U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

AMMTO & IEDO JOINT PEER REVIEW

May 16th-18th, 2023

Washington, D.C.

MANUFACTURING DEMONSTRATION FACILITY | AMMTO

Ryan Dehoff, Director, Manufacturing Demonstration Facility Consortia

24759 | October 2011 - Present

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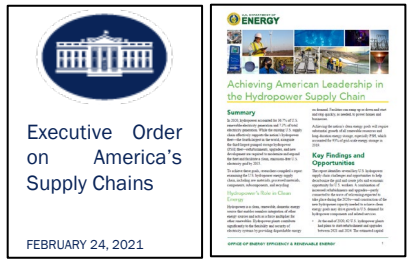
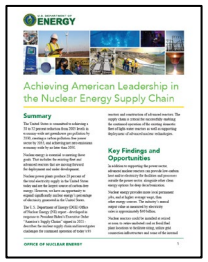
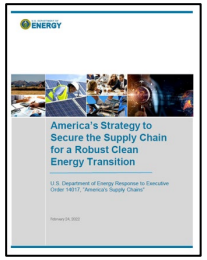
Project Overview

Mission: AMMTO supports the national plan to revitalize American manufacturing, secure critical **supply chains**, and develop diverse **innovation ecosystems** leading to **new manufacturing jobs** and increased economic strength of the nation.

AMMTO's Manufacturing Demonstration Facility, **MDF Innovation Ecosystem** provides access to 1,000's of companies, small business, universities and other stakeholders annually to **co-develop** advanced manufacturing technologies to secure a U.S. supply chain, address affordability of clean energy technologies, and improve the energy efficiency in fabrication and application of components







Energy, Emissions, & Environment:

AM is a critical and necessary enabling technology for the U.S. to achieve its ambitious national energy & decarbonization goals. The U.S. must expand domestic manufacturing capabilities, lower manufacturing costs of clean energy technologies and improve efficiency.

Cost & Competitiveness:

MDF has created unparallel research and technology commercialization mechanisms to broadly deploy advanced manufacturing to make the U.S. competitive in affordable clean energy solutions. Mechanisms include easy access for SMEs that are 98-99% of all manufacturers.

Technical & Scientific:

Advanced manufacturing technologies require integration of diverse disciplines in materials, modeling, controls, systems, and data science. The MDF Ecosystems maximizes investments in these disciplines and enables them to be applied rapidly to different technologies.

Other Impacts:

Over $1B impact on U.S. manufacturing with over a 20:1 ROI on MDF CRADA's leveraging over 250 Industrial collaborations, over 50 university partnerships. MDF publishes nearly 100 publications annually and receives approximately 10-20 awards per year.

