Understanding the Importance of Additive Manufacturing in Casting & Forgings

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PROUD MEMBER OF
America Makes

Advanced Manufacturing at Illinois

Research leaders with expertise in automation, polymer, metal, and composites AM, manufacturing processes, material properties, and metallurgy

50+ faculty and researchers in Manufacturing

Mechanical Eng, Materials Science, Electrical Eng, Aerospace Eng, Civil Eng, Bio Eng, Industrial Eng, Computer Science

Hundreds of graduate students and scientists working on research projects related to advanced manufacturing

Materials Research Laboratory with world-leading capabilities for materials property characterization

Exceptional computing infrastructure and expertise for AI, modeling and simulation, networking, and other topics

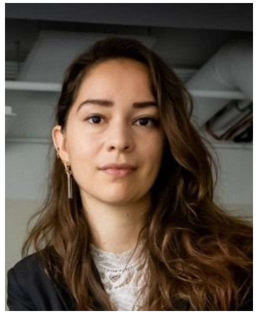
Many courses at the undergraduate and graduate levels

Bill King

Computer vision, Additive Mfg

Placid Ferreira

Manufacturing systems control



Marie Charpagne

Metallurgy, Alloy design

Shelly Zhang

Topology optimization

Katie Matlack

Non-destructive inspection; Ultrasonic measurements

Sam Tawfick

PhD Michigan

Composites mfg and properties

Katie Driggs-Campbell

Robotics and human interfaces

JC Stinville

Materials Informatics and Characterization

Our View on the Future of Manufacturing

AI and Embedded Intelligence

Reasoning, Decision Making, and Data Analysis

Manufacturing Machines & Processes

Next-Generation machine tools and manufacturing processes for 100X faster production

Modular, self-aware machines that can adapt and change

New materials for extreme applications: aerospace, drones, mobility, nuclear, space

Factory & Operations

Agile factories that can rapidly reconfigure to make new products on-demand

Manufacturing in resource constrained environments

Extreme automation with robotics, vision systems, and software defined operations

Supply Chain & Logistics

Resilient and flexible supply chains that rapidly reconfigure and respond in a crisis

Surge capability and capacity to respond to urgent needs

Automation and software intelligence for supplier validation, verification, and trust

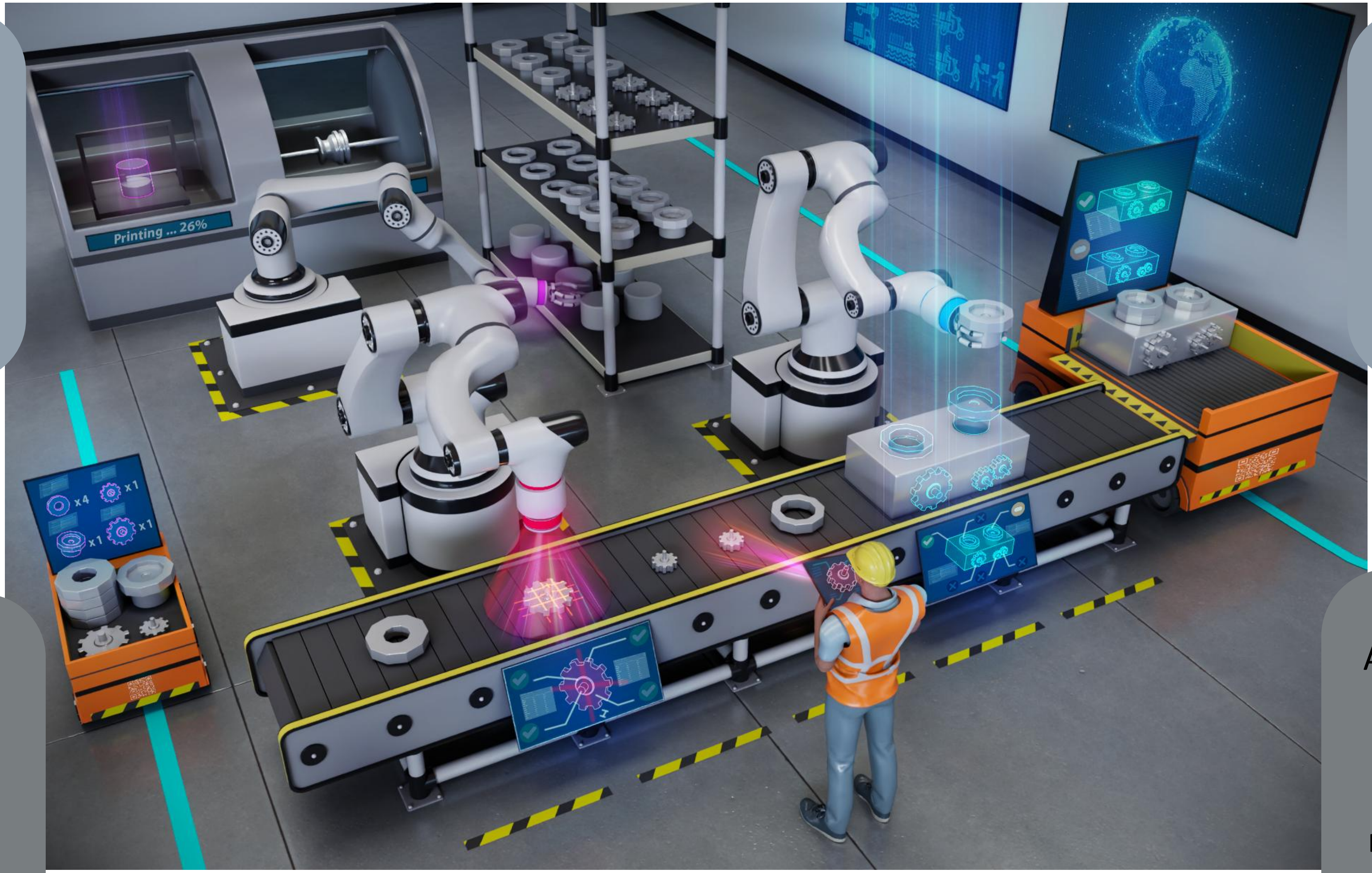
People

Workforce Skills, Human-Machine Interface, Knowledge Management

The future of manufacturing, created at the University of Illinois

Vision Automation
Self-aware robotic systems autonomously position cameras to inspect parts, measuring dimensions and detecting defects in real time

Process and Part Optimization
AI-driven vision and analytics continuously monitor manufacturing processes to optimize materials, workflows, and product quality



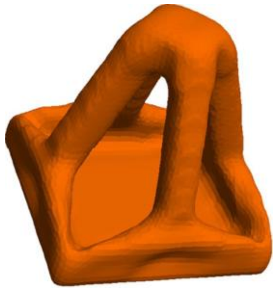
Digital Twin
High-fidelity digital replica of assets integrating geometry, process, and operational data for simulation, monitoring, and optimization

