Design & Man of Integrated NanoSystems:

Transitioning Nano To Air Force Systems

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Rich Vaia

Branch Chief & Research Lead

Nanostructured & Biological Materials Branch

Materials and Manufacturing Directorate

Wright-Patterson AFB OH

Richard.Vaia@wpafb.af.mil

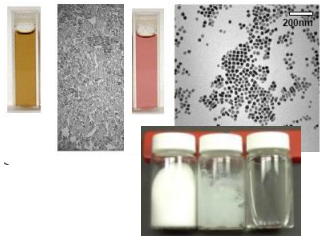
AFRL

THE AIR FORCE RESEARCH LABORATORY

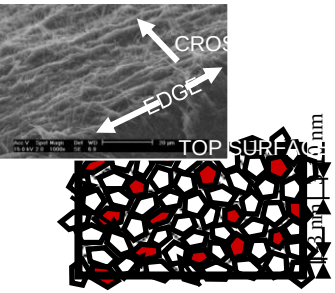
LEAD | DISCOVER | DEVELOP | DELIVER

“Nano” Technologies

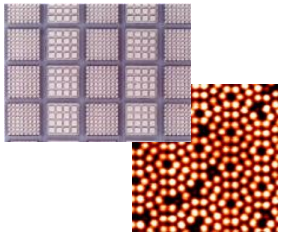
Nano-Particles & Powders

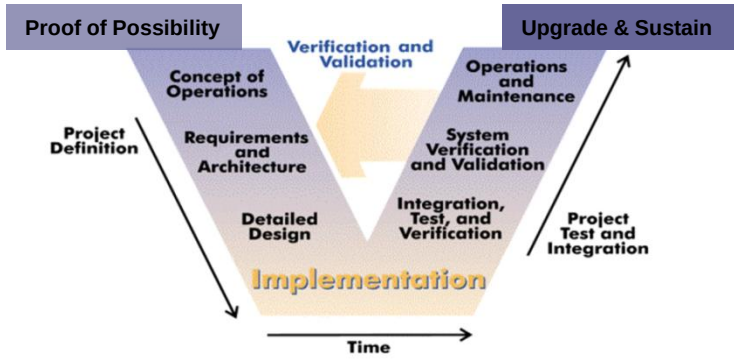


Nano-Composites & Materials

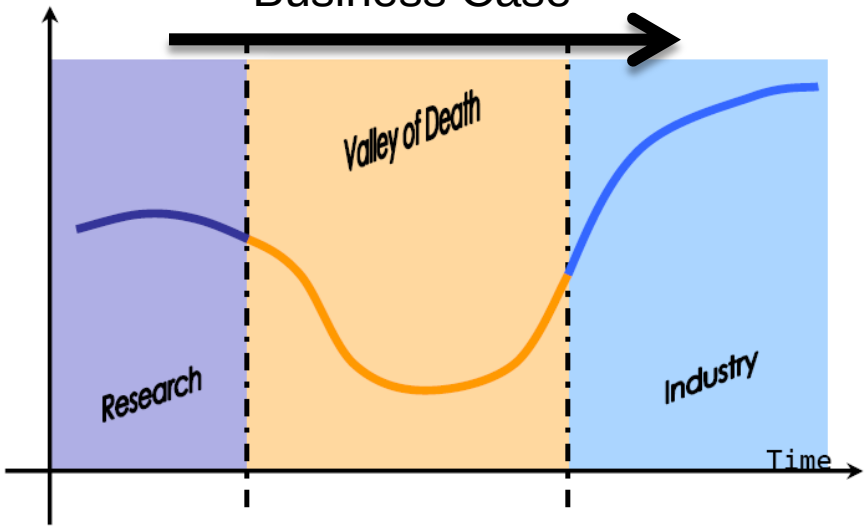


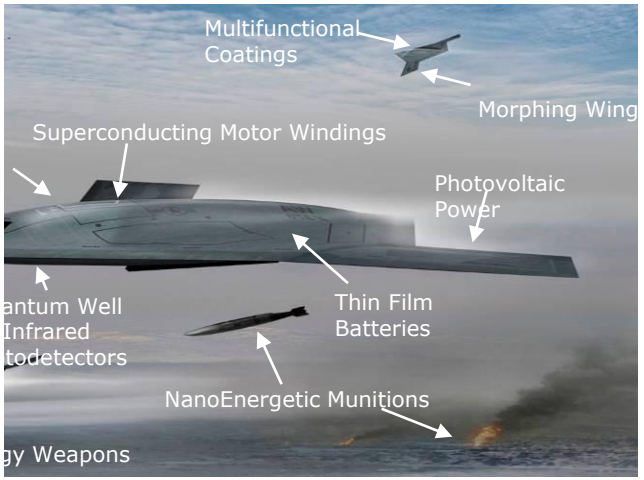
