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04 December, 2012

Hull Repairs for USS North Carolina Battleship Project
Submittal for the
The Pinnacle Awards
2011 Best Construction Project Competition

Submitted by: Taylor Bros. Marine Construction, Inc.

Executive Summary:

The Battleship North Carolina Hull Repairs project was a qualified bidder project that was awarded to Taylor Bros. Marine Construction on 01 March 2011. At first glance, this project seemed to be a fit for a major shipyard based company, but Taylor Bros. Marine immediately identified it as a great opportunity for the company, and for the Battleship North Carolina. The challenges seemed immense, and included replacing 132 feet of hull plating under the waterline on the starboard bow of the ship. Taylor Bros. Marine Construction overcame these challenges by planning and engineering in lieu of change orders and swelling the budget. Out of six companies pre-qualified, including very large shipyards, a North Carolina based small business was selected to complete the work. Not only did Taylor Bros. Marine Construction complete the work, it was completed ahead of schedule and under owner budget. Taylor Bros. Marine Construction is very grateful for this work and we are honored to have helped save this piece of world history. This project merits a Pinnacle Award because it was a very technically challenging and unique project that was completed safely, on time and within the owner's budget, without impacting the public's access to one of North Carolina's top tourist attractions. More importantly, this project helped save this historic icon from further degradation, ensuring that generations to come will be able to tour this magnificent tribute to American ingenuity and our World War II veterans, 10 of whom gave our country the ultimate sacrifice on her decks during the war.

Detailed Narrative:

The Battleship USS North Carolina's keel was laid down on October 27, 1937 at the New York Navy Yard and she was launched on June 13, 1940. Walking around this magnificent ship, it is hard to imagine how she was built in just over three years. The ship had a price tag of $76,885,750.00 in 1940 dollars, which was quite an investment in our nation's security.

That investment paid off, as she was the most decorated Battleship in World War II. She served in every major campaign fought in the Pacific Theatre, including Guadalcanal, the Solomon Islands, the Gilberts, the Marshalls, the Carolines, New Guinea, the Marianas, the Philippines, Iwo Jima, Okinawa, off the shores of Japan, and finally to victory in Tokyo Bay. On September 15, 1942, the Japanese submarine I-19 fired six torpedoes at her and other ships in company with her. Three hit and sunk the Aircraft Carrier Wasp, and one struck the North Carolina on her port bow, killing five men and leaving an 18 by 32 foot hole in her side. She listed 5.5 degrees from the flooding, which was corrected in six minutes by her expert crew. She continued in battle for three more weeks until repairs could be made in Pearl Harbor. Once safely at Pearl Harbor, she was dry-docked and repairs made.[i]

The USS North Carolina was removed from service in 1947 and berthed in Bayonne, New Jersey. In 1960 she was stricken from the Navy roster, and eventually designated for scrapping. The citizens of Wilmington, North Carolina, led by James Craig, Jr. and Hugh Morton started a campaign to bring the North Carolina home. Funded by the donation of many dimes by school children, including this project's architect, Charles Boney, Jr. of LS3P, over $330,000.00 was raised and the ship was towed to Wilmington on October 2, 1961. [ii]

The Battleship North Carolina is berthed in a slip on the Cape Fear River, directly across from the city of Wilmington. The ship was ballasted down when she was placed in the slip and sits firmly on the bottom. This slip has filled in with silt and mud over the years and ebbs out completely at low tide for two thirds of the ship's length. Since the ship is on the bottom, the tide rises and falls on her hull without the ship floating with it. This results in a wet/dry cycle for a five foot tall band around the hull (5 foot range of tides). This wet/dry cycle has caused coating failure, and subsequent galvanic corrosion (pitting) of the exposed steel.

