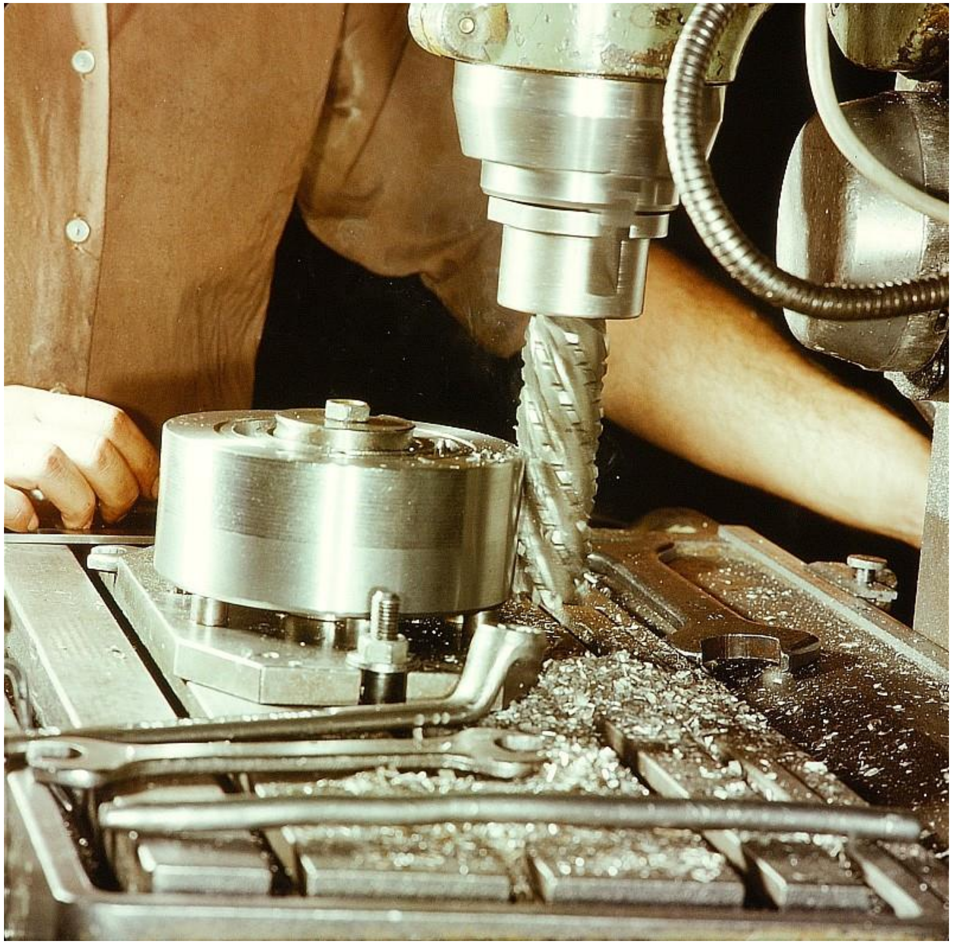
Introduction to Additive Manufacturing (AM 101)

8 December 2015

Caroline Scheck
Naval Surface Warfare Center, Carderock Division

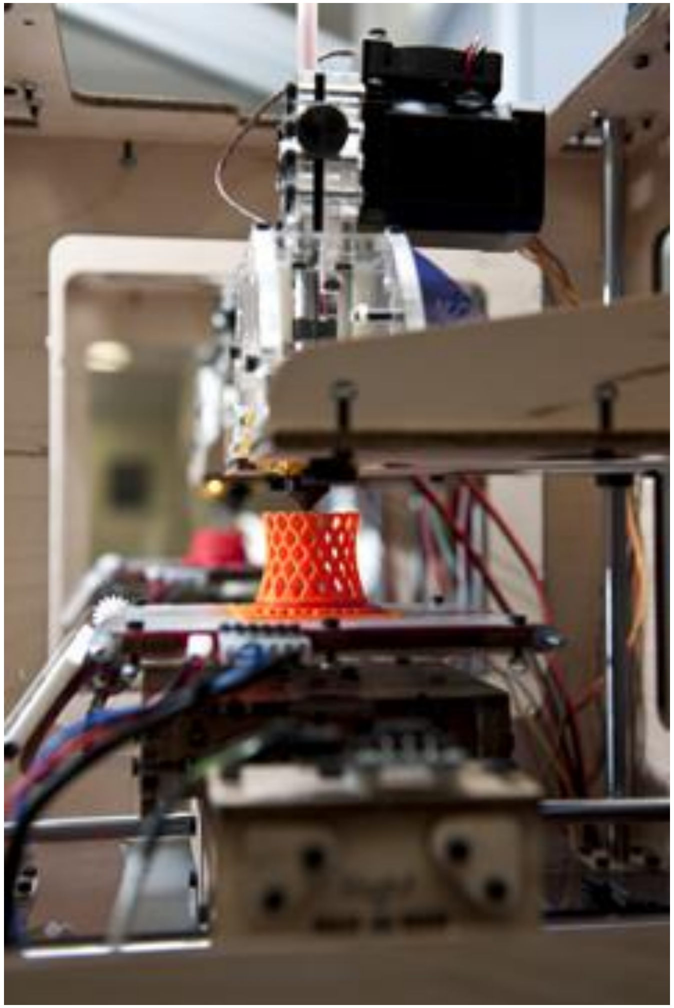
WARFARE CENTERS
Carderock

What is Additive Manufacturing?



Subtractive

vs.



