ASU Complex Adaptive Systems Initiative
Arizona State University

Advanced Manufacturing and Disruptive Technologies: Implications for Strategic Competitiveness

Dr. George Poste
Chief Scientist, Complex Adaptive Systems Initiative
and Del E. Webb Chair in Health Innovation
Arizona State University
george.poste@asu.edu
www.casi.asu.edu

Presentation at DHS-DOD Meeting:
Policy Implications of Digital Fabrication: 3D Printing and Beyond
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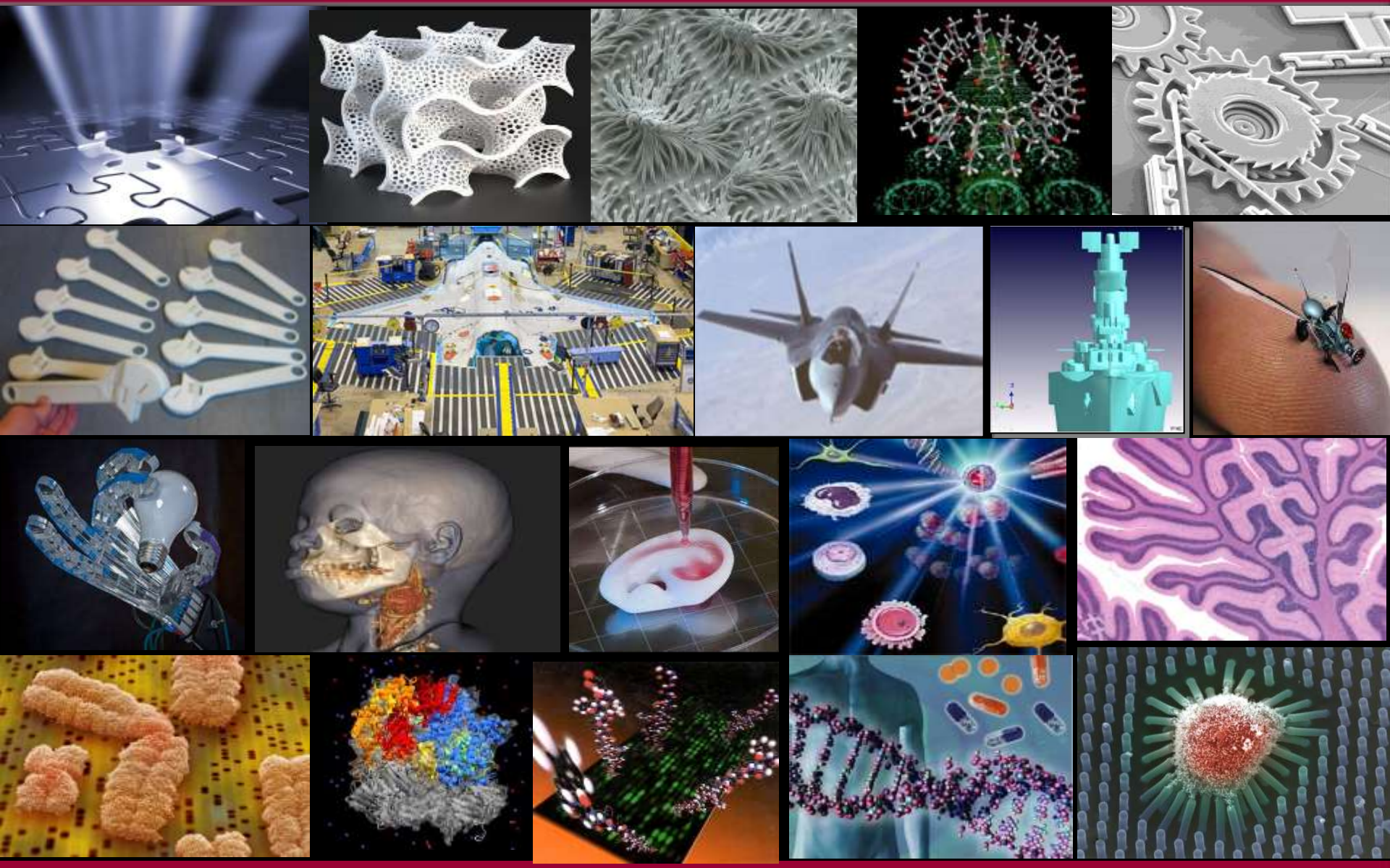
Advanced Manufacturing



