Layer by Layer

3D PRINTING IS NAVY'S FLEXIBLE SUPPLY SOURCE

BY EDWARD LUNDQUIST

A 3D printer conducts a diagnostic run aboard Wasp-class amphibious assault ship USS Essex (LHD 2), July 9, 2022. Essex is underway conducting routine operations in U.S. 3rd Fleet

U.S. NAVY | Mass Communication Specialist 3rd Class Isaak Martinez

The Navy is validating the capability of making parts using additive manufacturing — more commonly known as 3D printing — for ships at sea.

A number of Navy ships already have polymer 3D printers capable of making plastic parts. But Navy ships also need practical additive manufacturing solutions capable of fabricating metal parts when ships are underway and deployed.

Additive manufacturing (AM), or 3D printing, refers to the process of depositing material layer by layer to create an object. For the Navy, it's not practical to carry every replacement part for every system on a ship, and it can be difficult to forecast if or when parts will fail. AM provides a flexible source of supply with the ablity to make parts instead of ordering them. Making 3D printed repair parts on demand can save time, lower costs, and reduce the need for extensive parts inventories.

The recent permanent installation of a Phillips Hybrid Additive system on the amphibious assault ship USS Bataan (LHD 5) may be the precursor of widespread 3D printing capabilities in the fleet.

"We've been using polymer plastic printers on ships and submarines for several years. These are essentially desktop units that make relatively small plastic parts. But the feedback we were getting from the fleet is that they need larger metal parts," said Jim Pluta, additive manufacturing (AM) program manager at Naval Sea Systems Command (NAVSEA).

Hybrid Additive System

Bataan has a Phillips Additive Hybrid system — integrating a Meltio3D laser metal wire deposition tool head on a Haas TM-1 computer numerical control (CNC) mill — to employ both additive and subtractive manufacturing processes.

"It's essentially a digitized robotic welder that melts stainless steel wire using lasers as a heat source, and 'prints' material layer by layer," Pluta said. "The deposition head lays the material down layer by layer. That's the additive part. When it's done printing, you'll see a near net shape of what that part will be. The deposition head retracts and is replaced by the CNC milling head that machines the part into its final shape — that's the subtractive part. The hybrid system is more efficient, and substantially reduces waste."

According to Pluta, these recent demos showed the feasibility of using 3D printers in a non-industrial environment, as opposed to a laboratory or climate-controlled manufacturing facility.

The Bataan's equipment was installed under a joint effort between Commander, Naval Surface Force Atlantic, and Naval Sea Systems Command (NAVSEA) Technology Office. Although the project is funded as a research and development effort, Pluta said the Bataan's

Testing the Tech

The Wasp-class amphibious assault ship USS Essex (LHD 2) was the first ship to conduct testing and evaluation of a 3D printer during underway conditions. The Naval Postgraduate School (NPS) and Commander, Naval Surface Force, U.S. Pacific Fleet (COMNAVSURFPAC) partnered to install a Xerox ElemX liquid metal 3D printer on Essex during the Rim of the Pacific exercise (RIMPAC) 2022 last summer. The system was installed in a containerized workshop in a CONEX box.

The ElemX system uses a molten metal droplet deposition, where wire is fed into a crucible and melted into a bed of liquid metal, which is then electro-magnetically drawn onto a plate for deposition.

The goal of 3D printers is to enable ships to become more self-sufficient. "Having this printer aboard will essentially accelerate, enhance and increase our warfighting readiness," said Lt. Cmdr. Nicolas Batista, the Aircraft Intermediate Maintenance Department (AIMD) officer aboard Essex. The CONEX box was moved to USS Boxer (LHD 4), where the crew is receiving training and printing parts. The intent is for Boxer to continue experimenting with the capability.

The ElemX printer was a collaboration with Commander Naval Surface Force Pacific (CNSP) and NAVSEA leveraging the Naval Postgraduate School (NPS) cooperative research and development agreement (CRADA) with Xerox, which is a powerful tool for win/win applied research. "The ElemX effort not only demonstrated the technology in shipboard research use cases, but created a self-contained, mobile 3D metal printshop by outfitting a common shipping container that can be put on any ship, or plugged into any power source, such as a field generator so Marines can also have that capability," said Capt. Jeremy Gray, NPS Surface Warfare Chair for CNSP.

