Defense Systems Information Analysis Center

Integration of Shipborne Additively Manufacturing Systems Onto Naval Vessels and the Naval Supply Chain Impacts

Revolutionizing Naval Logistics: The Challenges and Prospect of Metal Additive Manufacturing (AM) on U.S. Navy Ships

Matthew Seidel
September 20, 2023

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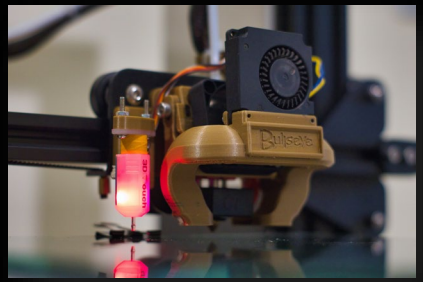

Photo by Kuba Grzybek: https://www.pexels.com/photo/black-and-yellow-metal-tool-4485456/

Education

- B.S., Mechanical Engineer From SDSM&T
- Harvard Business School Cert

Experience

- NAVAIR, Rapid Prototyping/Reverse Engineering
- Private Vessel Ship's Engineer
- SURVICE Engineering & Metrology
- PolyWorks USA
- Several DSIAC Publications Associated With 3D Printing

Hobbyist

- 3D Printing: Plastic FDM, Resin SLA (8+ years)
- 3D Modeling

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U.S. Navy photo by Mass Communication Specialist 2nd Class Zachary L. Borden (RELEASED) - http://www.navy.mil/view_image.asp?id=51717