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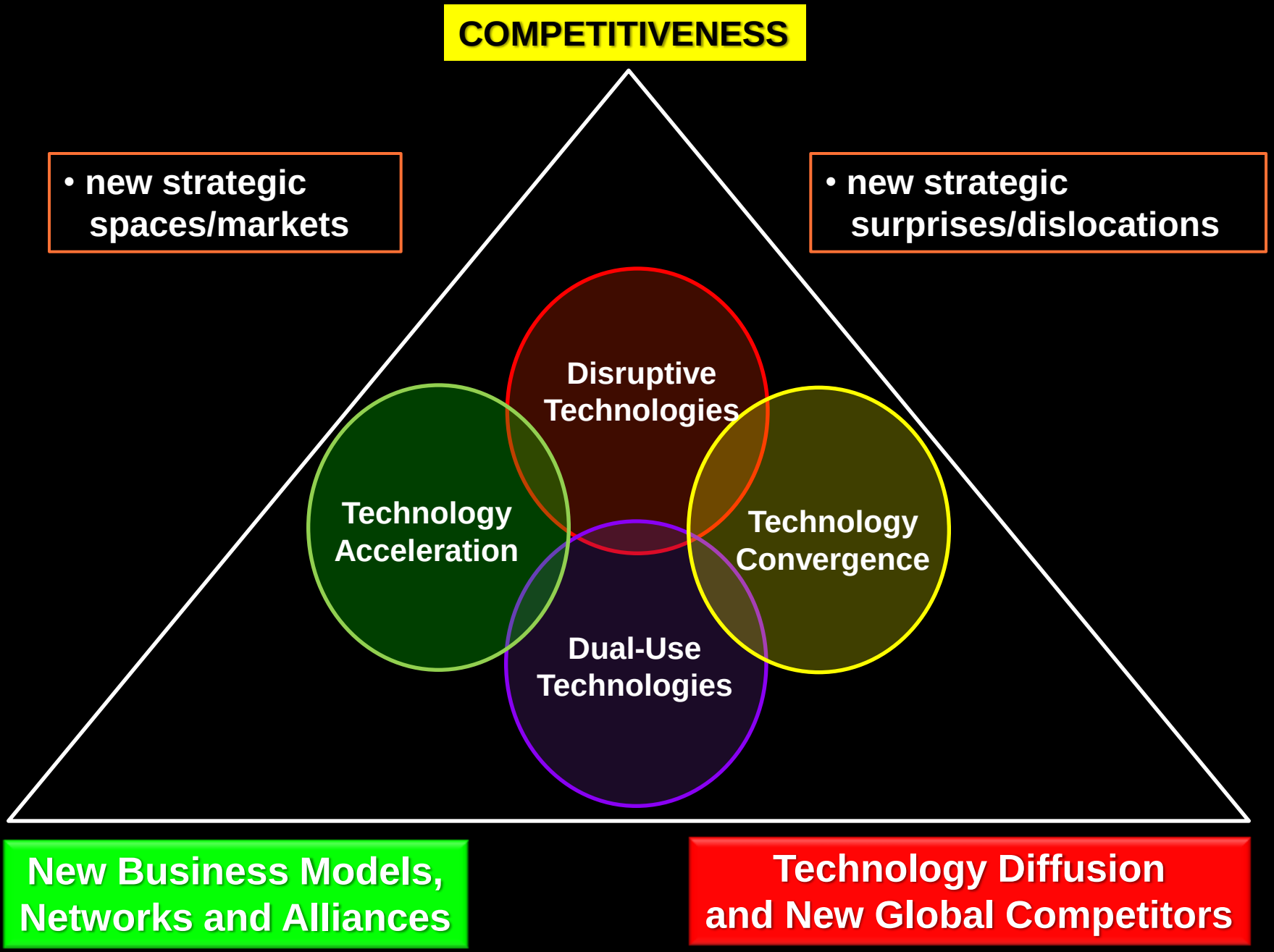
The Strategic Environment for Technology-Based Industries