Project Outline

Innovation: The Manufacturing Demonstration Facility Innovation Ecosystem

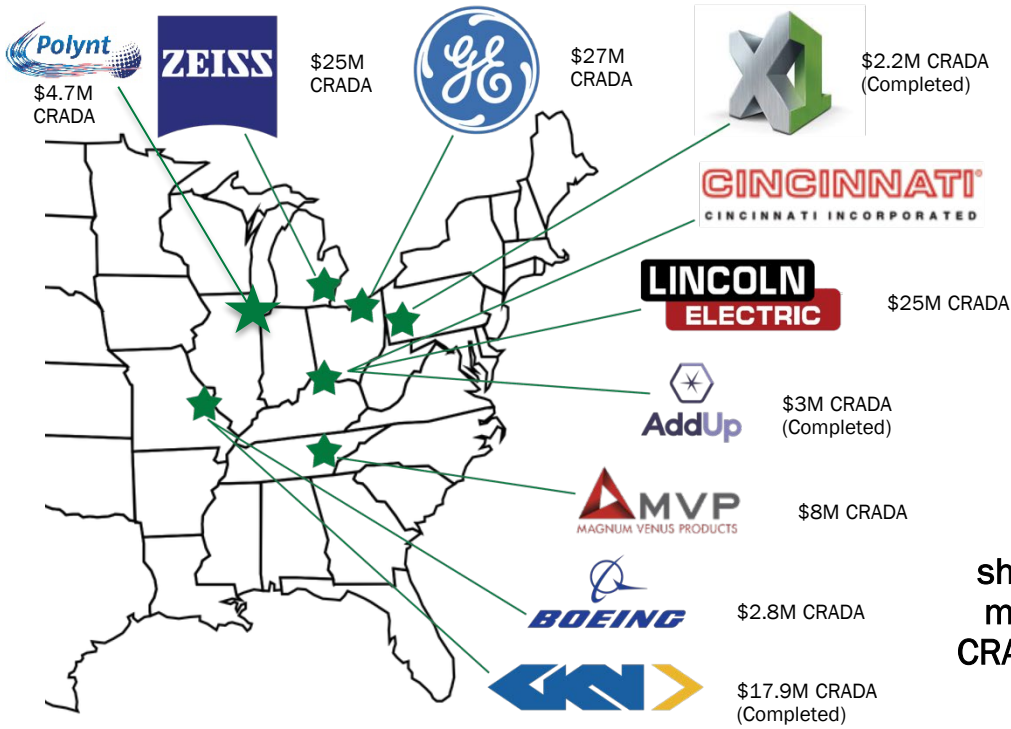
Project Lead: Ryan Dehoff

Project Partners: Over 250 industrial partners, 50 universities

Timeline: AMMTO Funded Consortium

Budget: $20M Annually

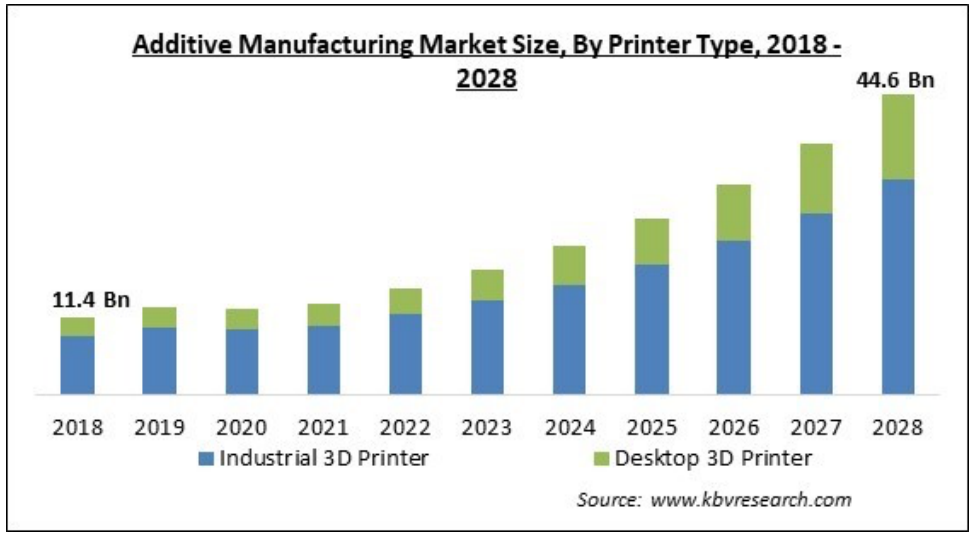
	FY21 Costs	FY22 Costs	FY23 Costs	Annual
Consortium Management and Convening Industry	$2M	$2M	$2M	$2M
Core Research Projects	$16M	$16M	$16M	$16M
Industrial Collaboration	$2M	$2M	$2M	$2M
Total DOE Funding	$20M	$20M	$20M	$20M
Project Cost Share	$17.5M	$14.1M	$10.5M	$10-15M



Values shown are maximum CRADA with 50% industry cost share

Background: Advanced Manufacturing is Critical for the Future

Additive manufacturing reduces energy use by 25% and can cut waste and materials costs by up to 90%[1], compared to traditional manufacturing methods.



Energy Relevant Benefits

- ✓ Innovation
- ✓ Part Consolidation
- ✓ Low Energy Consumption
- ✓ Less Waste
- ✓ Reduced Time to Market
- ✓ Light-weighting
- ✓ Agility of Mfg. Operations

Strategic Roadmap Targets

Demonstrate AM components whose physical properties and cost/value **outperform** selected **conventionally** produced parts by **20%**.

Develop rapid qualification methodologies that **reduce** certification **cost to 25%** of the total component cost.

Develop **new AM systems** that deliver reliable parts with **predictable properties** to six standard deviations ("six-sigma").

Challenges and Barriers:

- **Process control:** feedback control systems and metrics to improve precision, reliability, and quality.
- **Tolerances:** micron-scale accuracy.
- **Surface finishes:** finishes to achieve desired tribological and aesthetic properties.
- **Processing speed:** high-throughput additive processing methods to compete with conventional techniques.
- **Scalability:** capabilities for large-volume production, both in size and number of parts produced.
- **Materials compatibility:** new metal and polymer materials formulated for additive manufacturing, providing application-specific properties such as flexibility, conductivity and transparency.
- **Modeling:** physics-based models to understand the fundamentals of additive processes, especially for multi-material and multi-phase systems and interfaces.
- **Validation and demonstration:** established material properties for additive manufacturing materials and qualification of manufactured components.

Source: *Department of Energy, Quadrennial Technology Review 2015, Chapter 6: Innovating Clean Energy Technologies in Advanced Manufacturing, Additive Manufacturing, pgs. 4-6*

Approach: AMMTO's MDF Consortium Model

U.S.'s most effective laboratory consortium model for accelerating innovation for clean energy

America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition: The U.S. must expand domestic manufacturing capabilities, lower manufacturing costs of clean energy technologies and improve efficiency.

Challenge for Industry: Capital Investments and R&D are expensive endeavors, especially for SMEs. Diverse expertise is required to maximize impact.

