 to tow the ship from Bayonne for a total of $250,000 (Sneed 2010). USS *North Carolina* required several tugboats to move it up the Cape Fear River to its berth in Wilmington as seen in Figure 28.

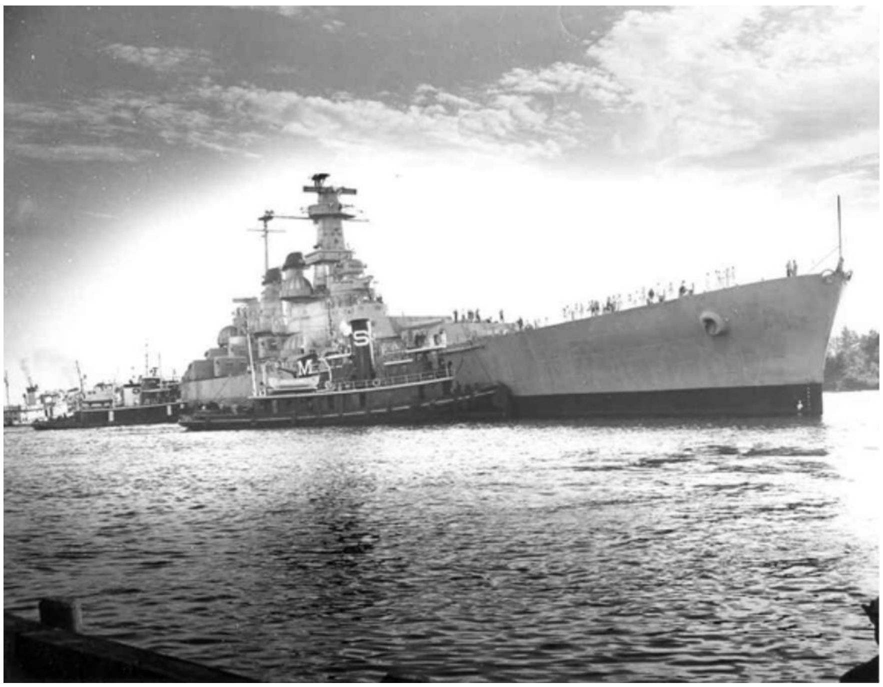


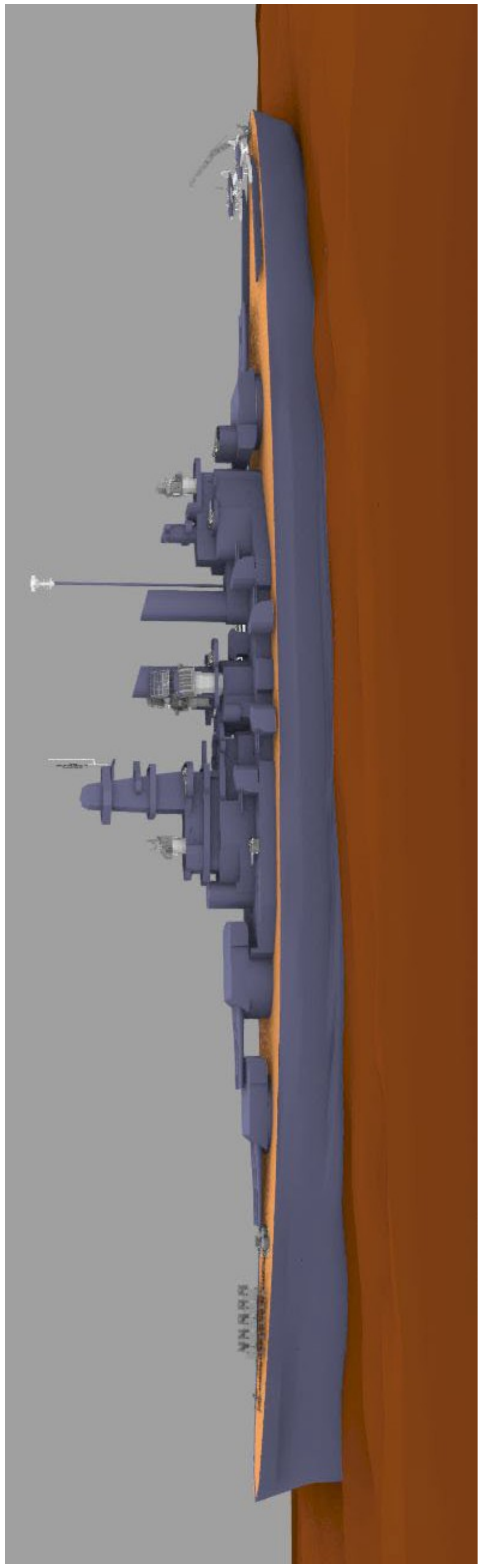
Figure 28. USS *North Carolina* being towed up the Cape Fear River (Image from Cape Fear Museum)

A proper berth and mooring system had to be prepared before USS *North Carolina* was towed to Wilmington. NAVSEA required the new owners of a transferred vessel to install an appropriate mooring system that would keep the vessel in place and prevent damage to it in the event of a 100 year flood event (NAVSEA 2009b:28) (Figure 29). USS *North Carolina*'s berth placed the vessel embedded in approximately 25 feet of mud as shown in Figures 30-31 (Battleship North Carolina 2018a) It was also attached to moorings embedded in the ground with several cables on both the port and starboard sides. Once it arrived in its new berth, USS *North*

Carolina was prepared for display as a museum ship, which required the removal of the preservative materials applied to it during its time in the Inactive Reserve Fleet. Once the ship transitioned to a museum in 1962, it did not receive any major drydocking or hull maintenance until 2011, and the only maintenance conducted on the hull was occasional repainting (North Carolina Department of Cultural Resources 2015:3). The hull zincs that provided a cathodic protection system were removed after some time, and as of 2006, USS *North Carolina* caretakers installed a new cathodic protection system, "by placing twenty-two titanium rods in a 'U'-shape around the inlet to act as sacrificial anodes" (Friedman 2006:6-7).

Figure 29. Image showing the mooring system installed to keep USS North Carolina in place. Image by Katelyn Litalien

Figure 30. Model showing USS *North Carolina* resting in 25 ft. of mud. Image by Author 2020.



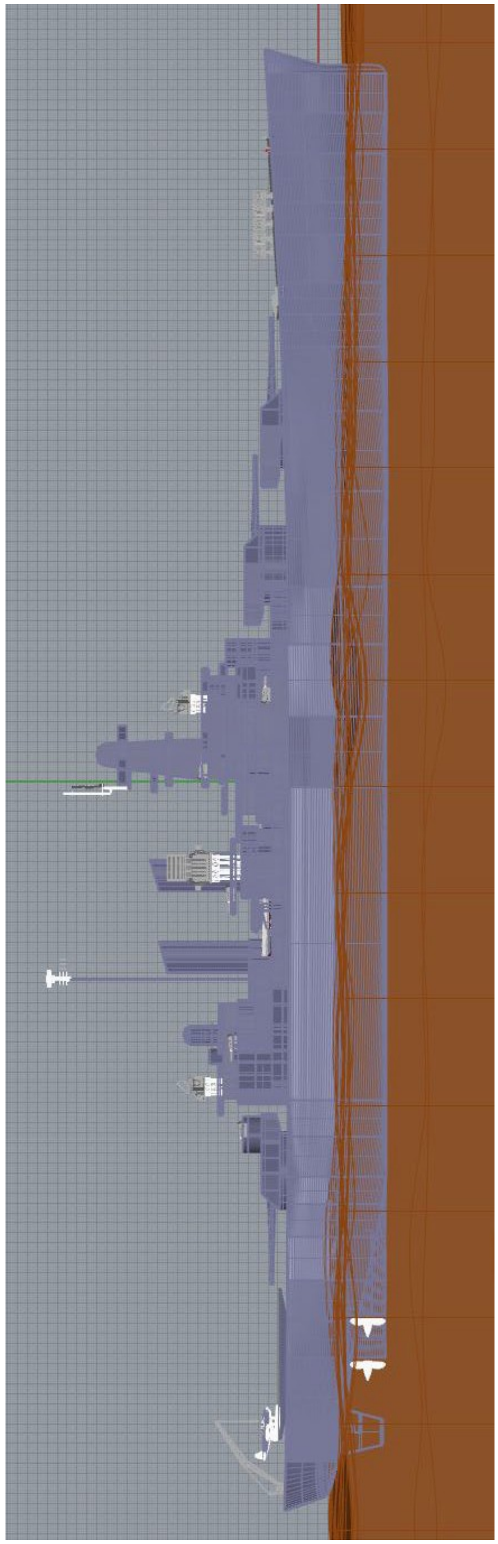


Figure 31. Ghosted plan view showing the portion of USS *North Carolina*'s hull that is settled in mud. Image by Author 2020

2011 Portable Cofferdam Project

In 2011, the state of degradation on portions of USS *North Carolina* reached a condition that required repairs. Initially, a survey of the hull damage was conducted by Ocean Technical Services, LLC., which identified the areas of the hull that required immediate repairs. The survey revealed leakage from frame 5 to frame 37 along the starboard side of the ship (Lombardi 2011:72). The plan for repair considered several options. One option included dredging USS *North Carolina* from its berth and towing it to a dry dock in either Norfolk or Charleston, but this would have required removing some of the superstructure since new bridges down river had been built after the ship arrived in 1961. Another option consisted of installing a sheet pile cofferdam around the bow or the entire ship, but that plan was considered too expensive, full of environmental permit issues, and extensive dredging was required (Lombardi 2011:72). The plan that was ultimately selected used a temporary cofferdam, as seen in Figure 32, to affect the repairs. (Lombardi 2011:107).