The Evolution of Production

Agrarian	Industrial	Digital
		
		
		

“It from Bits”
The Proliferation of Digital Design and Fabrication

Advanced Computing and Devices

“Cyberspace”

Ubiquitous Sensing/ Social Networks

“Connected Space”

Biotechnology and Synthetic Biology

“Bio-Space”

Complex Autonomous Systems

“Simulation Space”

Disruptive Technologies

?

“Threat Space”

"It from Bits"
The Proliferation of Digital Design and Fabrication

Advanced Computing and Devices	Ubiquitous Sensing/ Social Networks	Biotechnology and Synthetic Biology	Complex Autonomous Systems	Disruptive Technologies
				?
"Cyberspace"	"Connected Space"	"Bio-Space"	"Simulation Space"	"Threat Space"

Emerging and Evolving
Multi-Dimensional Matrices
of Knowledge Networks

Global Challenges

Systems of Innovation

Advanced Manufacturing: Technology Vectors

technology convergence

- life sciences, engineering, materials, robotics, computing

multiscale design

- simulation and fabrication at different scales
  - macro-, meso-, nano- and Ångstrom- level design

dramatic expansion of “design space”

- escalating distributed degrees of (design) freedom (DDOF)
- increasingly complex autonomous systems
- combinatorial assembly of increasingly diverse materials
- self-assembly and repair: learning from biology
- synthetic biology/directed evolution and exploring ‘biospace’

Complicated Systems (Low DDOF)








- predictable performance and failure points

Complex Adaptive Systems: Increasing DDOF



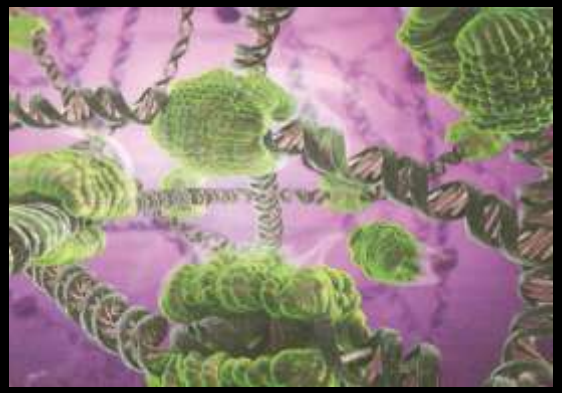
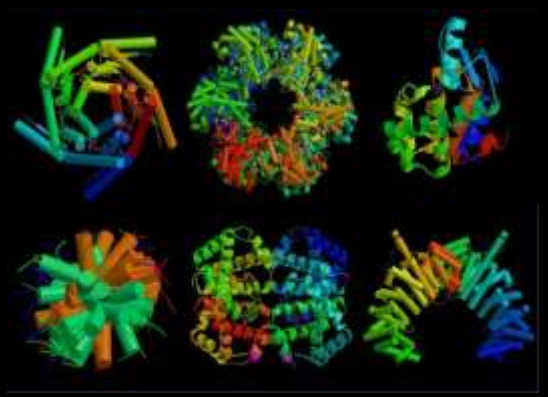