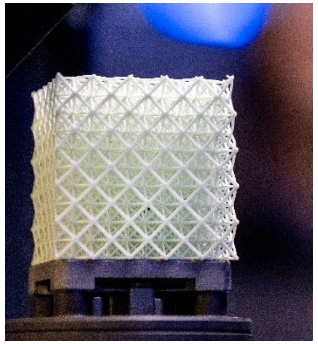
Manufacturing Forensics
AI-powered video analytics capture, time-stamp, index, and cross-reference visual data to reconstruct manufacturing events with high fidelity for analysis and accountability

Additive Manufacturing – Design, Manufacture, Qualify

Design

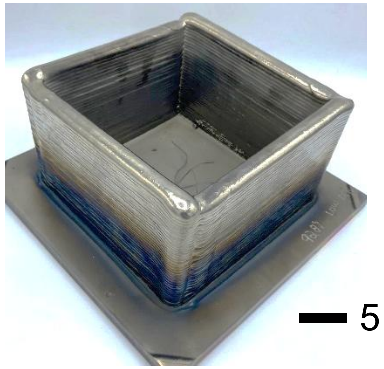
- New Metal Alloys
- Modeling and simulation; Virtual prototyping and manufacturing
- Topology optimization, design automation, design for manufacturability





Manufacture

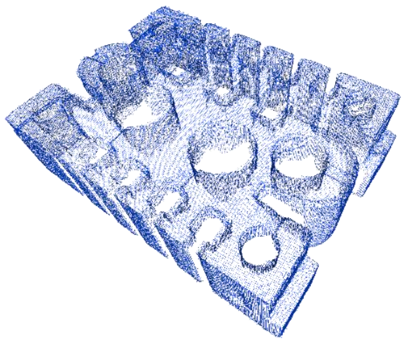
- Large format metal additive manufacturing (Wire DED)
- Micro additive manufacturing, in-situ process monitoring
- Applications in aerospace, automotive, medical, and other fields

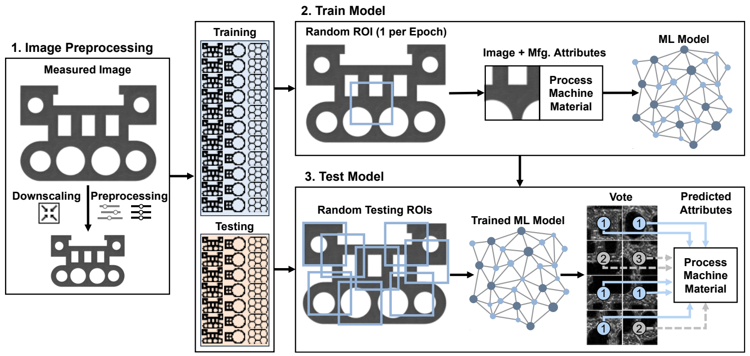


5 cm

Qualify

- Computer vision, process monitoring, inspection, qualification
- Automated metrology, overlay CAD with photographs
- Robotics and autonomy; Factory operating system

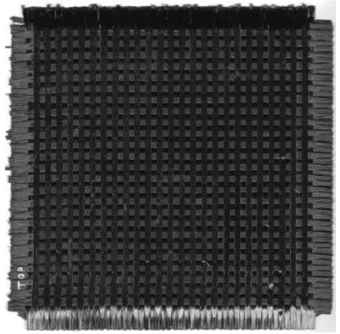




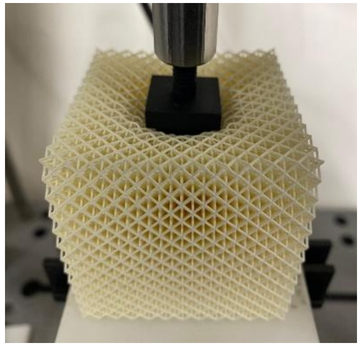
Polymers and Composites

- Long fiber / large format composites manufacturing
- Energy efficient manufacturing of thermoset polymers
- Soft materials for gripping, manipulation, comfort, and energy absorption

10 mm



50 mm



20 mm

Metal AM Equipment at Illinois

Meltio M600 with Blue Laser

Midwest Engineered Systems ADDere

Directed Energy Deposition (DED)

Concept Laser Mlab 100R

OPEN ADDITIVE

XACT Metal XM200G

Powder Bed Fusion (PBF)

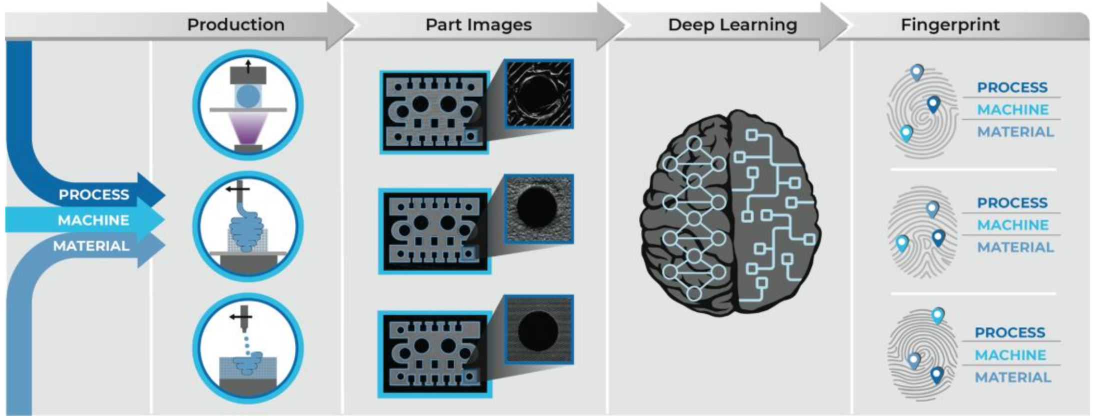
AI Computer Vision for Manufacturing

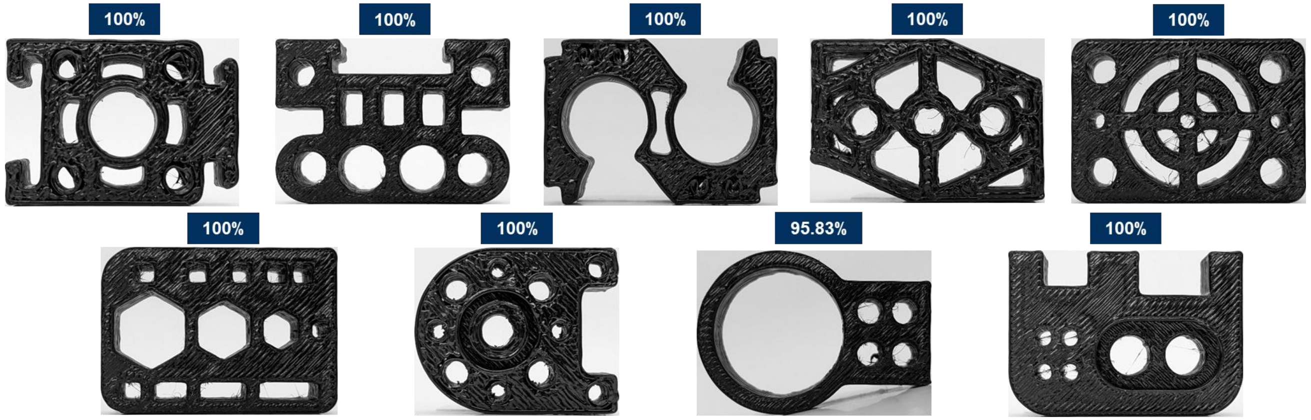
While current inspection tools flag defects, they don't answer the question that matters most: Is ***the part good?*** Our technology closes the gap with **real-time part classification,** turning raw sensor data into actionable quality decisions.