Nano-Structures & Devices



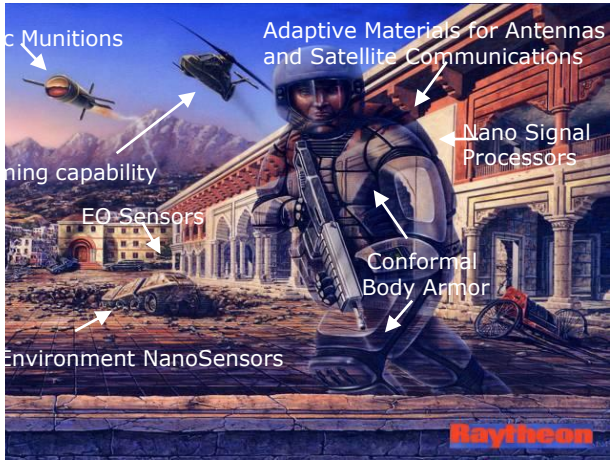


Design
Manufacturability
ROI
Supply Chain
Business Case





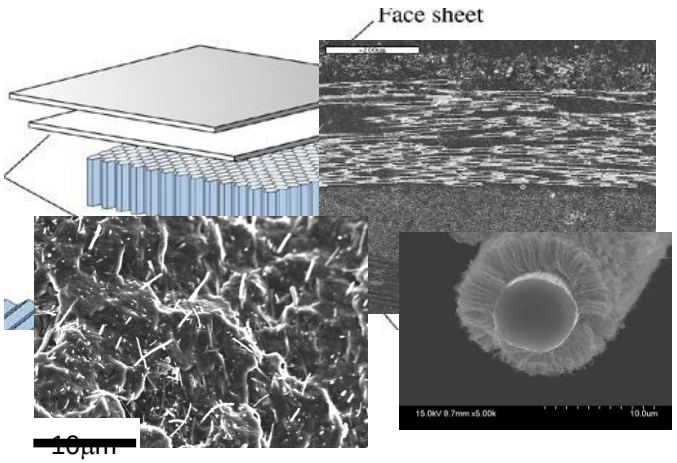
able new performance paradigms



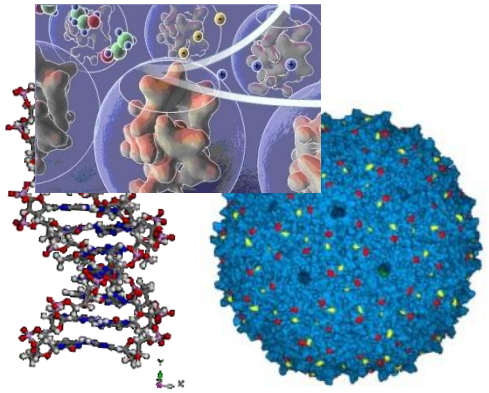
Challenges:
Design & Man of (Nano) *Systems*

System = Performance arises from designed interaction(s) between constituents

Nano-enabled Systems



Nano Systems



Digitization of the Materials Tetrahedron = Format Knowledge for Designers

Units
- Tools for Verification & Validation = Standards, Common Building Blocks

Inter-action
- Material Systems as Networks = Optimization for Performance
- Automated Discovery = Acceleration of Multi Body Formulation

