NAVSEA 05T Afloat Additive Manufacturing

Presented to:

Surface Fleet Summit

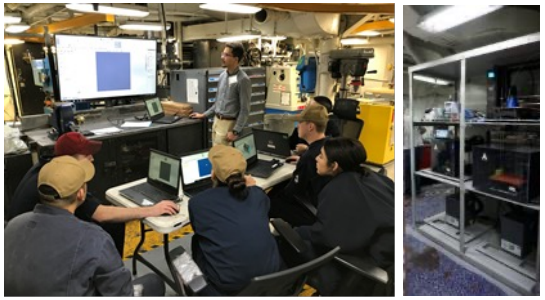
10-12 January 2023

NAVSEA 05 Additive Manufacturing Overview

- **Process Qualification/Component Certification**
  - Develop Technical publications for repeatable AM processes
  - Explore in-situ monitoring
  - Collaborate closely with industrial base
  - ➢ *To Date: Tech Pubs for metal AM processes; Over 500 approved parts, 300+ polymer TDPs available to fleet*
- **Afloat/Undersea Deployment**
  - Explore how to deploy and integrate advanced/additive manufacturing equipment surface and subsurface
  - Understand environmental/motion impacts on printing process
  - Metal AM capability installed on USS BATAAN in Oct, 2022
  - ➢ *Advanced manufacturing equipment installations on 8 ships; 4 submarines deployed with AM; over 4000 parts printed afloat; 50+ Sailors trained*
- **Digital Integration**
  - Identify file securing/transiting/storage solutions, including parts repository
  - Explore topology optimization and generative design
  - ➢ *Development of digital manufacturing environment to enable networked AM equipment ashore (NNSY in 2022) and afloat (USS BATAAN in 2022)*
- **Logistics/Supply System integration**
  - Incorporate components into logistics databases to enable part provisioning, tracking and 'buy or print' decisions
  - ➢ *146 AM parts have NSNs; initial cost avoidance and lead time metrics generated for afloat components*

TOP LEFT: DSO valve installed on CVN-75. TOP MIDDLE: CAT2 CASREP for satellite IP antenna printed during deployment. TOP RIGHT: AM deck drain installed on USS LABOON. BOTTOM LEFT: Approved metal bilge strainer for SSN. BOTTOM CENTER: Approved cease fire alarm horn installed on DDG. BOTTOM RIGHT: Fuse cover to prolong fuse life, installed several LHDs.

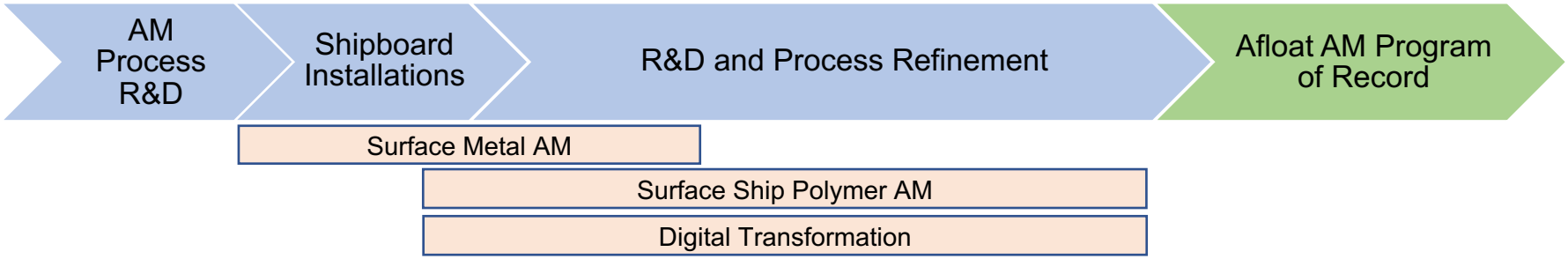
Scaled Propulsor Blade Test Build



LEFT: AM training on-board CVN-71. RIGHT: 3D printers on CVN-69

Programmatic Context

Afloat AM Development Phases



- Additive Manufacturing (AM) is currently an R&D Program of Record
- Currently installed polymer and proposed metal AM systems inform potential Fleet capabilities
- Pilot activities with Fleet shape Navy R&D efforts by:
  - Helping Navy establish acquisition and maintenance/sustainment requirements
  - Informing CONOPS and operational requirements for expeditionary use of AM
  - Establishing specific processes for afloat AM system evaluation and implementation
  - Assessing performance and establishing required environmental conditions for operation
  - Guiding future R&D strategies (i.e., developing solutions to fabricate and approve components of increasing criticality)
- As of DEC 2022: POM-24 Afloat AM Acquisition Program of Record accepted (OPNAV N4)