Fifty years after being berthed in Wilmington, the hull on the starboard bow suffered from major corrosion damage. The forward 135 feet of the ship is plated with 1/2" plate, which corroded through in several areas on the starboard bow just below the waterline (wind/waterline corrosion). The ship is built of much heavier plating and even armor aft of this point, and is in better condition. As seen in Figure 1, Typical Interior Conditions, the inside of the ship was suffering because of the breaches in the hull plating resulting in flooded compartments and accelerated deterioration.

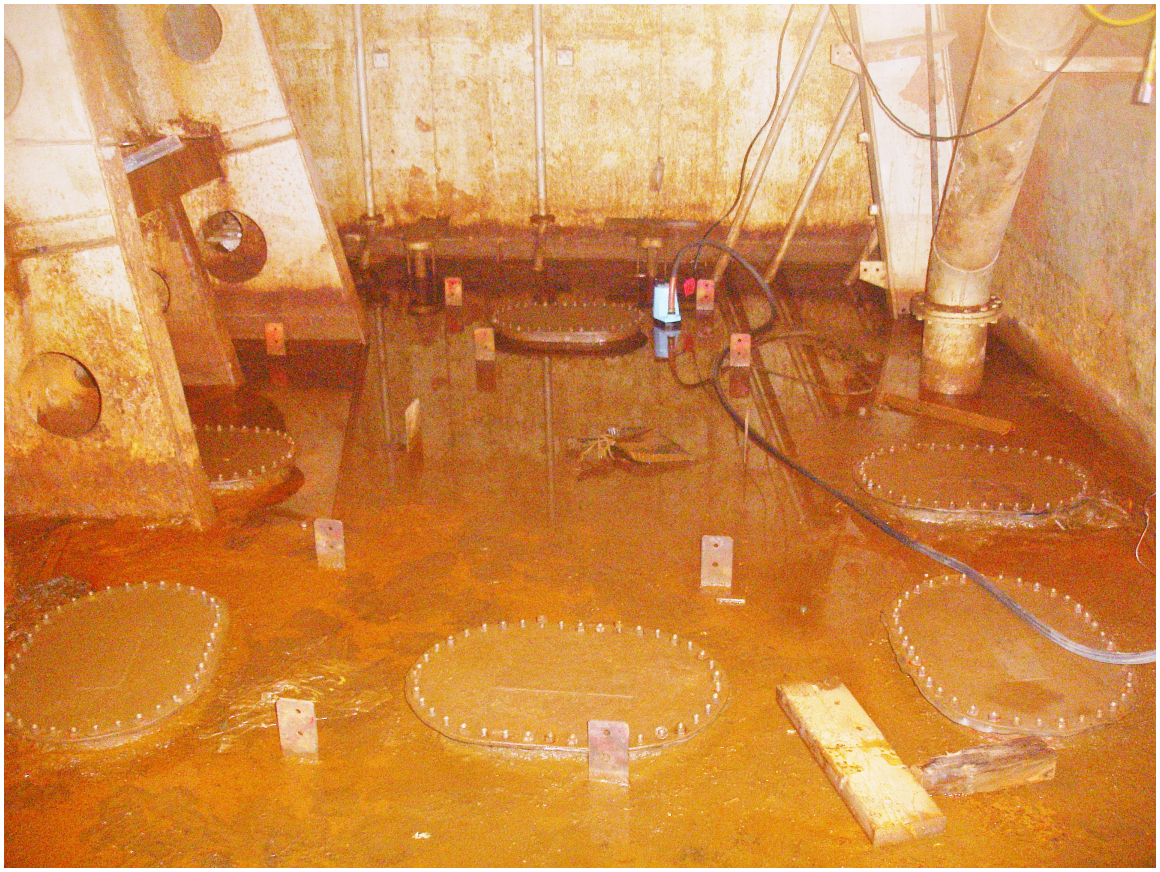

Figure 1. Typical Conditions

The Battleship North Carolina Staff contacted Joe Lombardi, a reputable Marine Surveyor with significant experience in museum ship restoration, to survey the ship. LS3P Associates, LTD was contracted as the architect, and a project was developed to repair the damaged hull. Six contractors were pre-qualified, and Taylor Bros. Marine Construction, Inc. out of Beaufort, NC won the bid for the project.