Deep learning model identifies the process, machine, and material that produced the part from a single image

• We start by training a deep learning model on parts* with different manufacturing attributes: Machine, process parameters, material, build, print location
• The trained model evaluates unseen parts to accurately predict manufacturing attributes (**exceed 99% accuracy**)

***Parts Summary:**
19,237 Individual Parts
378 Builds
55 Unique Machines
25 Part Designs
12 Manufacturers
14 Materials
6 Processes





Bimrose *et al.* Additive manufacturing source identification from photographs using deep learning. *npj Adv. Manuf.* **2**, 20 (2025). https://doi.org/10.1038/s44334-025-00031-2

Computer Vision and Manufacturing Software Intelligence

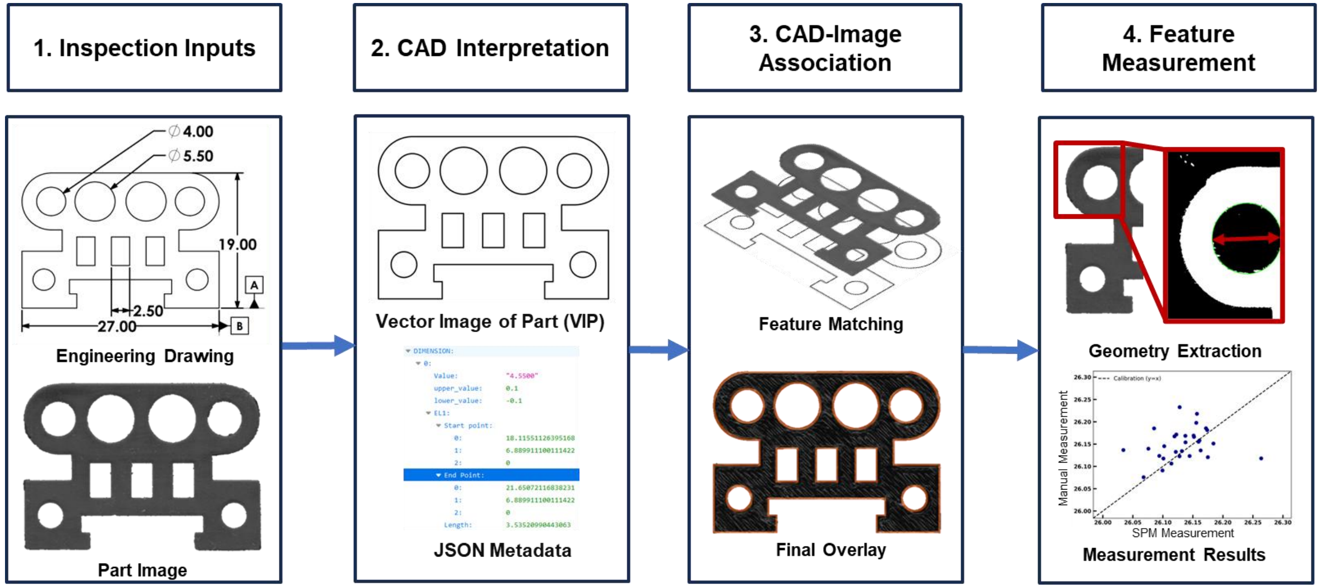
Automated CAD-to-Image Inspection System: Automate dimensional inspection by overlaying CAD geometry directly onto part images for accurate, repeatable feature measurement

How It Works:

- CAD Interpretation – Extracts geometry and dimension data from complex DXF drawings using logical heuristics and Y14.5 standards
- CAD–Image Association – Transformer-based model aligns CAD geometry to part images via RANSAC transformation matrix
- Feature Measurement – Uses edge detection and Hough transforms to extract and measure features; calculates deviation (DFT = Measured – Nominal)

Validation & Results:

- 4 manufacturing processes (DLS, MJF, SLA, FDM) and ten part designs tested
- SPM automatic measurements are compared to manually extracted measurements
- Mean Absolute Error (MAE) across five dimensions is 41 microns
- Accuracy comparable to industry-standard software



Impact: Fast, objective, scalable inspection reduces manual labor, enhances traceability, and accelerates quality assurance

Agile and Reconfigurable Supply Networks

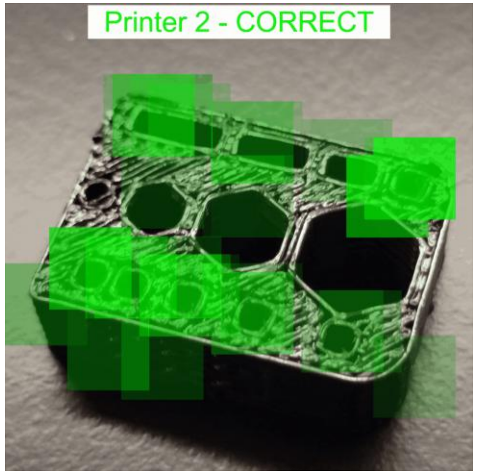
Developing computer vision and AI technologies for supplier assessment, qualification, and management

Resilience & Responsiveness Enablement: Designing and deploying manufacturing systems that prioritize rapid recovery and real-time response under stress, ensuring mission continuity even under shocks such as global disruptions

Adaptive & Autonomous Architecture: Leveraging automation, robotics, AI, and smart factory frameworks, embedding adaptability into operations so that systems evolve dynamically to changing conditions

Deep Supply-Network Visibility: With sensing, edge computing, and analytics, enabling visibility far into tiers of the supply network, so decision makers can anticipate bottlenecks and mitigate risk across the full chain by converting latent manufacturing capabilities

PRINT: Photographic Recognition and Identification using Neural networks for Traceability