Afloat AM Update

Legacy AM Equipment Installations:

- As of Aug 2022, NAVSEA R&D program installed polymer AM on 8 surface ships as R&D prototypes (2 CVNs, 4 amphibs)
  - AM assets installed via non-permanent Ship Change Document
  - Polymer AM capability deployed on three submarines (fleet funded equipment/NAVSEA supported)
  - 1 Metal (Aluminum) AM operating under DFS on USS Essex
- Nov 2021: Polymer printer installed via DFS on USS KEARSARGE (fleet funded equipment/NAVSEA supported)
- July 2022: Polymer printer deployed on USS NEW HAMPSHIRE (NHP)
  - NHP deployed with a desktop 3D printer (Lulzbot Mini 2) in 2020-2021 and shared lessons learned with SEA05T
  - SEA05T, SUBLANT, NHP and PMS394 coordinated to install and evaluate improved polymer printer on FY22 NHP deployment
  - Developing updates to submarine AM guidance document to reflect addition of improved printer

Recent AM Equipment Installations:

- Metal and polymer capability on USS BATAAN (LHD-5) – **COMPLETED NOV 2022**
  - Installation of Hybrid metal additive and CNC capability (Phillips Additive Hybrid)
  - Installation of polymer system (Markforged X7)
  - SURFLANT plans to replicate installation using self-procured assets for Jan 2023 availability on USS WASP
  - Conversion Balloon Inflation Room (01-127-2-Q) to Additive Manufacturing Shop, planned as common location across WASP-Class
  - SEA05T supporting deployment by conducting shore-based R&D and providing afloat support to BATAAN

Afloat Advanced Manufacturing Capabilities Legacy Deployments

- Installed using Non-Permanent Ship Change process
  - NPC-SCD 24036 – Carriers
  - NPC-SCD 25611 – Amphibious
- Aligns with current AM Guidance
- Introduces CNC capability (on select vessels)
- Reverse engineering capability
- *USS John C Stennis, USS Makin Island,* and *USS Dwight D Eisenhower* have full capability installed (identified in graphic right)
- *USS Boxer, USS Harpers Ferry, USS Theodore Roosevelt, USS John P Murtha* have only additive manufacturing capability installed
- All equipment is non-networked and data transfer between laptop and printers is air-gapped through use of SD card; laptop operates as standalone
- NAVSEA Providing reach-back support for deployed systems - "Apollo Lab"
  - Technical troubleshooting
  - Material and part supply
  - Design support

	Model: Stratasys uPrint SE Plus Type: Polymer AM Materials: Stratasys ABS polymer, Stratasys support material
	Models: Lulzbot Taz 6 & Mini 2 Type: Polymer AM Materials: Approved AM polymers, limited ability for high-strength engineering plastics
	Model: Tormach PCNC 440 Type: CNC Mill Materials: Aluminum, Steel, Titanium, polymers, composites, wood
	Model: Dell Latitude Workstation Type: Digital Package Capabilities: Laptop with SOLIDWORKS CAD and AM process control software

Equipment has reached End of Life and is no longer recommended for AM Afloat outfitting

Afloat Additive Manufacturing R&D Hybrid Metal System

- **Shipboard Metal AM**
  - Phillips Additive Hybrid Laser Metal Wire Deposition (LMWD) Hybrid AM technology
    - Wire-fed laser DED AM system (Meltio Engine)
    - CNC milling machine (Haas TM-1)
  - Combines additive and subtractive processes
- **Installed on USS BATAAN Oct-Nov 2022**
  - 5 Sailors trained (1 MR, 2 HT, 2 DC) on CNC operation, Hybrid LWMD operation, Polymer AM equipment operation (+3 KSG sailors), MasterCAM (Hybrid AM software), and SolidWorks (3D modeling) [5 weeks total]
  - MOA established between BATAAN, NAVSEA and CNSL to facilitate RDTE sample printing, data acquisition, print logging, and reachback support

