Net Shaped Aerospace Multifunctional Structures Workshop

Mia Siochi
June 9, 2015
Carbon Nanotube Gartner Hype Cycle

![Graph showing the Gartner Hype Cycle for Carbon Nanotubes]

- **1990**: Innovation Trigger
- **2000**: CNT Sheet Composite Publication (2010)
- **2010**: Peak of Inflated Expectations
- **2015**: Trough of Disillusionment
- **2020**: Plateau of Productivity
- **20??**: Slope of Enlightenment

**Technology Expectations**

**Technology Maturation**

- Early CNT Powders
- Commercial CNT Sheets
- CNT Fibers
- Commercial High Strength CNT Yarns
# Accelerated Technology Maturation thru Use-inspired Basic Research

<table>
<thead>
<tr>
<th>Quest for fundamental understanding?</th>
<th>Considerations of use?</th>
<th>Pure basic research (Bohr)</th>
<th>Use-inspired basic research (Pasteur)</th>
<th>Pure applied research (Edison)</th>
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<tbody>
<tr>
<td>Yes</td>
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Donald E. Stokes, Pasteur’s Quadrant: Basic Science and Technological Innovation, 1997.
Nano to Macro Challenge

Available materials have starting mechanical properties inferior to other SOA materials.
Progress in CNT Composite Properties

Experimentally Measured SWNT

- IM7 Fiber
- Project Objective
- CNT Sheet Composite (2013)
- CNT Sheet Composite (2012)
- CNT Yarn Composite (2014)
- Q-l IM7/8552
- CNT Yarn Composite (2012)
- Aluminum

Graph showing specific strength vs. specific modulus.
How is Structural Nano Different?

Experimentally Measured SWNT
Coupling Technologies

Boeing 787

Carbon Fiber

Robotic Composite Manufacturing

1958 1991 2012

Technology Maturation

Topologically Optimized Multifunctional Component

CNT Yarn 3d Printer

All non-NASA images from:  http://www.usa.gov/directory/federal/
Best of Both Worlds

Automated Fiber Placement
- Structural Materials
- Lightweight
- Tailored Layup
- Established Design & Analysis Techniques
- Modeling & Simulation Tools
- Industry Adoption
- Allowables Data
- Limited Geometries
- Part Complexity & Feature Detail
- Large Scale Only
- Manufacturing Rate
- Tooling
- Interlaminar Properties
- Single Material
- Multifunctional Materials

Additive Manufacturing
- Design Freedom
- Lightweight
- Part Complexity & Feature Detail
- Tooling
- Manufacturing Rate
- No Tooling
- Structural Materials
- Limited Design & Analysis Techniques
- Limited Modeling & Simulation Tools
- Small Scale Only
- Z-layer Properties
- Allowables Data

Structural & Multifunctional Materials
- Multiple Materials
- Design Freedom
- Part Complexity & Feature Detail
- No Tooling
- Manufacturing Rate
- Design & Analysis Techniques
- Modeling & Simulation Tools
- Allowables Data
Workforce Capability – Accelerated Technology Maturation Using Multidisciplinary Approach

Accelerate Technology Insertion with Focused Development Across Relevant Disciplines
Accelerated Technology Maturation thru Technical Community

Team with Technical Leaders … Stop Reinventing Everything
Workshop Objectives

- Engage technical leaders in the field in candid discussions
- Survey state-of-the-art in additive manufacturing
- Explore how to couple materials and manufacturing advances to enable net shape multifunctional structures
- Identify barriers for insertion of additively manufactured components
- Chart a path for strategic insertion of net shape multifunctional components in high payoff applications
## Net Shaped Aerospace Multifunctional Structures Workshop Agenda

