Materials Engineering for Affordable New Systems: Challenges and Opportunities for Implementation in Organic Matrix Composite Systems

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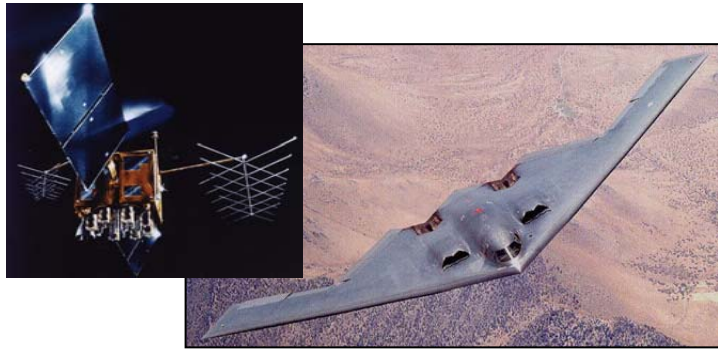
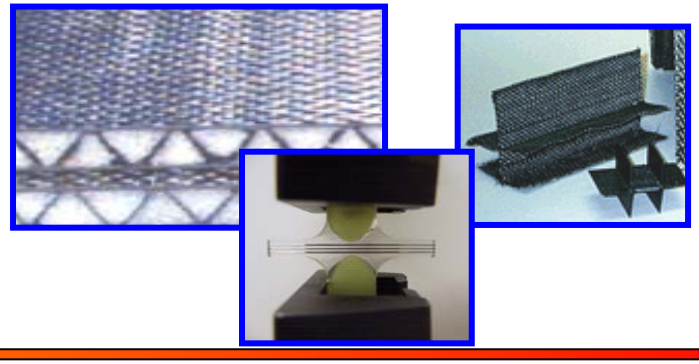
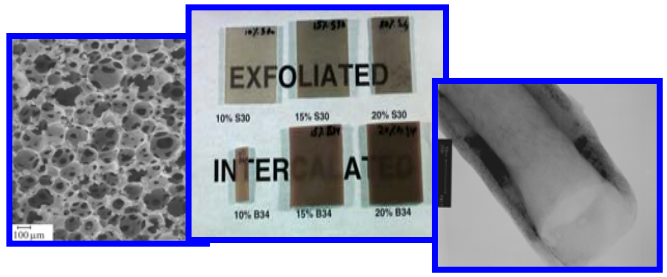
THE FUTURE FOR COMPOSITES – *Engineered Multifunctional Materials*

USAF Project Forecast

1963







- ***"Composites offer the greatest opportunities for significant advances in material design and function."***
  Materials Research to Meet 21st-Century Defense Needs, NRC, 2003
- **Hurdles for this generation**
  - **True use of materials through accurate predictive models**
  - **True tailorability – n-d; n-dimension, n-constituent**
  - **Multifunctional performance**

OMCs Need MEANS!

Challenge: Composites (and materials in general) continue to become increasingly complex…with ever closer relationships between material composition, processing, morphology and resultant properties.

Challenge:

Relative lack of maturity
Fewer predictive tools

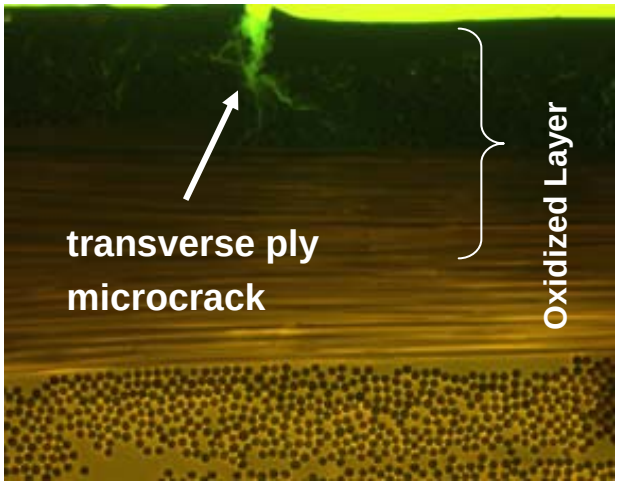
AND… **Composites have come far over past 25 years…based on robust research funding and transitions of past era.**

Times have changed….
Empiricism is no longer affordable.