Man
- Factory of the Future = Maximizing Specificity and Customization

Challenge: Tools for Verification and Validation

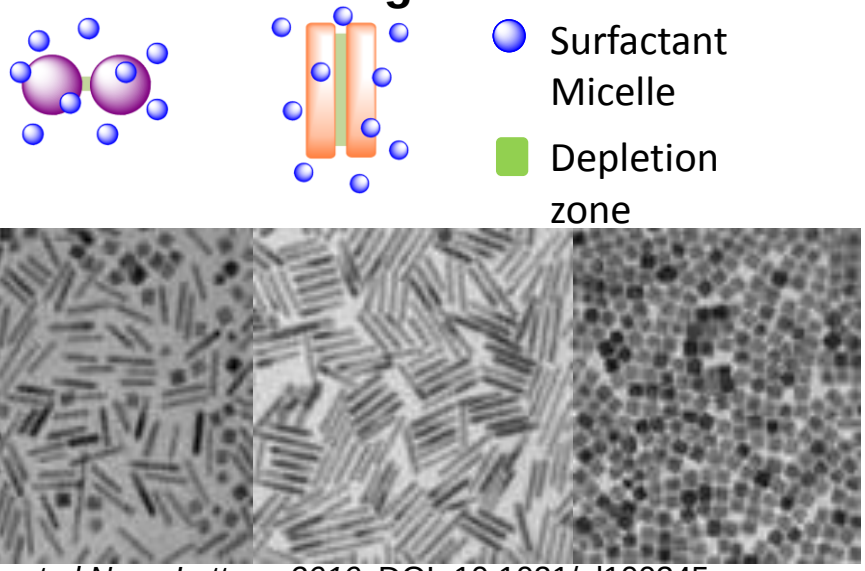
Issues: Control of Units

- Purity
- Distributions
- Standards
- Calibrated in-line monitoring for closed loop manufacturing

Approaches:

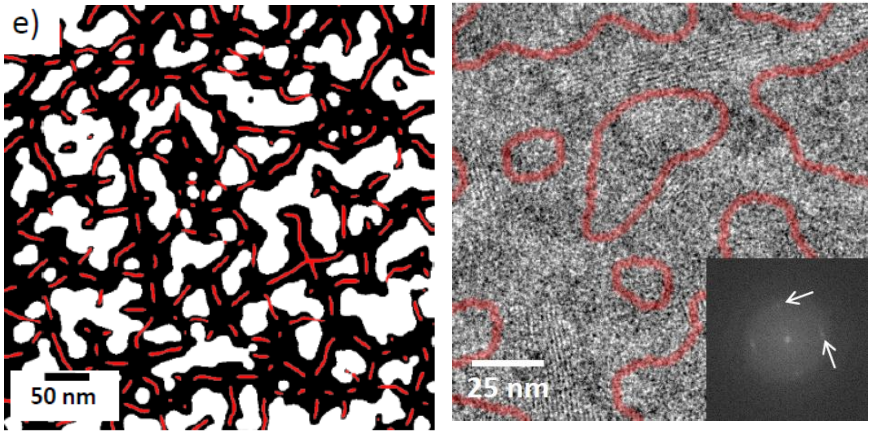
- Statistical Analysis of Idealized Limits
  - Novel Fabrication & Assembly Techniques
- Accelerated Spatial Characterization Tools
- Visualization Tools
  - Image Recognition & Machine learning
  - Common Database Expectations

Reversible Clustering & Purification



Park, et al Nano Letters, 2010, DOI: 10.1021/nl100345u

Energy-Filtered TEM and Low-Dose HREM



Drummy et al Chem. Mater. 2011, 23, 907–912 907

Challenge: (Nano)Materials Systems as Networks

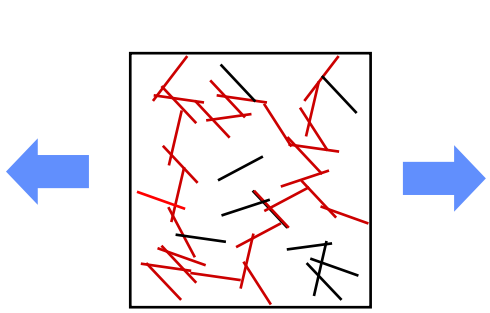
Issues: Design the Interaction Between Constituents

