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The anatomy of a fast-attack nuclear sub

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NORTH KINGSTOWN -- Victor McKenna snakes himself into a warren of pipes and metal ducts as the whir of power tools and hiss of welding torches fill the workshop. He stretches a wrench forward, trying to reach a bolt that will secure a piece of sheet metal.

The tiny bolt is one of the simplest parts in the most complex war machine ever made: a Virginia-class fast-attack nuclear submarine. The product of more than half a century of nuclear submarine design, the Virginia class marries the latest in technology — electronic, nuclear and stealth — with modern construction techniques.

The boats are designed to creep into shallow coastal waters and conduct 21st-century warfare while still excelling at a submarine's traditional mission: attacking other subs and surface ships at sea.

The life of these technological marvels begins in the top secret workshops at Electric Boat's Quonset Point shipyard, where nearly 2,000 Rhode Islanders fashion hull plate, bend miles of pipe into shape and form sheet metal into everything from beds and lockers to ventilation ducts and air-conditioning components.

The parts made at Quonset — from metal fixtures weighing less than a pound to "supermodules," a quarter of the 377-foot completed sub, weighing hundreds of tons — are shipped to Electric Boat's facility in Groton, Conn., or to Northrop Grumman Shipbuilding-Newport News in Virginia, both independent shipyards alternating final assembly of Virginia-class submarines.

The Journal was given unusual access into Electric Boat facilities in Quonset and Groton to view construction of the $2.2-billion submarines, including the Missouri, which is expected to be christened in several months after more than four years of work by thousands of workers.

The work at Quonset — in areas as small and quiet as doctors' offices to noisy ones larger than airplane hangars — is nearly as complex as the machine being built.

IN A HUSHED office, engineers use computerized three-dimensional models of the submarines to account for every inch of space in the boat, making sure everything fits and that every part — including the crew of 134 — will work in harmony.

In a shop smelling of oil, machinists grind metal for parts ranging from simple pipe connections to components of the classified nuclear propulsion system.

In a brightly lit, laboratory-clean work area, electronics technicians quietly splice fiber-optic cables and assemble the panels that will control torpedo and missile launchers.

But much of the work at Quonset is accomplished in cavernous, noisy workshops. Thunder and bright flashes of indoor lightning — from the arc of a welder — punctuate the ever-present scent of burning metal. Drills, grinders and metal punches

combine in a symphony of industrial racket. Conversations can only be held by shouting.

At Quonset, much of the work centers on supermodules, constructing finished interiors — including decks and bulkheads, machinery and equipment, piping and wiring — and sliding them into sections of hull.

The hull includes the skeleton and skin of the ship. It keeps air in and water out and withstands the crushing pressure of deep water. The maximum depth for Missouri and its sister ships is classified. The Navy will only say that it's more than 800 feet and less than the bottom of the ocean.

THE HULL BEGINS as flat pieces of steel plate. Like many of the critical specifications of the submarine, the exact composition and thickness of the metal are classified. The steel has been certified as SUBSAFE, having passed a quality-control program initiated after the 1963 loss of the nuclear submarine Thresher and all 129 onboard. Any part of a submarine that, if it fails, can result in loss of life or of the boat is subject to the SUBSAFE program.

The flat steel plates are fed through the rollers of a 5,000-ton press, curving them into shape. Curved plates are positioned in a fixture, a circular, swimming-pool-sized holder, and welded together to form a cylinder, reinforcing rings welded inside each to give it the strength to resist crushing.

Several cylinders are welded end-to-end to reach a height of about 30 feet in the vertical fixture. The connected cylinders are turned horizontal and welded into supermodules, some up to 100 feet long.

These supermodules will be outfitted with components built outside the hulls.

Interior construction is more complex. Compartments ranging from the mundane, such as dining areas and crew quarters, to the high-tech, such as the engine room and combat-systems areas, have to be fashioned and outfitted.

Much of the work begins in Department 921, where steel is fabricated.

"If you look at welding in general, that's the life's blood of what we do. That's what holds our cylinders together, our hulls together," says George Andrescavage, the department superintendent from the Chepachet section of Glocester. The work of the welders is subject to a variety of high-tech quality tests, including radiographic, ultrasonic and magnetic particle tests.

As Andrescavage speaks, he stands on what will become a deck in the command and control system module of the Minnesota. On this day, the module is little more than the flat steel of the deck and a single doorway.

Near the other end of the cavernous workshop that holds Department 921, James Reynolds, of Hope Valley, and Roger Hinrichs, of Coventry, work on high-pressure air flasks.