USS BATAAN Installation of Hybrid AM machine – Nov 2022

Dimensions *(L×W×H)*	168"×134"×110"
Build Envelope *(L×W×H)*	~20" × ~10" × ~12"
Machining Envelope *(L×W×H)*	~30" × ~12" × ~16"
Materials	316L Stainless Steel *(welding wire)*
Features	• 3-axis CNC milling operations • Parts designed using SolidWorks CAD software • Additive and subtractive operations controlled using MasterCAM A+

Afloat Additive Manufacturing Polymer System

- **Shipboard Polymer AM**
  - Markforged X7 Thermoplastic Material Extrusion AM system
  - Base polymer - Nylon with chopped carbon fiber (Onyx)
  - Capable of printing with co-extruded of continuous fiber (carbon fiber, Kevlar, fiberglass)
  - High ease-of-use; ideal for prototyping and tooling applications
  - Material properties allow for addressing a wider range of applications
  - High-reliability system – assessment based on testing at NAVSEA and partner sites
  - TPU update in October 2022 (Synthetic Rubber)

Markforged X7

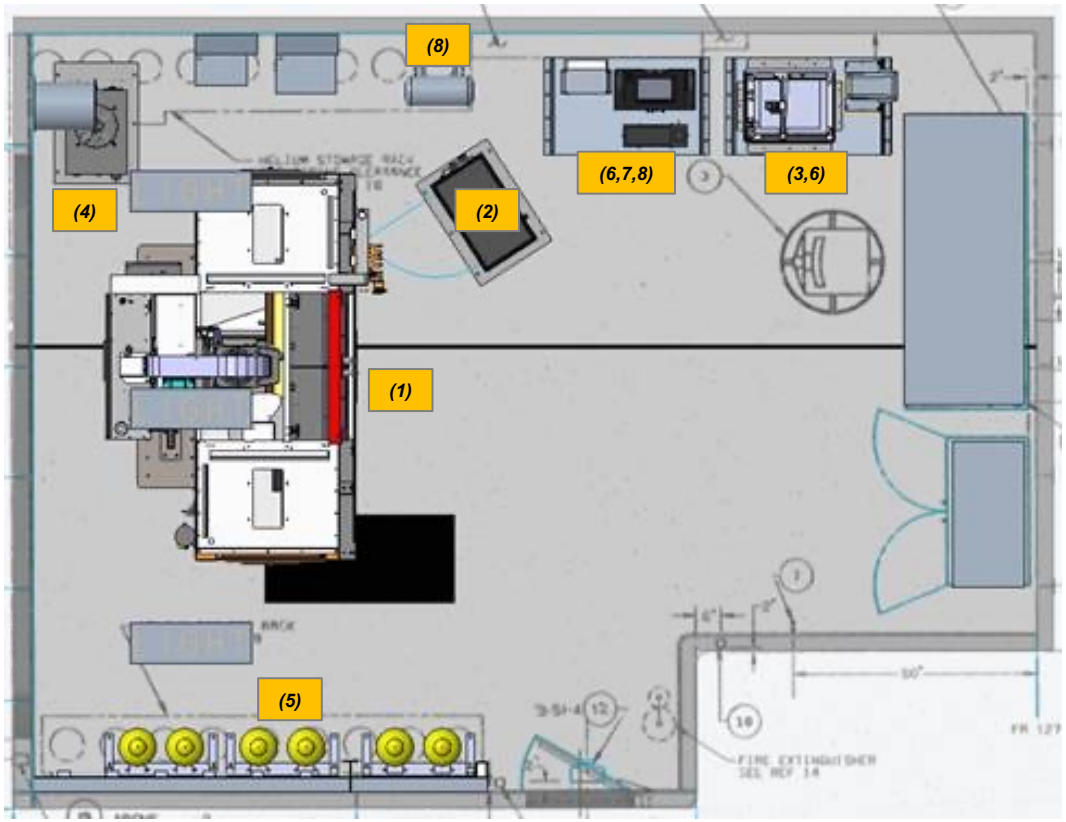
Markforged X7 AM System
(Pictured with lower base cabinet – not part of shipboard install)
[Image credits: Markforged]

Dimensions *(L×W×H)*	23"×10.6"×36"
Build Envelope	12.9" × 10.6" × 7.8"
Min. Layer Thickness	≥0.00197"
Materials	Onyx (nylon w/ chopped carbon fibers)
Features	• Print continuous-fiber composites *(carbon, kevlar)* • High-strength base polymer ideal for tooling applications