01

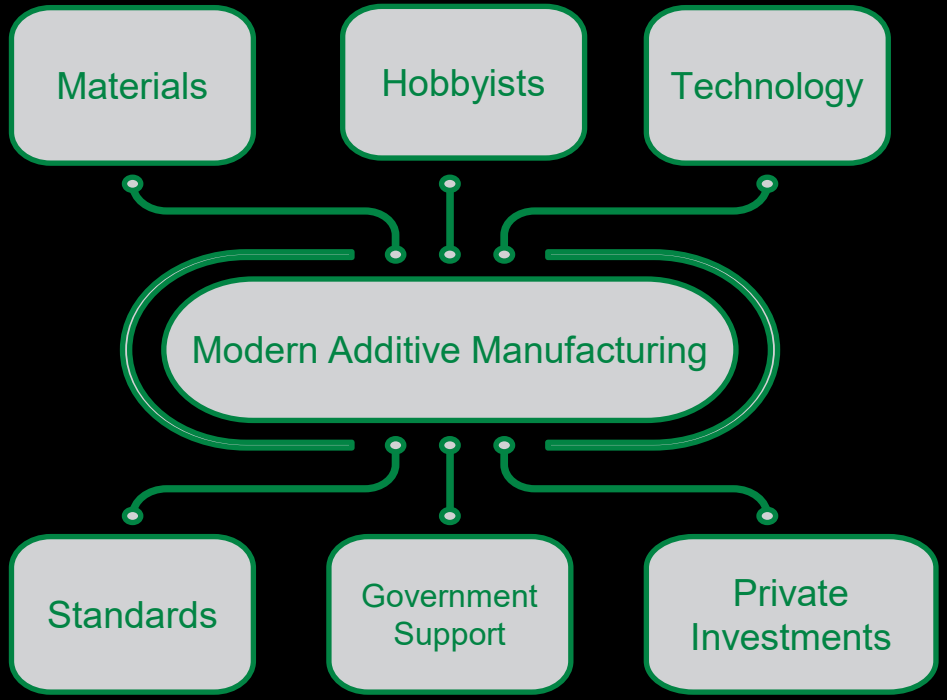
The Promise of AM

Brief History of AM

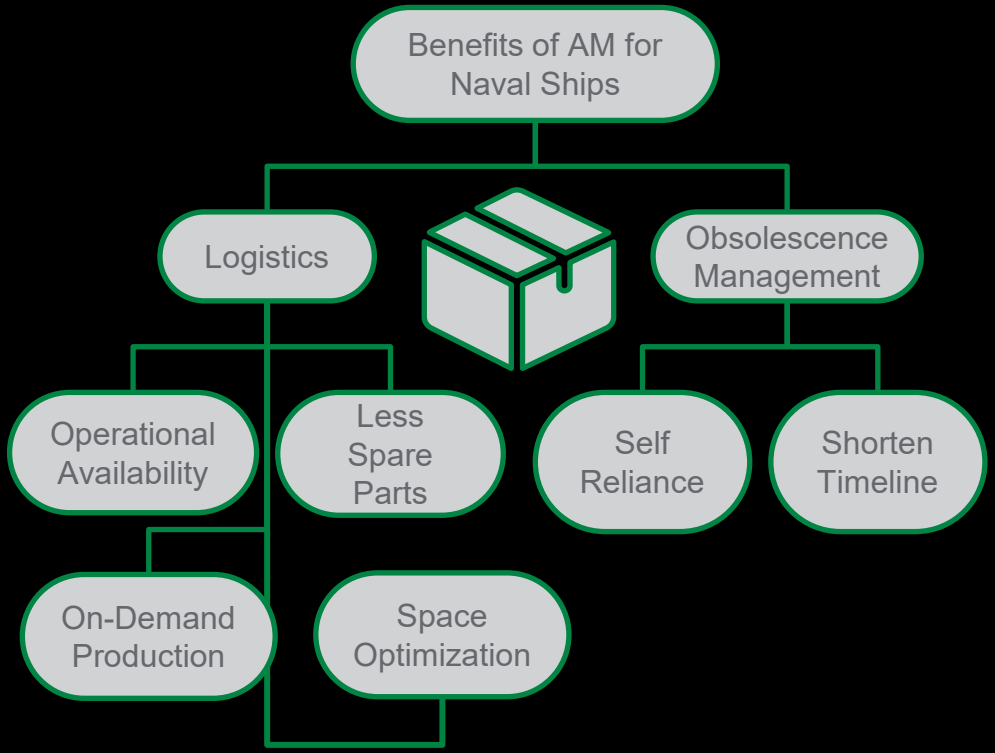
The AM “Renaissance”

- Formerly available for only large companies since its invention in 1986

- Many companies and the DoD have adopted, expanded, and made progress on certifications



A Logistical Revolution



Naval planners took note and followed suit with other government bodies in proposing shipboard augmentation of supply departments with AM.

"*Print Me a Cruiser*"
- LT Scott Cheney-Peters

02

The Challenges of Metal AM Integration

The Typical Metal AM Enviroment

Laboratory and Industrial Setting

- Ample Floor Space
  - Ample room for large machines, materials storage, and personnel safety measures
- Climate Controlled
  - Temperature, humidity, and cleanliness control
- Storage Space
- Evacuation Available
- Safety/Personal Protective Equipment (PPE)

Photo by Pixabay: https://www.pexels.com/photo/building-business-ceiling-empty-209251/

The Harsh Conditions of the Open Seas

Ocean Factors

- Salt fog/corrosion
- Inclement weather
- Motion of the ocean

- Damage delicate components
- Change powder distribution

Shipborne

- Consistent electrical power
- Adjacent projects
- Vibrations

- Change deposition rate
- Inject foreign material
- Loss of inert atmosphere

Safety

- Toxic/explosive materials
- Improper training

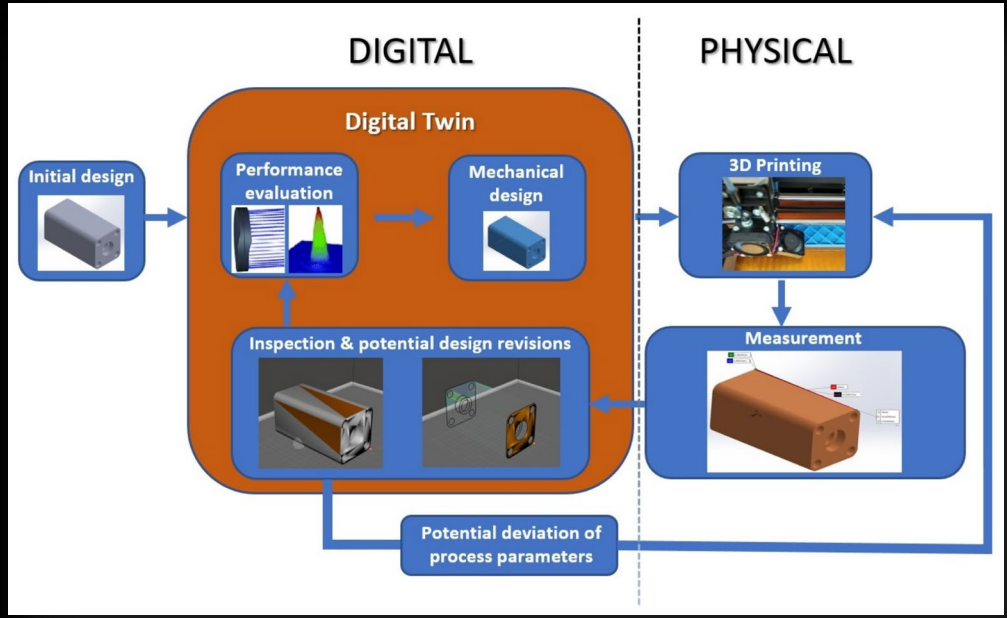
- Fire/explosion
- Danger to health
- Wasted material