The MDF Ecosystem enables access:

1. MDF research leverages next generation equipment. >50% of MDF equipment is industry owned with 90% of equipment placed at no cost to AMMTO.
2. MDF can pull from over 6,000 experts at ORNL with diverse backgrounds and experience including advanced materials, characterization, computational capabilities and energy systems.

Approach: MDF Ecosystem Amplifies AMMTO's Investment

DOE's Manufacturing Demonstration Facility (MDF) at Oak Ridge National Laboratory shows the power of this concept with its unique collaborative ecosystem that provides an interactive bridge between federally funded research, academia, and industry that enables cutting-edge decarbonization technologies and builds the work force necessary to meet national goals.

DOE & EERE

B
IEDO
Nuclear Energy
AI & Technology Office
Wind
Geothermal
ARPA-e
FEMP
Office of Science
Hydrogen & Fuel Cells
Water
Buildings
Fossil Energy & Carbon Management

Advanced Manufacturing is critical to ensure the US is competitive in addressing energy, environmental and nuclear challenges. MDF Core research is leveraged by EERE to help build the clean energy economy and accelerate the transition to a net-zero greenhouse gas economy by 2050.

Stakeholder Engagement

Core Projects

Technical Collaborations

AMMTO

Energy Technology Manufacturing & Workforce, Secure & Sustainable Materials, Next Generation Materials & Processes

MDF Investments are leveraged by AMMTO to revitalize manufacturing, secure supply chains and perform demonstrations.

Government Agencies

NASA
OSD
Air Force
NIST
NAVY
Others…

Other government agencies invest in the ecosystem to maximize the value to the taxpayer. These investments include equipment, knowledge development and opportunities DOE can use for decision making.

Industry

250+ industry partners
$170M in CRADAS
50% of systems **($34M)** owned by industry