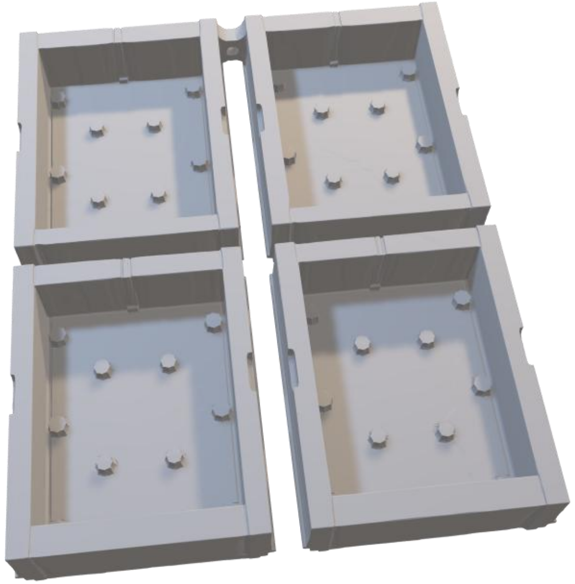
Using PRINT in the field and determining the original manufacturer

Reverse Engineering in Castings & Forgings

Ability to make parts from designs, parts in service, or combinations

Creating CAD models from parts, critical when prints are not available

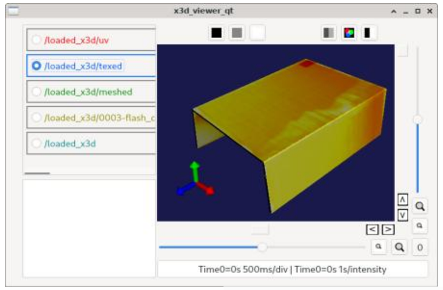
- Using the novel technology to demonstrate the capability of capture when no drawing is available

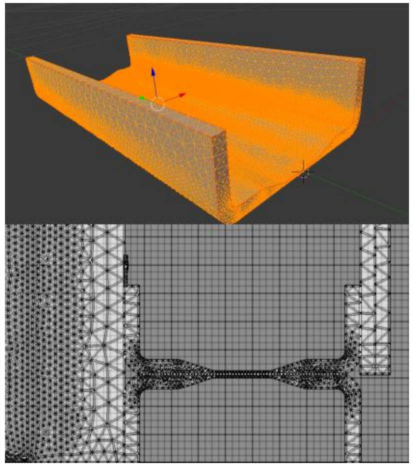


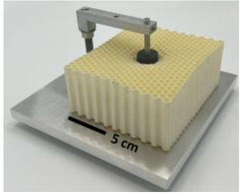
Leveraging digital engineering tools for quick and effective analysis

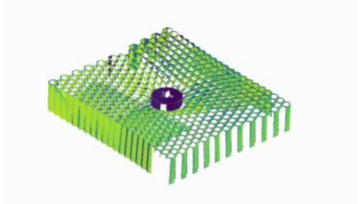
Digital Twins, linked to reverse engineering and rapid prototyping, utilize advanced NDE tools and computational techniques

- Reconfigurable instrumentation / rapid deployment of new measurement modalities
- Identification (CADMap registration) of data inconsistencies



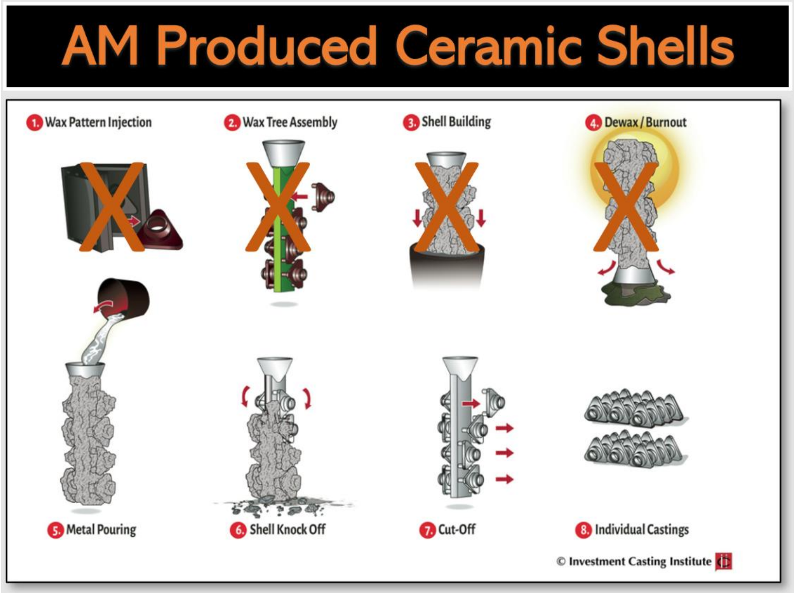






Advantages for using 3D printing in Casting

- Design Freedom
- Quick Turnaround
- Improved Efficiency (process & part)
- Reduced Material Waste
- Reduced Costs



Investment Casting Institute

America Makes Project 5554.002 – Additive Manufactured Ceramic Shell Technology for Investment Casting

