Building Interdisciplinary Research Excellence for Innovative Solutions to Global Challenges

Presentation to PCAST Subcommittee

25 August 2008
# New Challenges for the Academy

### Technology Convergence
- life sciences
- engineering
- computing
- scale
  - funding
  - teams

### Academic Culture
- fundamental reforms for sustained competitiveness
- broadened horizons
- relentless change

### Broadened Collaboration Networks
- global horizon scan and sourcing
- proactive capture of innovation
- IP
- regulatory issues

### Scale
- 3M projects
  - multi-investigator, multi-institution, multi-million

### Use-Inspired Research
- real world engagement
  - understanding industry’s needs
  - proof-of-concept and translational research
  - IP

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New Partnerships and Funding Sources
THE ARIZONA EXPERIMENT

"ASU is the most radical experiment going on in American higher education."
-George Poste

"It is a wonderful thing to be part of a place that is becoming, rather than a place that has been."
—Kip Hodges
Five Year Strategic Objectives

- Building an Entirely New Organization in an Era of Accelerating Change
- Use-Inspired Research
- Implementing a New Organizational Model for Cross-Disciplinary Academic Research: The Evolution of the ‘Tightly-Coupled’ Institute
The Challenge of Building a New Organization in an Era of Accelerating Change

- blurring of boundaries between traditional intellectual disciplines
- mastery of technology convergence
  - science, engineering and computing
- escalating funding requirements to support large scale, inter-disciplinary research
- new funding sources to counter anticipated constraints on USG agencies
- aggressive ROI and progression to economic independence
- globalization of research and intensifying competition
Technology Convergence

Biotechnology, Systems Biology and Synthetic Biology

Nanotechnology Materials Science and Miniaturization Engineering

Advanced Computing and Knowledge Management

• technologies with radical, pervasive and enduring impact

THE IMPERATIVE TO ADDRESS MAJOR GLOBAL CHALLENGES
The Challenge of Building a New Organization in an Era of Accelerating Change: Strategic Goals

- use-inspired research to address major global challenges
- high impact research
  - transforming advances versus timid incrementalism
- funding scale: 3M grants-multi-institution, multi-investigator, multi-million dollar
- become self-supporting with funding from external sources
- accelerate technology transfer and commercial development of innovative discoveries
- create new education and training capabilities
A “Tightly Coupled” Research Institute

- interdisciplinary
- integrated
- aligned
- high risk: high reward projects
- competitive

RETURN ON INVESTMENT

DELIVERY and ACCOUNTABILITY

IMPACT
A Tightly Coupled Institute

- new concept for academic research
- progressive evolution from traditional “loose federation” of collaborating units to increasingly coordinated integration
- alignment (tightly) around shared goals
- integration of diverse skills from specialized research centers (coupled)
- significant cultural and management transitions
- new governance mechanisms for oversight and coordination of project portfolio
- performance milestones
Progressive Alignment, Shared Goals and a Collective Ethos for Success
The Challenge of Radical Change

- radical change is disruptive
- radical change is threatening
- radical change places great demands on individuals
  - engaging with unknown/unproven
  - adoption of new methods and acquisition of new skills
  - mastery of constant ambiguity and doubt
  - relentless, and often hostile, opposition from status quo defenders
  - untiring advocacy in the face of naysayers, the petty and the malignant
  - generosity to commit to activities that don’t benefit individuals alone
Facilities

- on-time, on-budget construction
  - 172,000 sq. ft; $73 million
- building B
  - 175,000 sq. ft; $78.5 million
- specialized capabilities
  - low vibration/electromagnetic field zones
  - BSL-3 biocontainment
  - femtosecond laser laboratory
  - vivarium and surgical suites
- high security
  - CDC Select Agent regulations
- LEED Gold (Bldg A) and Platinum (Bldg B) Awards
- over 26 national awards for facility excellence
Five Year Accomplishments: Information Technologies

- scale, specialization and sophistication
- largest IT research infrastructure on ASU campus
- 53 servers with 238TB total storage
- full backup and disaster recovery
- adoption as best practices elsewhere in ASU
- comprehensive AV capability
  - videoconferencing, podcasting, full HD studio
- expanding web-based applications
  - Institute web site
  - intranet services
Five Year Accomplishments:
Competitive Funding and Return on Investment