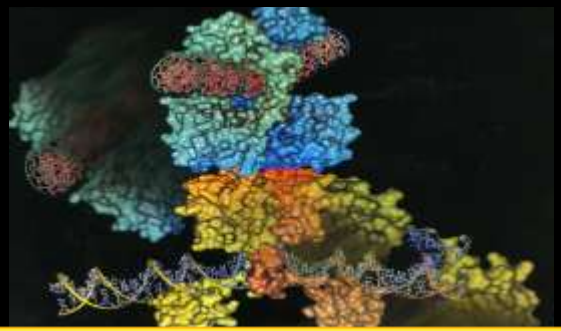
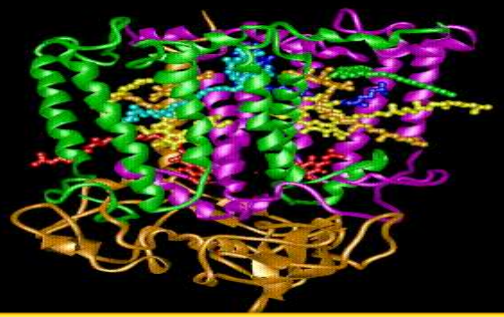

- graded levels of autonomous behavior (components, systems)
- escalating challenge of predicting system behavior and state shifts

DNA as Universal Programming Language for Self-Assembly Systems: The Rise of Synthetic Biology, Directed Evolution and Bio-CAD

Design and Regulation of Gene Expression

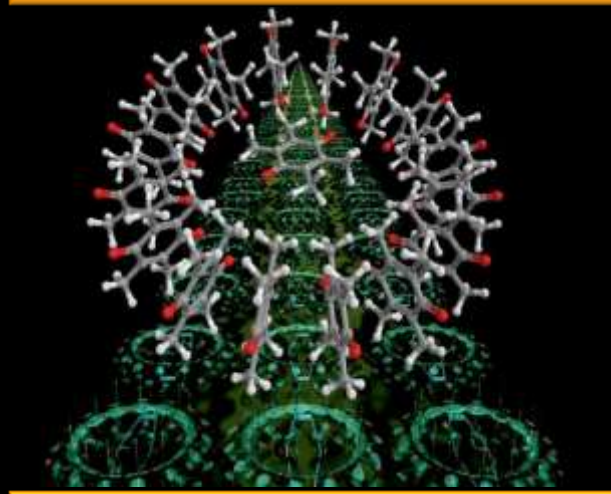
code	translation	protein product
		

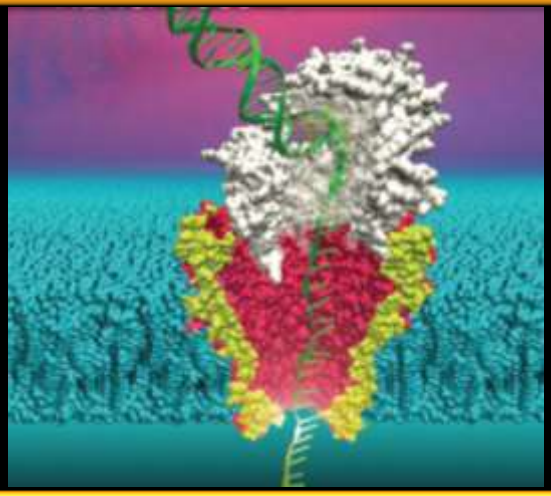
Directed Evolution

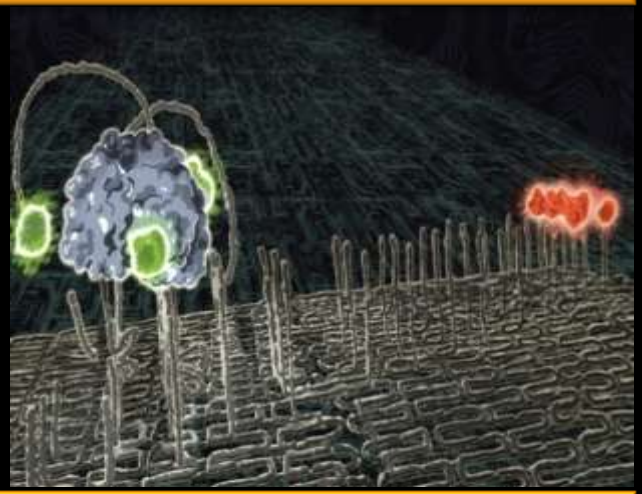
engineered gene control	molecular breeding	unique building blocks
		

