ADDITIVE MANUFACTURING: 
AN EXPOSÉ ON THE DIVERSITY OF INDUSTRIAL USE

National Academy of Engineering
German-American Frontiers of Engineering
Irvine, CA
April 26, 2013

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AMT - The Association For Manufacturing Technology
Agenda

• Introduction
• Requirements
• Applications
• Challenges & Opportunities
• Summary & Conclusion
Agenda

- Introduction

**Requirements**
  - How AM Answers the Call
  - Technology Alignments

- Applications
- Challenges & Opportunities
- Summary & Conclusion
Requirements: How Additive Answers the Call

1\textsuperscript{st}: Affordability
- Reduce tooling, waste
- Complexity = Simplicity

2\textsuperscript{nd}: Smart(er) Manufacturing
- Integrate processes
- Support RP & production

3\textsuperscript{rd}: Optimize Product Design
- Reduce weight, Support modularity
- Multi-functional parts

Traditionally: 9 piece welded duct assembly
AM: 2-piece bonded assembly
F-35 representative parts

With Additive You Can Design for \textbf{Functionality}
Requirements: Technology Alignments

Phase

<table>
<thead>
<tr>
<th>Concepts</th>
<th>Design/Engineering</th>
<th>Prototype</th>
<th>Low Volume Production</th>
<th>Mass Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tooling &amp; Molding</td>
<td>Composites</td>
<td>QuantumCast™ Cast Urethanes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNC</td>
<td>SLS*</td>
<td>DMLS</td>
<td></td>
<td></td>
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<tr>
<td>3D Printing (PolyJet)</td>
<td>SLS*</td>
<td>FDM</td>
<td></td>
<td></td>
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<tr>
<td>Z-Corp 3D Prints</td>
<td>Foam/Modeling Board</td>
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• Introduction
• Requirements

• Applications
  • Snap Shot
  • Industrial Use
  • Diversity
• Challenges & Opportunities
• Summary & Conclusion
Applications: Snap Shot

- **Polymeric Components**
  - **Laser Sintering (LS)**
    - Low-temp, non-structural (Aero, Auto)
    - FDA 510(k)-approved (implants)
  - **Hybrid Applications**
    - Embedded sensors / continuous fiber

- **Metallic Components**
  - **Laser and Electron Beam Melting**
    - Implants, replacements
    - Aerospace components

*Courtesy Materialise*

*Creates Difficult to Machine Shapes*

*Enables Hybrid Materials*

*Improves Performance*

*Provides Similar Mechanical Properties (NGC)*
Applications: *Industrial Use*

### Composite Interface Fitting (J WST)

<table>
<thead>
<tr>
<th>Traditional Manufacturing</th>
<th>Additive Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>~500 CNC machining hours</td>
<td>32 build hours</td>
</tr>
<tr>
<td>~16 – 26 week lead time</td>
<td>~4 day lead time</td>
</tr>
<tr>
<td>Nominal</td>
<td>60% - 70% cost savings</td>
</tr>
</tbody>
</table>

![Composite Interface Fitting (J WST)](image)

### Hot Air Mixer (UCAS-D)

<table>
<thead>
<tr>
<th>Traditional Manufacturing</th>
<th>Additive Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buy-to-Fly ratio 10 – 20:1</td>
<td>Buy-to-Fly ratio ~2:1</td>
</tr>
<tr>
<td>Min. 4-pieces w/ 2 welds</td>
<td>1 piece w/ no welding</td>
</tr>
<tr>
<td>Nominal</td>
<td>35% - 45% cost savings</td>
</tr>
</tbody>
</table>

![Hot Air Mixer (UCAS-D)](image)

Courtesy of Northrop Grumman Corp. and CalRam Inc.
SLS Gimbal
Aeryon Labs Inc. | Aeryon Scout UAV | Ontario, Canada
Air Duct – Orbis Flying Hospital

Meet all FAA (8130-3) requirements for flame, smoke, toxicity and airworthiness while remaining lightweight. (Courtesy of Solid Concepts, Inc.)
SLS Fuel Tanks
Area-I | Georgia
SLS of fuel tank, ailerons, control surfaces, mounting plates, more...

Courtesy of Solid Concepts Inc.
Applications: *Oil & Gas / Automotive*

- **70% Savings in Material and Cost**
  - Courtesy: DM3D

- **35% Weight Savings, 20% Greater Rigidity**
  - Courtesy: ExOne

- Fuel Tanks (Solid Concepts):
  - Internal Baffles (above)
  - Automotive Racing (below)

- **70% Savings in Material and Cost**
  - Courtesy: Rennteam Uni Stuttgart

Trending From Prototyping-Only To Now *Include Production*
**Applications: Medical & Dental**

Polymeric (PEKK) & Metallic (Ti-Al6-V4) Applications

FDA-Approved


Courtesy: OPM
Applications: Diversity

- Large Structures
- Sensors
- Antennae
- Functional Apparel
- Traditional Machined Casting
- Additive Selectively Builds
- Weight Reductions
- Multi-Functional Parts
- Toys & Model Hobbyists
- Complex Parts
- Functional Furniture

Additive Manufacturing: An Enabler for Next-Gen Production
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- Challenges & Opportunities
  - Industrial Base & Maker Movement
  - Roadmap Summaries
  - NAMII

- Summary & Conclusion
Challenges: Industrial Base & Maker Movement

Need: Harness Maker Momentum to Influence Industrial Sector
Challenges: Industrial Base & Maker Movement

2011 US Market

Machine Tool Source: AMT
Opportunities: Industry Metrics
Source – http://wohlersassociates.com

PRODUCTS: Direct Part Manufacturing (19.2%)
Functional Models (18.4%)

MARKETS: Consumer & Auto ~40%
Aero & Medical / Dental Accelerating

Trending From Prototyping-Only To Now Include Production
Challenges: Technical Summaries

Taguchi DOE for Optimized Density (>98% with bed consistency)

Need: Increased Understanding of Processes & Accelerated Metallic Maturation (Materials & Processes)
• Industrial Commons
• Technology Transition & Commercialization
• Workforce & Education

Opportunity: Collaborative Innovation Focused on Advancing AM Industry
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Summary & Conclusion

• The Technology
  – No longer just “emerging”
  – Design for functionality
  – AM is an enabler, compliment

• The Business
  – Increase education to non-AM communities
  – Prototyping to functional models to end-use production
  – AM discriminator: Knowing how to use AM

Additive Is A Compliment to Current Manufacturing
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