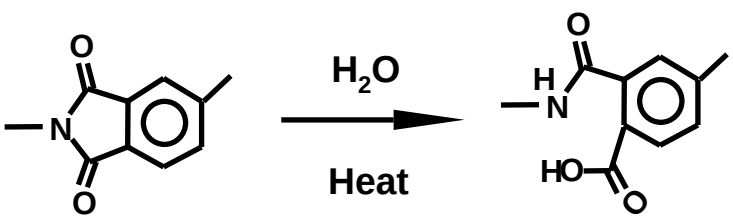
Challenge: Extreme Environments & OMCs

Chemical-Structure-Property Relationships

- Constitutive behavior dependent on the state of environmental degradation
- Chemical models required to predict behavior, especially irreversible effects
- Damage mechanisms based on chemical degradation may be critical



Relating Chemistry to Physical Behavior

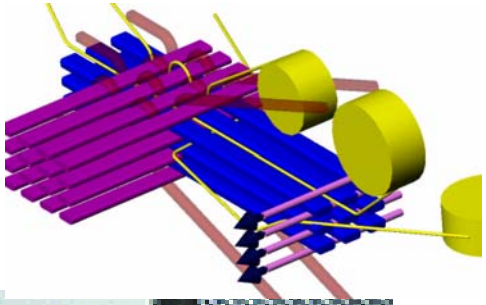


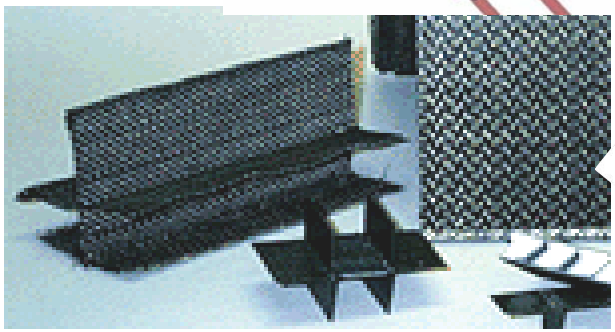
- Lifetime performance REQUIRES knowledge of chemical state
- Given thermal/environmental history: mechanistic description of reactions
- Empirical, constitutive descriptions of behavior

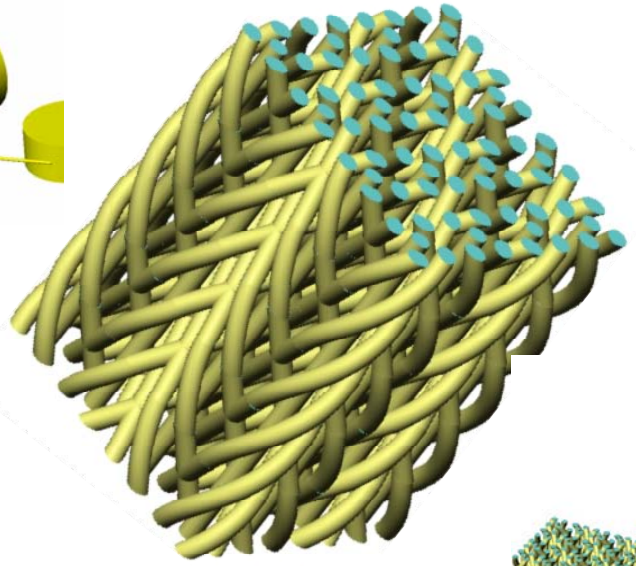
End-of-life properties are needed for designs