Taylor Marine of Beaufort, NC was contracted to complete the repairs and JMS Naval Architects and Salvage Engineers designed the cofferdam with measurements 30 feet long x 7 feet deep x 15 feet high. The cofferdam permitted replacement of portions of the starboard bow using half-inch thick A-36 mild steel plating inserts (Lombardi 2011:72). The repairs were carried out in five different settings of the cofferdam shown in Figure 33. The first set extended from frame 5 to frame 11, the second set ran from frame 10 to frame 18, the third from frame 18 to frame 24, the fourth from frame 24 to frame 31, and the fifth and final set ran from frame 31 to frame 37. Each set consisted of two shell plate inserts for a total of ten new plates inserted to replace the deteriorated sections of the starboard bow as shown in Figure 34 (Lombardi 2011:76). The repairs were completed in November 2011.

Figure 32. Image showing the portable cofferdam being fitted to hull of USS *North Carolina* (Image from Ocean Technical Services LLC.)

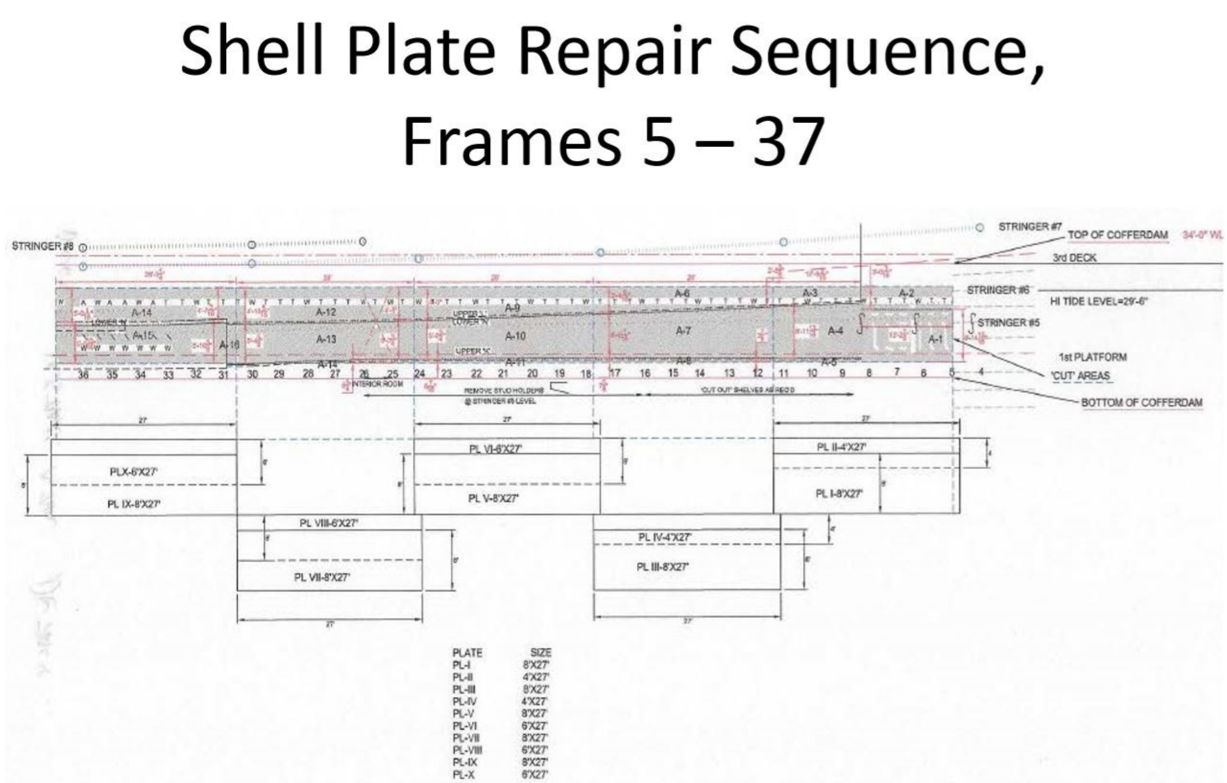


Figure 33. Diagram showing location of shell plates replaced in 2011 repairs. (Image from Ocean Technical Services LLC).

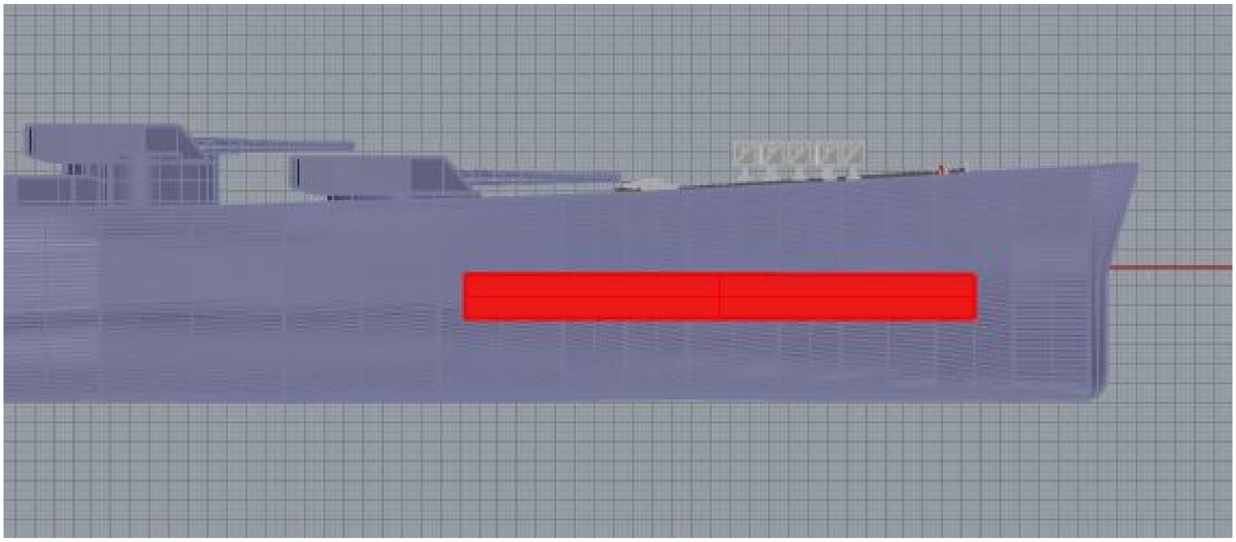


Figure 34. Image depicting location of hull repairs from the portable cofferdam project. Image by Author 2020.

Permanent Cofferdam Project

As mentioned previously in this chapter, USS *North Carolina* did not receive any major hull repairs since 1953. Since being berthed in Wilmington in 1961, the ship has been exposed to the corrosive effects of wind and water at the tide line, which left the hull dangerously thin (Battleship North Carolina 2018c). While sections of the starboard bow were replaced in 2011, several other sections of the hull reached the point where they needed repair. Thanks to the fundraising of the "Battleship Generations Campaign" repairs were scheduled for 2020. This repair project was on a much larger scale than the starboard bow repairs of 2011 though. The project chose to install a permanent cofferdam around the entire ship this time, much like that installed around USS *Alabama* in Mobile, AL (Figure 35) (USS Alabama Battleship Memorial Park 2017b). This option was chosen over dredging and towing the ship to drydock due to the same reasons for rejecting that option in 2011.

Figure 35. Image of permanent cofferdam installed around USS *Alabama*. Image from Amy Hotz 2010.

The cofferdam construction and hull repairs project was broken down into two phases: cofferdam construction and steel hull repairs and painting. During Phase I, a permanent steel cofferdam, shown in Figure 36-37, was installed around the perimeter of the battleship. This allowed workers to dewater the area surrounding the vessel inside the cofferdam while also providing an environmental barrier. The cofferdam was constructed by Orion Marine Group of Norfolk, Virginia (Battleship North Carolina 2018a). The constructed cofferdam was 50 feet tall and created a 1,909-foot perimeter around USS *North Carolina.* It consisted of 1,206 steel sheet piles supported by 229 vertical steel H-piles which were 55 feet long and 229 battered steel H-piles which were 60 feet long. The steel sheet piles and H-piles were driven deep into the mud roughly 40 to 50 feet. The cofferdam has 4 slide gate weirs, each being 10 feet 6 inches tall x 6 feet wide (Battleship North Carolina 2018a). As of April 2018, all of Phase I has been completed, with the permanent cofferdam installed and operational. Additionally, a memorial walkway was constructed that allows visitors to walk all the way around the outside of USS *North Carolina.*

