Net Shaped Aerospace Multifunctional Structures Workshop

Mia Siochi
June 9, 2015
Carbon Nanotube Gartner Hype Cycle

The graph illustrates the Gartner Hype Cycle for carbon nanotubes, showing the following stages:

- **Innovation Trigger** (1991)
- **Iijima Paper** (1991)
- **Peak of Inflated Expectations**
- **Trough of Disillusionment**
- **Slope of Enlightenment**
- **Plateau of Productivity**

The technology maturation timeline includes:

- **Early CNT Powders**
- **Commercial CNT Sheets**
- **CNT Fibers**
- **Commercial High Strength CNT Yarns**

Accelerated Technology Maturation thru Use-inspired Basic Research

Considerations of use?

<table>
<thead>
<tr>
<th>Quest for fundamental understanding?</th>
<th>Considerations of use?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Pure basic research (Bohr)</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Use-inspired basic research (Pasteur)</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Pure applied research (Edison)</td>
</tr>
</tbody>
</table>

Donald E. Stokes, Pasteur’s Quadrant: Basic Science and Technological Innovation, 1997.
Available materials have starting mechanical properties inferior to other SOA materials.
Progress in CNT Composite Properties

- Aluminum
- Q-I IM7/8552
- CNT Sheet Composite (2013)
- CNT Yarn Composite (2012)

Experimentally Measured SWNT
How is Structural Nano Different?

The diagram shows a comparison of specific modulus and specific strength for different materials. The x-axis represents specific strength (GPa/g/cc), and the y-axis represents specific modulus (GPa/g/cc).

- **Aluminum** is represented by a blue circle and is located at a specific strength around 1 and a specific modulus of 10.
- **Q-I IM7/8552** is represented by a yellow circle and is located at a specific strength of 1 and a specific modulus of 10.
- **Uni IM7/8552** is represented by a green circle and is located at a specific strength of 1 and a specific modulus of 100.
- **Lightly Doped CNT Composite** is represented by a blue circle and is located at a specific strength of 10 and a specific modulus of 1000.
- **Experimentally Measured SWNT** is represented by a blue circle and is located at a specific strength of 100 and a specific modulus of 10000.

The chart illustrates that CNT yarn composite and the experimentally measured SWNT have the highest specific modulus, making them potentially superior materials for structural purposes.
Coupling Technologies

Carbon Fiber

Boeing 787

CNT Yarn

3d Printer

Topologically Optimized Multifunctional Component

Robotic Composite Manufacturing

Technology Maturation

1958

1991

2012

2016

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
- Multiple Materials
- Multifunctional Materials
- Topology Optimization
- 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

- **7:00 am** Registration opens
- **7:45 am** Opening  
  - Donna Speller Turner
- **8:00 – 8:15 am** Welcome remarks  
  - Jill Marlowe
- **8:15 – 8:45 am** Intro/Workshop Objectives  
  - Mia Siochi
- **8:45 – 9:15 am** Additive Manufacturing and Materials for Space Systems  
  - Slade Gardner (Lockheed)
- **9:15 – 9:45 am** USAF Applications and Perspective  
  - Jeff Baur (AFRL)
- **9:45 – 10:00 am** Break
- **10:00 – 10:30 am** 3d Printing of Aerospace parts  
  - Ed Herderick (GE Aviation)
- **10:30 – 11:00 am** Additive Manufacturing of Aerospace Components  
  - John Waldrop (Boeing R&T)
- **11:00 – 11:30 am** Heterogeneous Materials for Electrically Functional Structures  
  - Ken Church (nScrypt)
- **11:30 am** Closing for morning session  
  - Donna Speller Turner
- **11:45 am – 12:50 pm** Lunch
- **12:50 – 1:00 pm** Load bus for tour
- **1:15 – 1:45 pm** EBF3, ISAAC, 3d Printing Lab – B1232
- **1:50 – 2:00 pm** Transit to B1267A
- **2:00 – 2:45 pm** Incubator tour – B1267A
- **2:45 – 3:00 pm** Transit to B2102
- **3:15 – 4:15 pm** Breakout session
- **4:15 – 4:45 pm** Report out
- **4:45 pm** Adjourn
- **6:30 pm** Group dinner at Tucano's
Net Shaped Aerospace Multifunctional Structures Workshop

Agenda

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

June 10
7:00 am  Registration opens
7:45 am  Opening  Donna Speller Turner
8:00 - 8:30 am  Advanced Manufacturing Materials and Technologies at ARL  LJ Holmes (ARL)
8:30 – 9:00 am  ORNL Perspective  Lonnie Love (ORNL)
9:00 – 9:30 am  Material Feedstock Concepts to Achieve Aerospace Quality Components  Brian Rice (UDRI)
9:30 – 10:00 am  Break
10:00 – 10:30 am  Additive Manufacturing and Architected Materials  Chris Spadaccini (LLNL)
10:30 – 11:00 am  Certification  Michael Gorelik (FAA)
11:00 – 11:30 am  Computational Modeling of CNT Composites  Kris Wise
11:30 am  Closing for morning session
11:45 am -12:45 pm  Lunch
1:00 - 1:30 pm  Lessons from CNT Composites Preparation/Processing  Bert Cano/Brian Grimsley
1:30 - 2:00 pm  Value of Systems Analysis in Technology Assessments  Jamshid Samareh
2:00 – 2:15 pm  Break
2:15 – 3:15 pm  Breakout
3:15 - 4:00 pm  Report out
4:00 – 4:15 pm  Next steps
4:15 pm  Adjourn
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.