The flasks are shaped like a medicine capsule, but taller than a person. Like medicine, the contents of the air flasks could save the lives of the sailors aboard a nuclear submarine. The air is stored at high pressure — the exact pressure classified — and can be used to blow all the water out of the sub's ballast tanks when the boat needs to surface quickly in an emergency.

AMONG THE MOST important parts aboard a submarine are pipes. They carry drinking water and waste water, supply water to the nuclear propulsion system to make steam, and move air and water in and out of the sub's ballast tanks.

The job of fashioning and installing pipes — called pipefitting — was, like many aspects of submarine building, a time-consuming job before computers carried the brunt of ship-design work. Pipes had to be bent inside the hull or fashioned from several angled parts to snake their way around obstacles already installed in the boat.

Now, work that could have taken hours can be done in minutes by machine in the workshop.

"The computer knows the shape," says Timothy Shelton, a pipe bender from North Kingstown. He tells a computer which pipe to make, and the computer guides a machine that rotates the pipe into position, bends it to the correct angle and moves it forward precisely for the next bend. It can fashion a complicated pipe with a dozen bends in less than a minute and a half.

After being bent and cleaned, the pipes are assembled as packages on jigs, blue metal frames that mimic the structure of the

pipes' future home.

The distinctive blue of the jigs is significant. Because metal used in submarine construction has to be top quality, Electric Boat and the Navy want to be sure that everything used to build the boat has been thoroughly inspected. So, metal fixtures in the factory that are not approved for use in sub building are colored blue.

These "pipe packages" — assembled and removed from their jigs — will go into supermodules, such as the one containing the command and control system module, where they serve such things as bathrooms, air conditioning and torpedo launch systems.

While the Minnesota's command and control system module in Department 921 is little more than framework, the same module for the Mississippi in Department 915 buzzes with activity.

Department 915 is where hull sections are formed and interiors are slid into place. It's housed in Building 2003 — a building 112 feet tall that covers nearly three times the size of the baseball field at Fenway Park.

It is also where Victor McKenna works. McKenna, 37, of West Warwick, a sheet metal technician, has worked on subs for the last seven years, leaving for two tours of duty in Iraq and Guantanamo Bay, Cuba, with the Army National Guard.

Most of the Cranston native's work is in the command and control systems module and the supermodule where sub crews will eat and sleep, known as 2B-to-5. He installs ductwork and associated parts, including work on the Mississippi.

"Sometimes it's like you turn wrenches all day," he says. "Other times it's a lot more complex and a lot more thought goes into it."

UNLIKE MOST interiors, the command module will not be inserted into a hull section before being barged to Groton. The module — like the one for the Missouri sent more than a year ago — will be wrapped and sent separately to Groton for the installation of electronics and testing. Eventually, the command and control module will be inserted into the bow supermodule by either Groton or Newport News, whichever is finishing the boat.

The command and control module includes three decks: the command and control center on the center deck, crew's quarters above and the torpedo room below.

The arrangement of the command center is new to the Virginia class. Because older classes had periscopes, the simplest place to build the command center was on an upper deck. But Virginia-class submarines use electronic cameras mounted on a mast that can be raised above the ocean's surface. The images from those cameras can be displayed on view screens anywhere in the sub.

Like everywhere else in the sub, the crew's quarters above the command center is small, seemingly inadequate for the 24 men that will live there for several months at a time. Bays of bunks line either side of a passageway smaller than the width of an adult's shoulders. Each bay has three stacked bunks.

Eight bays line the passageway, each 6 feet wide, the bunks 6 feet long. What if a sailor is taller than 6 feet?

"He, uh, bends his knees," says John Dugan, of Pawtucket, the sheet metal supervisor overseeing work on this module. "And there's a lot of those guys on a sub, so they learn to, you know, live within their means."

The plush digs go to the sub's commanding officer and executive officer. They have private rooms adjoining each other along a passageway a few steps from the command center.

Bruce Hopkins, a sheet metal mechanic finishing the officers' quarters on the Mississippi, estimates the commander has a room of about 8 feet by 4 feet. "Then, after all the equipment and furniture is in, he's got a pathway to walk through, about a 2-foot path," says Hopkins, of North Scituate. "This is a big room throughout the boat."

ON FEB. 23, 2009, the supermodule 2B-to-5, which houses crews quarters, the galley and machinery on the Missouri, sits waiting for its trip to Groton for final assembly. Many of the 150 people who worked on it over the last four years pose in its massive shadow for a "class photo" outside Building 2003.

“It’s the last module to leave Quonset Point for the 780 hull,” module superintendent Rick Phillips, of West Warwick, says, using the numeric designation for Missouri. “It’s a lot of months of six and seven days a week, a lot of hard work for the team. I feel proud. I feel great to send it out.”