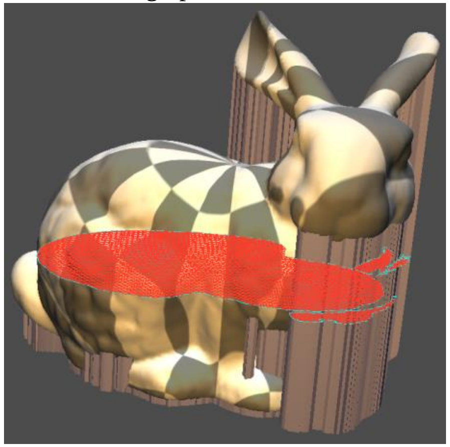
Additive

What is Additive Manufacturing?

Additive Manufacturing

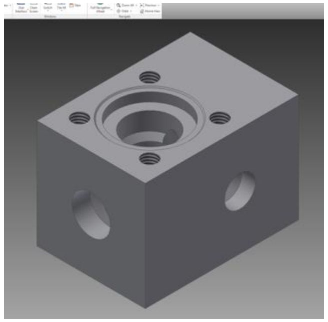
The process of joining materials to make objects from digital data, usually layer upon layer

Credit: graphics.stanford.edu

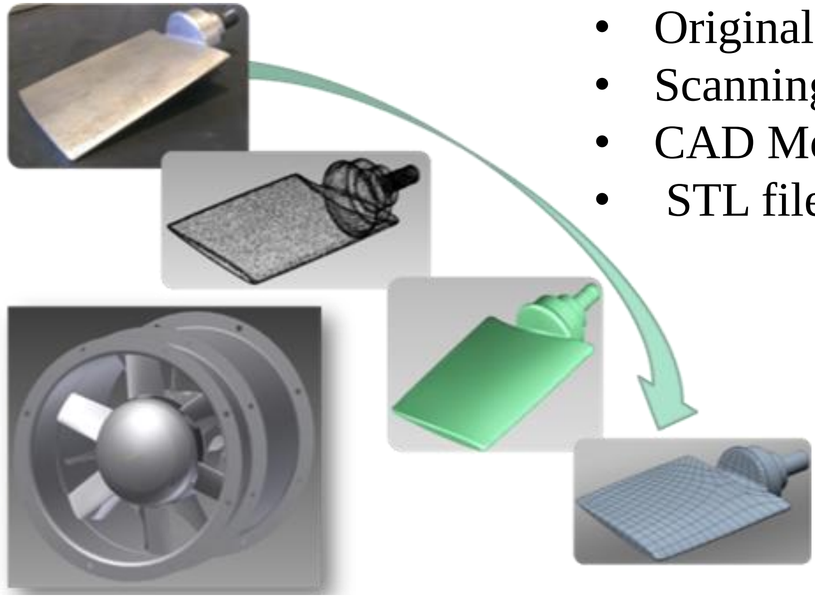


Credit: cybertron.cg.tu-berlin.de

Origins of 3D Data



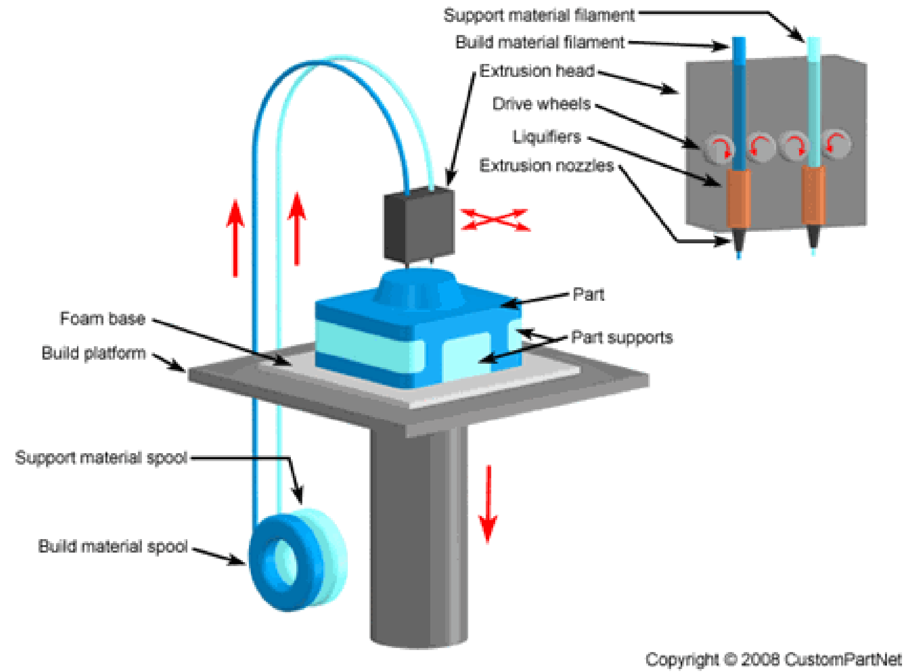
Direct CAD Model



Reverse Engineering

- Original part
- Scanning
- CAD Model
- STL file

Additive Manufacturing Methods