- received $71 million in TRIF funds from ASU
- generated $199 million in external funding
- 2.8X return-on-investment in 3.7 years
- 12 patents, 45 patents filed, 122 provisional patent filings, 212 records of invention
- catalyzed major reorganization of Arizona Technology Enterprises (AzTE)
Five Year Accomplishments: Robust Administrative Systems and Support Systems

- set quantitative performance metrics
- parameters for continuous improvement
- customer-centric responsiveness
- standardization and automation
- electronic tracking systems
- electronic laboratory notebooks and IP
Five Year Accomplishments: Robust Administrative Systems and Support Systems

- Office of Strategic Integration and Research Management
- establish comprehensive framework to support cross-disciplinary research teams
- significant reform/refinement of ASU policies
  - personnel, budgeting, purchasing, audit,
  - animal welfare, biosafety
  - sponsored research
  - standardized CDA/MTA procedures
  - clinical trials
- employee training and orientation programs
Five Year Accomplishments: Education

- design/participate in 10 new ASU courses
- new post-doctoral fellowship scheme
  - 108 fellows
- expand research opportunities for ASU students
  - 316 undergraduates
  - 174 graduate students
- new Ph.D. program in Biological Design
- launch new K-12 educational program
Five Year Accomplishments: External Review

- crucial importance of external assessment
  - quality of research
  - progress in meeting performance goals
  - rational use of expensive resources
  - operational barriers/problems

- established worldclass Institute Advisory Board (IAB)
  - 11 members of National Academies
  - 1 Nobel Laureate in Physiology and Medicine
Advisory Board

★ = National Academy Member
◆ = Nobel Laureate

Chairman:
★ Dr. Stephen Benkovic, Professor; Eberly Chair in Chemistry — Penn State

Members:
★ Dr. Allen J. Bard, Director, Laboratory of Electrochemistry — UT at Austin
★ Dr. Carolyn Bertozzi, T. Z. & Irmgard Chu Distinguished Professor, Department of Chemistry University of California, Berkeley
★ Dr. Charles R. Cantor, CSO — Sequenom, Inc.
★ Dr. John Donoghue, Professor of Neuroscience Division of Biology & Medicine — Brown University
★ Dr. David Eisenberg, Director, Institute for Genomics and Proteomics — UCLA
★ Dr. Larry Gold, Chairman and CSO — SomaLogic, Boulder, CO
◆★ Dr. Lee Hartwell, President and Director — Fred Hutchinson Cancer Center, Seattle, WA
★ Dr. Daniel Nocera, W. M. Keck Professor of Energy & Professor of Chemistry — MIT
★ Dr. James Rothman, Director, Department of Cell Biology, Yale Univ.
★ Dr. Lucy Shapiro, Director, Beckman Center for Molecular and Genetic Medicine; Ludwig Professor of Cancer Research — Stanford University School of Medicine
★ Dr. James Wells, President and CSO — Sunesis Pharmaceuticals
Five Year Accomplishments: An External Critique

- Institute Advisory Board Reports

“The Institute has made excellent progress, far more than many would have dreamed possible at ASU”

December, 2007

“The achievements of the Institute in these initial years has been remarkable.”

March, 2008
Making a Difference by Being Different

- vanguard initiatives that differentiate us from the current ‘leaders’
- mastery of cross-disciplinary research
  - organizational, financial and cultural transitions
- use-inspired research that excites us plus new sponsors
- audacious goals
- relentless focus on few high profile target areas in which we can attain worldclass status
High Impact Research on Major Global Challenges and Unmet Needs

- personalized medicine
- outpacing infectious diseases
- energy and environment
- securing a safer world
- synthetic biology
Leveraging Technology Convergence for Diverse Applications

Innovative Solutions for Major Global Challenges

- Personalized Medicine
- Outpacing Infectious Disease
- Energy and Environment
- Securing a Safer World
- Synthetic Biology