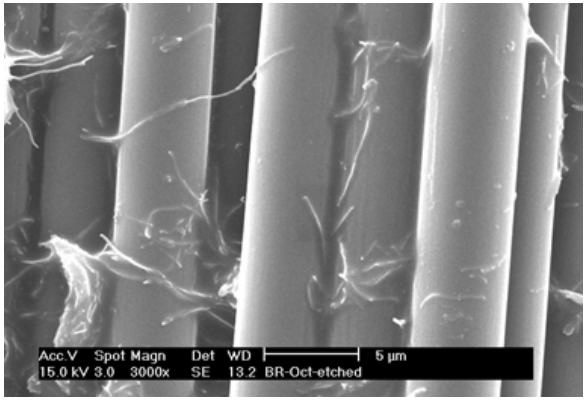
Must account for environmental factors in performance and failure prediction

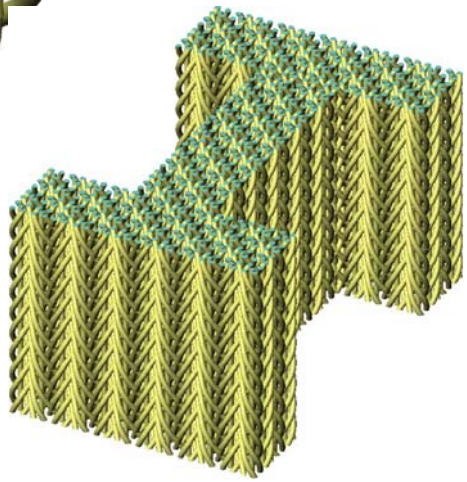
Challenge: Material Complexities… Directions & Dimensions





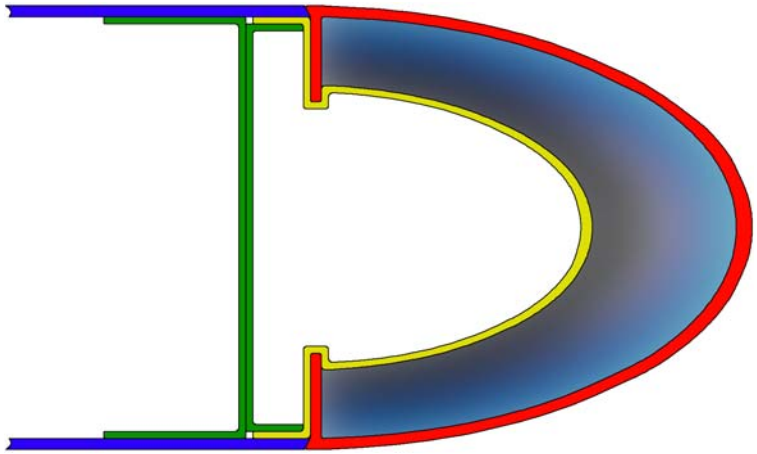


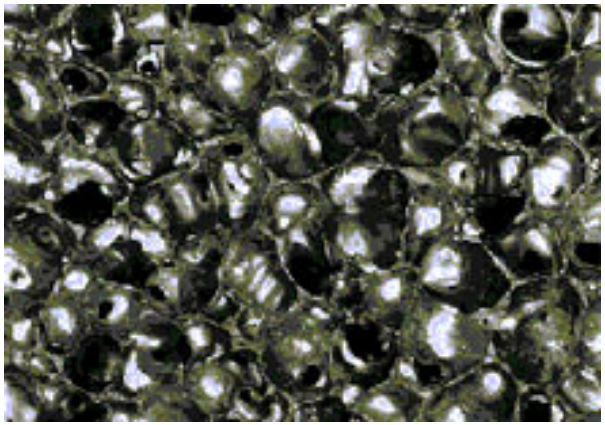


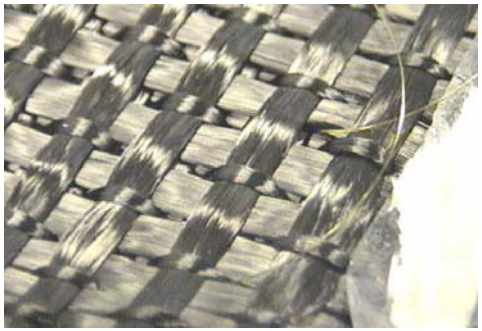


Complex materials….cannot rely upon nor afford empiricism.