Material Extrusion

- Multiple materials
- Layer thickness:
  - 0.01in to 0.160in

Credit: www.stratasys.com

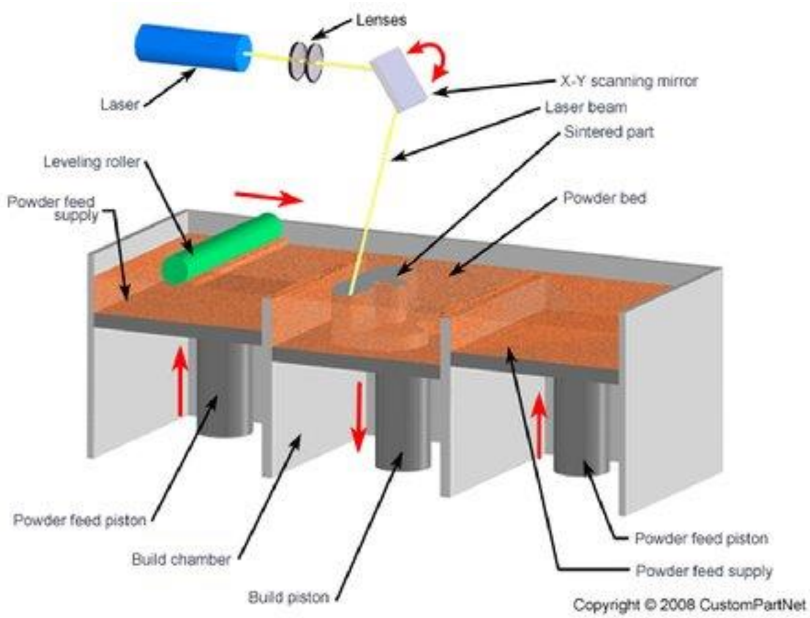
Credit: www.3dprint.com

NAVSEA WARFARE CENTERS Carderock

Additive Manufacturing Methods

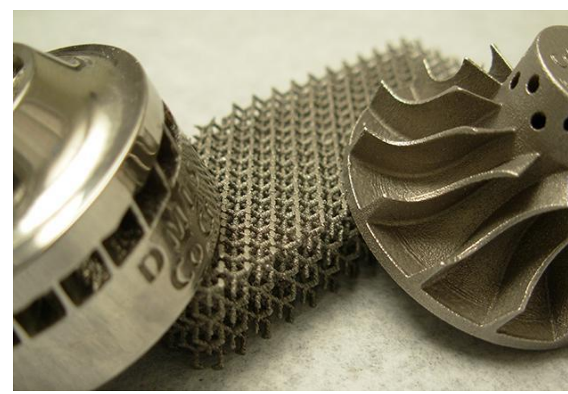
Powder Bed Fusion

- Metal and polymer
- Layer thickness:
    - 0.001in - 0.004in



Credit: site.ge-energy.com

Credits: NASA/MSFC/Emmett Given



Credit: www.3dprint.com

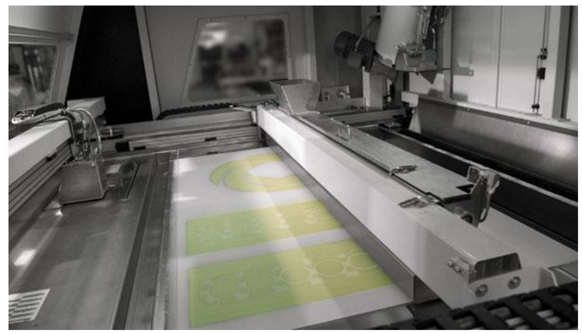
Powder Bed Fusion – Electron Beam Melting