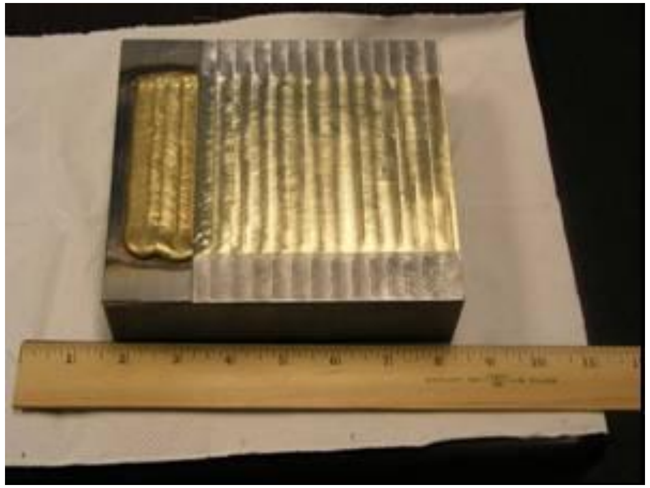
Redesign using AM

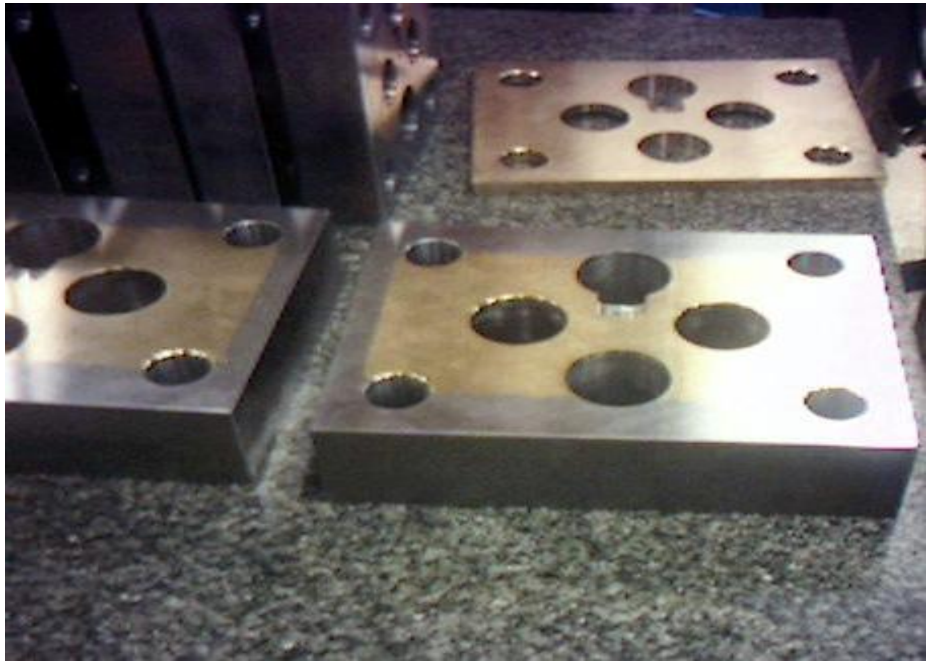
- Customer made parts

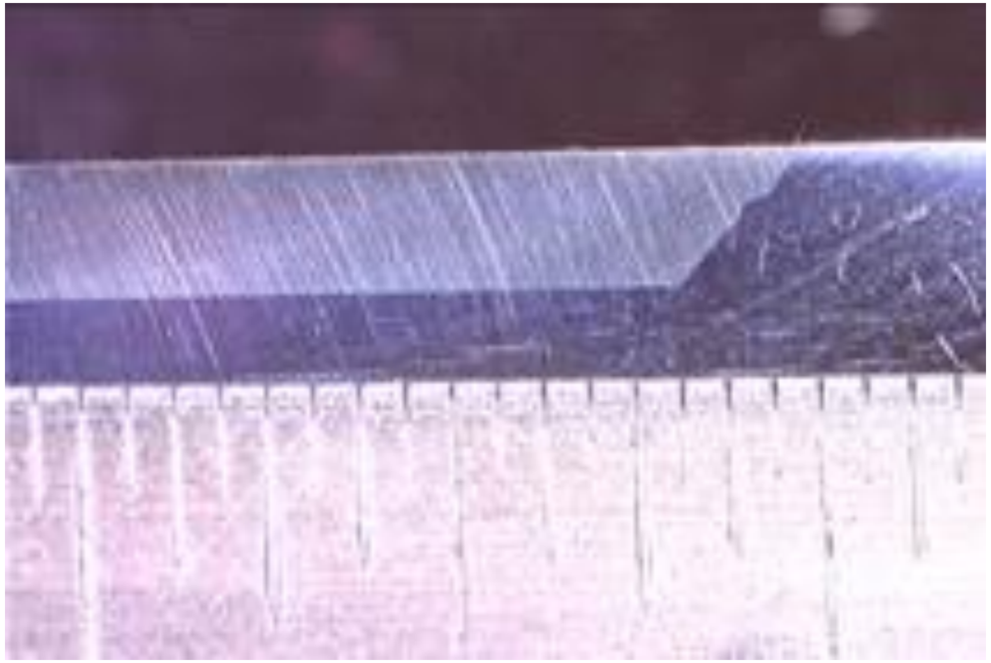
  ~ 1 /hr at a cost of- $125 per part.