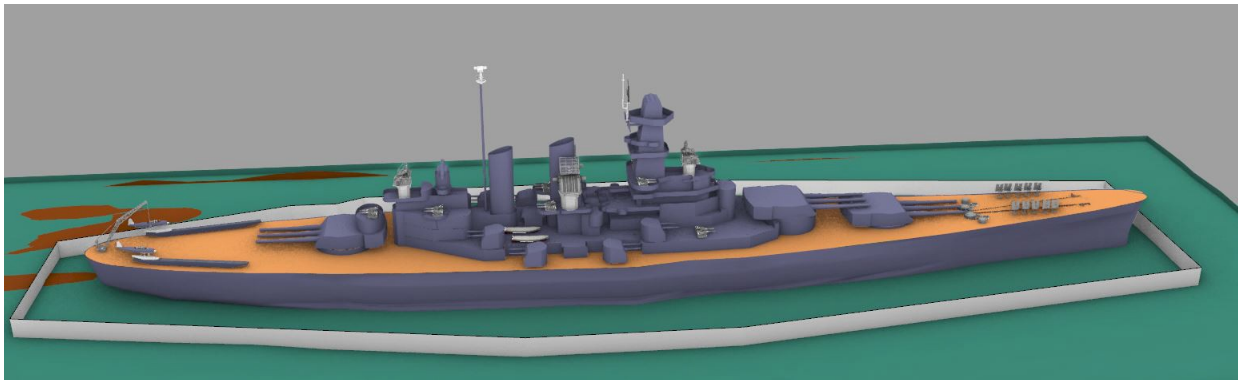


Figure 36. Model showing the permanent cofferdam. (Image by author)

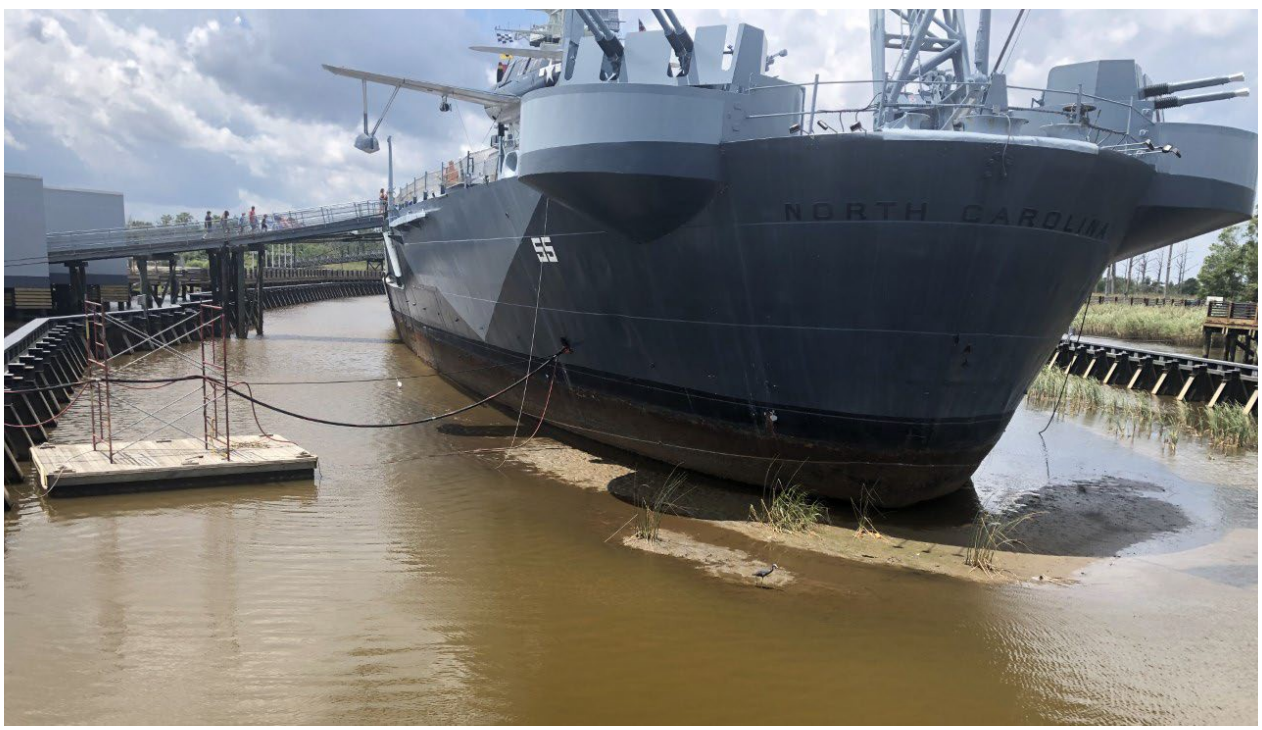


Figure 37. Stern view of USS *North Carolina* and cofferdam. (Image by Author 2020)

Phase II, which is currently in progress, consists of assessing the condition of the hull, repairing the hull, and refilling the cofferdam. Bidding for the contract to conduct the hull repairs was conducted in in February 2020, and the repairs deemed necessary were much more extensive than the 2011 repairs. The base bid called for removal of all plating below the 32’ 6” mark on both the port and starboard sides. The starboard side shell plates are to be replaced from the stem to frame 16 and be joined to the plating repaired in 2011. On the port side, the shell plating will be replaced from the stem back to frame 27. From frame 26 to frame 37, new half-inch A-36 mild steal will be installed outboard of tanks A-5F and A-14F with the top edge of the plating at the 32’ 6” draft mark (NC Department of Cultural Resources 2020). The port and starboard stern will be repaired in designated areas as well (Hemingway 2020b:3). The new steel for replacing the hull will be provided by Nucor Steel and should arrive with a primer coat already applied (Hemingway 2020a:3, 2020b:12). The provided sheets will be flat, half-inch x 40-foot sheets (Hemingway 2020b:12).

Currently hull repairs have begun at the bow of the ship. The permanent cofferdam allowed the workers to drain the water surrounding the ship, and platforms were placed over the mud in the areas the repairs are occurring at. The bow of the ship showed the worst signs of corrosion as shown by Figure 38 taken by the author in January 2019 where a hole in the hull can be seen along the severely rusted wind/waterline. A post by Facebook user Joe Hollifield shared images that provided a progress update of these repairs (Figure 39-42). These repairs were not incorporated into the model as they occurred past completion of data collection, but it would be irresponsible to not inform the readers that they had begun.

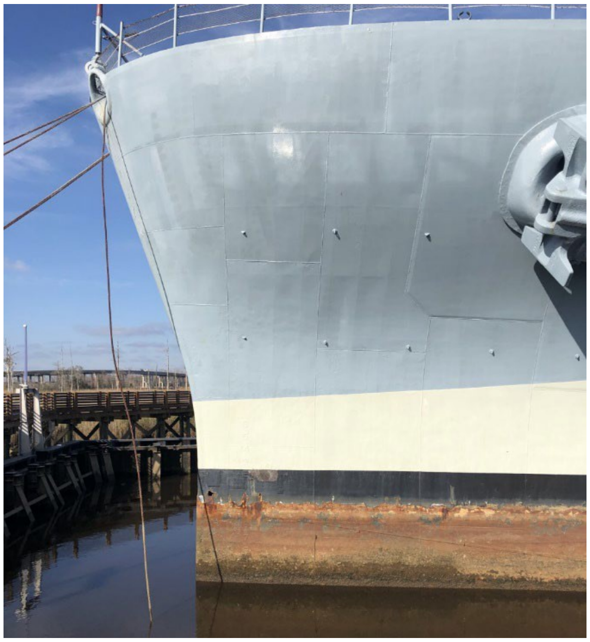


Figure 38. Image showing corrosion along the wind/waterline with a hole near the stem of the ship. (Image by Author 2020)

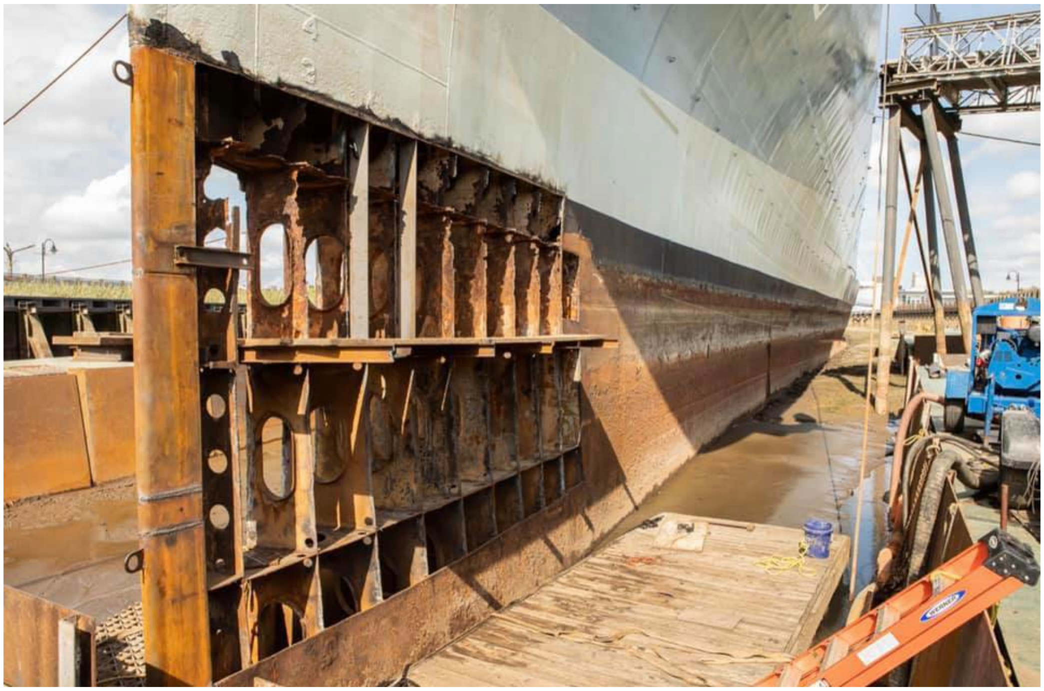


Figure 39. 3/4 view of current hull repairs along the bow of USS North Carolina. (Image by Joe Hollifield 2020)

Figure 40.Port side view of current hull repairs along the bow. (Image by Joe Hollifield 2020)

Figure 41. Front view of bow showing current hull replacement progress. (Image by Joe Hollifield 2020)

Figure 42. Image showing port side of USS North Carolina in a fully drained cofferdam. (Image by Joe Hollifield 2020)

Conclusion

A variety of factors have affected the state of the preservation on USS *North Carolina* throughout its lifetime. This chapter discussed the factors that affected USS *North Carolina* during its time as an active warship in the United States Navy. This included maintenance it received, torpedo damage it suffered, and the mothballing process it underwent. After discussing its time as an active warship, the preservation action USS *North Carolina* underwent as a museum ship were detailed. This section covered the initial transition of the ship to a museum, the portable cofferdam project in 2011, and the completed stages of the current permanent cofferdam project. Ascertaining knowledge about all the factors that affected the preservation of

USS *North Carolina* throughout its military and museum ship career was essential for analyzing the preservation of the ship's past, present, and future, which will be covered in the next chapter.