The specified scope of work for the project was to design, build, and install an external cofferdam on the starboard side of the ship from Frame 4 to Frame 38 (132' of hull) to complete the work, moving it as necessary and delivering the cofferdam to the owner upon project completion. Remediate all steel plating, framing, and bulkheads free of lead based paint as necessary to enable safe cutting and welding operations. Crop out and replace hull plating with new ½" thick A-36 steel plating within the confines of the spaces from Frame 5 to 38, and apply the specified coatings to the new steel, and any disturbed remaining steel. Taylor Bros. Marine completed the scope of work, plus three necessary minor change orders ahead of schedule and under owner budget.

A. Unique Aspects

To say that this project had unique aspects is an understatement. First, the project was the repair of a World War II Battleship hull. Very few existing companies have performed hull work on a WW II era battleship.

USS North Carolina is also one of the top tourist attractions in the state, and by far the largest tourism draw to the Wilmington area. Up to several hundred visitors per day visit the ship, and it was very important for our company to conduct this work with the safety of the ship's visitors as priority one. With heavy lifting (in excess of 50,000 lbs) taking place immediately adjacent to the starboard bow, it was necessary to implement a special lift plan to ensure that tourist were clear of the danger area when lifting. The tour route covering the bow was secured whenever heavy lifting was performed, but only then, to maintain the normal tour routes on the ship whenever possible.

Another unique aspect of this project was that the work was performed mostly underwater. The corroded steel extended from just below the waterline at mid tide to about 10 feet under the water at low tide. This required that a cofferdam be used to complete the work without flooding the ship. This method of construction will be fully explained in the following "challenges/innovations" section.

By far the most unique feature of this project was the purpose of the project – preserving a 75-year-old U. S. Navy Battleship. The ship is a time capsule of the late 1930s and early 1940s and WWII, and is a tribute to the men and women who built her, and the men that sailed on and fought her. It was quite an honor to be selected to work on the most decorated battleship in World War II.

B. Special Value to the Community

The Battleship North Carolina is a pleasant childhood memory for almost every child who attended school near the coast while growing up. I remember my 5th grade field trip like it was yesterday. These memories for generations all started in 1960 when James Craig, Jr. and Hugh Morton started the campaign to bring USS North Carolina to Wilmington. The "Save Our Ship Campaign" as it became known immediately took off with support from television celebrities such as Andy Griffith, Jane Morgan, and David Brinkley. [iii] About $330,000.00 was raised (over $2 million in today's dollars) and the USS North Carolina was delivered to Wilmington.

The Battleship North Carolina serves as a memorial to all of the veterans who served in World War II and to those who served on USS North Carolina. There are about 100 surviving crewmembers remaining today. A crewmember reunion is held each year, and 21 attended the most recent reunion in May 2012.[iv] She also serves as a memorial to the ten men killed in action on her decks during World War II. One of the former crewmembers told us about the port bow repairs that he took part in after a Japanese torpedo struck the ship in September 1942, killing five men. He bragged that it only took

his crew three weeks to repair the port bow, while it was going to take us 6 plus months. I have to add that his crew was larger in Pearl Harbor, and he had the luxury of a dry-dock, but I didn't tell him that.

The Battleship North Carolina also provides a huge economic boost to the local economy. The University of North Carolina Kenan Flagler School of Business recently performed a detailed Economic Impact Statement for the Battleship North Carolina. The ship had 2,373,186 paid visitors from the year 2000 to 2010. The revenue from these paid visitors results in 3,173 job-years (303 in 2010) with a labor income of $83.5M ($8M in 2010). This has resulted in $16.5M (1.6M in 2010) in tax revenue. Since the Battleship North Carolina is self-sufficient and does not depend on tax dollars, the return on investment (zero input) is excellent![v]

The thought of limiting the tour route, or closing the ship and scrapping her due to unsafe conditions is not acceptable. The Battleship North Carolina is extremely valuable to the Wilmington area, and even to our nation. The ship's revenue funded our project without state or federal tax assistance, and we worked hard to ensure that those dollars were not wasted. Our repairs arrested the internal corrosion and degradation of the hull, keeping the ship water tight and safe, and ensured that this icon will remain open to the public for the foreseeable future.