40,000+ visitors
1,100+ companies annually
60+ events annually

Academia

50+ university partners
100+ industry fellows
80-100 interns annually

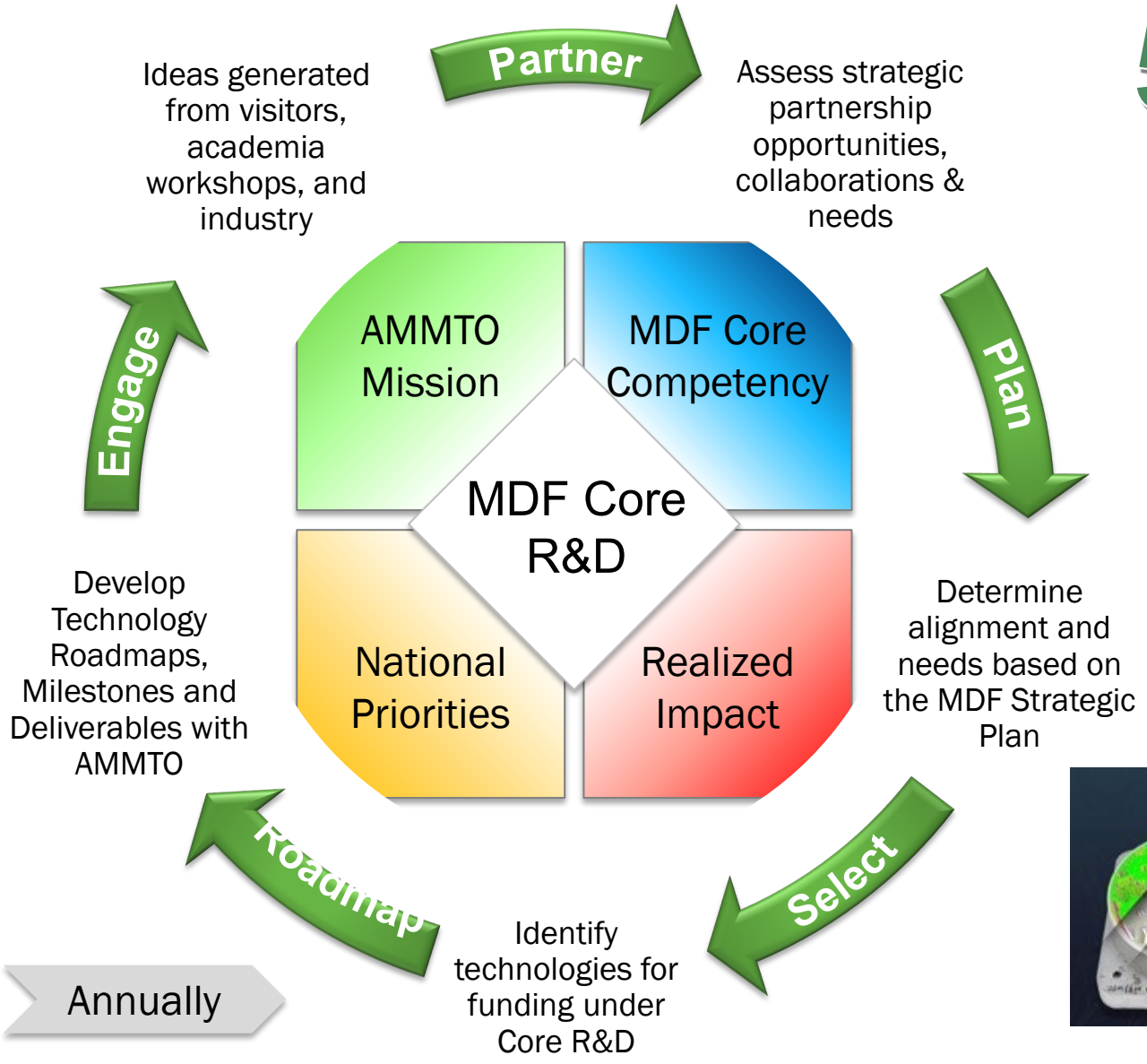
Core Mission

Mission Alignment

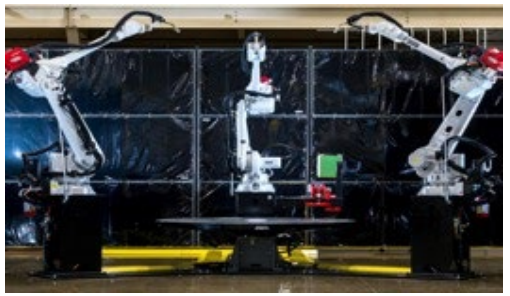
National Alignment

Technology Transfer

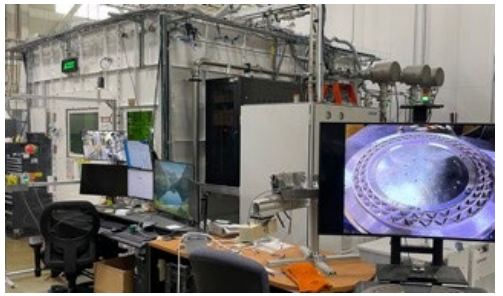
Core Research Cycle Drives Industry Adoption & Competitiveness



5 MDF Core R&D Portfolios



Directed Energy Deposition



Industrialization of Powder Bed AM

Integrated, Smart Polymer Processes

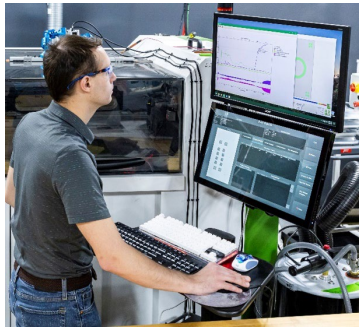
AM Hybrid Systems

Digital Factory

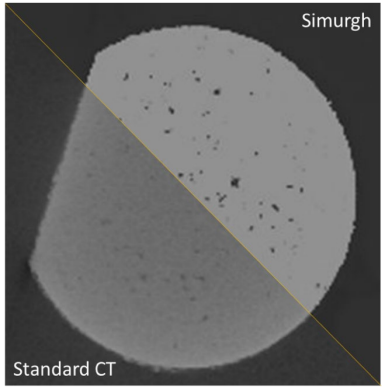
MDF Core R&D Results Drive Industry Adoption

Digital Factory

Peregrine: AI software for real-time 3D print monitoring licensed to 21 companies and recipient of a FLC 2022 award



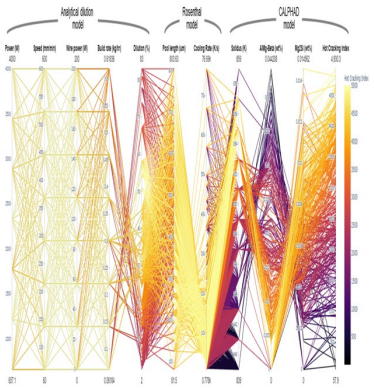
Simurgh: AI-based CT reconstruction achieved improved detection capability while reducing scan time by 6X



Powder Bed AM

3D printed Al alloys with superior high temperature performance

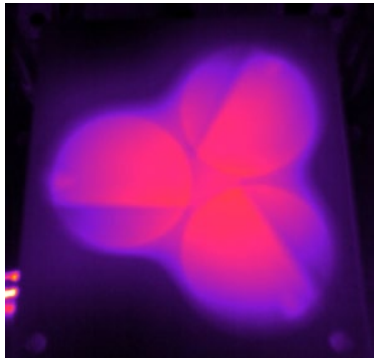
Linking high throughput thermodynamic calculations to AM process conditions



Polymer AM & Composites

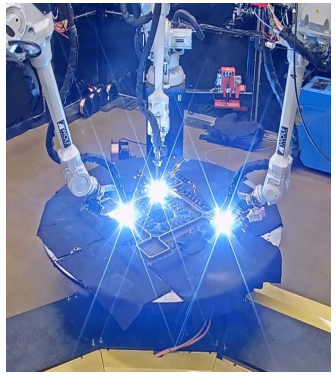
Scaled-up implementation of novel manufacturing technique: additive manufacturing with compression molding