CHAPTER SIX: ANALYSIS OF PRESERVATION STRATEGIES TAKEN BY THE USS *NORTH CAROLINA*

Introduction

The purpose of this study was to examine preservation issues of steel-hulled battleship museums and analyze how they are managed by using the USS *North Carolina* as a case study. This was accomplished by conducting historical research and creating a model of the ship through the 3-D modeling program *Rhinoceros 5.0.* The 3-D model was used to depict preservation issues and activities through color-coding. This chapter will analyze and interpret the data collected from historical research and 3-D modeling by drawing comparisons from theories and results discussed in Chapter 2 and Chapter 4. This will start with an analysis of the ways maintenance practices and torpedo damage affected the condition of USS *North Carolina* as an active warship. It will then move on to examining different preservation strategies used on USS *North Carolina* as a museum ship as well as speculating how these strategies can be used to improve preservation strategies for other battleship museums. Finally, this chapter will examine the impacts of tourism on the preservation of USS *North Carolina.* This chapter will also provide answers to the research questions asked in the introduction of the thesis.

Analysis of Active Warship Maintenance Strategies

During the time that USS *North Carolina* was serving as an active warship in the United States Navy, it was given the greatest amount of resources and care that were available to it during its lifetime. The United States Navy had tremendous resources and facilities that were used to keep all its ships in peak shape during wartime. This means that the USS *North Carolina* received regular dry dock maintenance, which allowed for upkeep of its cathodic protection systems and reapplying antifouling and anticorrosion coats of paint. However, the ship also endured wear and tear during its lifetime. During this portion of its career, USS *North Carolina* was torpedoed and participated in dozens of battles, while also enduring normal fouling and corrosion ships that naturally occurs on ships.

Maintenance

Proper maintenance was very important to ensure that an active warship was prepared to fight. During its active duty career, USS *North Carolina* was manned by anywhere from 1,500 to 2,300 sailors, who would sweep the decks, scrub away rust and repaint corroded areas on the ship, and make sure cathodic protection systems were working properly (Blee 2005:39-40). Many crew members made the task of keeping such a large vessel corrosion free manageable. The ability to keep a ship with such a large surface area free of corrosion when it is constantly subject to natural elements and weathering becomes much more difficult when it is manned by a miniscule crew that relies largely on volunteers, which is what happened once the ship was mothballed and converted to a museum ship. These changes to crew size and a decrease in monetary resources available will be discussed later in this chapter.

While the crew could keep certain areas of the ship corrosion free, much of the ship's hull was only accessible to maintenance when the ship was dry docked. As discussed in Chapter 4, USS *North Carolina* sailed into a port for maintenance or repairs of some sort five times during World War II from September 1942 through May 1945 (Whitley 1998:294, Blee 2005:92-93,96,106,113). This averages out to one visit to a port for maintenance every six and a half months. The regular maintenance of USS *North Carolina* in a port coupled with the daily maintenance the crew carried out ensured the ship was in the best condition possible during this time. The final major maintenance the ship received was when it was prepared for inactivation at the New York Navy Yard before entering the Reserve fleet at Bayonne, New Jersey in June 1947 (Blee 2005:145). The effects of the mothballing process will be discussed in its own section in museum ship preservation analysis, but the process made sure the ship was in a good state of preservation before being placed in the reserve fleet. It is unlikely that the regular maintenance of USS *North Carolina* would have had any negative impact on the future of the ship. Instead, it is more likely that it ensured the longevity and peak performance of the ship until it was inactivated. The only potential detrimental effects that active service as a warship might have had on the long-term preservation of USS *North Carolina* came from the torpedo damage the ship suffered.

Torpedo Damage

On 15 September 1942, USS *North Carolina* suffered the only major damage that was inflicted on it by the enemy during World War II. (Whitley 1998:293-294). The torpedo hit left a hole 32 feet by 18 feet on the port bow of the ship and required emergency repairs by the repair ship USS *Vestal* at Tonga-Tabu before USS *North Carolina* could return to Pearl Harbor for full repairs shown in Figure 43 (Navy Department 1949:7). At Pearl Harbor, a large steel panel was welded in place to cover the hull and return the ship to its original state. Potential preservation issues related to the torpedo damage and subsequent repair were broken down into two possible concepts.

The first concept deals with corrosion rates for that, that if all parts of the hull are subject to the same rate of corrosion, then because the area where the torpedo damage was sustained was replaced with newer steel than the rest of the hull, then this area would be in the best state of preservation. However, as discussed in Chapter 2, the area of the ship that is most exposed to the elements, thus most susceptible to corrosion, is the wind-waterline. The torpedo hit occurred 20 feet below the waterline and had a depth of 18 feet according to the damage report. That would mean that the hole extended 8 feet further up and would place the top of the steel replacement panel about ten feet from the average draft of the vessel. During active service, the wind/waterline was probably a greater area because of rough seas and constantly changing loads of the ship due to fuel, foodstuffs, and ammunition, but also more protected due to regular maintenance and repainting.

Figure 43. Workers at Pearl Harbor repairing damage to USS North Carolina suffered by a Japanese torpedo. (Battleship Memorial Archives 2019)

The second concept that potentially affected future preservation deals with the issues that arise from welding and cathodic protection. Fatigue is usually the governing limit for marine structures and welding joints that connect materials are typically the weakest link of the structure (Besten 2018:804). Current studies have observed that "Despite applying cathodic protection (CP) and coatings…corrosion and cracking usually occurs at coating disbondments formed close to weld lines" (Ashari et al. 2020: 2137). The study referenced above discusses the effects of corrosion on steel pipelines protected by coatings and cathodic protection. The pipelines become subject to corrosion due to coating disbondments that occur due to incoherency on the pipe surfaces located near welding lines. When protective coatings become detached, soil solution can penetrate the coating and create an environment that is suitable for anodic dissolution, which leads to cracking and corrosion (Ashari et al. 2020:2136). This issue has the potential to affect USS *North Carolina* at the welding lines creating a higher potential for corrosion if the protective paint coating is worn off around the welding lines of the repairs implemented after the torpedo damage. It is also important to indicate that an additional thirty percent of USS *North Carolina'*s hull was welded and not riveted during initial construction as discussed in Chapter 1 (history). This means that the portions of the ship that were welded instead of riveted have a higher risk of corrosion if protective coatings fail. Another important factor to mention is that this issue was less likely to occur when USS *North Carolina* was an active warship due to increased inspection and maintenance of the vessel. This issue was far more likely to occur once the ship transitioned into a museum ship for multiple reasons. This is because USS *North Carolina* received far less maintenance, had a smaller crew, and fewer resources to repaint any lapses in protective coatings as a museum ship. Additionally, the ship was berthed in 25 feet of mud as discussed in Chapter 4, which made it prone to the introduction of soil solutions underneath the protective coating. As such, this issue will be further addressed within the painting and cathodic protection sections of museum ship preservation analysis.

Museum Ship Preservation Analysis

Once USS *North Carolina*'s active warship career ended, it entered the portion of its existence that it was subjected to the most potential preservation issues it could experience. This section of the chapter will provide an analysis of the preservation activities used on USS *North Carolina* by examining case studies of practices used by similar museum ships as well as theories and best practices discussed in Chapter 2, and comparing those results with the results of actions taken by caretakers of USS *North Carolina.* These activities will be broken down the previously discussed topics: mothballing, berth type, painting, cathodic protection, and maintenance schedules. Additionally, a discussion of the ways the preservation strategies of USS *North Carolina* can be used to improve, if at all, preservation strategies taken by battleships that transitioned to museum ships more recently.

Mothballing

The mothballing of USS *North Carolina* was the last point at which it had access to the considerable resources of the United States Navy for maintenance and repairs. An in-depth discussion of what the general mothballing process entailed in relation to hull preservation was provided in Chapter 4. Although there are not exact records of what USS *North Carolina* underwent during its mothballing process, it is likely that these procedures are what USS *North Carolina* was subjected to when mothballed (Bureau of Ships 1956: 1-103).