C. Construction Challenges/Innovations

The challenges faced on this project were in plain view from day one. They were:

1. Build and deliver a 30' long, 15' tall, 12' deep steel cofferdam for use underwater.
2. Access the work site without going through the ship, or over its teak decks.
3. Create a detailed map of the existing curvature of the hull in each location where the cofferdam will be placed.
4. Attach that cofferdam to the hull without damaging or overstressing the existing hull.
5. Position the cofferdam against the hull for attachment, under the rake (over-hang) of the bow (cannot directly lower into position with a lift crane).
6. Remediate lead based paint within 4" of any torch cut, both inside and outside of the hull.
7. Clean out and make safe for hot work 8 fuel tanks – 3 of which were part of the side of the ship replaced.
8. Cut out and remove corroded hull plating, and replace with new plating.
9. Prepare and coat all new steel and existing framing to like new conditions.

The project specifications required that we use JMS Naval Architects as the designer of the cofferdam. Taylor Bros. Marine worked with JMS to develop a design that could be feasibly handled by our 100-ton crawler crane on a barge and still be large enough to allow the work to be done feasibly. The JMS design included the cofferdam only.

Taylor Bros. Marine designed the system to attach the cofferdam to the hull (hinge plates), and the system to move the cofferdam from the edge of the barge out to the hull (transfer system). The transfer system was necessary because the rake (overhang) of the ship's bow prevented the crane from directly placing the cofferdam on the side of the ship. See Figure 2, Cofferdam Installation.

Figure 2. Cofferdam Installation

The cofferdam was fabricated at the Taylor Bros. Marine fabrication yard in Beaufort, NC. It was trucked to Jarret Bay boat yard where a 200 ton marine travel lift was used to load it onto a Taylor Bros. Marine barge for transport to the jobsite in Wilmington.

The work site was the starboard (right hand when facing forward on the ship) side of the bow. We were tasked with cutting out and replacing 132 feet of hull plating, 10 feet tall, at and below the waterline. Some of the hull cutting was directly into Nr. 6 oil (Bunker C) tanks, so those tanks required cleaning. Accessing the site was a challenge. Fuel tank cleaning hoses and transporting material across the teak deck of the ship was problematic in that is posed a safety threat to visitors unless the bow was completely secured, and it threatened damage to the beautiful teak deck of the ship. Since the bow is such an important part of the tour route, Taylor Bros. Marine created a floating bridge from the shore on the port side of the ship, out and around the bow, to the work site. This bridge was made of Taylor Bros. Marine sectional barges spudded (anchored to the bottom using long, heavy pipes attached to the sides of the barge) at each end. This bridge provided a secure place to tie down all tank cleaning and lead base paint remediation hoses, while provided a safe platform to access the site. Steel plate could also be transported directly to the site using a small fork lift. Hand rails were placed along each side of the bridge for

personnel safety. It also allowed the crew to park vehicles out of the way, and walk to the site without interfering with the ship operations or visitors. This system proved to be very efficient and saved countless days accessing the work site. See Figure 3, Site Plan.