A Joint Effort

- Naval Post Graduate School, Coast Guard, Marines, and Army
- No All-Encompassing “Standards” Exist for AM
- Cross-Disciplinary Expertise Exchange
- Learning From Other Departments' Success (and Failure) Stories

Testing

- The goal of all metal AM technology on today's ships is testing.
- Test prints on shore and compare to shipborne test.
- Array of sensors will measure every factor.
  - Gyroscopes, pressure, humidity, temperature, etc.
- Digital twins.
- Metrology/quality control.



Kantaros A, Piromalis D, Tsaramirsis G, Papageorgas P, Tamimi H. 3D Printing and Implementation of Digital Twins: Current Trends and Limitations. Applied System Innovation. 2022; 5(1):7. https://doi.org/10.3390/asi5010007

AI and 3D Printing

Quality Control

Analyze 3D-printed objects using computer vision techniques, identifying defects, deviations from design, and other quality issues to ensure the final product meets specifications.

Parameter Tuning

Fine-tune printing parameters such as temperature, speed, and layer height for specific materials and designs, optimizing print quality and minimizing failures.

Generative Design

AI can create innovative and efficient designs by exploring a wide range of possibilities and iterations, often resulting in organic and novel shapes that might be hard to conceive manually.

03

Current State of Metal AM on Ships

USS Bataan

- Wasp-Class Ship; Homeport: Norfolk
  - Amphibious Assault Capability
  - Flight Deck and Well Deck
  - Enhanced Command and Control
- Wasp Class Chosen for More Research and Capacity for Exposure
  - Marine and Navy Material
- In 2022, Received “Phillips Additive Hybrid Powered by Haas”

U.S. Navy, Photographer’s Mate 3rd Class Dennis Timms - U.S. Navy NewsStand photo ID 990717-N-6605T-501 U.S. Navy NewsStand

Phillips Additive Hybrid

- Hybrid System
  - Haas CNC with Meltio laser metal wire deposition head
  - Combines the high precision of multiple lasers in a compact print head.
- Haas TM-1 is proven platform for sea service
  - Less factors/variables
- 316L Stainless Steel wire fed into machine and laser melted and deposited into rough shape

"NAVSEA 05T Afloat Additive Manufacturing", Surface Fleet Summit, January 12, 2023.

Metal wire melted and deposited into rough shape layer by layer → Green part +/-0.010" precision → CNC refines rough shape → Final part

Phillips Additive Hybrid Cont.

Similarities to Cold Spray:

- Layer-by-Layer Deposition
- Material Adhesion and Bonding
- Targeted Repair

Advantages Over Cold Spray:

- Structural Integrity and Material Strength
- Design Flexibility
- Precision and Accuracy

USS Essex

- Wasp-class; Home Port: San Deigo
- Later in 2022: Xerox ElemX- “The mini factory in a Conex box”
- Same unit was at NPS in Monterey, California
    - 2 years of testing, twin part print tests

U.S. Navy, Photographer’s Mate 3rd Class Dennis Timms - U.S. Navy NewsStand photo ID 990717-N-6605T-501 U.S. Navy NewsStand

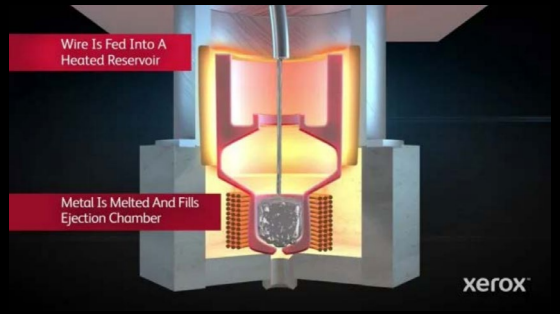
Xerox ElemX

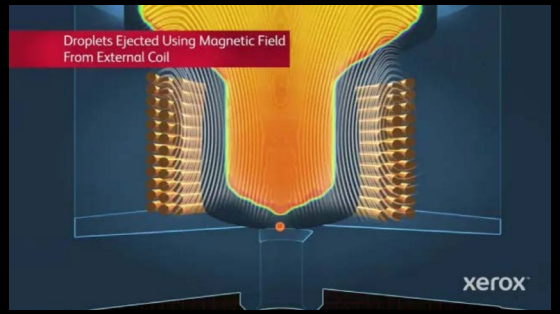
- Printer uses a proprietary “liquid metal” technology
- “Unlike alternative AM technologies, there are no metal powders used with ElemX and no need for PPE or other considerable safety measures…”
- Tech takes Xerox’s heritage technology and adds a 3rd dimension.