https://www.youtube.com/watch?v=M_qSnjKN7f8

Courtesy of ORNL and Arcam

Additive Manufacturing Methods

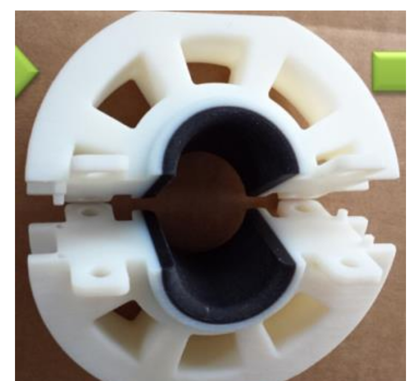
Credit: www.exone.com



Credit: www.ceramicindustry.com

Binder Jetting

- Multiple materials
- Layer thickness:
  - .0035in



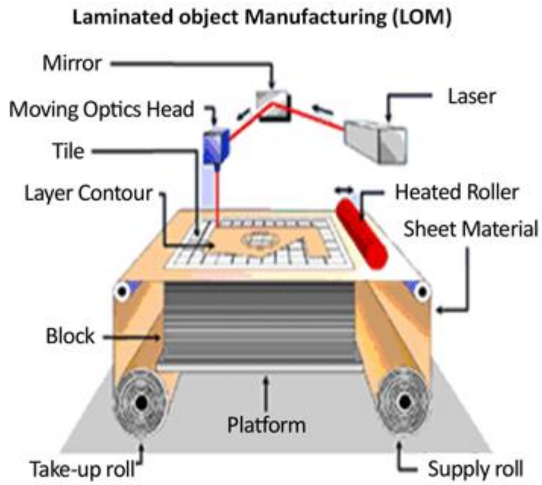
Material Jetting

- Typically polymers
- Layer thickness:
  - 0.0006in to 0.001 in

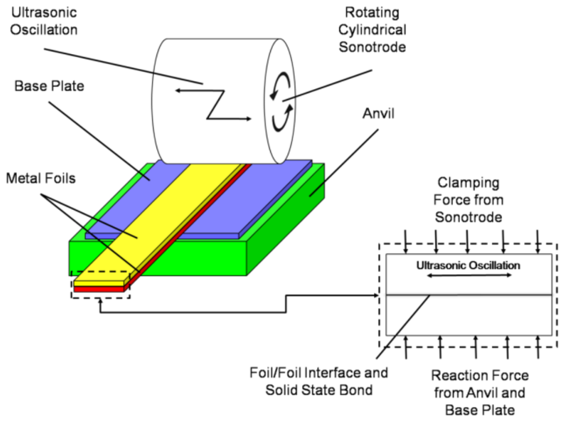
Additive Manufacturing Methods

Sheet Lamination

- Metal, paper, plastic
- Layer thickness:
  - variable

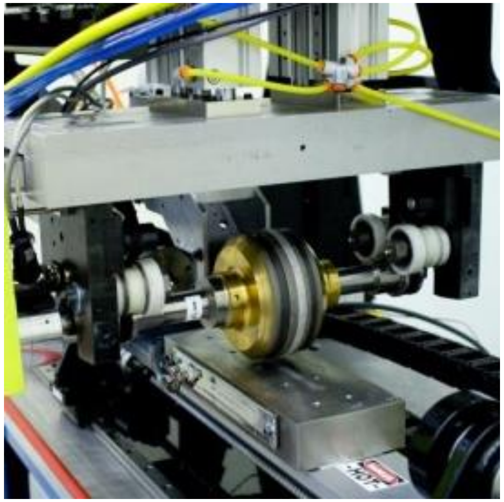


Credit: www.metal-am.com



Credit: Mmrjf3

Credit: www.fabrisonic.com



Credit: www.automateddynamics.com

Credit: www.mcortechnologies.com

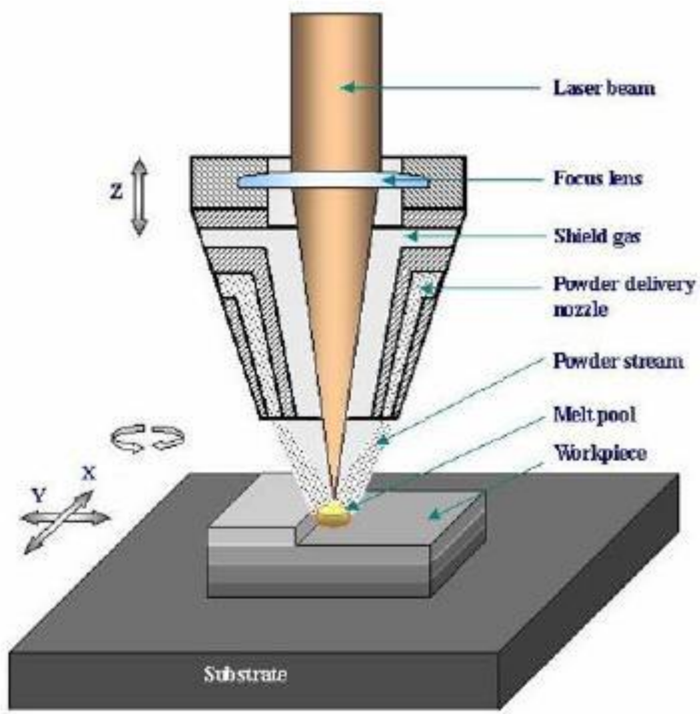
Additive Manufacturing Methods

Directed Energy Deposition

- Metal
- Layer thickness:
  - Varies depending on feedstock material and settings

www.optomec.com

www.optomec.com

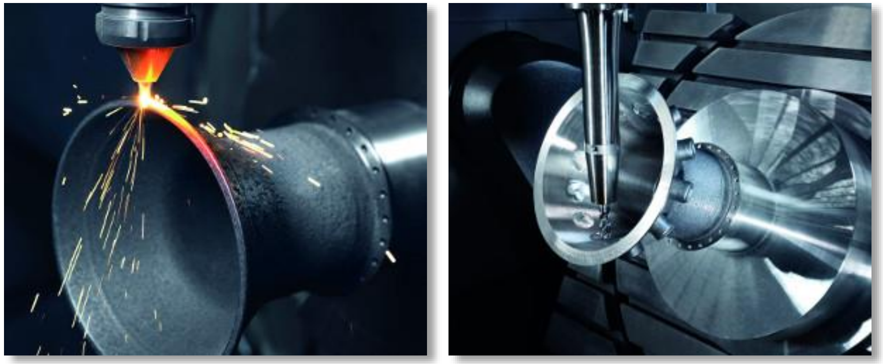


chms.ucdavis.edu

Additive Manufacturing Methods

Additive + Subtractive

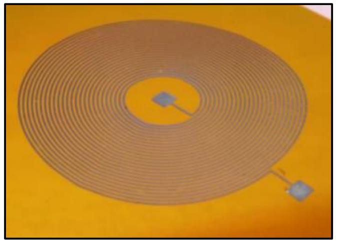
- Combines additive technology with CNC machining
- Generally metal
- Uses directed energy deposition (power or wire) AM processes
- Can use laser for local heat treatment

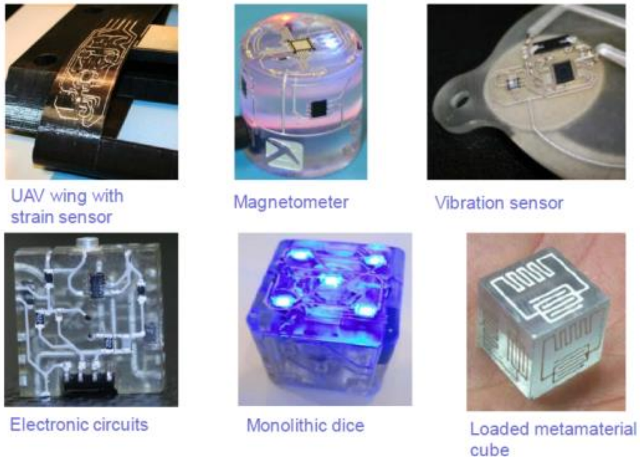


DMG MORI LASERTEC

Direct Write Technology

- Writing or printing passive or active electronic components directly from a CAD file
- Conductive inks (silver, copper, etc.) are printed onto a substrate material