Figure 3. Site Plan

Once the cofferdam was in place and a system was set up to access the site, Taylor Bros. Marine was ready to go to work. The next phase of the project was to create a system to map the curvature of the hull, and create seals for the cofferdam. The shape of the sealing surface of the cofferdam was critical to ensure minimal leakage while cutting into the hull at depths of up to 12 feet underwater. A hull gage was designed and fabricated and then used to measure and record the profile of the existing hull at each planned cofferdam set location. The gage consisted of a square tubing frame that measured 15' tall by 30' long (same dimensions as cofferdam sealing surfaces). A lockable pin was installed every 12" along the frame. See Figure 4, Hull Gage. The frame was held into position about 3 feet off of the hull using strong magnets on jackscrews at each corner of the gage. Once the gage was in position, the jackscrews were adjusted to ensure that the gage was exactly plumb and level. A diver then positioned each pin against the hull, and locked it into place. Once all pins were locked, the gage was removed, and each pin measured and recorded.

Figure 4. Hull Gage

This created an exact contour of the hull every 12” along the cofferdam seal. The open end of the cofferdam mating with the hull was fitted with a large flange. The removable flange face was fitted with 1/2” thick, framed plate. This plate was marked every 12” with the hull gage data, faired, and trimmed with a torch. A ½” by 10” wide flat bar was welded to that cut edge to form the seal face. Finally, a 2” thick, by 10” wide piece of oil resistant foam insulation, very similar to that used on air conditioning lines, was glued to the seal face. See Figure 5, Cofferdam Flanged Seal Face.

Figure 5. Cofferdam Flanged Seal Face

Five seal sets were made in advance, and two flanges were made (one in use, and one being prepared for the next set) to minimize down time between cofferdam sets. The extra flange saved approximately 15 work days on the critical path because the crew could prepare the next seal set in parallel with work going on inside the cofferdam.

When attaching a large cofferdam to a ship, several forces must be analyzed. First the buoyancy of the large cofferdam was over 280,000 lbs at high tide. Also, the hydrostatic force pushing the cofferdam horizontally into the ship was over 140,000 lbs. Conventional means of attaching cofferdams to ships use bellybands – cables that run from the opposite side deck under the ship to the bottom of the cofferdam. Our cofferdam was far too large for this, and the condition of the 75-year-old hull on the bottom was unknown. The ship also sits in 30 feet of mud, which made this means impossible. Taylor Bros. Marine designed a means to connect the cofferdam to the side of the ship by using a large pad eye on the ship, and a pin connection on the top of the cofferdam. Once the cofferdam was in position, the pin could be inserted, and the cofferdam would hang in position against the hull. The cofferdam attachment pad eyes were attached to the hull using large hinge plates. Each plate was 1.5" thick, and measured 2' x 8'. The ship has is framed on 2' centers. The 8' dimension ensured that the hinge plate engaged at least three of the ship's frames on the inside of the skin of the ship. Taylor Bros. Marine engineering analysis of the ship's framing system ensured that the ship could withstand the shear, moment, and compressive forces imparted onto each

hinge plate. Each hinge plate contained two large pad eyes on its face. The spacing of the pad eyes was critical and allowed the overlap the cofferdam covered work area to take place without moving the hinge plates each time. As said, the task was to replace 132 feet of plating, 10 feet tall, on the starboard bow. By moving and slightly overlapping the cofferdam on each move, this could be done in five sets of the cofferdam.

The transfer system was necessary to allow horizontal movement of the cofferdam from the edge of the work barge over to the hull. The rake of the bow, especially at the forward most end of the work area, prevented hanging the cofferdam immediately next to the hull. The transfer system consisted of two large beams extending from the deck of the barge to each hinge plate. Each hinge plate contained two extra pad eyes just for the transfer beam-ends. A cross beam also connected to the two free ends of the transfer ends to prevent the beams from spreading apart while the cofferdam was on the beams. The cofferdam was lowered onto the transfer beams and rested on four removable rollers. Once the cofferdam was resting on the beams, the lift crane was disconnected from the cofferdam, and connected to the transfer system cross beam. The cross beam was lifted with the lift crane to permit the face of the cofferdam to engage the hull squarely, or slightly top in with a gap at the bottom of the cofferdam. The rollers allowed the crew to roll the cofferdam into position relatively easy with large chain ratchets. Once the top of the cofferdam was against the hole, a large pin was inserted through two slotted holes in the cofferdam-handling rig, engaging the hinge plate large pad eye. This fixed the top of the cofferdam to the hull. The cross beam was lowered, and the cofferdam came to rest against the hull of the ship. The slotted hole was critical in the design and allowed the top of the cofferdam to move in and out to prevent binding while lowering the cross beam and seating the cofferdam. See Figure 6, Transfer System with Slotted Hole Visible. A large turnbuckle was attached at each top end of the cofferdam to draw in the top of the sealing surface and ensure that pressure was maintained on the top of the sealing surface at all times. The rollers and transfer system were then removed, and the cofferdam dewatered with a large pump.