Kelty, Kahra L. “Influence of the AS-Printing and Post-Printing Processes on the Mechanical Properties of Liquid Metal Jetted 3D Parts”, Naval Postgraduate School. June 01, 2022. AD1184968. [A, Approved For Public Release]

Xerox ElemX

- Material: A356/4008 aluminum alloy wire
- Ideal for marine environments
- Requires Noble Gas atmosphere
- Claims to be a user friendly Metal AM solution
- Requires less PPE





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Objectives of these printers

1

Testing Purposes

Known Factors
Unknown Factors

2

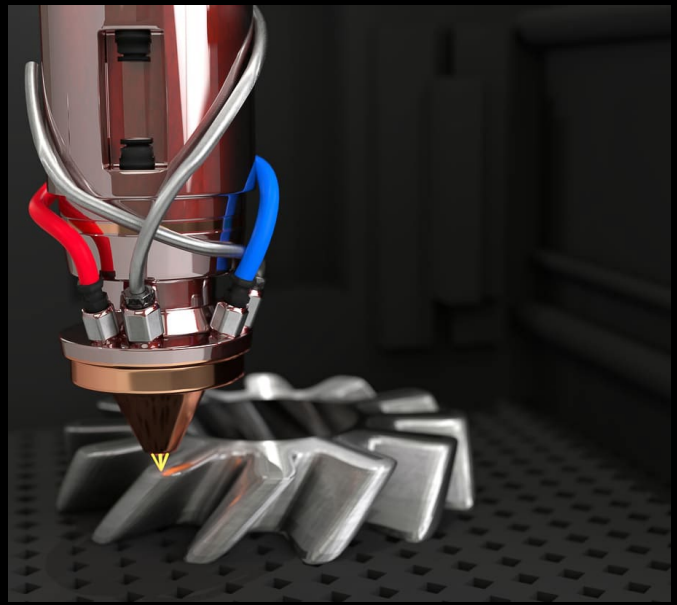
Twin Expirements

Every possible factor compared to shore prints

3

Shared Knowlege

Partnerships with Industry and Research Institutions
Cross-Disciplinary Expertise Exchange
Learning from Other Sectors' Success Stories



Source: https://www.wallpaperflare.com/laser-3d-cogwheel-additive-technology-metal-indoors-close-up-wallpaper-gmyii

The current objective at this stage is not to print parts for installation on Navy/Marine materiel

Why were these printers chosen?

Avoiding powderized metal

Self Contained Raw Materials, Avoids Dust, Explosions

Small part replacements

Not Designed for Printing Large Scale but Focus on Small Scale First

Self Containment

Avoiding Variables from Harsh Environment

Readily available consumables

Majority of Consumables would be on Hand or Easily Accessible (Welding)

“OTS” Printers

Add-ons to certified equipment

Reduction of PPE

“User Friendly” Laboratory Setting Not Required

Future Impacts of Metal AM

Enhanced Naval Readiness:

- Reduced Downtime for Maintenance
- Quick Replacement of Critical Components
- Print Components at Remote Locations

Supply Chain Resilience:

- Reduction in Lead Times
- Reduced Dependency on Traditional Supply
- Shift in Maintenance and Repair Paradigms
- Mitigation of Supply Chain Disruptions

On-Demand Printing Capability:

- Print Components at Remote Locations
- Mitigation of Supply Chain Disruptions
- Rapid Prototyping and Customization
- On-Demand Spare Part Production
- Complex Geometries and Lightweight Structures

Thanks!

Do you have any questions?

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Back-up – Update based on August news release

- The USS Bataan, utilized on-board metal additive manufacturing to replace a sprayer plate for a de-ballast air compressor (DBAC) while at sea.
- The metal sprayer plate is used to force pressurized air through saltwater tanks and discharge the accumulated saltwater. These tanks are filled to lower a ship's draft for amphibious operations.
- The replacement was completed in just five days, marking the first time the ship's permanently installed metal additive manufacturing machine was used under these conditions.
- This technology helped the ship avoid the time and logistics challenges of obtaining a replacement assembly, enhancing operational readiness.
- "This success story shows the self-sufficiency we can achieve when our Sailors are provided with cutting-edge technology," shared Rear Adm Joseph Cahill, commander, Naval Surface Force Atlantic (SURFLANT).

Source: https://www.metal-am.com/navsea-improves-readiness-of-uss-bataan-with-on-board-metal-additive-manufacturing/