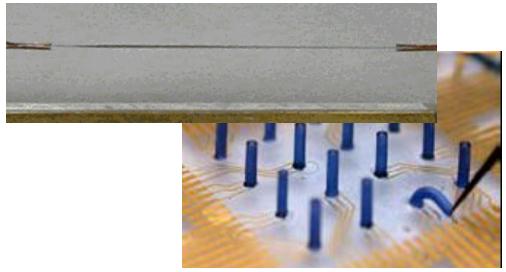
- Critical Path
- Critical Defects
- Distributions
- Nonlinearity
- Regulation
- Integration with higher-level systems

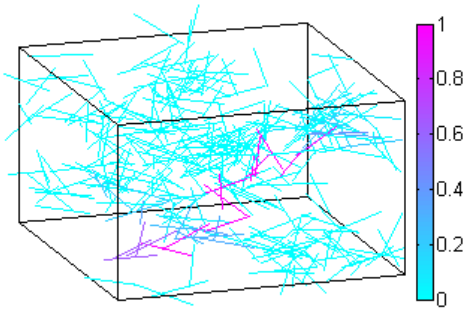
Approaches:

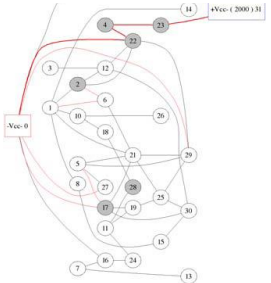
- Information Flow = Response & Transport is Processing and Info
  - Graph & Network Theory
  - Path Distributions
- Emergent Phenomena
  - Stability via interaction of non-stable processes
  - Performance
- Regulation of Cellular Processes

Piezo Resistive PNCs



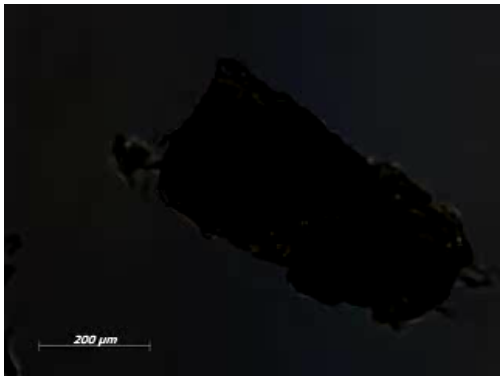


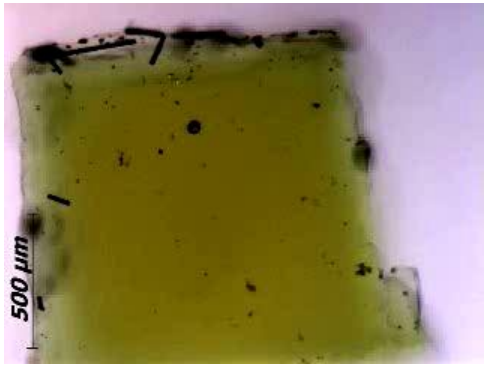




Adv. Material 2010, 22, 3430 2010; PRL 102(11), art no. 116601
Macromolecules, 2008, 8053; Simoes et al, 2010, DOI 10.1166/jnn.2010.1373;
G. Forest et al in press

Autonomic Behavior (BZ Hydro-Gels)





Challenge: Automated Guided Discovery

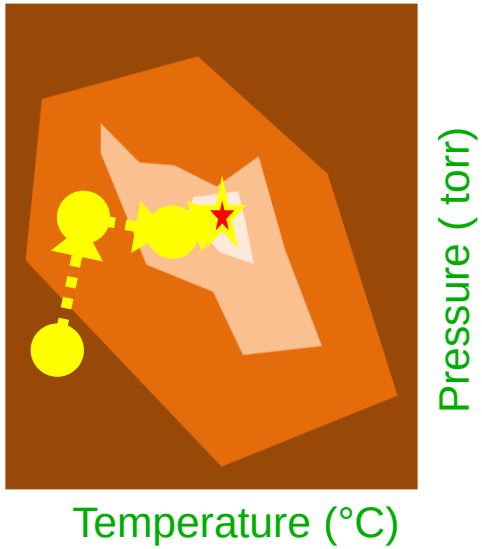
Issues: Uncertainty in exploration of solution space