The Navy's first-ever Repair Technology Exercise (REPTX)-2022 was held at Naval Base Ventura County in Ventura County, California, sponsored by Naval Sea Systems Command's (NAVSEA) Naval Systems Engineering and Logistics Directorate Technology Office (05T).

Teams from 60+ technology companies, government and academic laboratories participated. They showcased repair and maintenance technologies — including unmanned aerial vehicles and submersibles, additive manufacturing equipment, ship-to-shore communication systems, inspection and repair tools, and above- and below-water visualization devices — aboard the Navy's Self Defense Test Ship, the Spruance-class destroyer ex-Paul F. Foster (DD 964).

Janice Bryant, sustainment technology manager at NAVSEA 05T and the sponsor of REPTX, said the exercise will, "provide a realistic fielding environment," and immerse the technologies in a variety of shipboard scenarios, such as loss of lighting, an unidentified object on the hull, pipe corrosion and leakage, and damage to the ship's superstructure. ■

printer is not temporary. "This is the first, true 3D metal printer installation aboard a ship. There are no current plans to take it off anytime soon."

Jonathan Hopkins leads the additive manufacturing branch at Naval Surface Warfare Center Carderock Division in West Bethesda, Maryland. "We're supporting fielding equipment, training sailors and marines, and conducting research and development so that we can be successful with this technology as quickly as possible," he said.

The Navy also recently tested a Xerox ElemX aluminum printer during actual underway conditions aboard USS Essex (LHD 2). However, Pluta remarked that spools of 316 stainless steel welding wire are already carried onboard for welding. "That certainly played into the calculus of why we selected the Phillips Hybrid system," he said.

Parts on Demand

While many ships have desktop polymer printers, Bataan's hybrid system is big — 96" long x 68" deep x 80" tall, and weighs about 4,700lbs. — and requires a dedicated space.

According to Capt. Paul Burkhart, Bataan's executive officer, the ship has repurposed the compartment previously used to store meteorological balloons that aerographer's mates would send up for weather observations. "We no longer use that method of environmental sensing, so the space was available. We have two AM units in the compartment. In addition to the metal printer, we have a smaller printer that makes polymer parts."

For the 843-foot, 41,000-ton Bataan, a multi-purpose amphibious assault ship that can carry 2,500 Sailors and Marines — along with boats, vehicles, and aircraft — there will be plenty of things to fix.

Burkhart said the system is a way to fix a part or component in a system to get it operational again, instead of having to replace the entire system. The system saves time and money, but most important, it helps to maximize operational readiness.

"Instead of having to order the whole, large assembly, and wait for it to get delivered wherever we are in the world, we just manufacture the subcomponent or part that's required, and that we don't normally carry. Up

until now, if we need to replace a valve handwheel, we've had to get a new valve assembly," Burkhart said. "We have thousands of valves on the ship, and you'll find broken handwheels not infrequently. Now, we can manufacture the replacement handwheel and get the valve assembly working properly again without replacing the entire valve unit."

Pluta said the parts printed on the ship will not have been tested or certified and are not always expected to be permanent replacement parts. "These fixes may be temporary in nature, but they can help get systems back up and running until they return to port to procure the certified part, or they can get the fabricated parts certified."

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Dan Porter, a Xerox technician assembles a 3D printer head aboard Wasp-class amphibious assault ship USS Essex (LHD 2), July 9, 2022. Essex is underway conducting routine operations in U.S. 3rd Fleet.

According to Burkhart, the printer showed up at the right time. "We've just finished the basic phase of our deployment workups and are now entering the intermediate phase of our training. We'll be operational for deployment next year, so the timing is good."

Bataan has sent HTs (hull technicians) and MRs (machinery repairmen) to Phillips for four weeks of OEM training, to include two weeks of the CNC system, and then the additive system and the integration of the two for both systems.