Demonstrated highly energy efficient additively manufactured mold through incorporation of heating elements



Large-Scale Metal

Single-torch deposition rates increased to greater than 35 lb/hr



Casting die used by Mercury Marine to make 4000 parts

Hybrid

Complex 5 axis toolpath algorithms enabling conformal cooling

Co-development and installation of worlds largest metal hybrid AM system

Industrial Collaborations Program

- Provide open, affordable and convenient access to national lab infrastructure, hosted resources, tools, and expertise to facilitate rapid development and adoption of new energy efficient manufacturing technologies.
- Collaborate with industry through cost shared projects to investigate, improve, and scale process methodology to reduce the risk and accelerate the development and deployment of innovative energy efficient manufacturing and materials technologies.
- Enable creation and preservation of domestic manufacturing jobs.

254 Approved Projects with Industry through TC Program

The Collaborative Process

Explore

Opportunities for industry to discover and apply new manufacturing technologies.

Find a willing industrial partner.

Engage

Work with MDF staff and the industrial partner to develop the scope of work.

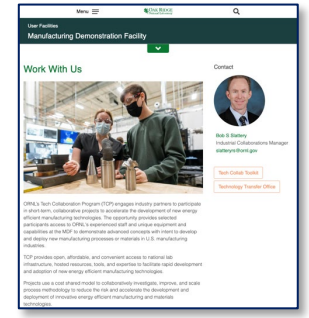
Execute

Non-Negotiable *Collaborative Research and Development Agreement (CRADA)*

Phase 1 $40K
Phase 2 $200K

1:1 Cost Match

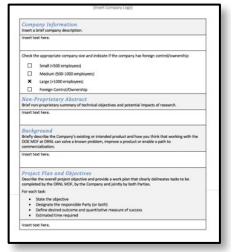
DOE funds support MDF Staff
Companies supports their activities



SAM.gov beta

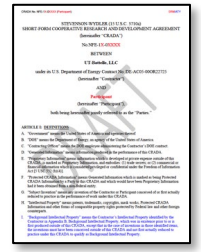
Open Solicitation

Project Proposal Template



DOE-AMO Review/Approval

Short-Form CRADA or User Agreement (ORNL-Industry Partner)



New Short Form CRADA initiation< 60 days

Industrial Collaboration Program Impacts Clean Energy

emrgy

Modular Hydropower Engineering and Pilot Scale Manufacturing

Prototyping and Manufacturing of Magnetic Gearbox Components using innovations in Castings

Follow on Impact: Emrgy Signs agreement with GE Renewable Energy to manufacture low head hydropower devices for Emrgy Hydro

Vestas

Additive Manufacturing of Large-Scale Metals and Composite Structures for Wind Power Nacelles

Metal additive wire-arc printing of skeleton node load bearing joint for wind turbine nacelles

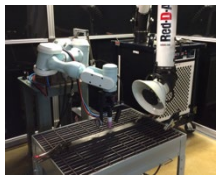
Follow on impact: Metal additive allows for advanced designs and optimized lightweight components that aren't feasible with traditional processes

MDF Ecosystem: The Model for Successful Technology Deployment

National Priority Identified

2015

Initial System at MDF



Significant Interest from multiple stakeholders

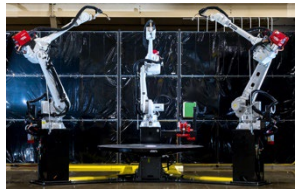
America Makes

Printed propeller using innovative slicing software

NSF IUCRC Engagement

Increase Robustness of U.S. Supply Chain

Large Scale Metal in Core Research



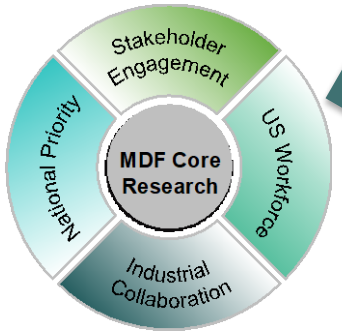
Development of large-sale, high-rate metal multi-material system

Lincoln Electric Additive Solutions Formed

2023

Future

- Process Qualification
- Commercial AM Systems
- Controls & Automation
- U.S. Supply Chain for Energy