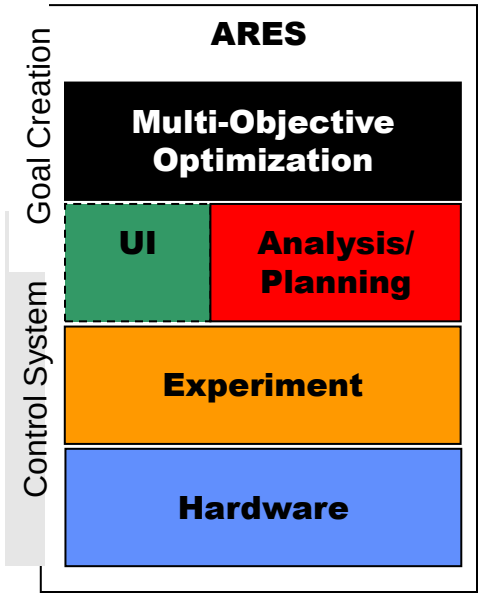
- Comparable Interactions
- Dynamic response
- Multi-variable input
- Durability
- Sustainment

Approaches:

- In-Situ library generation
  - In-line research rather than process control
  - Objective functions
  - Steepest Descent
  - Machine intelligence
- Bio-discovery (e.g. Phage) evolutionary – selection driven discovery

Goal-seeking AGD





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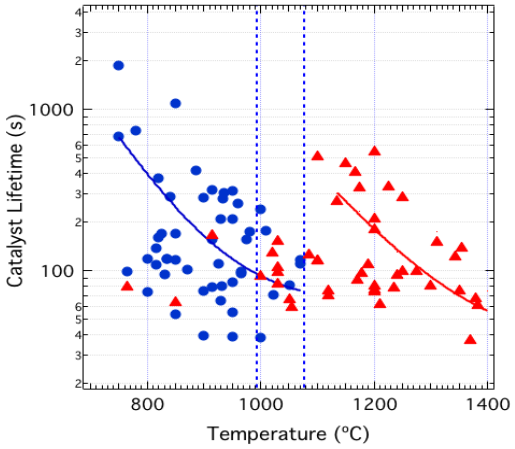
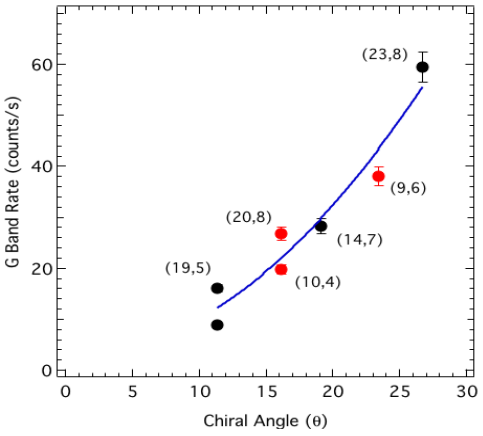


Maruyama et al 2011

Growth & Chirality



Yakobson et al www.pnas.orgcgidoi 10.1073pnas.081194610

Challenge:
Factory of the Future (AF Man Strategic Vision)

Issues: ROI

- Reproducibility
- Risk
- Lot size
- Unique Platform
- ESOH
- Supply Chain

Factory of the Future

- Next gen mfg tech developed with process and cost models
- Lean & agile, lot size insensitivity
- Robotics and next gen automation
- Advanced/ wireless factory C2

Moving Manufacturing Left

- partner with academia and small business on high risk/high payoff opportunities
- Develop tools and methods that promote early consideration of mfg implications during concept development

Cradle To Cradle Digital Thread

- Increase digital density across life-cycle
- Enable increased reusability of materials and components, and optimize impact on the environment

Responsive, Integrated Supply Base

- IB capabilities and risks are known, available, and integrated into product development
- 21st century supply chain mgmt principles
- Capability for rapid formation of global partnerships