The first step in the mothballing process required the ship to undergo an inactivation overhaul (Bureau of Ships 1956:2). As mentioned in Chapter 4, the main purpose of the yard overhaul was to accomplish any repairs that were too complex or costly to be achieved by the ship's crew. These types of repairs would have included underwater hull maintenance that was much easier to complete in a dry dock, which would have included having the hull sandblasted and repainted while in drydock (Bureau of Ships1956:26-27). Repainting the ship properly with fresh coats of anti-corrosive anti-fouling layers means the ship would have been in as good of shape when entering the Inactive Reserve Fleet in 1947 as it was while serving as an active warship. USS *North Carolina* entered the dry dock for repairs one additional time while in the Inactive Reserve Fleet in 1953 for repairs and repainting, which was within the five to six-year lifespan of paint effectiveness (Bureau of Ships 1956:26-27). The ship was not drydocked again and transitioned to a museum ship when it was transferred to the state of North Carolina in 1961. This put the ship past the typical lifespan of the protective coatings of paint, but it is likely that a portion of the $100,000 spent to condition the ship for display was used for applying new coats of paint to the above water and boot-topping areas of the hull. Because the ship was not drydocked before being transferred to Wilmington, it would not have been possible to repaint the underwater portion of the hull. If the ship were berthed afloat, this would likely be a much bigger issue, but because USS *North Carolina* is berthed aground and embedded in 25 feet of mud, it is perhaps still relatively protected from corrosion due to the lack of oxygen in the areas of the hull submerged in mud.

Additionally, during the mothballing process, new hull zincs would have been installed on USS *North Carolina.* As discussed in Chapters 2 and 4, $1^{1/4}$-inch high-purity hull zincs that have a life span of ten to fifteen years, were installed on the ship when it underwent its yard overhaul in 1947 (Bureau of Ships 1956:26; DoD 2004:8). This would put the hull zincs, a GCP system, near the end of their effective lifespan by the time USS *North Carolina* transitioned into a museum ship in 1961. No reference to ICCP systems being installed on ships were discovered in “Chapter 9- Readiness and Care of Vessels in Inactive Status” from *Bureau of Ships Manual* (1957), but more recent literature published on the topic, “Chapter 050- Readiness and Care of Inactive Ships” from Naval Ships’ Technical Manual (2005), advises the use of ICCP systems to prevent deterioration (NAVSEA 2005:50-2). This is likely due to increased research and knowledge, as well as advances in technology that make using ICCP systems more economically feasible.

Overall, the mothballing process maintained the structural integrity of USS *North Carolina* and the steps implemented to inactivate the ship were effective means for preventing corrosion on its hull. Maintaining protective coatings and cathodic protection, the two most effective ways to prevent corrosion, were both actively pursued while USS *North Carolina* was in the Inactive Reserve Fleet. However, it should be noted that both protective coatings and cathodic protection would have been near the end of their effective lifespan at the time that the ship transitioned to a museum ship. While indirect references of painting are included in the acknowledgment that $100,0010 was spent to “prepare the ship for display” as a museum ship, no reference is made regarding the cathodic protection of the ship (Sneed 2010). In fact, Capt. David Shceu informed East Carolina students Adam Friedman and Michelle Damian in 2006 that the hull zincs providing cathodic protection had been “removed years ago” (Friedman 2006:6). However, it should be noted that it was likely at the time of the removal of the hull zincs that the ICCP system was installed to provide cathodic protection. While USS *North Carolina* was transferred to the state of North Carolina in a good state of preservation, it was reaching the point that its protective coatings and cathodic protection needed to be renewed, which made the initial actions taken by the caretakers of the ship incredibly important.

Type of Berth

The type of berth a museum ship is placed in is one of the first and most important aspects should be considered when preparing to take ownership of a vessel. The type of berth the ship is placed in determines what the best methods for preserving it are after that as well as what the most common preservation issues are that may arise due to the manner of the ship's storage. USS *North Carolina* was berthed aground in 1961 and has remained so since. In 2018, the project that constructed a permanent cofferdam around the ship was completed, which allows caretakers to pump water away from the ship in order to facilitate repairs and protect it from flooding (Battleship North Carolina 2018a).

The choice to berth a ship aground comes with both positive and negative consequences. As discussed in Chapter 3, berthing a ship aground is typically a cheaper option as opposed to berthing a ship afloat, because berthing a ship aground does not require the installation of significant mooring facilities that berthing a ship afloat does (Morss 2002b). USS *North Carolina* rests in roughly 25 feet of mud, and the bottom of the ship covered by this mud is more well preserved than the wind-water line of the ship (Figure 44-45) (Battleship North Carolina 2018a). This is largely due to the lack of oxygen underneath the mud with prevents oxidation reactions such as rust.

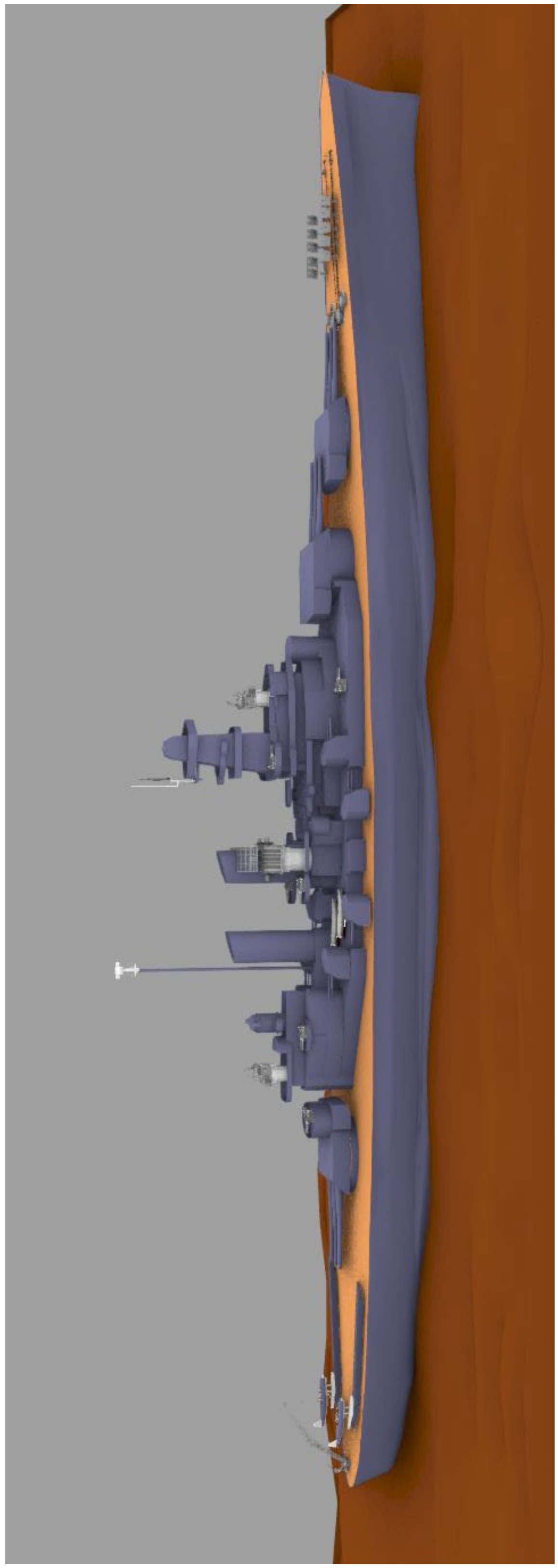


Figure 44. Model depicting USS *North Carolina* berthed aground in mud. (Image by author)

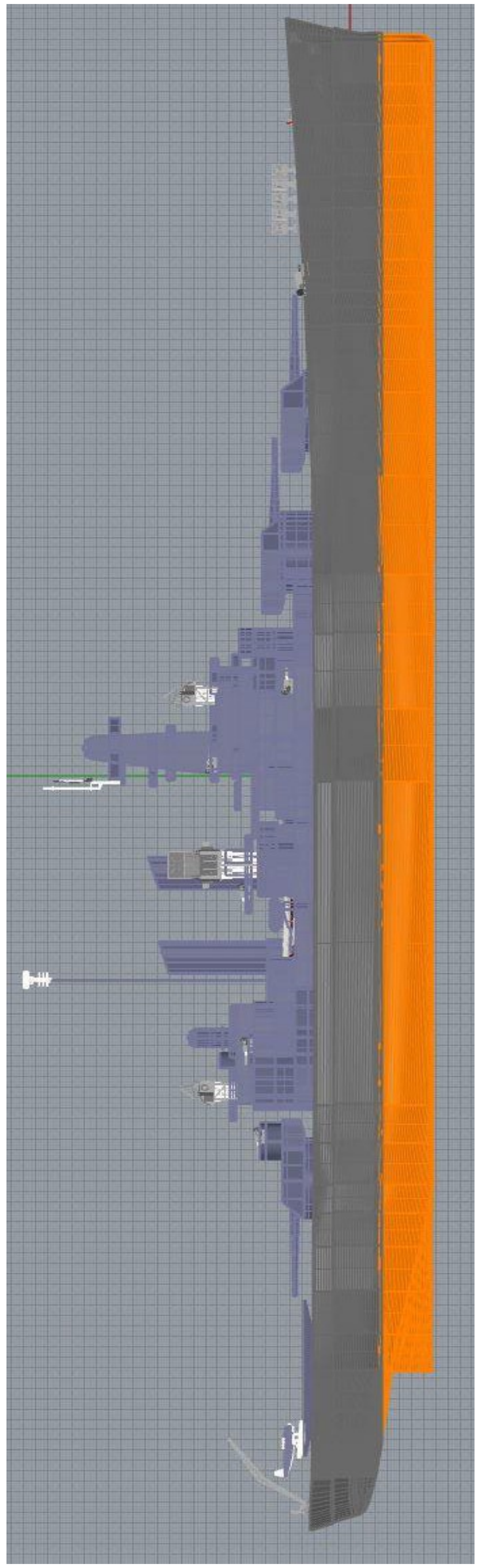


Figure 45. Profile view depicting area of USS *North Carolina* submerged in mud. (photo by author)

Some of the negative consequences of berthing a ship aground include increased corrosion risks, structural strain, and damage from floating due to high tides or flooding (Morss 202b). Because the ship is resting in mud, the area underneath the mud cannot be inspected. While it is likely at a much lower risk of corrosion due to the lack of oxygen in the mud, any issues that do that do arise will not be able to be identified. This could allow them to cause damage that is not repairable until it is too late. When a ship is berthed aground, it does not typically float, which creates a much larger wind-water line area on the ship compared to a ship berthed afloat. If a ship is floating, it will rise and fall with the tide, which limits the area waves and tides will affect, but because a ship berthed aground remains stationary regardless of water level fluctuation, the area of the hull subjected to changing water levels is larger. It is important to minimize the wind-water line as much as possible, because this has been identified as the area of the ship most susceptible to corrosion. The installation of the permanent cofferdam should allow the caretakers of USS *North Carolina* to control the water level surrounding the ship, which will minimize the wind-water line area as well as making access to that area for repairs much easier.

