

# The Advanced Manufacturing Revolution

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## Overview

- Introduction
- AM in the Spotlight
- JAMR
- EXMAN



# Midwest Tough











## SPAWAR SSC PAC



Information Dominance through research, development, delivery, and support of integrated C4ISR, cyber, and space systems across all warfighting domains

Source: Generic Command Overview 25JAN16

### AM in the International Spotlight



**IAMR** 

Out of the Box

Source: The Economist Feb 12-18, 2011

Increased public awareness "Print Me a Stradivarius", The Economist, Feb. 2011

> 3D Printed Gun (confiscated) University of Texas Law Student



Source: Science Museum UK



Expiring patents – DIY and technology democratization

Source: MakerBot® Replicator® 3D Printers

National and International Focus | Presidential Initiative America Makes mentioned in State of the Union 2012



Source: americamakes.us

# AM: A Perfect Storm

- Revolutions in Production Technology
  - Material Science:

IAMR

Out of the Box

- Alloys, cements, composites, nano, macro
- Digital Design and supply chain
  - 3D Multi-media digital workflow
- Remote and embedded sensing
  - High fidelity, low cost, networked
- Manufacturing Tools and Techniques
  - Additive
  - Advanced Subtractive
  - Batch
  - Hybrid
- A Convergence of IT and OT
  - Information Technology
    - On-demand computing:
    - Cloud Apps Big Data Analytics
  - Control Technology
    - Industrial Control Systems, SCADA

Outcome: What can be made today, could never be made before ... and we are at the beginning of this megatrend



#### Advanced Manufacturing Diversified Portfolio





#### AM Technology ASTM F42 Categories

- Vat Photopolymerization
  - Process in which liquid photopolymer in a vat is selectively cured by light-activated polymerization
- Material Extrusion
  - Process in which thermoplastic is selectively dispensed through a nozzle
- Powder Bed Fusion
  - Process in which thermal energy selectively fuses regions of a powder bed
- Material Jetting
  - Process in which inkjet droplets of build material are selectively deposited and UV cured
- Binder Jetting
  - Process in which a bonding agent is selectively deposited (ceramics, metals, sand)
- Sheet Lamination
  - Process in which sheets of material are bonded to form an object and subtractively removed
- Directed Energy Deposition
  - Process in which focused thermal energy is used to fuse materials by melting as deposited



Source: Keck Center for 3D Innovation | University of Texas at El Paso

## Importance of AM

• AM presents a previously unobtainable design space

JAMR

Out of the Box

 Enables new 'material – geometric – functional' combinations that were previously un-manufacturable



# Composites

 $a_2$ 

 $a_1$ 

- Fiber Reinforced Composites
  - Advantages

IAMR

Out of the Box

- High stiffness/density
- High strength/density
- Limitations
  - Dynamic response











- Extraordinary dynamic behavior
  - Band-gap
  - Negative effective properties
  - Negative energy refraction
  - Previous limitations
    - Manufacturability

## Periodic Composites



ABS Gradient Bending Resonator design for SONAR stealth in 0.5 – 5 kHz range for submarine coating. (Source: Prof Amirkhizi of University of Massachusetts at Lowell)

JAMR

Out of the Box



3D phononic crystal composed of steel and epoxy for large all-angle stopband. (Source: Prof Srivastava of Illinois Institute of Technology)

### National Security Linkages

#### Mobilization

IAMR

Out of the Box

- Defense Industrial Base Surge Capacity
- Defend the Homeland
  - Critical Infrastructure Protection
- Cybersecurity Readiness
  - Industrial Control Systems
  - Cyber-Physical Outcomes
- Innovation
  - Automation, Efficiency, Effectiveness





#### SECNAV Tasking Memo Additive Manufacturing / 3D Printing

- Develop an integrated and detailed implementation plan that will achieve the following:
  - Increase development and integration of additive manufacturing systems
  - Develop the ability to qualify and certify AM parts
  - Standardize the digital AM framework and tools and enable end to end process integration
  - Establish DON advanced integrated digital manufacturing grid
  - Formalize access to AM education, training, and certifications for the DON workforce