Industrial Equipment Collaboration

4 Industrial User Collaborations

DOD Research Project

MDF Core Research

U.S. Workforce

Industrial Collaborations

U.S. Place Based Innovation

MDF Core Research enables groundbreaking of 3 new industry facilities

LINCOLN ELECTRIC Additive Solutions

3D-Arc Welding of Large Metallic Component Fabrication

75k ft^2 Cleveland, OH

On-shoring of infrastructure scale energy components

BEEHIVE INDUSTRIES

Metal Powder Printing of Aerospace components

62k ft^2 Knoxville, TN

Domestic supply chain of energy efficient combustion technology

GKN AEROSPACE

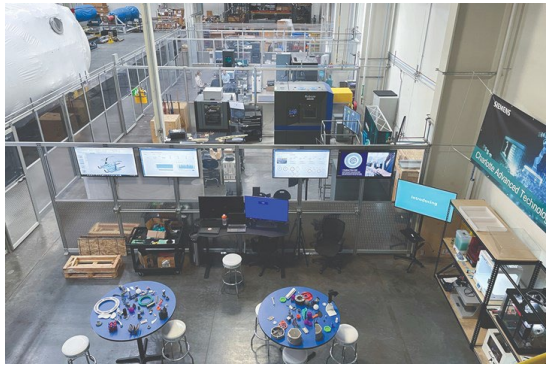
Laser Printing of Affordable Titanium Components

100k ft^2 Fort Worth, TX

Lightweight components for transportation

SIEMENS

adopting MDF model to industry

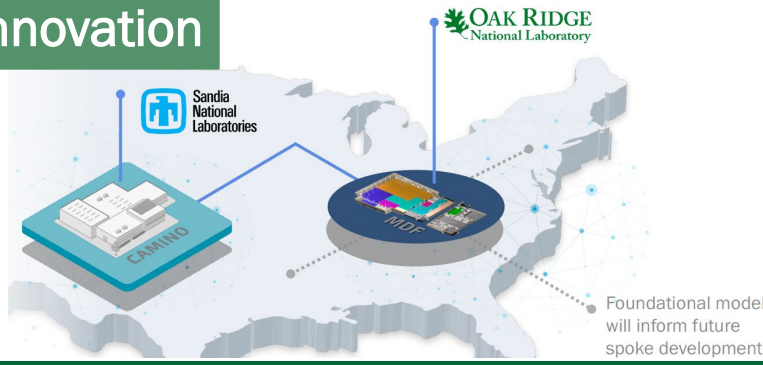


"The partnership between **Siemens and ORNL's MDF** has enabled the cooperative investigation of multiple modalities of advanced manufacturing and materials solutions for wide range of applications. The **joint fundamental research at a micro to meso-scale at MDF to address industrial problems demonstrates the success of the MDF model** and clearly shows the need for path to industrialization through similar hubs in Industry working on higher TRL levels for manufacturing technologies. **In April of 2022, Siemens launched its Charlotte Advanced Technology Collaboration Hub (CATCH) to fill this void."** - Siemens

NNSA Deploying MDF Model at Sandia National Laboratories to Maximize Innovation

"The management and activities of the MDF could be a core of technology transition across various DOE and DOD agencies. Practical and nimble leadership development is often a check box in various agencies that sometime is taught by business management professionals (e.g. MBA type professionals). However, the example in the MDF follows a new approach of "management by doing it" that should be taught by technical professionals with depth of technical knowledge like the MDF team. Having that as a standalone activity to execute training sessions for various agencies and industrial partners could be an additional ROI on the money invested to flourish such a unique and efficient management style"

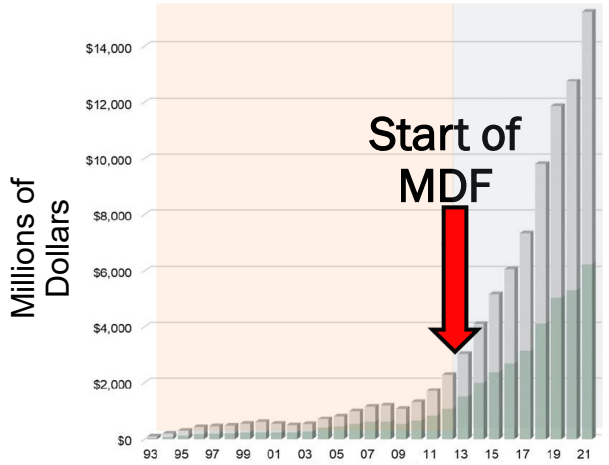
- FY22 MDF Peer Review Memorandum Recommendations



Results and Achievements

AM Market is Growing Exponentially

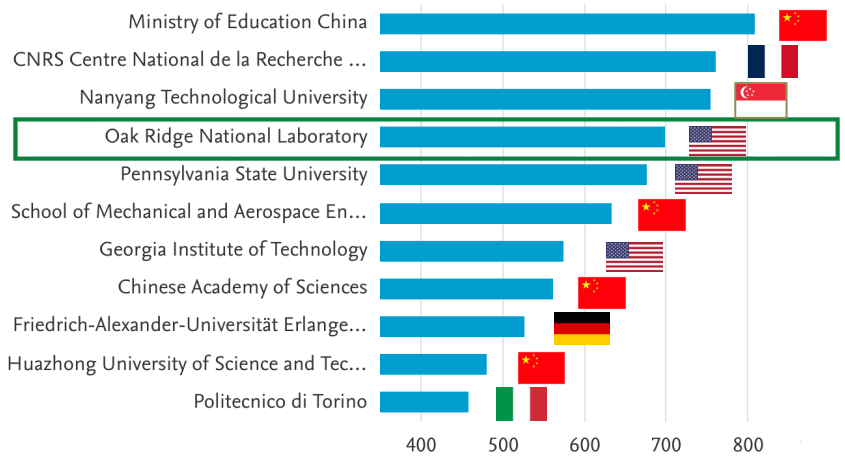
2023 Global AM Market Size ~$13.8B per year, Projected to be $76B by 20281