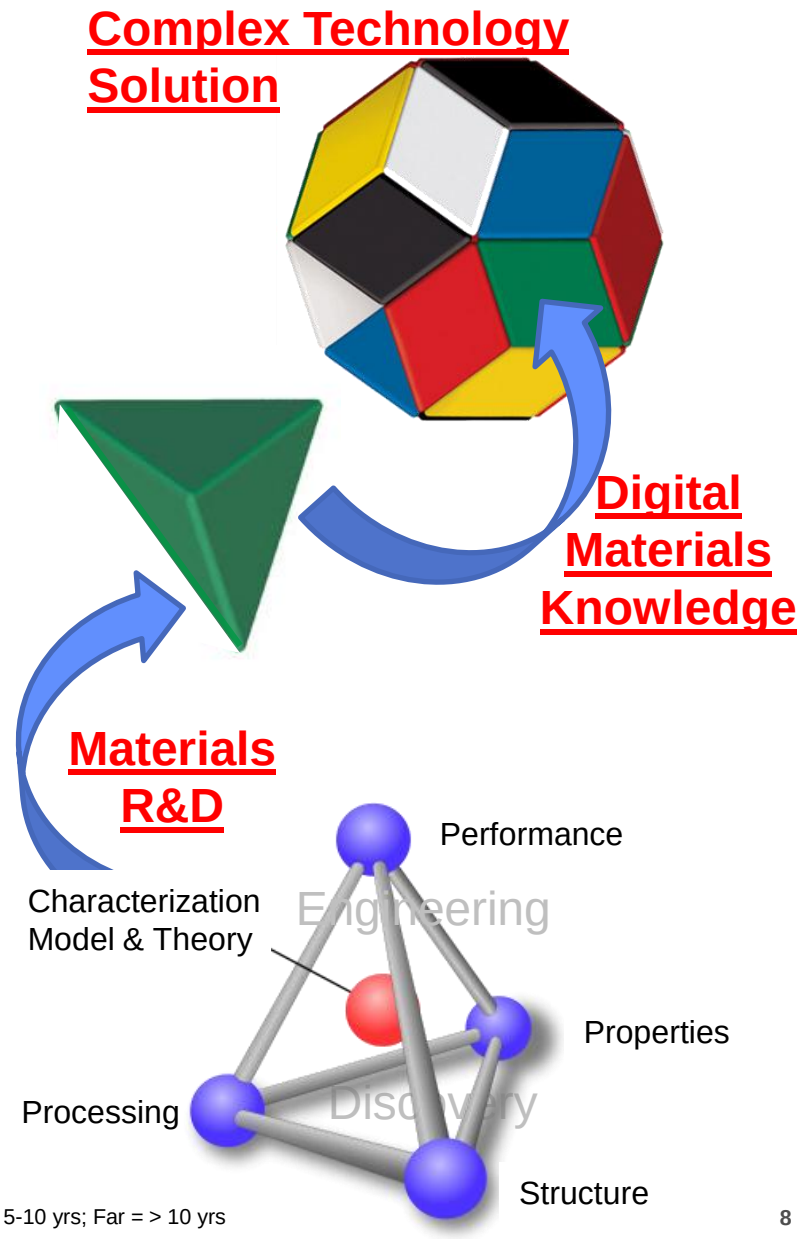
Summary: Path to Nano-Systems through Digitization of the Materials Tetrahedron

Main technical hurdles preventing us from manufacture of complex nano systems today?

- Truth in advertisement – fidelity in technical assessment (hype or reality?)
- Incompatibility & stability issues (enhance v. new platform, environments)
- ROI calculation including Sustainment & Durability
- Computational gaps (ICMSE)
- Manufacturability metrics
- ESOH issues

How do we surmount these hurdles?

- Develop Tools for V&V (Near-Far)
- Integration of informatics capabilities (Mid; technical challenges)
- Development of Robust & Integrated Design Tools (Mid-Far)
- Establish pilot development manufacturing capabilities (Near-Mid; limited funding)
- Adoption of new concepts, such as BioPharma (Near; language)
- Quantification of Stability & Duribility
- Technical workforce (Mid-Far)



Near = 0-5 yrs; Mid = 5-10 yrs; Far = > 10 yrs

References and Background

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