Ships are designed to float in the water, and therefore the structure of the ship is designed to support pressures associated with floating, not pressure from resting on a solid surface. This means that ships berthed aground are prone to place more stress on areas of the ship that were not designed to handle that level of pressure, and this can lead to preservation issues and even structural failure in the worst cases. However, berthing a ship aground that is partially in the water still will not produce as much stress as berthing a ship high and dry or berthed embedded above ground. While berthing a ship high and dry would minimize much external corrosion, the structural strain on a vessel as large as USS *North Carolina* would be detrimental. Most ships berthed high and dry and embedded in the ground are smaller vessels compared to USS *North Carolina,* such as destroyers and submarines (i.e. USS *Drum,* USS *Stewart, and* USS *Cavalla*; see HNSA 2014a, 2014b, 2014c).

When a ship is berthed aground, it does not float under normal circumstances nor is the berthed designed to protect the ship if it were to float. Therefore, if a ship berthed aground were to float due to extreme high tides or floods, it could lead to major preservation issues. USS *North Carolina* normally rests flat on the bottom, which supports the weight of the ship evenly. If the ship were to float a little during a flood, it could settle wrong when the flooding recedes. This could potentially put pressure on the wrong place (Price 2019). The "Living With Water" initiative as well as the permanent cofferdam project are both geared towards limiting the impact that flooding can have on the ship. These are important measures to take because the ship resides in Wilmington, NC, which is constantly affected by hurricanes' storm surges and flooding from runoff upriver (Price 2019).

A discussion in Chapter 3 provides the excellent case study of USS *Texas,* for issues related to a ship berthed both afloat and aground. Like USS *North Carolina,* USS *Texas* was initially berthed aground, however, USS *Texas* rested in about 12 feet of mud instead of the 25 feet that USS *North Carolina* did (Morss 2007). USS *Texas* experienced severe leaking due exterior hull penetrations from corrosion (Moss 1993:3). The amount of flooding USS *Texas* experienced to the significantly less amount of flooding USS *North Carolina* experienced is likely due to a larger portion of the hull being protected by the oxygen-deprived mud it settled in. Because the hulls of ships berthed aground are settled in mud, it is difficult to inspect them for damages, which is what led to the deterioration that caused leaking. USS *North Carolina* was lucky to have the external bottom of its hull protected from corrosion but still suffered from wind water line corrosion, that finally became an issue that required repairs in 2011 through the temporary cofferdam project. This issue has likely been resolved with the permanent cofferdam project, which allows water to be pumped away from the ship and inspections and repair to the level of mud to be made much easier. The permanent cofferdam also controls the wind-water line level, which can limit the area that is at the highest risk of corrosion. After spending millions of dollars to repair USS *Texas*, it was berthed afloat in 1988 (Moss 1993:61). After being berthed afloat for over 20 years, major preservation issues struck again in the form of two major flooding events in 2012 (Smith and Davis 2012). While flooding events are an issue in a ship berthed aground, they are even more so in a ship that is floating, because a ship run aground will not sink if flooded, but a ship that is floating could. While the best manner for berthing a ship depends on many factors, it seems that caretakers of USS *North Carolina* have done a good job recently of limiting factors that could lead to preservation issues with the type of berth the ship is in.

<u>Painting</u>

One of the most effective methods for preventing corrosion on a ship's hull is with protective coatings of paint. As mentioned in Chapter 2, *The Bluejackets Manual 11th ed.* claims that "the only effective protection against rust is good paint properly applied to metal surfaces" (United States Naval Institute 1943:254). When USS *North Carolina* was an active vessel in the United States, it received continual maintenance and repainting that ensured paint coatings never exceeded their five to six-year periods of effectiveness (Bureau of Ships 1956:27). Once the ship was mothballed, it still underwent proper painting procedures to remove rust and prevent corrosion. USS *North Carolina* underwent one drydocking period while in the reserve fleet in 1953, during which it would have had the hull sandblasted and repainted (NC Department of Cultural Resources 2015:3).

The ship transitioned into a museum ship in 1962, which would have put the last coating of hull paint at the end of its period of effectiveness. $100,000 was spent to condition the ship for display, which would have included undoing many of the preservation measures implemented during the time the ship was mothballed, but also likely included applying new paint coatings as well. The ship was not drydocked during this time, so it is not likely that new protective coatings were applied to the underwater portions of the hull. While the bottom 25-feet of the hull were largely protected by the anaerobic environment created by the mud it settled in, the area from the mud to the wind-waterline was at a high risk for corrosion. "Occasional repainting" was conducted on the ship from 1962-2011, but it would have been difficult to apply new paint to the areas of the ship underwater since the ship could no longer be drydocked or the water level controlled to access these areas. The inability to repaint underwater areas of the ship, particularly the wind-waterline, shown in Figure 46, has created major preservation issues for the caretakers to deal with. In 2011, corrosion and holes in the ship's hull on the starboard bow required replacing a portion of the bow using the temporary cofferdam. Even on visits to the ship the author took from 2017-2019, the ship had many holes and visible corrosion along the wind-waterline. This issue was addressed by the building of the permanent cofferdam, which allowed the caretakers of USS *North Carolina* to access and assess these areas. Currently, portions of the port bow are being replaced with other areas of risk scheduled to be repaired and repainted soon.

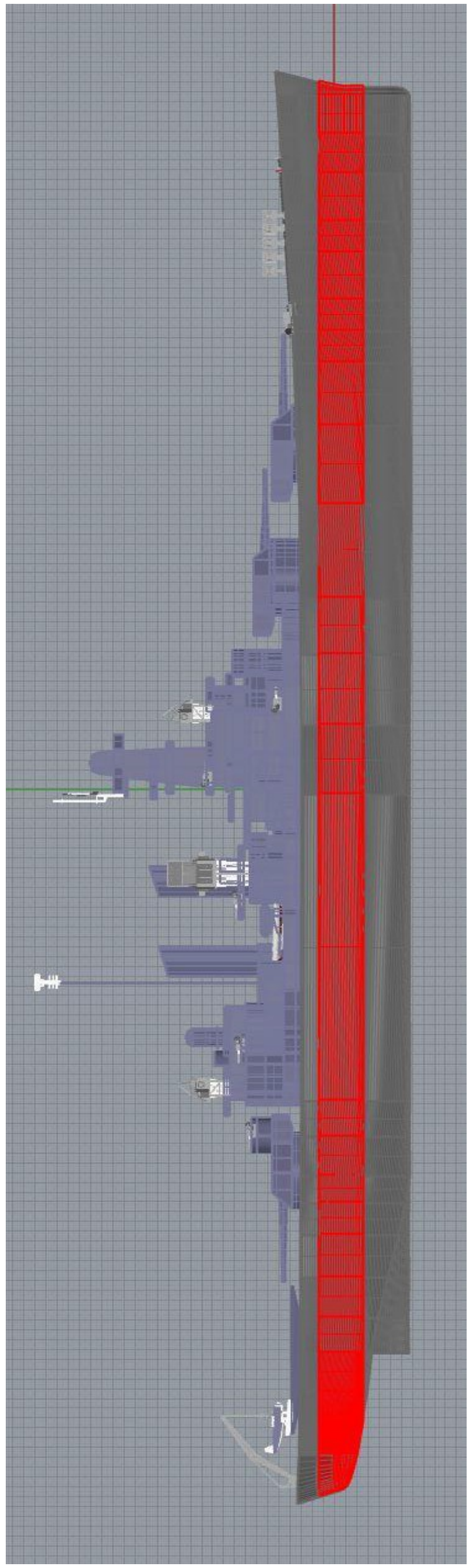


Figure 46. Image depicting wind/waterline of USS *North Carolina.* (Image by Author 2020)

Cathodic Protection

Besides protective coatings, cathodic protection is one of the best methods for preventing corrosion. Hull zincs were installed and maintained on active warships as well as ships in the reserve fleet. However, these hull zincs were removed at some point after USS *North Carolina* transitioned to serving as a museum ship and no other cathodic protection system was installed to replace them until 2006, when twenty-two titanium rods were placed in a U-shape around the mouth of the inlet where the ship was berthed (Friedman 2006:6-7). This means that during a period where the underwater portion of the hull was not accessible to painting (the primary method for preventing corrosion), the secondary means for preventing corrosion was also not active. Cathodic protection is only effective on portions of the ship completely underwater where the saltwater serves as an electrolyte for the cathodic protection system. Knowing that the underwater portion of the hull, from the wind-waterline to the mud is the area of the ship at highest risk for corrosion, it seems hard to understand removing the preservation system that is designed to protect that area when protective coatings would be hard if not impossible to maintain in those areas. The lack of both cathodic protection and protective coatings along the underwater portions of the hull, are likely the main reasons for the extent of corrosion and preservation issues that occurred on USS *North Carolina.*