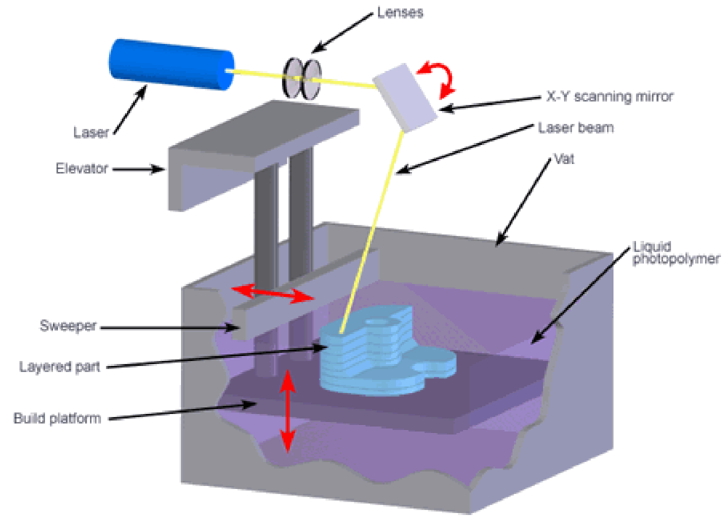


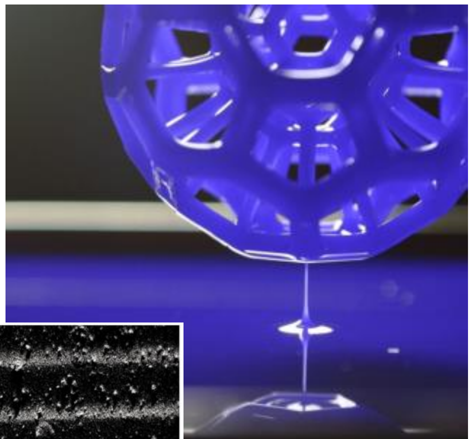
Functional direct write structures from nScrypt

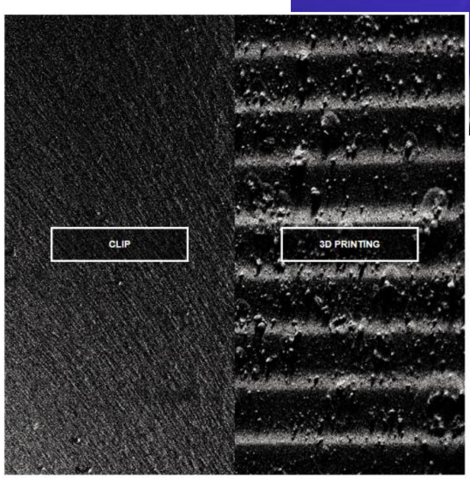
Additive Manufacturing Methods

Vat Photo Polymerization

- Typical cures with ultraviolet light
- Layer thickness:
  - 0.001in to 0.006 in







Credit: carbon3D.com

Credit: formlabs..com

Credit: 3DSystems.com

Navy Additive Manufacturing Applications

Additive manufacturing is generally suited for applications that meet the following criteria:

- Low production volume
- Complex part geometry
- Exploratory designs

Advantages

- Rapid part turnaround
- Shortened design time
- Inexpensively obtain geometric complexity
- Reduction in material waste (sometimes)
- Limited tooling required
- Reduced labor costs

Applications

Examples

Rapid prototyping

- Design iterations
- Geometric fit-checks
- Scale models
- Working prototypes

Rapid tooling

- Custom fixtures
- Injection molds
- Trimming tools

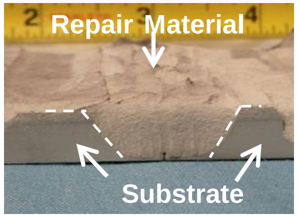
Custom trim tools

Rapid manufacturing

- In-house manufacturing
- Printed assemblies
- Legacy part development
- Highly customized products
- New designs