#### Advanced Manufacturing is the Cornerstone of both Economic Security & Naval Modernization

## Importance of AM

- Augments and extends existing manufacturing processes
  - Better, faster, cheaper in some cases

JAMR



Dorsey Rust Buster "Rust Never Sleeps and Neither Do I"





#### JAMR Goals

#### Joint Advanced Manufacturing Region

#### Public

#### **Private**

<ul> <li>Develop         <ul> <li>Design Considerations for notional Smart Manufacturing Grid</li> </ul> </li> </ul>	<ul> <li>Understand         <ul> <li>Emerging technical trends, threat drivers, fiscal environment and perceived needs of DoD</li> </ul> </li> </ul>
<ul> <li>Define         <ul> <li>Security, Safety, Privacy and IP "needs" for Digital Thread</li> </ul> </li> </ul>	<ul> <li>Influence         <ul> <li>Standards, specifications, implementation patterns and secure, strategic architecture to improve Infrastructure resilience</li> </ul> </li> </ul>
<ul> <li>Collaborate         <ul> <li>Across Agencies, Commands and Manufacturing Communities of Practice</li> </ul> </li> </ul>	<ul> <li>Collaborate         <ul> <li>By sector, value-chain, PPP, region or discipline</li> </ul> </li> </ul>
<ul> <li>Expand         <ul> <li>Reduce the barrier to entry for non-traditional suppliers to DoD</li> </ul> </li> </ul>	<ul> <li>Respond         <ul> <li>Provide profitable, executable, proposals to solicitations coming from DoD / Public sector</li> </ul> </li> </ul>
<ul> <li>Advise         <ul> <li>Naval and DOD leadership on findings and recommendations</li> </ul> </li> </ul>	<ul> <li>Grow         <ul> <li>Get a piece of the expanding industrial pie</li> <li>Take advantage of the reshoring phenomenon</li> </ul> </li> </ul>

Critical Manufacturing Independence by 2025

Advanced Manufacturing Cluster by 2020



### Smart Manufacturing Grid

Digital Manufacturing	Distributed Manufacturing	<b>On-Demand Value Chain</b>
Network	Topology	Management

- Information Technology
- **Operational Technology**
- **Cyber-Physical Systems**



(Source: Committee on National Security Systems Instruction (CNSSI) No. 1253)

- Node Location
- **Physical Logistics**
- Capacity / Mix Optimization



- eProcurement
- eCommerce

GSA

ERP / SCM / PLM



http://www.gsa.gov/portal/category/25574)

Smart Manufacturing Grid provides the resilient, secure, digital and physical critical infrastructure that will support the "reshoring" of emerging advanced manufacturing capabilities back to the United States.



### Smart Manufacturing Scope





Inspection

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Source: ©2016 Dassault Systemes SolidWorks Corporation

Most of a product's costs (80 to 90%) are locked in, or committed at the end of the design stage.

A dollar spent on design and development can reduce costs in the later stages of the product's life cycle by \$8 - \$10 according to Shields and Young.



Adapted from the CAM-I conceptual design p. 140. Original source, Blanchard, Design and Manage to Life Cycle.

#### JAMR Smart Maintenance, Repair & Operations

- Combines advanced control and information technologies with new production tools, methods and materials
- Augments existing manual processes that are reducing the profitability and competitiveness of manufacturers
- Creates a new hybrid supply chain of complimentary digital and physical components





#### Expeditionary Manufacturing EXMAN

- Capture Pertinent Design Data Directly From the Field
- Immediate Concept Models Directed by Actual, Current Field Needs
- Rapid Design and Prototype Testing in the Field, Instantly
- Produce High-Quality, Low-Cost Solutions



AM as a Process, Product, and Service is Complex and Still Emerging Continuous experimentation under actual operational conditions is essential



**JAMR** 

Out of the Box

#### Virtual Secure Manufacturing Cloud



# Print to Fleet

JAMR

UxV



Source: Universitat Politecnica De Catalunya

## Connected World

- Is a popular case study representing broader megatrends
  - Distributed, Digital, Smart Manufacturing

JAMR

Out of the Box

Connected World: Industrial Internet of Things



Source: © Libelium Comunicaciones Distribuidas S.L

## Thank You

**JAMR** 



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