Directed Molecular Assembly and Materials Science

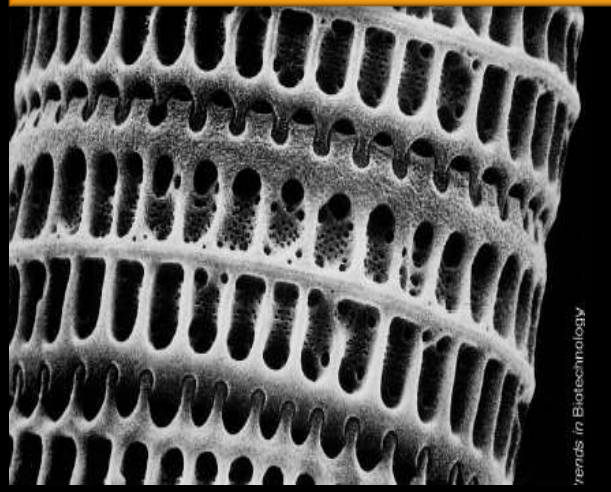
Sensors and Molecular Machines

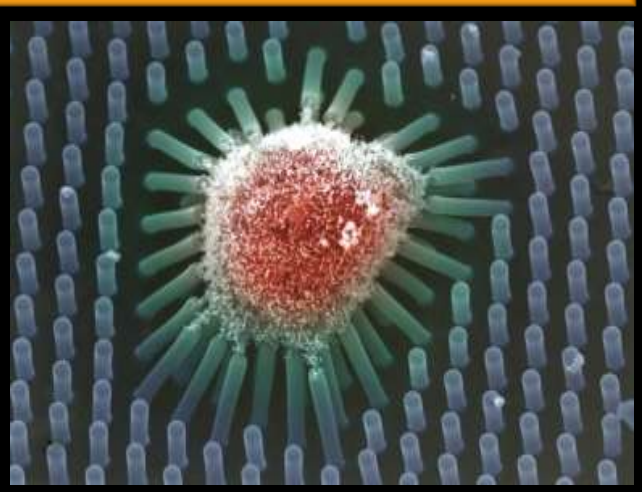






Biomimetic Design: Organic-Inorganic Hybrids





Synthetic Biology: Bio-inspired Systems Engineering

- designed-organisms as bio-factories
- complex, multi-step syntheses, high performance materials made in completely different ways
- manufacturing at room temperature in water versus high temperatures and toxic solvents
- mimic resource efficiency of natural ecosystems
  - self-sustaining
  - limit depletion of non-renewable resources
  - limit/eliminate waste stream cost/hazard
- highly distributed manufacturing units

“It from Bits”: Modeling and Simulation of Complex Autonomous Systems as Foundation Competencies for R&D and Advanced Manufacturing

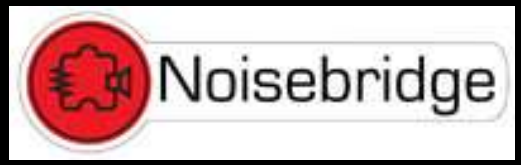
- large scale computer simulations of complex phenomena
- big data and open source data
- systemic application of advances in cognitive neurobiology and human: machine interactions for improved design and decision making
- simulation modeling and scenario gaming for systems performance assessment and public policy options
- Investment in national digital infrastructure and new educational curricula

Advanced Manufacturing
Distribution and Democratization of the Manufacturing Base