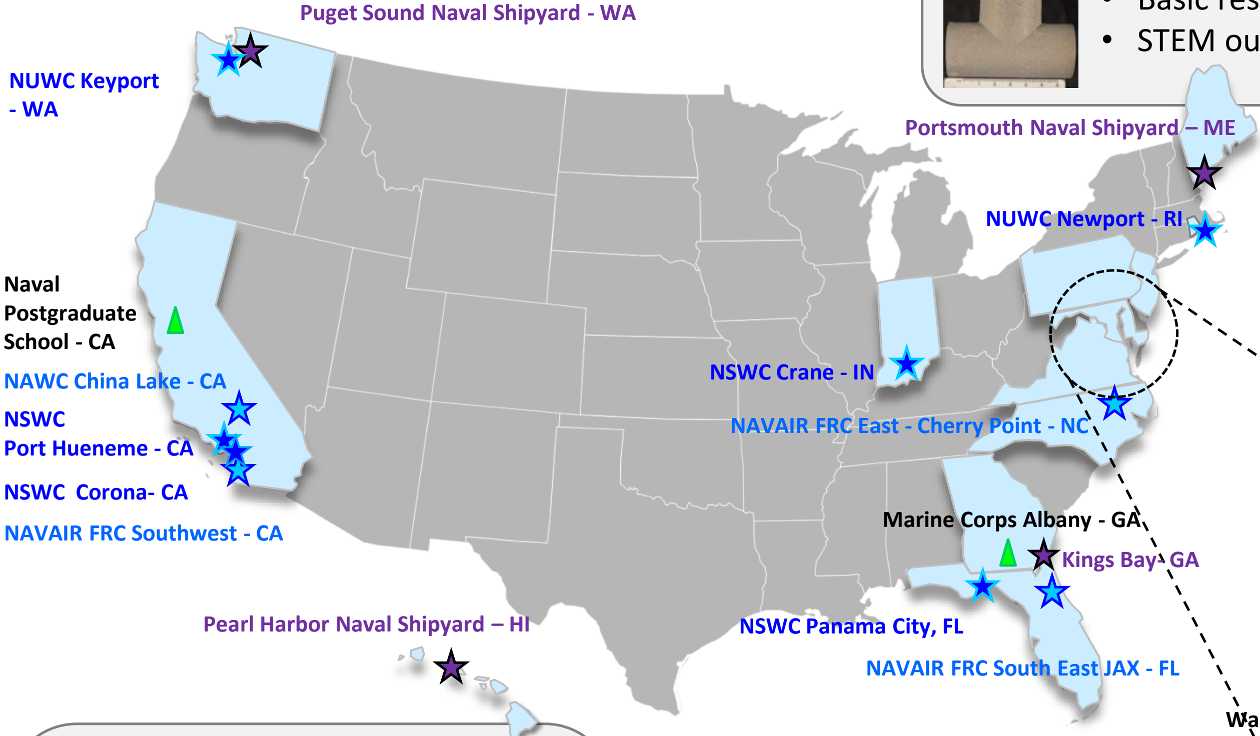
Repair

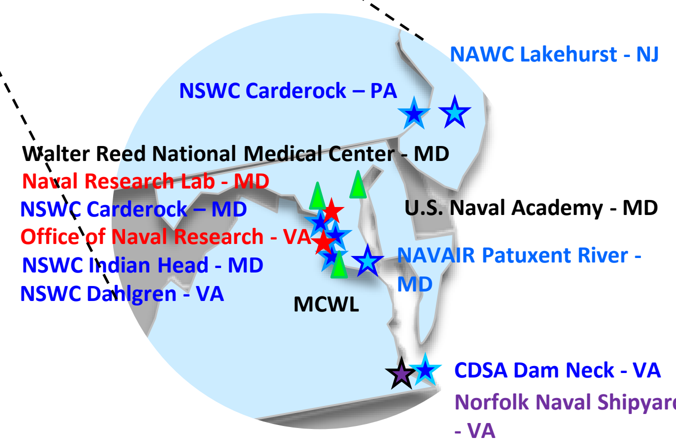
- Machining errors
- Casting errors
- Worn parts



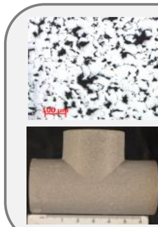
Naval Additive Manufacturing Enterprise

★ *ONR*
★ *Shipyards*
▲ ***Service/Academia Other***
★ ***NAVAIR***
★ ***NAVSEA***





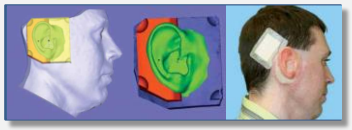
ONR ★



- NAMTI
- Basic research
- STEM outreach

Service/Academia Other ▲

- Custom medical tooling
- Basic research
- Cyber security

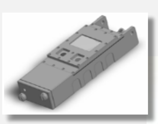


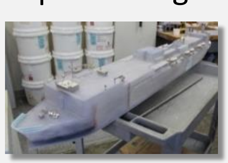
Shipyards ★

- Rapid tooling and molds
- Rapid prototyping
- Replacement part development

NAVSEA ★

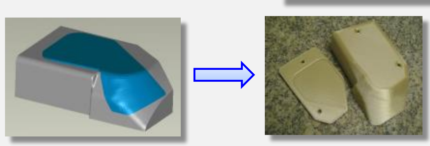
- Sand casting
- Ship models
- Working prototypes
- Rapid tooling





NAVAIR ★

- Rapid prototyping
- Custom parts
- Rapid tooling



NAVSEA 05 AM Capabilities

AM Machines

- Material Extrusion – All warfare centers and shipyards
- Vat Polymerization – PSNS&IMF, Panama City, NSWCCD
- Material Jetting – NSWCDD, CDSA, Crane
- Binder Jetting – NNSY, NSWCCD, Keyport
- PBF (Polymer) – NSWCDD, NSWCCD, Crane, Panama City, Keyport
- PBF (Metal) – NSWCIH, NSWCDD, NSWCCD (Dec 2015), NSWC Crane

Prevalent Materials

- Polymers: ABS, Nylon, ULTEM, PLA
- Metals: 316L, 17-4 PH steel, Ni Alloy 625
- Others: Sand

Capabilities supporting implementation of AM

- Materials Development
- 3D Modeling and Analysis
- 3D scanning and metrology
- Advanced Nondestructive evaluation
- Integrated Computational Modeling
- Ship Motion Simulation

AM Capability/Equipment Database

NAVSEA 05 AM Vision and Goals

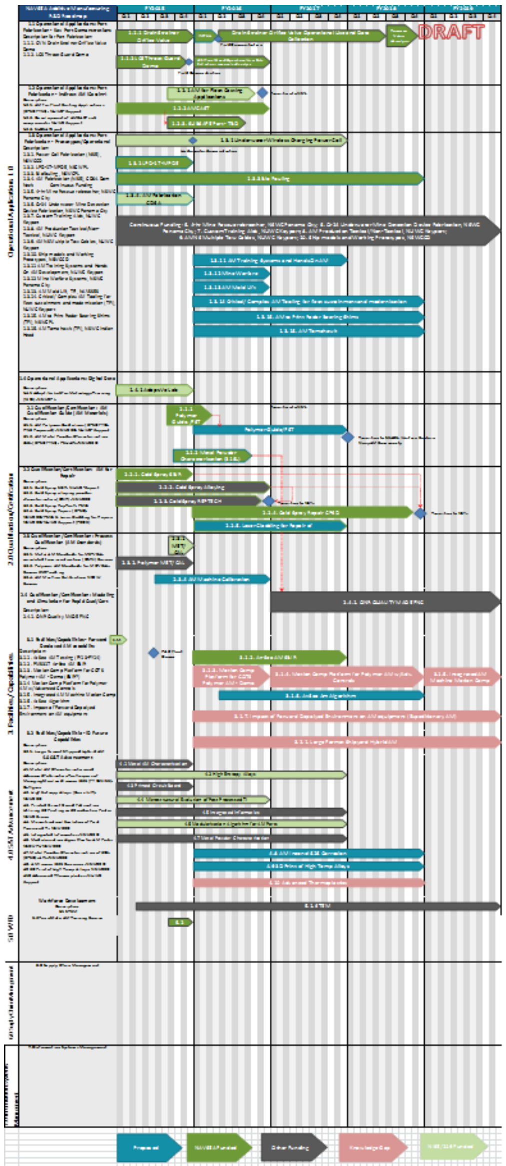
Establish the processes, specifications and standards for use of AM for ship acquisition, design, maintenance, and operational support.