In the picture is Victor McKenna, who installed ventilation equipment in the supermodule. He credits the engineers who designed the boat with making sure all the equipment fits while leaving room for the sailors who will man the ship. That’s not always exactly the case for the workers who build it. “Sometimes we’re stepping on each other; we’re in each other’s way,” says McKenna. “It’s pretty much sardines in a tin can.”

After the picture, riggers take the mammoth supermodule on a twisting path through a half-mile of shipyard, past raw steel that waits to become part of future subs.

The trip ends at the Sea Shuttle, a barge which stands on three legs that have been jacked down to concrete pads on the floor of Narragansett Bay. Without the legs, the barge could tip when workers drive the 100-foot-long, 1,700-ton supermodule onboard. The supermodule is tied to the barge with wire rope, ready for the trip to Groton, 51 miles away by water.

The next evening, the supermodule rides up the Thames River toward the Electric Boat dock. Three weeks earlier, the bow of the Missouri — supermodule 1-to-2A — arrived from Newport News. When the 2B-to-5 reaches the dock, all four giant pieces of Missouri will be at Groton for final assembly.

BUT LONG BEFORE this milestone, crew members chosen for the Missouri were already starting to put their future ship through its paces. More than a year before the final parts arrived, the boat’s command and control system module had been shipped from Quonset and into one of the most secret buildings at Groton’s riverside shipyard — the COATS facility.

COATS is a revolutionary concept in submarine construction.

In the past, a sub was nearly finished, perhaps even already in the water, when workers installed the electronics systems that control the boat, give it eyes and ears and the ability to fire weapons. The equipment had to be carried in through hatches and installed in the sub’s cramped confines, adding to the time it took. Also, because installation and testing came near the end of construction, the process could prolong completion of the boat.

But with COATS, equipment is installed and tested more than a year before the command center module is inserted into its supermodule. In fact, the “OAT” in COATS stands for “off-hull assembly and testing,” according to Joan Sienkiwicz, an engineer and project manager in the facility.

“We test with both real ship equipment — antennas, the periscope or photonics mast, with simulation equipment to replace what’s not here because the whole ship is not here,” says Sienkiwicz, of Pawcatuck, Conn.

When the simulation equipment is set up, the command center is so realistic that the ship’s crew trains on the actual equipment they will use at sea. The stations for the pilot and copilot, the sailors who have their hands on the joysticks that control the sub, are fully functional. So are the sonar station and the weapons-firing station.

WHILE THE WORK in COATS is important, the main action goes on inside Building 260, a 140-foot-tall structure large enough to hold three complete Virginia-class submarines, each 377 feet long and 34 feet across.

Late in 2008, the two supermodules that make up the back half of the Missouri arrived at the barge dock. Workers unloaded the supermodules and drove them into Building 260 using a system of strongbacks and transfer cars. Strongbacks are giant metal frames with brackets on top to hold the curved shape of the hull section. The transfer cars fit under the strongbacks and ride on rails in the factory floor. They allow the massive supermodules — and even the 7,800-ton finished submarine — to be maneuvered inside the factory.

After the aft supermodule arrived, workers installed the shaft that will drive the propulsor — a modern version of a propeller. Then, they used the transfer cars to align that supermodule with the one that goes in front of it.

“We paired these two quarters of the submarine together, and we welded all the way around, first on the inside, and then out here on the outside of the hull,” says Mike Nowak, ship manager for the Missouri as he leads a tour of Building 260 in early April. “At this point, two quarters of the submarine became a half, the entire aft end of the submarine.”

The aft half holds the nuclear reactor, engine room, ballast tanks, propulsor, and rudder and stern planes, which steer the boat left and right and up and down

On the other side of Building 260, the front half of Missouri rests on strongbacks. This includes a bow section that arrived from Newport News in early February and the 2B-to-5 assembled in Quonset Point.

“Saturday, after lunch, we’re going to drive the whole bow half of the ship out of the building, and then we’re going to move it south, back into the building, south again into position to make my two halves one submarine,” says Nowak, of Mystic, Conn. “By Monday after lunch, all the steel will be touching.”

Less than a month later, on May 1, the welding is complete. Fifty-one months after starting as steel plate and sheet metal, Missouri is a whole submarine, though interior work — connecting pipes and cables between sections and other details — remains.

MANY POINTS along the way from flat steel to sleek submarine are marked with ceremony. But Victor McKenna has attended only one. He took his wife and two young sons to the keel laying for the Missouri, a rare chance for his family to see the place he works.

“It is an awesome weapon, the complexity of it and the amount of people who work on it to do the job,” he says.

When the Missouri is christened later this year, the sheet metal technician will not likely be there. “You spend a year on the boat, and the last thing you want to do is go see it again,” he says.