Figure 6. Transfer System with Slotted Hole Visible

Taylor Bros. Marine was very concerned that the leakage rate would be excessive and that constant pumping would be required to maintain the cofferdam dry enough to work in. The first cofferdam set was made, and the cofferdam was seated very late in the day. The decision was made to send everyone home for rest and dewater the cofferdam the next day. One small electric garden hose sized pump was left in the cofferdam by mistake when the crew left that night. We came in the next morning to find one burned up garden hose pump, and a completely dry cofferdam. The leakage rage was zero, and conditions actually got dusty in the cofferdam later that day. The system worked far better than imagined. See Figure 7, Looking at the Hull For the First Time in 50 Years.

Figure 7. Looking at the Hull for the First Time in 50 Years

While some of the crew was working on setting the cofferdam, others were busy remediating lead based paint inside of the ship. The lead based paint remediation crew had to remediate a 4" wide strip on either side of any planned cut of the hull. This meant that every frame in the 132 foot by 10-foot tall work area was remediated. This work area included over 12 spaces internal to the ship. Once the cofferdam was dewatered, scaffolding was installed, and the remediation crew remediated the hull exterior so that cutting could begin. The exterior of the hull was remediated completely (not just where the cutting would take place) so that a pre-cut inspection could be performed. This inspection allowed Joe Lombardi and Taylor Bros. Marine to layout the cut lines to minimize cutting out non-corroded plating, saving the ship some money on the plating replacement allowance.

Cofferdam work and lead based paint remediation was started at the forward end of the 132-foot work area. The aft 80 feet of work included cutting into 4 of the ships fuel tanks, therefore a crew commenced cleaning those tanks, and the 4 adjacent tanks once the access system was set up. Tank cleaning consisted of accessing each tank, pumping all of the existing fuel to a tank on shore, then spraying the interior of the tank with diesel fuel. The diesel was pumped out, and more sprayed in until the tank walls and structure were clean enough to wipe clean with towels. This usually took three or four iterations of diesel spraying to clean a tank, and it was arduous work. Once the tank was cleaned, a forced ventilation system was set up in each tank to clear harmful and flammable gases and maintain the atmosphere safe for entry and for hot work. The plan was for the tank cleaning to be complete prior to the cofferdam and work area reaching the fuel tanks, and that developed as planned. See Figure 8, Fuel Tank Prior to Cleaning. As seen in this photo, cleaning the tank was no trivial task.

Figure 8. Fuel Tank Cleaning

Once dewatered and remediated, the hull was inspected and the cut lines were marked for cut and removal. A track torch was used to make the cuts straight and beveled, which saved time when new plate was fit in. Once the outer boundary cut was made, each section between frames within that boundary was cut out and removed. See Figure 9, Hull Plating Removed. Inspection of this photograph makes it obvious why the cofferdam leakage rate was so important.

Figure 9. Hull Plating Removed

The remaining framing was cleaned up and prepared for welding in the new plate. Taylor Bros. Marine had the new plate shop-blasted and coated with the specified primer prior to arrival, which saved more time. The new plate was cut, fit and dogged into place, and welded out. See Figure 10, New Plating Installed. As seen in this photograph, the original plate lapping lines were maintained when the new plating was installed.