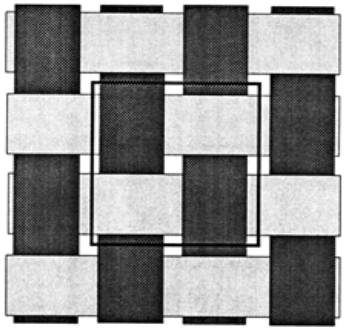
Materials … Multifunctional Performance







Capacitors



Unit Cell of a Plain Weave Material with Capacitors

Air Force invention number D511, Patent Filed

Must incorporate models of structure-process-property relationships into design

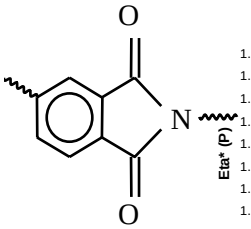
Specific OMC Challenges

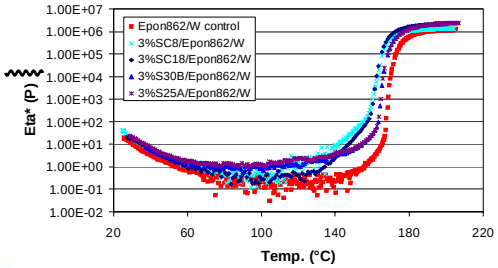
- **Chemistry - coupled degradation mechanisms**
  - **Effects of environment**
  - **Life & durability**
- **Tailorability & complexities**
  - **Interfaces – property (CTE, E, K,…) mismatches**
  - **Interfaces – diffusions**
  - **Multifunctional materials**
- **Variability**
  - **Constituents**
  - **Processing induced**

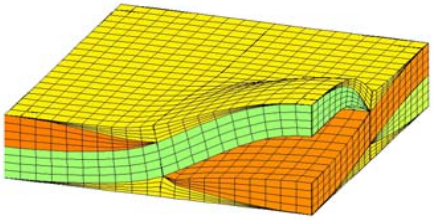
OMCs Require Interdisciplinary Teams for Successful Development & Insertion

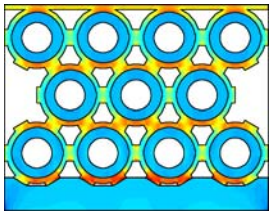
Advanced Composites Program – Integrating Research with Customers