Unifying Technology Platforms

Unique Signatures

Signature Detection

Actionable Information
Innovative Solutions for Major Global Challenges

Unifying Technology Platforms

Objective

Profile  Sense  Act

Unique Signatures  Signature Detection  Actionable Information
Integrated Functional Platforms to Exploit Technology Convergence

Identification of Unique Signatures

Detection of Signatures in Diverse Settings

Format and Transmit Actionable Information for Optimum Decisions

Profile

Life Sciences and Mathematical/Statistical Tools for Complex Signal Analysis

Sense

Nanotechnology, Miniaturization Engineering, Materials Science

Act

Large Scale Informatics and Information Architectures
Leveraging Common Technology Platforms for Diverse Applications

- **Personalized Medicine**
- **Outpacing Infectious Disease**
- **Energy and Environment**
- **Securing a Safer World**
- **Synthetic Biology**

**Unique Signatures**

- Molecular Detection Systems: Diagnostics, Sensors & Taggants
- Remote Monitoring: Wireless and Network Architectures

- Personalized Medicine
- Vaccines
- Safe Water
- Bioremediation
- Bioenergy
- Tag, Track, Locate
- Bio-inspired Mfg.

- Informatics: Complex Signal Deconvolution, Data Formatting & Visualization
Building a Project Portfolio of Graded Maturity

Apollo Projects
- major projects and significant interdisciplinary collaboration
- dedicated project management resources
- supported by significant external funding

Gemini Projects
- maturing high profile projects with anticipated progression to Apollo status 18-24 months
- mixture of internal (TRIF) and external funding

Frontier Projects
- highly innovative concepts that require confirmatory data to attract external funding
- ‘seed’ funding for one year

Core Technologies
- advanced technologies that support multiple Apollo and/or Gemini Projects
Innovative Solutions for Global Challenges

- **Personalized Medicine**
  - Point-of-Care Molecular Diagnostics
  - Partnership for Personalized Medicine
  - Cancer Vaccines

- **Outpacing Infectious Disease**
  - New Era Vaccine Technologies

- **Energy and Environment**
  - Tubes-in-the-Desert

- **Securing a Safer World**
  - Forensic Profiler

- **Synthetic Biology**
  - Living Systems Engineering
  - Bio-inspired Design, Assembly and Manufacturing
Innovative Solutions for Global Challenges

Personalized Medicine
- DNA Scaffolding*
- Next Generation DNA sequencing*
- Population Proteomics*
- Dark Genome

Outpacing Infectious Disease
- Synthetic Genomics for Immunization*

Energy and Environment
- Biohydrogen*
- Molecular Photovoltaics*
- Biomimetic Fuel Cells*

Securing a Safer World
- Dirty Bomb DX*
- Nanowires*
- Sensors for Explosives Detection*
- On Body: In Body Sensors (OBIBs)

Synthetic Biology
- Ecogenomics*
- Metagenomics*
- Dark Genome

* = external funding to supplement TRIF
Technology Core Platforms

Sophisticated Planning and Integration for End-to-End Solutions

New Expertise in Project Management
R&D Competencies for Bioinspired Energy Production and Bioremediation

- Systems biology and synthetic biology
- Protein engineering, directed evolution and enzymology
- High throughput assay automation
- Computing and systems modeling
- Molecular bioenergetics and biological physics
- Directed molecular assembly
- Bioprocess engineering
- Proof-of-concept for industrial interest

Systems-Based R&D: Obligate Focus on End-to-End Solutions

Intellectual Property (IP): Building an IP Fortress
Research fusion

ASU is launching a major new initiative that will revolutionize academic research through the innovative convergence of science, engineering, social sciences and computing – building on the intellectual principles of success pioneered by ASU’s Biodesign Institute.
The Complex Adaptive Systems Initiative (CASI)

- both exemplar and a catalyst to expand use-inspired, cross-disciplinary research more broadly at ASU
- leveraging Biodesign’s success to launch additional research initiatives in which ASU can achieve worldclass status
  - focus on nascent, emerging areas arising from the ‘convergence’ of previously distinct research domains
- draw upon substantial but dispersed expertise at ASU
Design Principles in Complex Adaptive Systems

- understanding connectivity patterns and unitary organizational principles in seemingly highly different entities
- ultimate resolution as patterns of information flow
  - “it from bits”
  - “the ecology of information networks”
  - “the ecology of knowledge”
- overarching and unifying concept for the integration of knowledge
  - science, technology, humanities, law, social sciences, business
CONVERGENCE
new interaction patterns and complex adaptive systems
EMERGENCE

- new strategic spaces
- new strategic surprises?