Figure 10. New Plating Installed

Each Taylor Bros. Marine welder was qualified in accordance with American Bureau of Ships standards prior to work start. Once each welder laid down 12" of weld, each was evaluated via radiography to ensure weld-ability of the material, and to ensure that the welder was capable. All welds were then tested by using dye penetrate and the Ultrasonic Shear Wave method.

Once welding was complete, the new steel and existing framing was cleaned, prepared and coated with the specified primer and topcoat. All coatings were tested for quality and thickness. Of note, an independent third party testing agency performed all testing. Once the test reports were reviewed and all discrepancies cleared, the cofferdam was flooded by removing two plugs in the bottom. The cofferdam was removed and placed on the deck of the barge, and the next seal set bolted onto the flange. The process was repeated five times.

D. Safety Performance

Safety was a major concern on this project because of the unique challenges and risks faced. Also, close proximity to the visiting public made safety even more critical.

Three safety risks stood out on this project. Not unusual to any construction project, they were fall protection, crane safety, and confined space issues.

Taylor Bros. Marine invested in two scaffolding sets for use on the project. One was for cofferdam work inside of the cofferdam when it was in place on the hull. This scaffolding system provided two work levels with handrails in place for each. The other system was used when the cofferdam was on deck. To change out the seals between sets, the cofferdam was laid down on its back, and scaffolding erected inside of it to allow easy and safe access to the seal flange. These two systems eliminated the temptation for the crew to climb and crawl into situations requiring fall protection.

Crane safety was also critical due to the location of the crane. If the boom were to collapse during a cofferdam lift, it would likely fall across the bow of the ship. Therefore, prior to any lifting with the crane facing the ship, the bow area of the ship was secured to visitors. The time was minimized and was usually kept to 3 hours every few weeks. All OSHA crane standards were followed, and all Taylor Bros. Marine crane operators are NCCCO certified.

Taylor Bros. Marine was forced to work in several confined spaces on the ship, including the performance of hot work inside of fuel tanks. Prior to work start, Taylor Bros. Marine stood up and trained a confined space rescue team and conducted several space evacuation drills. Although not required by law, Taylor Bros. Marine also coordinated with the governing fire department technical rescue team to back up our team.

Another unique risk faced was the constant threat of new leaks forming in the areas not yet repaired. This became a serious problem once the fuel tanks were cleaned and opened. Special patches were made and staged in likely leak areas. The patches could be attached by lowering them down on the side of the ship with a pole. A bolt was passed through the leak, and the patched tightened to the hull from inside the ship. This patch method was used 6 times prior to replacing the corroded hull in the after sections. See Figure 11, Patching a New Leak.

Figure 11. Patching a New Leak

All of the safety preparations and expenditures paid off. We suffered Zero lost time accidents and Zero injuries on this project.

E. Excellence in overall Project Management

The Battleship North Carolina is a completely self-sufficient organization that receives no money from the State of North Carolina in taxes. All of the funding for this $2M project was generated by the ship through visitor ticket sales and paid events on the ship. Taylor Bros. Marine recognized that ship visitors were the lifeblood of the ship's cash flow, and approached this project with a goal of never closing the ship for operations. Taylor was able to do that by using the sectional barge bridge system to prevent accessing the site through or over the top of the ship. This approach resulted in no lost operating days for the ship during the project. As stated previously, the only impact on ship visitation was the securing of the ship's forecastle during heavy crane lifts which only lasted for a few hours once every 3 weeks or so.

Taylor Bros. Marine also took steps to make the job site OSHA compliant so that outside agencies such as local news media, Navy tour groups, Friends of the Battleship (fund raising group), as well as employees and others could safely walk out to the actual cofferdam and see the work in progress, when properly supervised by Taylor Bros.

Marine. This extra effort by Taylor Bros. Marine resulted in numerous televised and published news stories on the ship, raising awareness and visibility of the project and the ship itself.