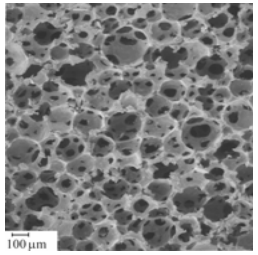
Basic Research…

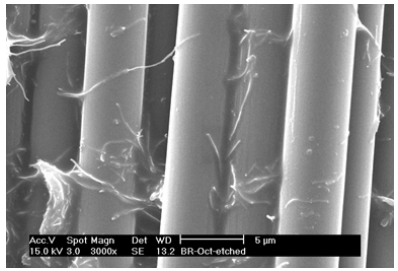




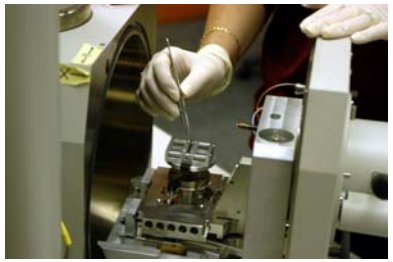


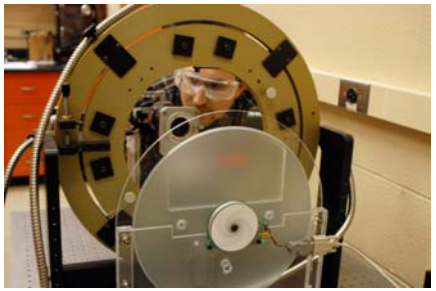




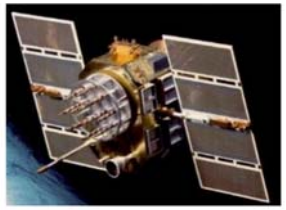


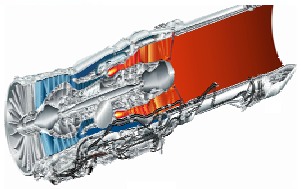
Development…

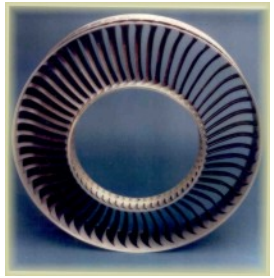




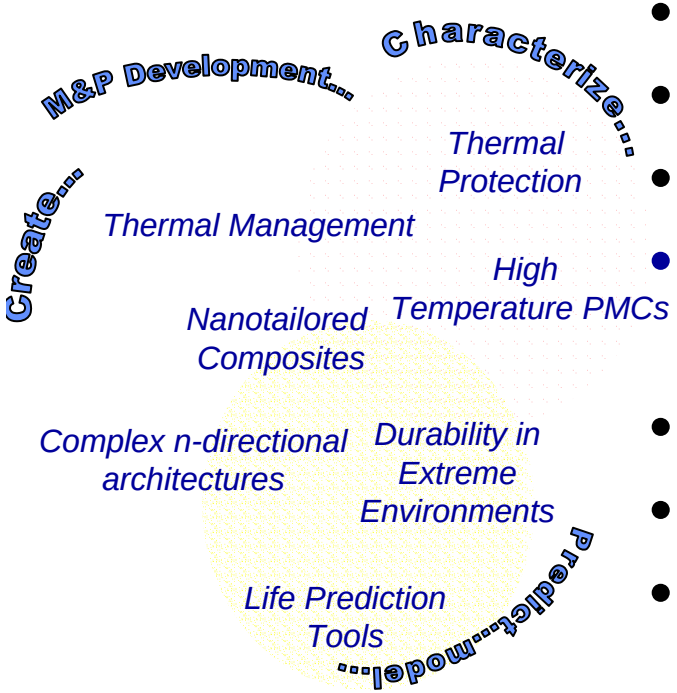
Transition





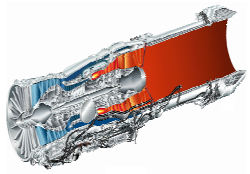


Opportunity Areas



Pervasive

- N-D complex materials
- C-C and carbon forms
- Multi-dimensional nanotailored OMCs
- Design/modeling tools

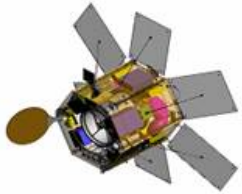


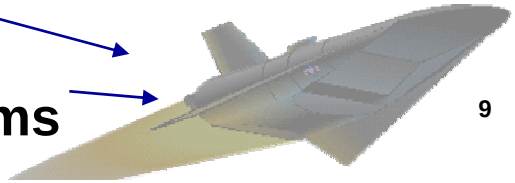
Air Platforms

- High temperature PMCs
- Thermal management
- Integrated structural concepts

Space Platforms

- Thermal management
- Composites in extreme environments
- Thermal protection systems





Summary

- **Organic matrix composites (OMCs) cannot be treated as static entities during service life, challenging for life prediction**
- **Opportunity to truly change the way this class of materials is transitioned through true understanding of material behavior coupled with computational modeling tools**
  - **Reduce time, cost associated with testing for transition**
  - **Enable early integrated material design trades to guide new material development**
  - **Predict life time performance in service with confidence**
- **Assistance in project coordination**
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