Technology acceleration
Technology convergence
Culture and worldview disparities

Rapid diffusion and ubiquity of advanced technologies

The limits of current institutions
Rise of new economic centers
## Initial Research Areas for CASI

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**Dual-Use Complexity**

**Science and Industrial Policy, Regulation and Oversight**

**Socio-Cultural, Ethical and Legal Implications**
Synthetic Biology

- emerging technology with myriad applications across diverse industrial sectors

Healthcare | Public Health | Agriculture | Functional Foods | Novel Materials | Textiles

Bioenergy and Biofuels | Industrial Enzymes | ‘Green’ Mfg | Bio-remediation | Clean Water | Ubiquitous Sensors
Synthetic Biology: Inter-disciplinary Convergence and Complex Policy Issues

- Systems Biology
- Computational Biology
- Materials and Nanobiotechnology
- Industrial Bioprocess Engineering

Specific Applications

- Occupational Safety
- Dual-Use Applications
- Public and Media Responses
- Public Policy and Regulatory Oversight
Meta-Planning for Synthetic Biology

- metagenomics
- ecogenomics
- biobricks*
- biofoundry*

- materials*
- bioengineering*

- pattern analysis
- simulation of complex systems

- chemistry
- physics
- mathematics

- biogeochemistry

- Astrobiology*

- sustainability initiatives*

- ethics/science policy/regulation

* major opportunity for 3M collaboration(s)
The Infocosm: Emerging Networks of Global Connectivity
Ubiquitous Sensing and Ambient Intelligence: A Burgeoning Infocosm and An Expanding Metaverse

- everything is a reporter
- everything goes everywhere
- everybody sees everything
- everything moves fast
Design of Context-Dependent Data Mining and Visualization Tools and Integration with Advances in Cognitive Biology
Integrated Components for Understanding the Design Principles of Complex Adaptive Systems (CAS)
Integrated Components for Understanding the Design Principles of Complex Adaptive Systems (CAS)

- **CAS Modeling, Engineering and Nanoscale Design**
- **Ubiquitous Sensing**
- **Systems Biology and Synthetic Biology**
- **S&T Policy**
- **Ecological CAS and Sustainability**
- **Advanced Computing and Knowledge Mgmt**

**Multi-Scale Analytics**
- nm to universe
- directed molecular assembly and nanofabrication
- systems and subnetworks design
- synthetic biology
  - ecogenomics
  - metagenomics

**Synthetic Biology**
- ecogenomics
- metagenomics

**Advanced Computing and Knowledge Management**
- complex signal deconvolution
- novel data visualization
- cognitive neuroscience and optimized analysis / learning

**Ubiquitous Sensing**
- bio-inspired products/materials services
- synthetic biology
- biomimetic materials
- environmental
  - urbanization
  - infectious diseases
  - water
  - energy
  - ecosystem modeling
  - national security

**Ecological CAS and Sustainability**
- bio-inspired products/materials services
- synthetic biology
- biomimetic materials
- environmental
  - urbanization
  - infectious diseases
  - water
  - energy
  - ecosystem modeling
  - national security
Leadership in Research on Complex Adaptive Systems: ASU can be Ahead of the Curve

strategy, policy and solutions

- relentless technology blending
- the expanding infocosm: navigating the metaverse
- culture and worldview disparities

collection

framing the right questions

analysis
Future Thinking for Thinking About the Future

- what is possible?
- what is probable?
- what is preferable?
- what is preventable?

how do we develop and apply new tools to understand complex systems
  - scientific research
  - technological solutions
  - institutional reform
  - education and training
Intellectual
“Grand Challenges”

Pragmatic
“Real World Challenges”

Competency,
Courage and
Commitment
to
Engage Complex
Issues

“Urgency”

“Focus and Resolve”

“Passion and Purpose”