Before that day, the Missouri will be driven from Building 260 to the water of the Thames River. In the days of smaller submarines, the boats were slid down rails to splash into the river. But the Virginia class and other modern subs are too heavy. Instead, the Missouri will meet the water in Graving Dock 3.

The 40-million-gallon chamber, 617 feet long, 96 feet wide and 63 feet deep, has a gate at one end that opens to the river. This allows the shipbuilders to flood the empty dock, open the gate and float the sub into the river.

At the bottom of the dock lies a hollow concrete pontoon. The pontoon can be adjusted so it floats or sinks when the dock is flooded.

When Missouri is finished toward the end of 2009, workers will flood the dock, a process that takes 12 hours, and bring the pontoon level with the adjacent pier. The pontoon will then be shifted to rest on concrete columns that hold it steady as the submarine is driven onto it.

After the boat is on the pontoon, the platform is shifted off the columns, and the dock is drained, causing the pontoon and sub to descend. When the pontoon reaches the bottom, workers adjust it so it won’t float. The dock will be refilled, and Missouri will float off the pontoon, a free floating vessel.

While this “floatoff” is a significant milestone, the real celebrating will come in early December, when Missouri officially receives its name during its christening, complete with a bottle of champagne smashed on the hull — actually, a striker bar mounted on the sub’s sail just for the christening.

Some finishing work and comprehensive testing will follow, and then Electric Boat will hand the sub over to the Navy for sea trials. After about a year, Missouri will return to Groton, bound for Graving Dock 1 or 2 for a PSA, or post-shakedown availability.

“PSA is basically the one-year checkup that we do on the boat,” says Tony Calkins, of Stonington, Conn., who is managing the PSA for the North Carolina. “We do any repairs necessary that the ship finds during that one year. It’s basically the warranty period.”

About a year after coming in, Missouri will join the active service, patrolling the world’s oceans and hugging its coasts for a lifespan that’s expected to surpass 30 years.Cutting the metal

Electric Boat uses a variety of methods for cutting metal. The method chosen depends on the size and properties of the metal

and the shape of the part to be cut. Among the more advanced methods are:

Plasma cutters

A high-speed stream of inert gas is passed through an electric arc, which converts the gas to plasma. The extreme heat of the plasma slices through metal like the proverbial hot knife through butter.

Laser cutters

Computer-controlled lasers slice through sheet metal. In one machine, laser cutting is combined with computer-controlled punches that shape the metal. For example, the machine can cut slits for an electrical cabinet, and the punch can pound out the area near the slit to form a ventilation louver.

Water jet

A stream of water with abrasive grit at pressures of about 50,000 pounds per square inch blasts through steel several inches thick. A modern mission

Virginia-class submarines are among the most technologically advanced machines ever built. The sub equals or exceeds the stealth of its predecessor, the Seawolf, the quietest and hardest sub to detect before Virginia. But Virginia adds capabilities well beyond the more heavily armed Seawolf.

The Navy has four classes of subs among the 251 active commissioned ships of all types on the Naval Vessel Register. Three of the sub classes, Los Angeles, Seawolf and Virginia, are attack subs. The other class, Ohio, is divided into two types of boats, one firing nuclear ballistic missiles and the other firing guided missiles.

Five Virginia-class subs are listed as active commissioned ships. A total of 30 Virginia subs are planned, of which 18 have already been contracted for by the Navy, including the 5 in service and 6 under construction.

Like submarines of the Cold War era, Virginia was designed to attack surface ships and other submarines on the high seas. But it also is built to creep into shallow coastal waters and conduct 21st-century warfare, including:

•Attack shore targets with Tomahawk cruise missiles.

•Conduct surveillance on land areas, coastal water and foreign navies on the high seas.

•Deliver and support special forces for land and sea missions.

•Lay mines and map minefields.More work ahead

In 2011, Electric Boat will start building two Virginia-class subs a year. It will mean hundreds of more jobs at Quonset Point. Current work force:

Quonset: 2,100.

Rhode

Islanders: 1,865.

Also 256

vendors supply the shipyard.

Groton: 8,200.

Rhode

Islanders: 1,429.

ABOUT THE AUTHOR

Paul Edward Parker is a 22-year veteran of The Providence Journal. He has covered more than a dozen communities in that time, including North Kingstown, home to Electric Boat's Quonset Point facility. He also has been the computer-assisted reporting specialist on the newspaper's investigative team, where he contributed to the paper's coverage of the Station nightclub fire, which was a finalist for the Pulitzer Prize for Public Service. Before settling on a career as a reporter, he studied physics and engineering at the University of Connecticut.

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