Maintenance Schedule

Ensuring that a historic vessel is properly preserved requires its caretakers to constantly be vigilant. Scheduled maintenance and analysis of preservation measures such as cathodic protection and painting are essential. These protective systems are the primary methods for preventing corrosion, but if not functioning properly, they serve as little protection and often accelerate the corrosion process. Examples discussed in Chapter 3, such as the continual preservation issues that USS *Texas* and USS *Olympia* experienced as museums demonstrate how important assessing and repairing/reapplying these systems is to preventing corrosion. The inability of these teams to access and analyze at-risk areas of the ship, as well as not receiving hull maintenance needed through drydocking, allowed extensive corrosion issues to occur. Until the early 2000s, caretakers of USS *North Carolina* do not seem to have had done a particularly good job of identifying areas of the ship that are at risk and maintaining protective systems as evidenced by the lack of cathodic protection for several years and the inability to reapply paint to underwater portions of the ship. The current team in charge of managing USS *North Carolina* has done a much better job with the temporary cofferdam project in 2011, and the installation of the permanent cofferdam to make it easier to repair the rest of the ship's hull. Although access to drydocks allows the best access to hull maintenance, the way USS *North Carolina* is berthed along with other factors made creating a permanent cofferdam the best option to allow regular maintenance and inspections to areas of the ship not usually accessible when underwater.

A variety of factors affect what areas suffer from preservation risks. The topics discussed above have shown that certain areas of the ship are at a higher risk of corrosion than others. The wind/waterline and portion of the ship below the mudline are at the highest risk for corrosion, with the wind/waterline being the highest risk. The freeboard portion of the hull is at lower risk of corrosion than the other two sections. The 3D model was used to show these areas of risk in Figure 47-50. The red area represents the highest zone of risk at the wind/water line and the orange area represents the portion of the hull beneath the mud. While the area below the mud is protected by a lack of oxygen, it is at medium risk because it is much harder to monitor for corrosion. The freeboard portion of the ship highlighted in green is at the lowest risk. Identifying and working to minimize the risk in these areas is crucial to museum ship preservation.

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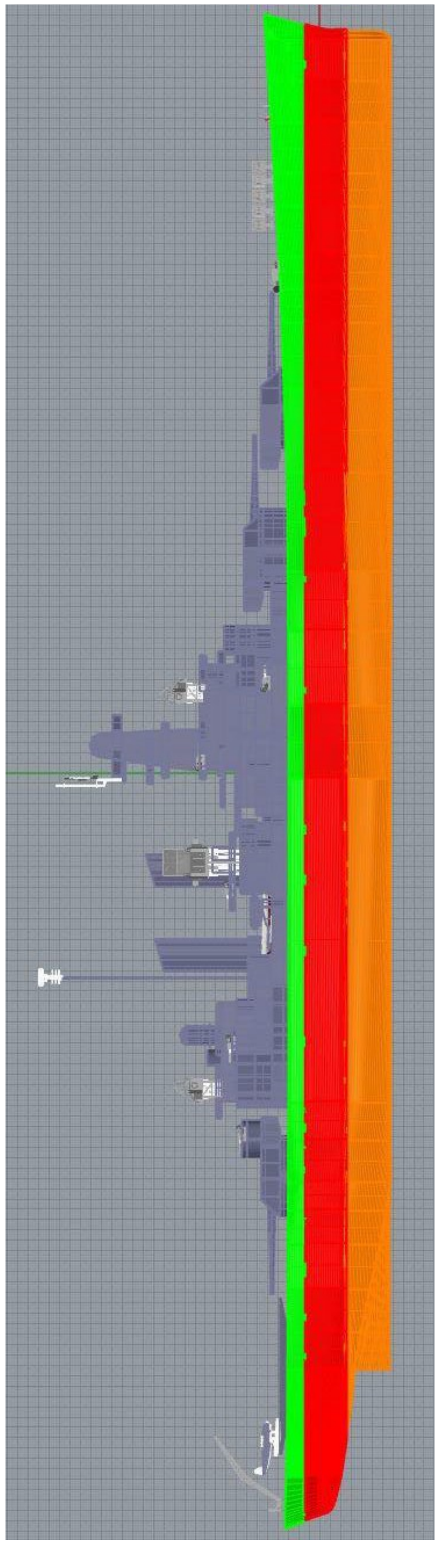

Figure 47. Image depicting degrees of corrosion risks on USS *North Carolina.* (Image by author 2020)

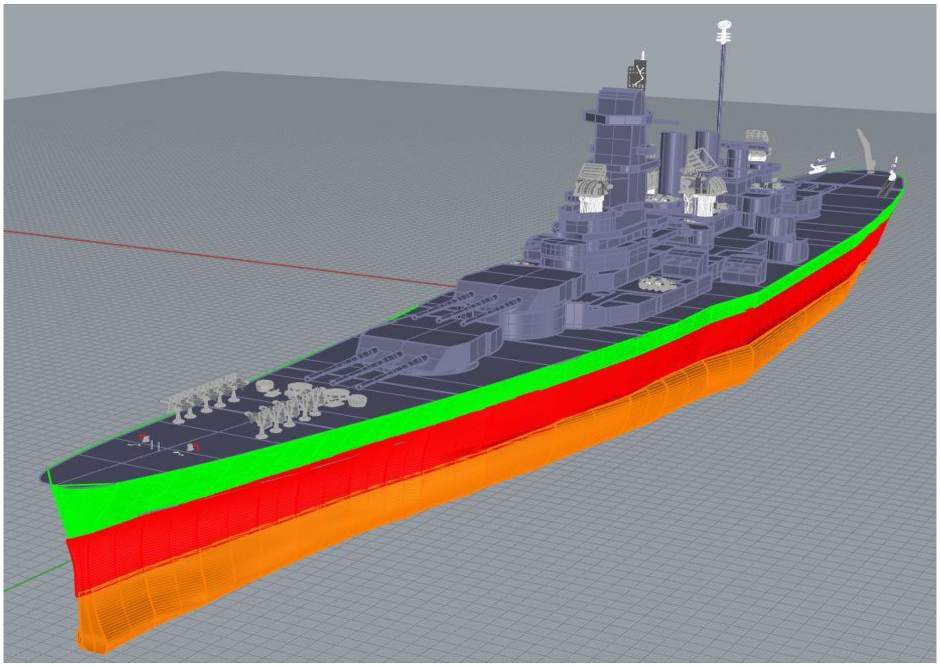

Figure 48. 3/4 Starboard bow view with color coding to show degrees of corrosion risk. (image by Author 2020)

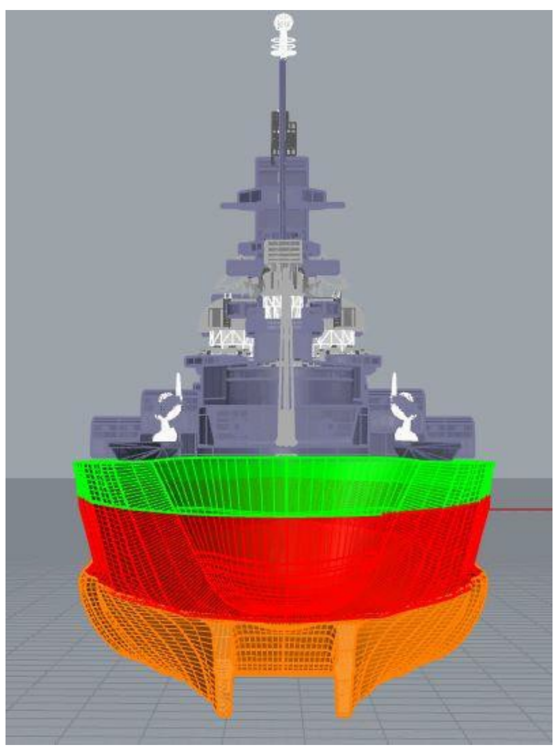

Figure 49. Stern view with color coding. (Image by Author 2020)

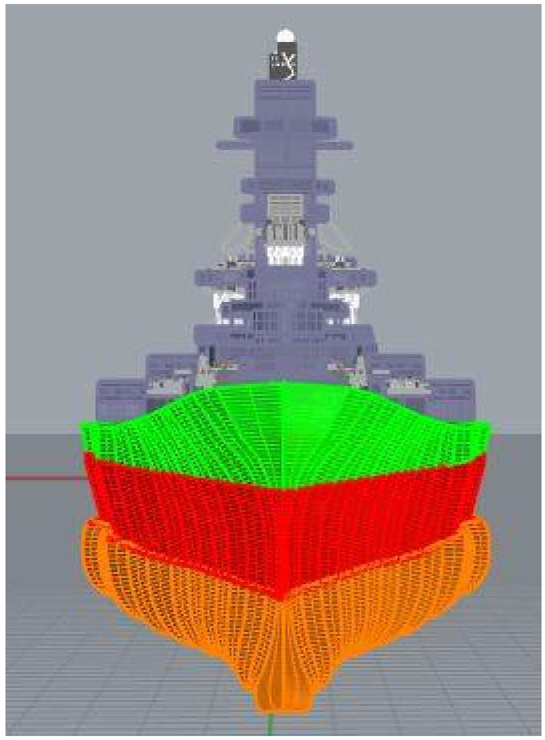

Figure 50. Bow view color coding. (Image by Author 2020)

Impact on other Battleship Museum Preservation Strategies

Naval vessels from World War II constitute a significant portion of the museum ships in the United States (Museum Ships 2020). There are currently eight battleships serving as museum ships in the United States: four *Iowa*-class battleships (USS *Iowa*, USS *New Jersey,* USS *Missouri*, and USS *Wisconsin*), two *South Dakota*-class battleships (USS *Alabama* and USS *Massachusetts*), a *New York*-class battleship (USS *Texas*), and a *North Carolina*-class battleship (USS *North Carolina*). As shown in Table 1, USS *Texas,* USS *North Carolina,* and USS *Alabama* were converted to museum ships by the early 1960s, while USS *Massachusetts* and the *Iowa*-class ships were not converted to museum ships permanently until the late 1990s and early 2000s (Texas Parks & Wildlife 2018; USS Alabama Battleship Memorial Park 2018; Battleship North Carolina 2018b). The preservation issues occurring at USS *North Carolina* throughout its career provide an opportunity for research to show whether the methods used to deal with these issues are effective or not.