Product Authenticity and Provenance

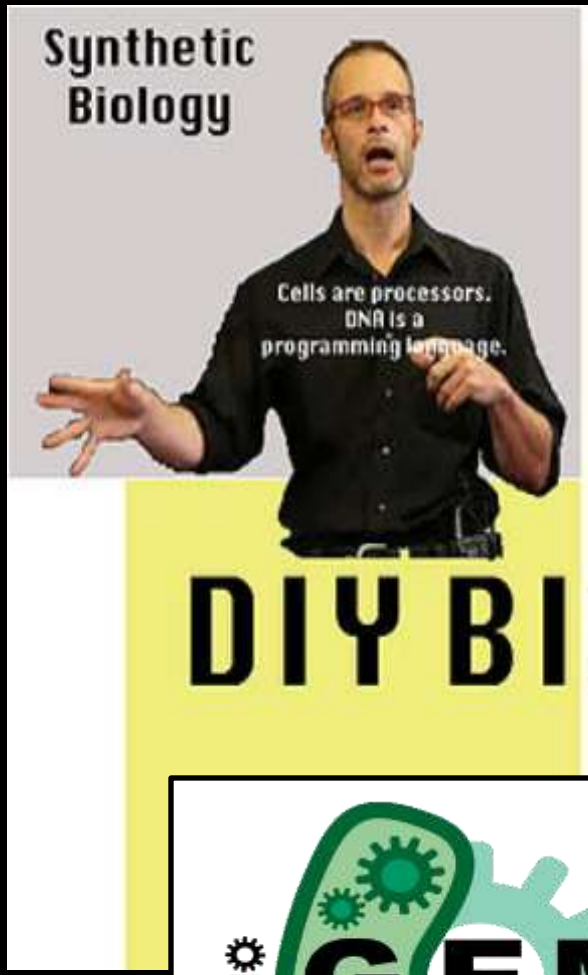
- source(s)
  - QA/QC, safety, performance
- counterfeit detection
  - dynamic, evolvable tags
- IP protection
- export controls
- ‘trojan horse’ detection
- dual use monitoring
- classified methods

Social Manufacturing: Democratization of Manufacturing: The Maker Movement and Mobile Multiple Markets of One



Energy Development

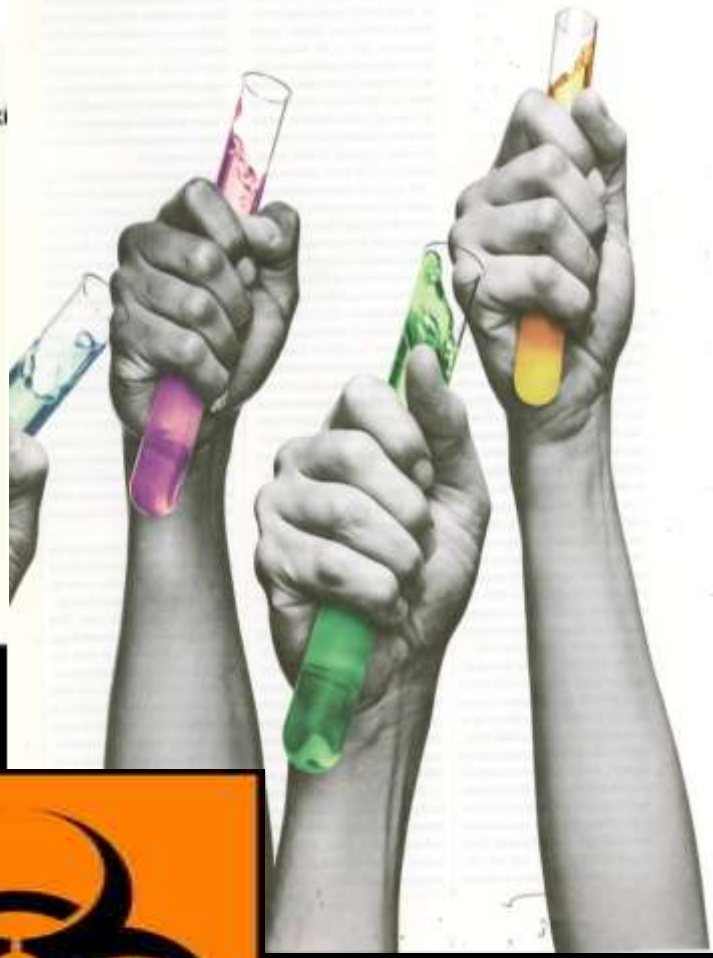
Crowd- and Citizen-Science, Gamers and Hackers