Collaborate and partner with other government activities, Fleet, industry, and academia to:

- Build process, material, and design confidence in AM.
- Ensure that AM ship and weapon system components are safe, reliable and effective for the intended application.
- Expand the current use of AM for rapid design development, prototyping & tooling.
- Employ AM in maintenance & repair.
- Identify and forecast necessary S&T investments to provide enabling capabilities for the NAVSEA enterprise**.**

Operationalize AM in support of the Fleet - where it makes sense.

NAVSEA 05 AM Vision and Goals

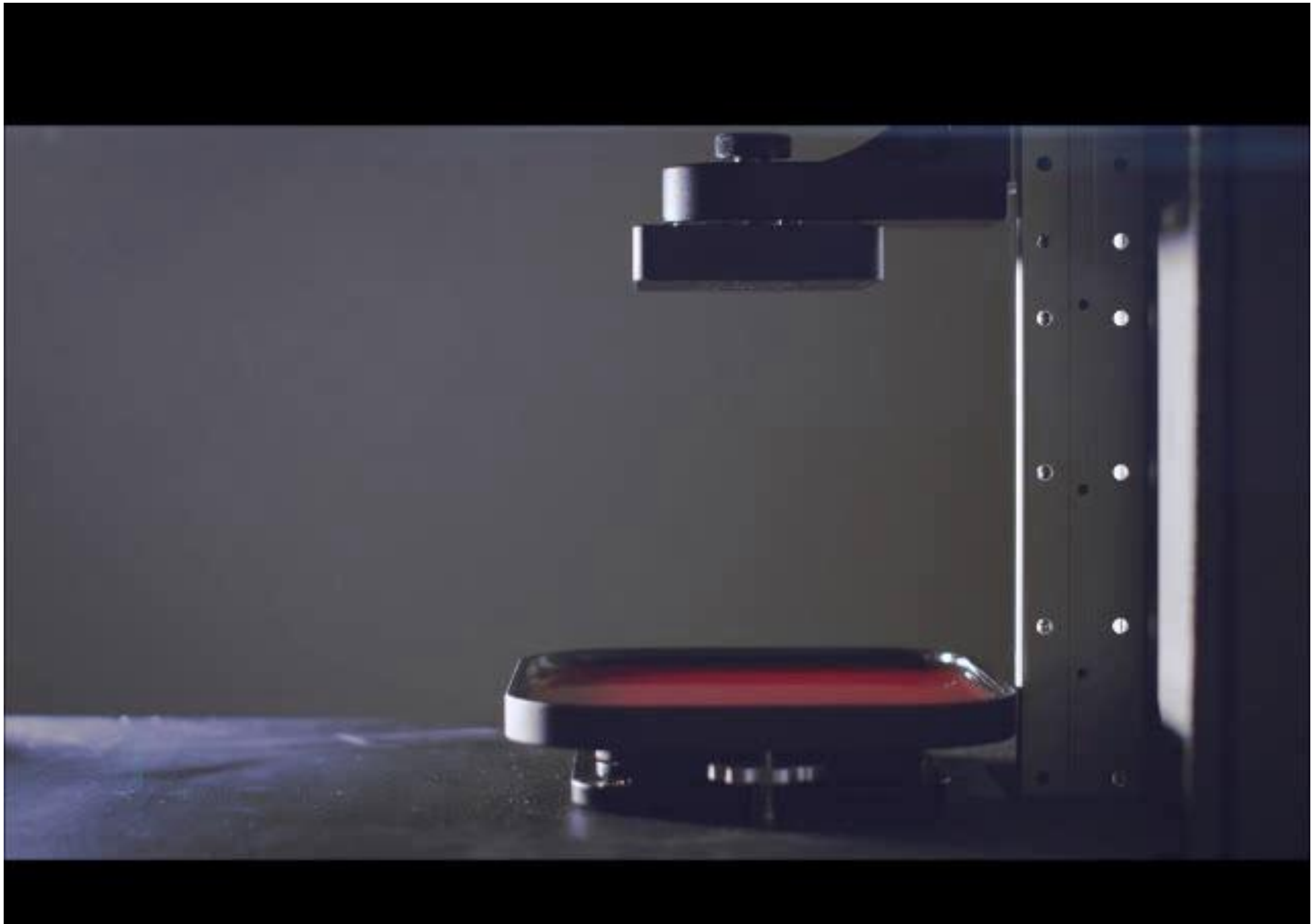


- NAVSEA 05 has surveyed the warfare centers and shipyards to consolidate funded and proposed AM efforts onto one roadmap
- Project mapping allows for determination of knowledge gaps in AM technology
- Ensures no duplication of efforts
- Research institutions can leverage projects throughout enterprise
- Current research focused on development of metallic materials

NAVSEA POC for AM:
Justin M. Rettaliata, Ph.D.
Acting Technical Warrant Holder for Additive Manufacturing
justin.rettaliata@navy.mil

Questions?