"After we've had some run time with the system, we're looking at expanding and bringing in some of the aviation ratings from our Air Intermediate Maintenance Department (AIMD) and get them qualified, as well," Burkhart said. "We're creating a job qualification record (JQR) that our people can follow and go through all of the steps of the training and become qualified on the equipment. Eventually, we should be able to train our own people."

Building a Design Library

NAVSEA is providing the ship a library of approved, digital computer aided design (CAD) files that the system can make. "They're looking at a process of how we can then expand system capabilities by adding files to the library," Burkhart said.

If there is a need to make a part and no file is available, there is a reach back capability to one of the Regional Maintenance Centers or warfare centers where parts could be reverse engineered, or examples located and digitized so the CAD file can be transmitted or otherwise delivered to the ship."

Bataan already has CAD software and computers, as well as precision measuring tools so the crew will be able to develop their own designs. And they won't have to forge ahead alone. "We're working closely with the crew as they use the equipment. They have a lot of reach-back capability with us," said Shaun Verrinder, an additive manufacturing engineer at Naval Surface Warfare Center Philadelphia Division. "We have our Apollo Lab, which can provide design assistance, remote troubleshooting, and liaison with the OEM (original equipment manufacturer) to provide distance support to the ship, so when they go to print, they will be successful."

Verrinder said the Apollo Lab is a site and capability established at NSWC Carderock as a hub for reach-back support to the operators for the deployed AM equipment. "The Apollo Lab has the same CAD software, precision measuring tools and printer as deployed

shipboard to allow our distance support team to help diagnose and troubleshoot issues that might occur on deployed equipment, as well as provide design assistance for parts that Sailors are developing."

Smaller ships may not have the room, demand, or trained personnel to operate a metal additive manufacturing system. However, if a larger ship has one it can support smaller ships in company, such as an aircraft carrier strike group, where the escorts can be supported by the carrier's 3D metal printer.

"There is a limited ability to evaluate sample parts made on the ship. That's why one of our goals with this installation is to better understand the quality of parts the system can make so we can have higher confidence in how we use them. For now, however, we have to be deliberate in what we make on the ship as opposed to a shoreside repair facility, where we have more access to testing the parts," Verrinder said.

A Scalable Solution

The concept is scalable. Jonathan Hopkins, who leads the additive manufacturing team at NSWC Carderock Division, said the Bataan's system complements the training and expertise that Navy people already have. "Stainless-steel welding is a capability found on our larger ships, and the wire feed stock for the printer is the same as used in our welding machines — it's in the supply system and is commercially available. Likewise, we have carriers and tenders that already have the Haas CNC system, so, there's already a fundamental knowledge and experience base. So, it's possible to add the Meltio system and Phillips integration to existing CNS tooling to upgrade a ship with this capability."

Pluta said the Navy's efforts to leverage additive manufacturing illustrates enterprise-wide business process reform and innovation. "NAVSEA subject matter experts and industry partners are working together to test, evaluate and field the most advanced AM technologies to improve readiness and increase capabilities as demonstrated through our work on Bataan," he said.

The success of the experience will determine if other ships receive this capability. "We're looking at Bataan's deployment to give us the evidence we need to transition to a permanent system that will go aboard other ships, as well," Verrinder said. "Ultimately, that success is dependent on the ingenuity and imagination of the Bataan Sailors.

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Kenya Latham, assigned to East Coast Repair, coordinates the on load of a three dimensional printer aboard the Wasp-class amphibious assault ship USS Bataan (LHD 5), Oct. 19, 2022.

Burkhart agrees. "Once our Sailors start using the system, they'll get innovative with what they're building. They find ways we can use that system that we haven't even thought about yet. It will increase the library even more, and help make us even more self-sufficient. The capability will accelerate and enhance our warfighting readiness, it will save the ship time and money in accomplishing repairs, and it will greatly enhance our self-sufficiency in repairing things ourselves instead of having to go outside the lifelines." ■