Revenues for AM (Wohlers 2021)

MDF is World Leading in AM

Peer-reviewed literature by Organization



Scopus Search: Additive Manufacturing

MDF R&D 100 Awards

2022	**DuAlumin-3D: An Additively Manufactured Dual-Strengthened Aluminum Alloy Designed for Extreme Creep and Fatigue Resistance** *Oak Ridge National Laboratory, General Motors, Beehive Industries*
2021	**UCC: Ultraconductive Copper-CNT Composite** *Oak Ridge National Laboratory*
2021	**MSC MillMax ®** *Oak Ridge National Laboratory, MSC Indutrial Supply Inc., Manufacturing Laboratories Inc.*
2021	**Domestic Supply Chain of Filter Media and Face Masks** *Oak Ridge National Laboratory, Techmer PM, DemeTECH, Cummins*
2020	**Biomacromolecule Engineering by Soft Chain Coupling Technology** *Oak Ridge National Laboratory*
2019	**High Strength Binder System for Additive Manufacturing** *Oak Ridge National Laboratory, The ExOne Company*
2018	**Ambient Reactive Extrusion Additive Manufacturing** *PPG Industries, Inc., Oak Ridge National Laboratory*
2017	**ACE: The Ageless Aluminum Revolution** *Critical Materials Institute, Eck Industries, Oak Ridge National Laboratory, Ames Laboratory, Lawrence Livermore National Laboratory*
2017	**Additively Printed High Performance Magnets** *Oak Ridge National Laboratory, Ames Laboratory, Critical Materials Institute, Magnet Applications Inc., Tru-Design, LLC, Momentum Technologies*
2017	**Large-Format Additive Coating Solutions** *Tru-Design, LLC, Polynt Composites, Oak Ridge National Laboratory*
2017	**TEAMM – Electrafil PPS 3D; Electrafil PPSU 3D** *Techmer PM, Oak Ridge National Laboratory, BASF*
2015	**Big Area Additive Manufacturing (BAAM-CI)** *Cincinnati Incorporated, Oak Ridge National Laboratory, Tennessee Tech University, Local Motors*
2015	**GENOA Software** *Alpha STAR Corp., Oak Ridge National Laboratory*
2013	**SYMMETRIX HPX-F Nanocomposite Separator for Improved Lithium Ion Battery** *Porous Power Technologies LLC, Oak Ridge National Laboratory*
2012	**Asymmetric Rolling Mill: A Novel Route for Processing Sheet and Plate (Mechanical Systems)** *FATA Hunter, Inc., Oak Ridge National Laboratory, Magnesium Elektron North America*
2012	**Low-Cost, Lightweight Robotic Hand Based on Additive Manufacturing (Mechanical Systems)** *Oak Ridge National Laboratory*
2012	**Low-Cost Plasma Processing System for Research and Pilot Production** *Structured Materials Industries, Oak Ridge National Laboratory*
2012	**NanoSHIELD Coatings [Nano – Super Hard – InExpensive – Laser Deposited Coatings] (Materials Science)** *Oak Ridge National Laboratory, Carpenter Technology Corporation, Colorado School of Mines, Lawrence Livermore National Laboratory*

National Recognition of the importance of AM Technologies and MDF

FACT SHEET: Biden Administration Celebrates Launch of AM Forward and Calls on Congress to Pass Bipartisan Innovation Act

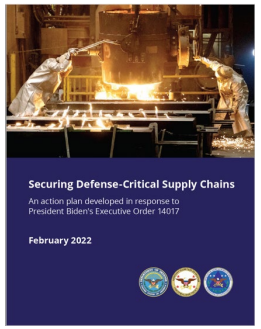
AM Forward will help lower costs for American families by improving the competitiveness of America's small-and-medium-sized manufacturers, creating and sustaining high-paying manufacturing jobs, and improving supply chain resilience through adoption of additive manufacturing

President Biden's top economic priority is to fight inflation by lowering costs that working families face, and lowering the federal deficit.

One of the best ways to lower the cost of the goods and services that families rely on is to make more things in America, with more secure, resilient supply chains. We've learned this the hard way during this crisis – when brittle supply chains and hollowed out manufacturing resulted in backlogs, bottlenecks and higher prices for families.