There are a variety of factors that affect corrosion on the hulls of museum ships. The type of berth a ship is in affects the size and location of the wind/waterline, the condition of a ships paint and cathodic protection, and how frequent inspections and maintenance are carried out. Additionally, the type of environment a ship is in will have effects on the rate and location of corrosion. While many of these factors vary from museum ship to museum ship, some of the conclusions taken away from this research can be extended to other museum ships as well. The most important step that can be taken to prevent corrosion is routine inspections. Inspections on the condition of the hull, its paint, and cathodic protection systems installed to prevent corrosion. The highest risk area of a museum ship is the wind/waterline, so special attention should be given to that area. Therefore, ship museums should develop maintenance strategies based on the type of berth and the environment they are in to minimize and manage the risks of corrosion in this area. While small repair projects can cost museum ships a large sum of money, the expenditure on smaller projects will not add up to the massive costs associated with major repairs that will be required if proper maintenance provided.

Impacts of Hull Preservation Strategies on Public Outreach

Ships are converted to memorials to remind the public of ideals and people that stood for them from a past era. USS *North Carolina* serves as a memorial for the 11,000 North Carolinians, across all branches of service, who gave their lives fighting for the United States in World War II (Battleship North Carolina 2018d). USS *North Carolina* is self-supporting, and does not receive funds from state, federal, or local tax dollars to support its operation or administration (Battleship North Carolina 2018c). Therefore, the ship largely relies on income from tourism, fundraising, and grants. This means that the ship's ability to operate relies on it being open to generate income from tourism, so any closures from repairs not only cost the ship the repair fees, but also the income that is no longer generated from visitors.

Throughout the two major repair projects conducted on the ship, neither has forced closing the ship to visitors. The newest cofferdam and memorial walkway project have extended its outreach abilities by making the port side of the ships exterior available for visitors to view. These repairs have also served as excellent opportunities to educate the public on the preservation issues the ship deals with through projects such as the Battleship Generations Campaign and Living with Water (Battleship North Carolina 2018c). The purpose of museums is to provide public outreach and make history accessible to the modern citizen in a relatable way. While the major repairs are sometimes necessary, the ability to remain open during these projects has benefited both the ship and the public.

Conclusion

The caretakers of USS *North Carolina* have made many decisions over its lifetime that have had both positive and negative impacts on the vessel. This chapter analyzed how the actions have affected the ship starting during its time as an active warship. After discussing maintenance and the torpedo damage the ship suffered during World War II, analysis of the mothballing strategies for naval vessels at the time was provided. After that, analysis of a variety of aspects of museum ship preservation strategies were provided. The ways the preservation strategies of USS *North Carolina* could be used to impact preservation strategies of newer battleship museums was also discussed in the section. Finally, the impact that hull preservation strategies have had on the public outreach ability of USS *North Carolina* was included. As a museum ship, periods neglect led to the need for major repairs, but current projects seem to be working towards fixing these problems and making them much easier to manage in the future.

CHAPTER SEVEN: CONCLUSIONS

USS *North Carolina* began its career as a symbol of power and prestige in the United States Navy when it was launched in 1940. After an illustrious career culminating in fifteen battle stars in World War II, USS *North Carolina* found itself outdated and was retired to the Reserve Fleet in Bayonne, New Jersey. The ship was saved from the scrapping yard in 1961 when its namesake state raised the funds to have it towed to Wilmington, NC where it was converted into a museum ship and memorial for veterans of North Carolina who lost their lives fighting in World War II. It has remained berthed resting in mud for almost 60 years now where it has experienced a variety of preservation issues and actions.

This study implemented a multifaceted plan to develop a series of 3D models that illustrated the variety of actions and the effects of those actions on the preservation of USS *North Carolina.* The use of a 3D modelling program, *Rhino*, and a historic preservation and cultural tourism theories were instrumental in the development of the three research questions. Collecting historical data and researching these theories were essential to analyzing the transformation of USS *North Carolina* throughout its lifetime. The historical data was incorporated into a 3D model of the ship, which allowed the illustration of these transformations for analytical purposes. The 3D models provide exceptional visual references for the transformation of USS *North Carolina*, but as mentioned above, also act as an analytical tool that shows areas of risk and how they develop.

Research Questions

Three primary research questions were presented to guide the purpose of this study:

1) What preservation strategies have been used to preserve the Battleship *North Carolina*, and how do those strategies impact the future integrity of the vessel?
2) How can the hull preservation strategies of the Battleship *North Carolina* be used to impact and improve other battleship museum's preservation strategies?
3) How have hull preservation strategies improved or impeded the public outreach abilities of the Battleship *North Carolina?*

Regarding the first question, Chapters Five presented a chronological list of all known actions affecting preservation that were implemented on USS *North Carolina* as both an active warship and a museum ship. It discussed maintenance, torpedo damage, and mothballing the ship when it was a warship, and followed that with a discussion of the initial preservation activities and major preservation projects that occurred when USS *North Carolina* became a museum ship. Chapter Six went on to analyze these actions using theories and case studies discussed in Chapter Three. Research showed that for its first forty years as a museum ship, USS *North Carolina* did not always receive the hull maintenance or maintain the necessary corrosion preventing systems it needed, especially along the wind/waterline. Actions taken in the past decade have begun to correct these issues and implemented plans to prevent them in the future as well. The installation of the permanent cofferdam is a suitable method for controlling water levels on the ship's hull and allowing for easier maintenance and repairs in the future.

The second question necessitates a more complex answer. The main point that should be made is that a proper maintenance schedule is possibly the most important part of a ship museum's preservation strategy. If the management team does not regularly inspect the ship and its protection systems, the risk of these issues reaching a critical state and costing more that the managing institution can afford becomes incredibly high. Additionally, the area that is typically at the highest risk of corrosion on a ship museum is the wind/waterline. While the size of the wind/waterline area will be affected by the berth type and other factors, it is important to constantly inspect and maintain this area of the ship. While there are takeaways from the preservation strategies used by USS *North Carolina* that can be used to improve strategies used at other battleship museum ship, it is also important to realize that each battleship museum is located in a different aquatic environment with a different climate and these factors will change the types of preservation challenges they will face. Each battleship museum will also have to balance economic factors with its preservation needs.

The final question asked how the preservation strategies have improved or impeded USS *North Carolina*'s public outreach abilities. This is an area that the management of the ship has always excelled at. Throughout all the major repair projects the ship has undergone, it has never had to close its decks to the public. The newest permanent cofferdam project also allowed the construction of a walkway around the ship that lets visitors see the starboard side of the vessel as well. The ability to keep the ship open to the public is huge from both a public outreach and economic standpoint. Maintaining a battleship is not cheap, and revenue from ticket sales and donations is the primary way the ship funds its upkeep. Overall, managers of USS *North Carolina* have done well in balancing public outreach with preservation strategies.

Future Studies

The use of 3D modeling in this study has the potential to serve as a basis for future studies on museum ship preservation. While this study focuses on basic principles of preservation theories, future studies can expand the types of data collection and methods of modeling to improve the ability to identify areas of risk. Collecting samples of the soil, water, and hull would be some of the obvious variables that should be considered in future studies.

Also, more in-depth analysis of factors such as average tides to more accurately measure the size of the wind/water line and voltage of cathodic protection systems would benefit future studies. Additionally, methods of improved modelling accuracy could be implemented. With technological advancements in drones and their ability to capture high quality images and videos, photogrammetry has the potential to contribute to this study immensely. This would reduce inaccuracies in measurements that may have occurred in this study due to user error and discrepancies in scanned blueprints that are not originals. Furthermore, accessing other areas of research, such as the National Archives, state archives, and other ship museum archives could provide more historical data that could improve future studies.

Conclusion

This study spanned from 2018-2020 and investigated how past preservation activities affected the current and future state of USS *North Carolina*'s preservation. Through historic research and studying historic preservation theories and museum ship common practices, analyses were able to be drawn. Ultimately, despite shortcomings in the past, USS *North Carolina* seems to be heading in the right direction with its preservation strategies and will serve as a monument and memorial to the World War II veterans of North Carolina for many decades to come. Hopefully, this project will provide a foundation for using 3D modelling as a tool to identify and analyze areas of risk on other ship museums around the world.

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