  - Quality varies tremendously
  - Process is primitive and unsafe for operator

- Using AM it was possible to make 4 parts per hour at $15 per part

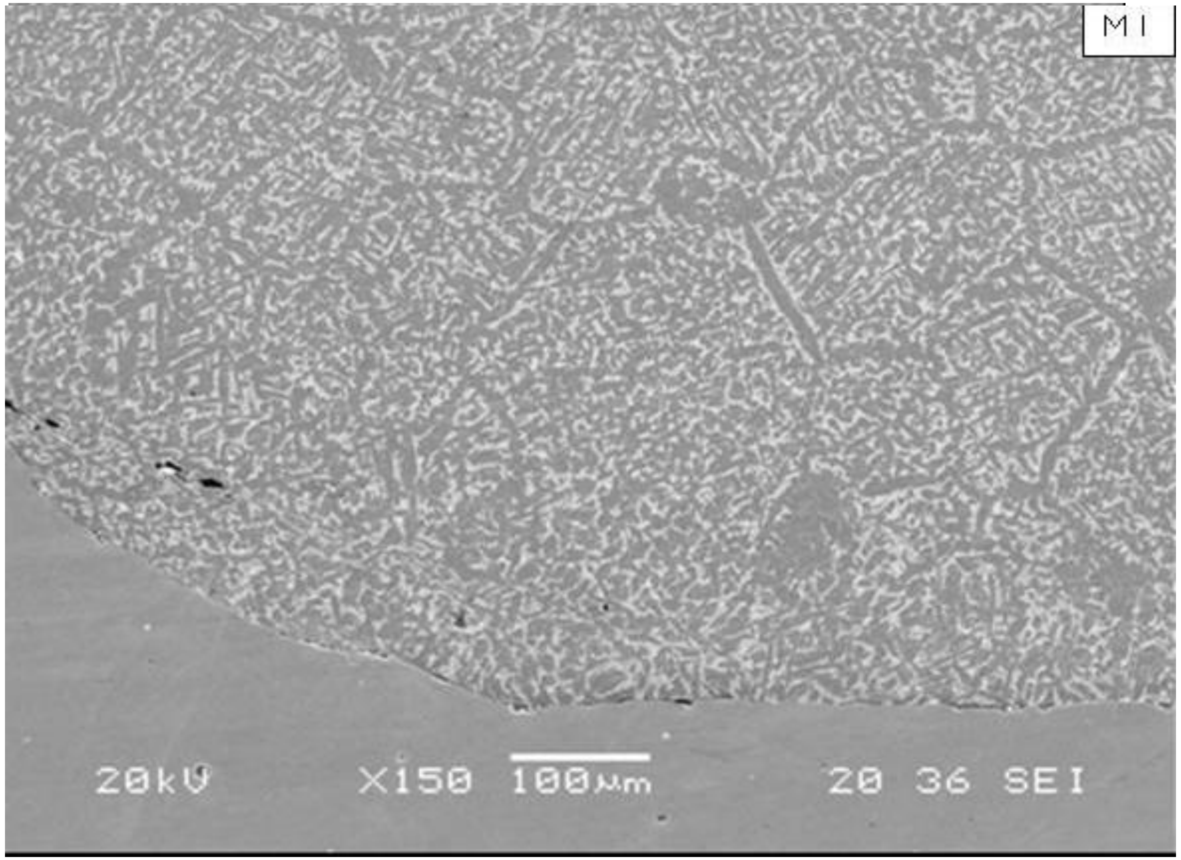






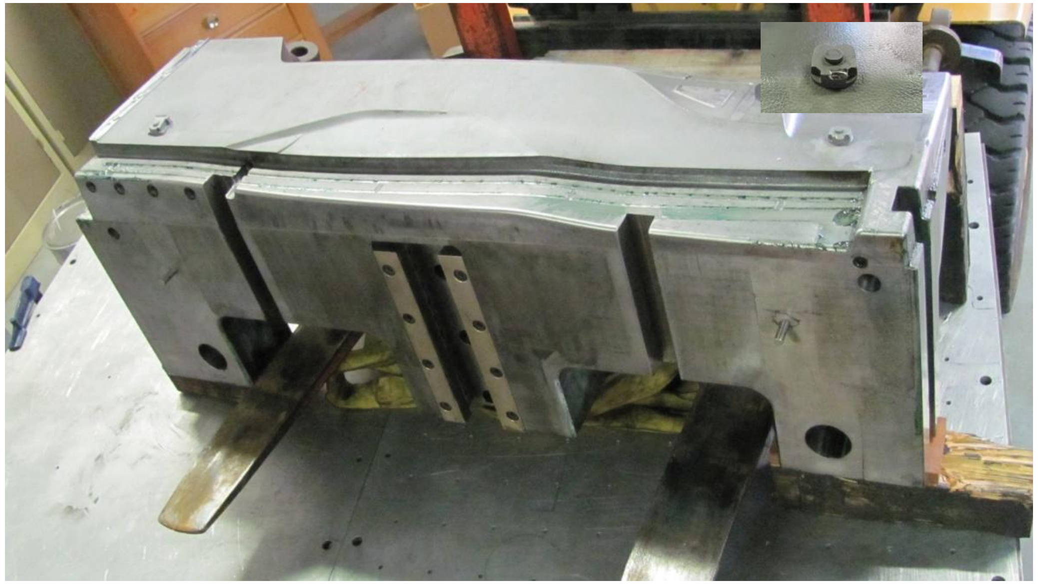
Note: done with one pass
Dilution within spec.

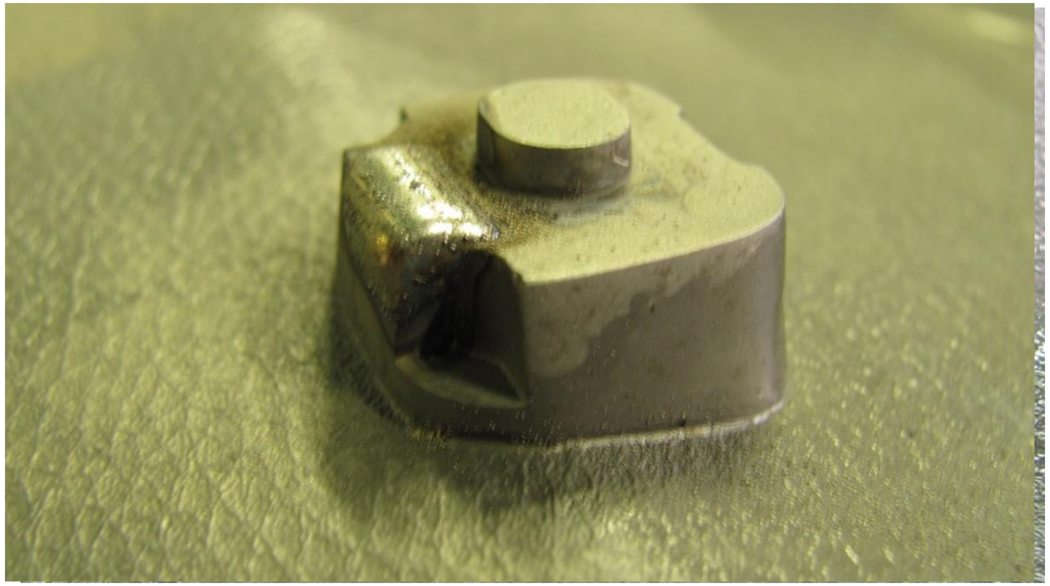
http://files.aws.org/wj/2008/09/wj200809/wj0908-36.pdf

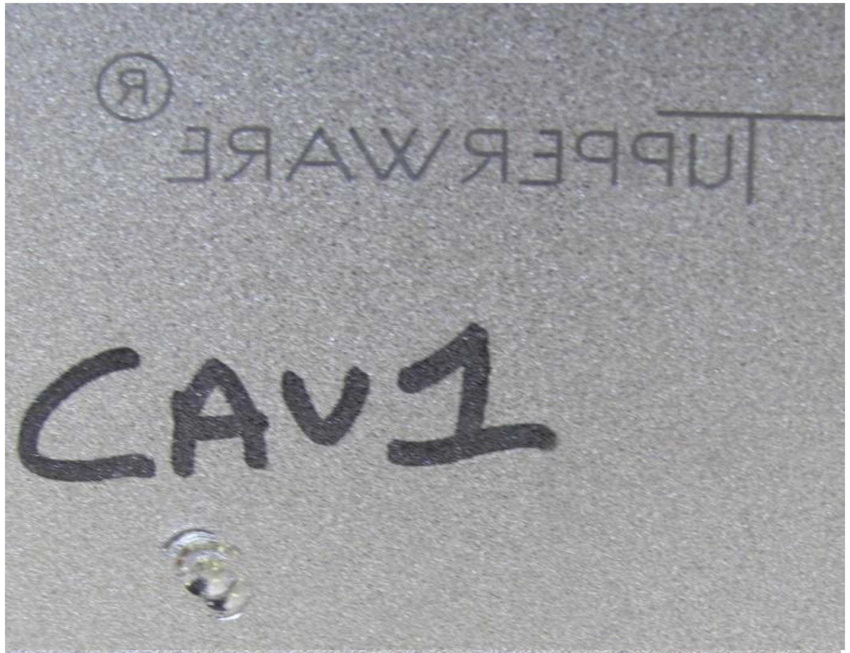


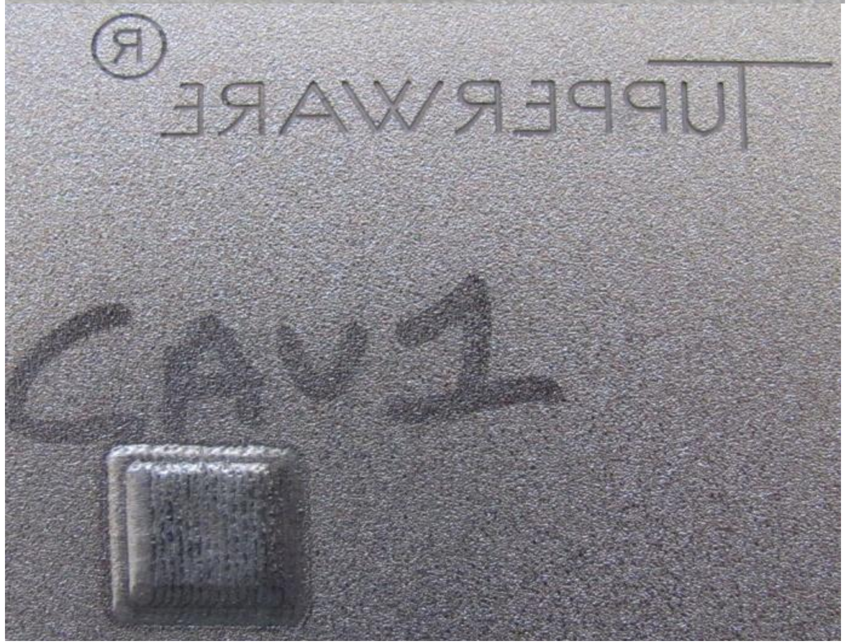
Region on bottom of bearing plate where it was anticipated that a majority of heat would penetrate on the corner, minimal HAZ is observed

Quick Turnaround: Localized repairs of high-value molds









To manufacture new inserts, harden and polish = 4 weeks of work

Cost to manufacture new inserts $3,200+ time lost in production due to new parts being manufactured.