Biocurious
Eri Gentry
Tito Jankowski

GARAGE BIOLOGY

Biodesic
Robert Carlson



Public Policy Implications of Next-Generation Manufacturing Systems

- growing gap between technology frontiers and US Institutional analytical and acquisition agilities in disruptive technologies
  - academic silos and USG funding policies
  - ‘rapid’ and ‘translation’ are countercultural to much of academia/USG agencies
  - financial short-termism and risk aversion in private sector R&D
  - lax cybersecurity: espionage-exfiltration
- outdated or lack of coherent USG policies
  - sclerotic, anachronistic FAR
  - regulation, trade policy, export controls
  - IP, counterfeits and product provenance
  - international harmonization

USG Leadership in Advanced Technologies

Big Bang-Big Metal Defense Systems

- DOD as pioneer of new conceptual and technology advances
- integrated DoD-industrial ecosystem
- seeding of major innovation in non-defense sectors
- risk to technical: economic strategic superiority?

USG Leadership in Advanced Technologies

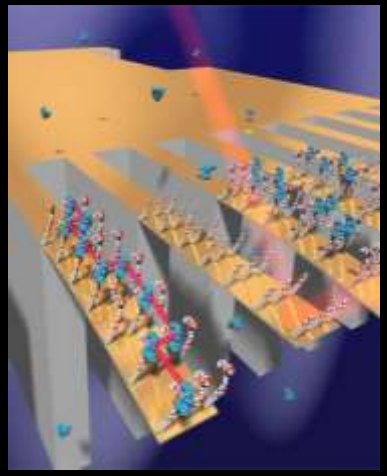
Network-Centric Warfare, Intelligence and Cyber-Threats

- sophisticated purchaser versus embedded systemic innovation and seeding of new industrial domains
- classified innovation domains?

USG Leadership in Advanced Technologies

Biotechnology and Molecular Medicine





- private sector innovation versus lagging USG initiatives
  - Dx, Rx, Ix, Vax
  - novel materials, sensors, biomimetic devices
  - m(mobile)Health
  - synthetic biology and new manufacturing platforms

USG Leadership in Advanced Technologies

Biodefense, Surveillance and New Counter-Measures

- poor ROI?
- mission(s) and accountability?
- poor engagement of proven industrial expertise?
- combating agent-X, rapid response capabilities and agile stockpile management?

Understanding Complexity

Building New Systems of Innovation

Boldness Must Trump Timidity

Advanced Manufacturing: A Critical Strategic Asset for US Competitiveness and National Security

"It from Bits": Digital Design

- impact on multiple defense and civilian sectors
- technology acceleration and convergence
- rapid diffusion and ubiquity of disruptive technologies
- escalating complexity in systems design
- modeling and simulation capabilities
- verification and validation protocols for complex autonomous systems
- new economic and defense threats
- Schumpeterian winners and losers

Advanced Manufacturing: A Critical Strategic Asset for US Competitiveness and National Security

USG actions

- organization and funding of transdisciplinary academic research
- agency accountability for poor ROI
- FAR reform
- build defense R&D and manufacturing capabilities in emergent domains (bio-inspired technologies)
- policy voids: regulation, trade, export rules, IP, antitrust
- cybersecurity and technology espionage/exfiltration

improve translational science

- reverse VC and industry retreat and the Valley of Dea(r)th
- USG agency missions/competencies/accountabilities
- pre-competitive consortia ‘Apollo Projects’ to capture critical technology platforms

Ultimate Frontiers in Advanced Manufacturing

Mike Teavee and the Television Chocolate Camera

Star-Trek Teleportation

Unicorn Meat

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