F. Budget/Schedule Considerations

The time of completion for the project was 180 calendar days, which was very tight considering the volume and complexity of the work. In order to meet this aggressive timeline, Taylor Bros. Marine worked very hard in the pre-bid, and pre-award phases to save project time. First, Taylor Bros. Marine conducted a very detailed survey of the work area prior to bidding the job. A set of detailed CAD drawings were developed for use in hull strength analysis. This extra work enabled Taylor to analyze the strength of the hull and subsequently design the cofferdam attachment system prior to bid day – eliminating "extra" money added to the bid as a guess for that design, saving the owner money.

Another significant time saver was the design and construction of the cofferdam prior to contract signing – a huge risk for a small company to take. Taylor evaluated the low risk of the cancellation of the project after award versus the time saved by starting the off-site cofferdam fabrication and determined that the risk was acceptable. Taylor Bros. Marine paid for all material and labor for the cofferdam prior to contract signing.

Taylor Bros. Marine also hired an excellent Project Management and Scheduling consultant to develop a very detailed project schedule prior to bidding the project. This was another financial risk that paid off. The schedule was invaluable in the preparation of a competitive proposal that readied Taylor Bros. Marine to start the project efficiently.

Expending significant design work and funds for cofferdam construction prior to contract signing was a risk that saved at least 8 weeks of time on the schedule once the Notice to Proceed was issued and the project was completed prior to the required completion date. This project was full of risk, and good risk evaluation and mitigation was the key to its success.

The budget for this project was a concern for the owner since the risk of growth work due to change orders was high. Taylor Bros. Marine lowered this risk significantly by thoroughly investigating the ship, means and methods to complete the repairs, and by taking ownership of our means and methods once started. Only three change orders were generated during the project. The first change order was to add 4 zinc anodes to the hull exterior during each of the five cofferdam sets. The ship's cathodic protection system was out of commission during the project, so galvanic corrosion of the existing hull around the newly installed steel was unknown. Adding the 20 total zinc anodes was cheap insurance to give the ship time to bring the cathodic protection system back online. The second change order was a result of new leaks springing in the hull in areas ahead of the repairs. The aft most space in which the hull would be re-plated contained six fuel tanks. These tanks were cleaned as discussed previously and were left open to ventilate

the tanks for the subsequent repair work. These new leaks threatened to flood the open fuel tanks, which would have been extremely expensive to dispose of the water that would have flooded the tanks. A change order was accepted to apply a high strength epoxy coating to the inside of the hull, and no more leaks occurred. The third and final change order was issued to cut out and remove the interconnecting steam heating coils inside of the fuel tanks to prevent water in those tubes from migrating from tank to tank. All of the change orders totaled to about $13,500.00 and kept the project well under budget. See Figure 12, Final External Product with Zinc Anodes.

Figure 12. Final Exterior Product with Zinc Anodes

The Battleship North Carolina Hull Repair Project was full of risk and unknowns. Hard work and the expenditure of funds prior to contract signing reduced the risks and unknowns, and allowed Taylor Bros. Marine Construction to complete this great project ahead of schedule and under budget. The success of the project can be measured in many ways, but it is obvious by inspecting Figure 13, Compartment A-405-A Existing Condition, with Figure 14, Compartment A-405-A, Post Repairs.

Figure 13. Compartment A-405-A Existing Condition

Figure 14. Compartment A-405-A Post Repairs

It was the privilege of a lifetime to be selected to conduct repairs on this piece of history, and the project was a huge success for our company, the ship, the community, and the nation. See Figure 15, Pinnacle Award Project. This project is most deserving of the Pinnacle Award for Best Building Project.

Figure 15. Pinnacle Award Project

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[i] Captain Ben W. Blee, USN(Ret), "Battleship North Carolina

[ii] www.en.wikipedia.org "USS North Carolina (BB 55)

[iii] www.ourstate.com: "Saving the Battleship"

[iv] www.starnewsonline/article: "Former crew members gather for USS North Carolina Reunion.

[v] E. Brent Lane, "Battleship North Carolina Economic Impact Statement"