Additive Under Development



https://www.youtube.com/watch?v=74BjdHDJeE0

Additive Manufacturing at
Naval Surface Warfare Center Carderock Division

NAVSEA WARFARE CENTERS Carderock

The Naval Surface Warfare Center Carderock Division (NSWCCD) is the Navy's center of excellence for ships and ship systems with sites in Bethesda, MD and Philadelphia, PA. Carderock specializes in the following:

- Ship Design & Integration
- Hull Forms & Propulsors
- Structures & Materials
- Signatures, Silencing Systems, and Susceptibility
- Environmental Quality Systems
- Vulnerability & Survivability Systems
- Machinery Systems

Additive Manufacturing Systems

Bethesda , MD:

3D Systems 5000 (Vat polymerization/polymer)
3D Systems iPro 9000 XL (Vat polymerization/polymer)
3D Systems Vanguard Hi-Q (Powder bed fusion/polymer)

Philadelphia, PA:

Z-Printer 650 (Binder jetting/polymer)

Current Programs

The Model Fabrication Facility in Bethesda, MD has produced functional parts for prototype testing for over 12 years. In Philadelphia, PA, the advanced data acquisition, prototyping technology and virtual environments (adapt.ve) lab allows for rapid digital data capture of machinery which can then be rapidly prototyped with any design/functional changes desired.

Future Focus

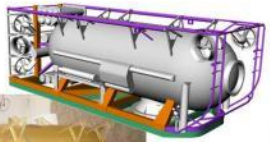
Future focus areas include the following:

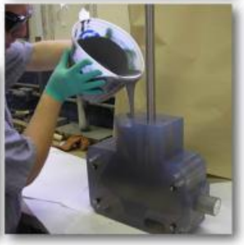
- Fabrication of scale ship models
- Machinery systems training
- Metallic materials for manufacturing
- Repair to composite materials for structures and other components
- Exploitation of at sea AM

Applications

- Scale ship models
- Tooling and test fixtures
- Working prototypes
- Training/visual aids

Parts are used in a variety of seakeeping and wind tunnel experiments to allow engineers and researchers to rapidly and accurately collect data. Additionally, AM combined with laser metrology equipment is used to scan the real machinery systems and components to create a computer-generated model for 3-D printing. These parts are used in the classroom training environments to increase knowledge retention and allow for a more hands-on approach.





Benefit to the Warfighter

Additive manufacturing allows for rapid, complex fabrication of ship models to support the warfighter mission in development of new ship structures. AM components are used in the classroom training environments to increase knowledge retention and allow for a more hands-on approach in advanced logistics concepts and HM&E life cycle logistics support. This technology has significant ability to impact Navy logistics at sea and on land.

USNS Comfort

WAVES

December 2012 - January 2013 Review

Page 4

FROM THE TOP | DTD CORNER | TECHNICAL RESOLVE | LATEST | EVENTS | OUTREACH | BUSINESS | AWARDS | SAFETY | SPOTLIGHT | HISTORY | HR

Technical Resolve

NSWC Carderock Division delivers first fabricated model with new 3-D printer

By Nicholas Malay, NSWC Carderock Division Public Affairs, (Previously published in Jan. 24 NAVSEA Newswire)

3-D printer fabricated model of USNS Comfort (T-AH 20) in progress. U.S. Navy photo.

Naval Surface Warfare Center (NSWC) Carderock completed a fabricated model of the hospital ship USNS Comfort (T-AH 20), marking the first ship model to be created using a new 3-D printer, Jan 10.

The state-of-the-art 3-D printer, which is one of four in the United States, provides Carderock with the capability to deliver large, complex ship models. Additionally, the ship models require less assembly time and can be fabricated unattended, 24 hours a day.

"3-D printing technology is currently being used in industry to produce parts, structures and models for various applications," said NSWC Carderock engineer Francisco "Paco" Rodriguez. "For more than a century, Carderock engineers have been at the forefront of technology in delivering ship models in order to build the Navy's future fleet. This next generation technology provides Carderock unprecedented capability to deliver fabricated ship models faster and at a more affordable cost for the Navy."

NSWC Carderock engineers and technicians upload computer-aided design (CAD) drawings of a ship model into the 3-D printer. As the printing process begins, an epoxy resin is exposed to ultraviolet light, changing its state to a solid. A wiper applies a coat of the liquid to a flat surface on the machine and the ultraviolet laser then traces the shape of the part to be constructed. Once solidified, the wiper continuously applies additional coats of epoxy until the ship model is completed.

Partnering with Naval Air Systems Command and Military Sealift Command, the model testing of USNS Comfort (T-AH 20) will be conducted in the NSWC Carderock Anechoic Flow Facility, a closed-loop wind tunnel which quantifies aerodynamic and acoustic properties of scaled ship or aircraft models and sub-system components. The testing will focus on measuring the airflow of anemometers, wind measurement sensors that are installed on the superstructure of Navy ships.

"The results will determine a usable range of wind directions for the anemometers to help ensure safety while launching and recovering aircraft," said Naval Air Systems Command engineer Joshua Butler. "The wind indications within the established usable range are used to provide wind speed and direction measurements to aircraft."

In addition to delivering ship models, the 3-D printer will also provide NSWC Carderock the capability to produce large parts of any shape that can be downloaded as a CAD file.

"The model of the T-AH 20 was created within 25 days," said Rodriguez. "Prior to the installation of this 3-D printer, we would have conducted four different builds in the previous machine followed by attaching all of the components together, resulting in more than double the time to reach completion. Not only was less time spent building, but now the model will have fewer seams than before."

The use of 3-D printing for ship design is tied to NSWCCD's technical capability providing naval architectural and integrated surface ship and submarine design analysis capability to support ship systems integrated designs for acquisition programs, and to generate advanced concept ship designs for future naval capabilities.