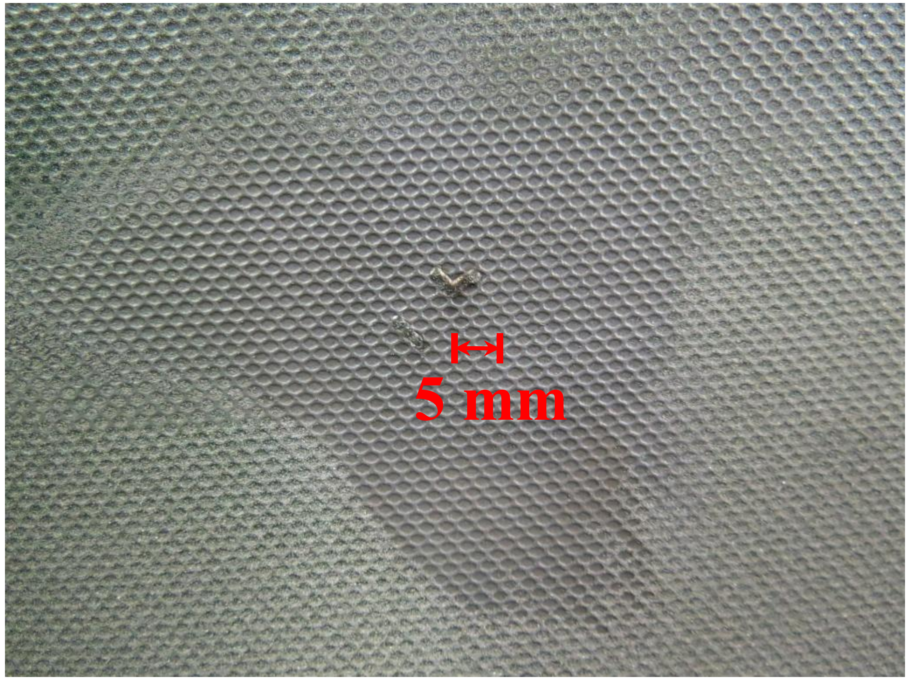
AM-repair, re-machine and polish inserts = 1 week’s work.

Total cost to repair US $1,000

For other applications, saved months of downtime and over $19,000 in savings

Tupperware®

Saved local company from $15k/minute penalties for stopping their Ford line



Improved Efficiency: Hybrid - Two Machine Process

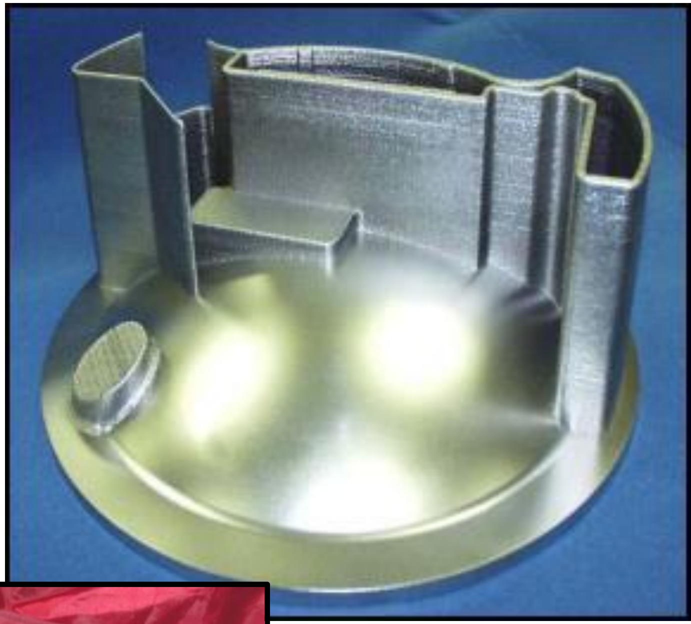
EXAMPLE: Tough to Cast, Lead time: 52 Weeks

Machine disk base on Mill

3D print Vertical Thin Walls on AM

Finish on Mill

Delivery Time: 3 Weeks, 30% cost savings



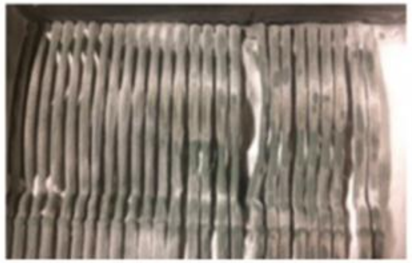
ADVANTAGES

- Optimize Utilization
- Lower Cycle Time Cost for Expensive Mills
- Balance Process Throughput
- Easier to Recover Powder

Reduced Material Waste

HOW HUMTOWN CONVERTED CNC TOOLING INTO 3D PRINTED PARTS

PROBLEM:A Humtown customer had CNC cut tooling produced several years ago and due to the very small 1/8" diameter of the core, the tooling had worn out. To get the core box to fill, Humtown had to increase the blow pressure of the machine, which wears out tooling even faster than usual. Once a core box starts to wear out, either clay or gasket material is used to keep pressure in the cavity, but the downside of that is that loose sand sticks in the material and further damages the tool.



SOLUTION: Humtown proposed creating a 3D CAD model of the core and 3D printing the cores instead. Not only that, but they would print the cores in a box that could be shipped straight to the foundry. To date we've produced over 10,000 cores using this 3D solution and the customer has seen improved casting yield, lower scrap in shipping, and found an added bonus that the 3D printed cores clean out better from the casting! If you are interested in converting traditional, worn out tooling into 3D printed parts, click the button below.

HOW HUMTOWN TURNED A SCRAP JOB INTO A PRODUCTION JOB

PROBLEM: A foundry and their OEM customer were frustrated. They had spent all of this time and money cutting all of the tooling for three highly complex engine components, but they kept having to scrap the castings. These three cores were so intricate and the assembly was so complicated that even after spending significant time manually gluing each component into position, they still had to scrap most of their castings. Out of time and running low on patience, this foundry needed to find a solution, and find one fast.

SOLUTION: Quickly running out of options, this foundry contacted Humtown Additive. However, they had trepidations about the volume of parts they could produce. They had heard 3D sand printing was great for prototyping, but not for production. They quickly learned they were wrong.