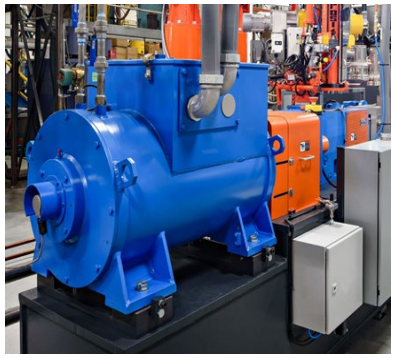
"To support AM Forward, the Department of Energy will make its Manufacturing Demonstration Facility at Oak Ridge National Laboratory available to SME manufacturers to test new additive techniques."

""Recommendation C2.1: Expand government and industry partnerships. Guided by strategy, DoD should continue to expand its current partnership, America's Cutting Edge (ACE, with DOE's ORNL to refine ways to supplement C&F capabilities, including additive and hybrid manufacturing processes and metrology.



More than $1B Impact on US Manufacturing

Local Startups	Company Growth	U.S. Tooling Manufacturing	Commercialization	US Acquisition of Advanced Tech	New Industries
Volunteer Aerospace has hired >50 people and fabricated flight-critical, qualified components in under 3 years. Recently acquired by Beehive industries and building an ~62,000 sq. ft. facility.	AES has experienced 110% yearly revenue growth, hired >8 employees, and large-scale AM and machining systems. Enabled new products in molds, UUVs, etc.	Lincoln Electric initiated an 75,000 sq. ft. research facility and purchased 8 automation companies including Baker based on research with ORNL.	ORNL developed over 120 composite material combos. Techmer PM commercialized materials polymer AM, opening dedicated production lines.	ORNL developed parameters for over 9 Ni super-alloys and refractories leading to GE procuring Arcam. Recently, ORNL & GE initiated $27M CRADA.	ORNL enabled large scale printing including metals, thermoplastic and thermoset printers. Over 15 companies now fabricate printers using this technology. (MVP RAM shown)



AMMTO & MDF Support DOE Program's to Enable Clean Energy

MDF research is accelerating advanced manufacturing to impact clean energy

1) Securing a U.S. supply chain
2) Addressing affordability of clean energy technologies
3) Improving energy efficiency in fabrication & application

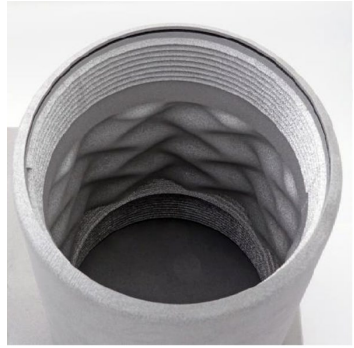
DOE & EERE

AMMTO

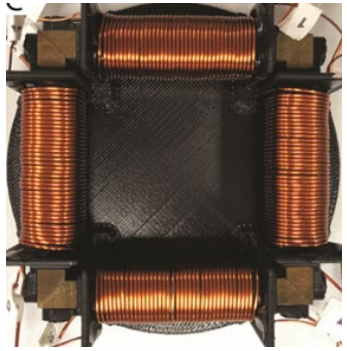
Stakeholder Engagement

Core Projects

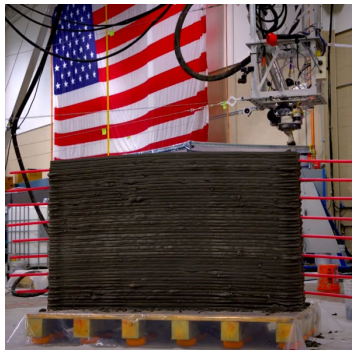
Technical Collaborations



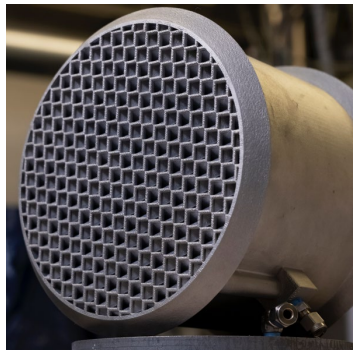
Complex geometries for Geothermal Prize: Geothermal



Printing of Transformers for Grid: Office of Electricity

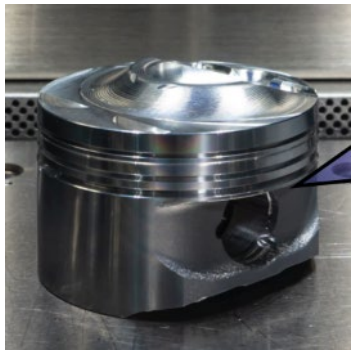


Thermal Energy Storage for Buildings: EMPOWER Wall FEMP / Buildings



Enhanced CO2 Emission Capture: Fossil Energy and Carbon Management

Deposition of Tungsten for Plasma Facing Surfaces: Fusion Energy



New Materials for Efficient Transportation: Vehicles

Digital Certification of AM for Nuclear Components: Nuclear Energy

Wind Turbine Blade Manufacturing: AMMTO & Wind

Affordability for Low Head Hydro Power: Water Power & AMMTO

Questions?

Manufacturing Demonstration Facility | AMMTO

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