R&D-Related Partners:
Johns Hopkins University-Applied Physics Lab (JHU-APL), Advanced Technology & Research Corp. (ATR)

Afloat AM Ship Integration
USS BATAAN

- **SCD 28425: Hybrid Metal and Polymer AM system installation**
  - Balloon Inflation Room (01-127-2-Q) identified as installation space
  - Balloon Inflation Room currently unused
  - Converts from Aviation Space to Maintenance Space
- **SCD 28121: Digital Manufacturing Environment installation**
  - Secure connection between CANES and R&D assets supporting AM equipment
  - Enables streamlined workflow for accessing part files, receiving technical data updates, equipment operation and monitoring
  - Land-based preliminary laboratory testing successful; final validation tests with CANES at Pt. Loma



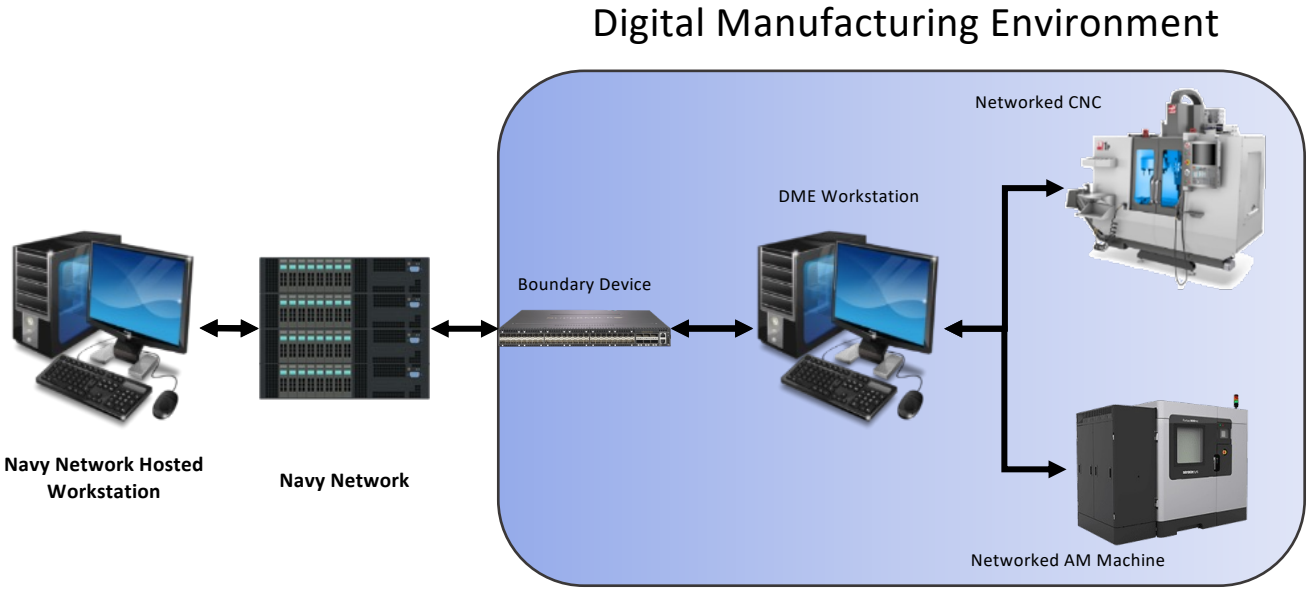
USS BATAAN AM Equipment Working Arrangement

[Image credit: JHU-APL]

(1) Phillips Additive Hybrid LMWD
(2) Meltio Engine Controller
(3) Markforged X7
(4) S&A CW 5300 Laser Chiller
(5) Argon Cylinders
(6) Material Storage Cabinets
(7) X7 Data Acquisition System
(8) DME Network Switch
(9) Air Compressor

Digital Infrastructure

- NAVSEA is prototyping the Digital Manufacturing Environment (DME) to address the need for advanced manufacturing cybersecurity and streamlined communication between ashore and afloat activities
- The DME provides a scalable, proof-of-concept secure network boundary that separates manufacturing equipment and workstations from the host network
- Two DME pilots to demonstrate secure connections and communication between digital manufacturing equipment and navy networks
  - Ashore DME pilot with NNSY July 2022
    - Finalized Updates 1 Sep 2022
  - Afloat DME pilot with USS BATAAN installed concurrently with AM equipment Oct-Nov 2022



Questions?