**June 9-10, 2015**  
**NASA Langley Research Center**  
**Hampton, VA 23681-2199**

### June 9

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Speaker/Contact</th>
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<tbody>
<tr>
<td>7:00 am</td>
<td>Registration opens</td>
<td>Donna Speller Turner</td>
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<tr>
<td>7:45 am</td>
<td>Opening</td>
<td>Jill Marlowe</td>
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<tr>
<td>8:00 – 8:15 am</td>
<td>Welcome remarks</td>
<td>Mia Siochi</td>
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<tr>
<td>8:15 – 8:45 am</td>
<td>Intro/Workshop Objectives</td>
<td>Slade Gardner (Lockheed)</td>
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<tr>
<td>8:45 – 9:15 am</td>
<td>Additive Manufacturing and Materials for Space Systems</td>
<td>Jeff Baur (AFRL)</td>
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<td>9:15 – 9:45 am</td>
<td>USAF Applications and Perspective</td>
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<tr>
<td>9:45 – 10:00 am</td>
<td>Break</td>
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<tr>
<td>10:00 – 10:30 am</td>
<td>3d Printing of Aerospace parts</td>
<td>Ed Herderick (GE Aviation)</td>
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<tr>
<td>10:30 – 11:00 am</td>
<td>Additive Manufacturing of Aerospace Components</td>
<td>John Waldrop (Boeing R&amp;T)</td>
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<tr>
<td>11:00 – 11:30 am</td>
<td>Heterogeneous Materials for Electrically Functional Structures</td>
<td>Ken Church (nScrypt)</td>
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<tr>
<td>11:30 am</td>
<td>Closing for morning session</td>
<td>Donna Speller Turner</td>
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<tr>
<td>11:45 am – 12:50 pm</td>
<td>Lunch</td>
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<td>12:50 – 1:00 pm</td>
<td>Load bus for tour</td>
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<tr>
<td>1:15 – 1:45 pm</td>
<td>EBF3, ISAAC, 3d Printing Lab – B1232</td>
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<td>1:50 – 2:00 pm</td>
<td>Transit to B1267A</td>
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<td>2:00 – 2:45 pm</td>
<td>Incubator tour – B1267A</td>
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<td>2:45 – 3:00 pm</td>
<td>Transit to B2102</td>
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<td>3:15 – 4:15 pm</td>
<td>Breakout session</td>
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<td>4:15 – 4:45 pm</td>
<td>Report out</td>
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<td>4:45 pm</td>
<td>Adjourn</td>
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<td>6:30 pm</td>
<td>Group dinner at Tucano’s</td>
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<tr>
<td>Time</td>
<td>Activity</td>
<td>Speaker/Institution</td>
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<td>8:00 - 8:30 am</td>
<td>Advanced Manufacturing Materials and Technologies at ARL</td>
<td>LJ Holmes (ARL)</td>
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<td>8:30 – 9:00 am</td>
<td>ORNL Perspective</td>
<td>Lonnie Love (ORNL)</td>
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<td>9:00 – 9:30 am</td>
<td>Material Feedstock Concepts to Achieve Aerospace Quality Components</td>
<td>Brian Rice (UDRI)</td>
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<td>Break</td>
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<td>Additive Manufacturing and Architected Materials</td>
<td>Chris Spadaccini (LLNL)</td>
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<td>10:30 – 11:00 am</td>
<td>Certification</td>
<td>Michael Gorelik (FAA)</td>
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<td>Computational Modeling of CNT Composites</td>
<td>Kris Wise</td>
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<td>1:00 - 1:30 pm</td>
<td>Lessons from CNT Composites Preparation/Processing</td>
<td>Bert Cano/Brian Grimsley</td>
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<td>1:30 - 2:00 pm</td>
<td>Value of Systems Analysis in Technology Assessments</td>
<td>Jamshid Samareh</td>
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<td>Next steps</td>
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<td>4:15 pm</td>
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Breakout Sessions Questions

1st Day
1. What is the industry’s candid perspective on the role that AM can play?
   a. Advantages and disadvantages of AM
   b. Challenges/barriers for technology insertion/acceptance
2. Gaps in state of the art -- aerospace?
3. Areas of highest payoff
4. What’s the future direction for AM – timeframe – 1, 5, 10

2nd Day
1. What role can gov’t labs play in advancing AM?
2. What are opportunities for collaboration?
   a. Common problems that can benefit from collaborative efforts?
3. Assessment of strengths in capabilities that LaRC – do we need to ask Jill about what question to ask. (Nano, AM, Nano used AM)
4. Assessment of strengths in capabilities that LaRC can bring to the table in collaborative partnerships?
5. Suggestions for design challenge that would be of interest to the community given the objective of the incubator.