This foundry sent their design files to Humtown Additive, and we were able to 3D print these three core designs as one core. This core consolidation eliminated all manual assembly – and the time and cost associated. Eliminating manual assembly also led to 0% scrap rate, an astounding statistic when you factor in the complexity of the piece. And their production fears were put to rest as Humtown Additive went on to produce tens of thousands of cores and molds for this customer. If you are interested in series production orders, click the button below.

Reduced Costs

HOW HUMTOWN CONSOLIDATED 8 CORES INTO 1

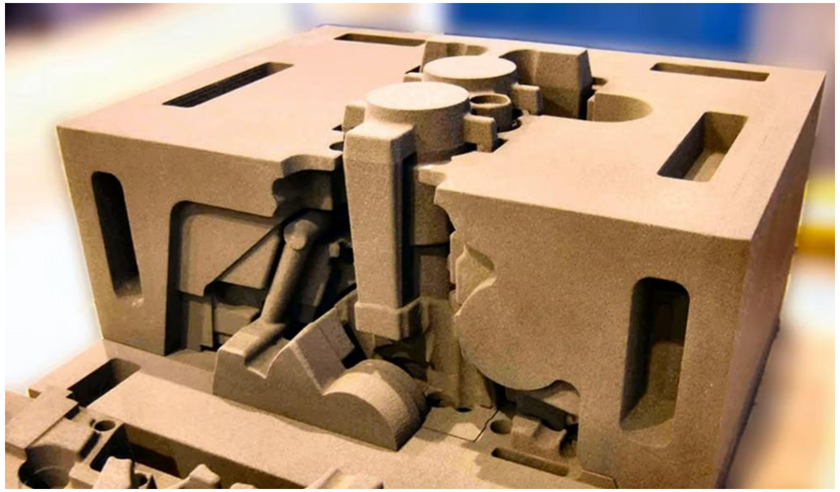
PROBLEM: A foundry had a problem – their project was going to require 8 different cores (!!!) to be produced and then assembled. Not only was this project going to require the production of 8 different sets of tooling and 8 different cores, but it was also going to involve assembly steps that included jigs, fixtures and the gluing together of all 8 components. An assembly this complex was likely going to lead to extensive skilled labor hours and a very lengthy production time. The glue and fit of the cores were also added areas of concern due to the high level of variability and scrap which were inevitable during the casting process. That's why this foundry turned to Humtown Additive.

SOLUTION: Humtown's no-assembly cores were a no-brainer for this project. Through our 3D sand printing, we were able to print one core that consolidated all 8 components, completely eliminating all of the assembly that would have been required. For our customer, switching to 3D sand printing...

- Reduced from 8 cores to 1 core
- Eliminated the need for any tooling
- Removed all gluing tolerances Increased accuracy of component placement
- Eliminated extensive skilled labor assembly hours
- Produced a better casting with less scrap

Not only did the 3D printed cores perform better during the casting process, but the cores were produced in 75% less time and for 20% less cost. The higher the level of complexity, the better the case for Humtown Additive. If you are interested in how Humtown's 3D sand printing can consolidate your cores, click the button below.

The 3D printed sand core for the cylinder head of the B48 BMW engine (Source: Voxeljet/Loramendi)



3D printed sand molds and cores can have an accuracy of ± 0.25mm and printed is a few days (Source: Castings Technology)

The underbody of the General Motors Cadillac Celestiq is made using 3D printed sand cores that allow for stiffening features to be incorporated into the hollow sections (Source: General Motors, Voxeljet)

OK Foundry in Virginia uses a 3D printed sand mold to case a 1912 Velie engine block (Source: OK Foundry)

Additive Manufacturing Technology Roadmap for Casting & Forging

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National Center for Defense Manufacturing and Machining
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The U.S. casting and forging industry faces challenges related to capability and capacity, workforce, and U.S. Government policies

Reductions Across Foundries

- With a **67% reduction in the number of U.S. foundries since 2000**, the U.S. Castings and Forgings ecosystem supply chain is clearly dwindling

Customer Prioritization

- High-quality, domestic purveyors of castings and forgings tend to **prioritize high-value/high-quantity customers** such as in automotive and other high-demand industries

DoD Supply Chain Implications

- The **DoD's high mix/low volume quantities** are **not as profitable for domestic foundry operations**

The challenges with the CF supply chain can pose immediate risks to our national security interests and wartime readiness for critical platforms

Fortunately, AM has shown potential to improve CF lead times

America Makes is leading the way by convening AM and CF ecosystems to strategically assess opportunities for augmenting casting and forging with additive manufacturing.

Roadmap Objectives:

Identified the significant issues affecting CF supply chains and their common characteristics

Prioritized and mapped AM opportunities to those issues, defined the **scope and investment** required

Examples may include:

- Leveraging AM for Tooling
- Leveraging AM for Replacement Parts
- Hybrid Manufacturing

Determined what infrastructure is needed to address the challenges identified

Insights + Key Discoveries

KEY THEMES:

Theme	Insight
AM for Tooling	**AM for tooling is the most feasible solution** as the final part is not being altered, easing qualification requirements while speeding up the time to get tooling and lowering the cost
Confidence in AM	Due to underdeveloped standards and limited characterization of the material properties, there is a **general lack of confidence in the repeatability of AM** compared to casting and forging
Modeling and Simulation	Desire to **improve modeling and simulation tools** to improve decision-making, increase confidence in part performance, and speed up the qualification process
Assisted 3D model creation	Desire for **improved tools** to assist with converting **2D drawings to 3D CAD models** when the drawing exists and **tools for reverse engineering** when it does not
Workforce Enablement	**Workforce enablement** was cited as a current pain point with CF, and as a gap to implementing AM solutions

TOP PAIN POINTS

- The qualification process is challenging, lengthy, and costly
- The wealth of knowledge in the DIB is declining
- Converting 2D drawings to 3D CAD models
- Bidding on low volumes is too risky
- Tooling can be difficult to manage

TOP OPPORTUNITIES

- Modeling & simulation to improve the design process
- Printed tooling for forgings and castings
- AM for tool & equipment repair to keep manufacturing “in the fight”
- AM for hybrid manufacturing
- Tools/guides to assist with technology selection and design

What Is Needed to Succeed

KEY INGREDIENTS:

- **Path to Print** | Playbooks to deploy AM technology for patterns, molds, dies, and repairs
- **Shared Understanding** | Common guidance on when to print, capable vendors, and how to measure performance
- **Integrated Tools** | AM material property predictions as input to broadly used software
- **Digital Foundation** | Common TDP structure with processes to build digital stockpiles
- **Sustainable Training** | Accessible AM resources contained and grown within Casting and Forging communities

Casting Project Priorities and Impact

- Reduced NRE cost
- Reduced variation
- Removed bottlenecks with parallel path
- Improved confidence in AM outcomes

Forging Project Priorities and Impact

*Prioritization calculated using a weighting of 75% Impact and 25% Effort.

- Extended tooling life
- Simplified supply chain
- Reduced cost/time of tooling repair
- Increased process flexibility

THANK YOU

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