Overview of Chemical, Bioengineering, Environmental, and Transport Systems

JoAnn S. Lighty
Division Director
Advisory Committee Meeting
October 23, 2014

VISION OF CBET

- **CBET supports fundamental engineering research that involves:**
  - **the transformation of matter by chemical, thermal, or biological means**
  - **the exchange of mass, energy, or momentum**
- **With the goals that:**
  - **The quality and length of life will be maximized**
  - **Humans will live sustainably on earth**

http://www.cnh-lcms.org/uploads/hands_earth_many2_280x240.JPG

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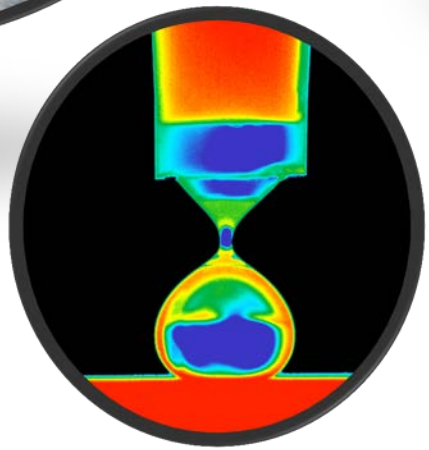
BROAD BASE OF ACTIVITIES

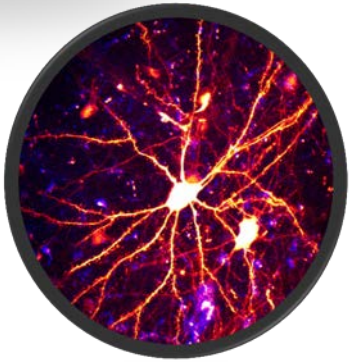
Over 75% of the community is:

Civil/Environmental Engineering, 14%

Chemical Engineering, 24%



Mechanical Engineering, 22%



Bioengineering/Biomed Engineering, 16%

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CBET ORGANIZATIONAL CHART

Seventeen programs across four clusters

Updated September 2014

Division Director
JoAnn Lighty

Deputy Division Director
Susan Kemnitzer

Chemical and Biochemical Systems

1401 - Catalysis and Biocatalysis
George Antos

1417 – Chemical and Biological Separations
Rose Wesson

1403 – Process and Reaction Engineering
Maria Burka

Bioengineering and Engineering Healthcare

1491 - Biotechnology and Biochemical Engineering
Friedrich Srienc

5345 - Biomedical Engineering
Thanassis Sambanis

7236 Biophotonics
Leon Esterowitz

7909 Nano-Biosensing
Rajakkannu Mutharasan

5342 – General and Age Related Disabilities Engineering
Alex Leonessa

Environmental Engineering and Sustainability

7644 - Energy for Sustainability
Gregory Rorrer

1440 -Environmental Engineering
William Cooper

1179 -Environmental Health & Safety of Nanotech
Nora Savage

7643 – Environmental Sustainability
Bruce Hamilton

Transport, Thermal, and Fluid Phenomena

1407 – Combustion and Fire Systems
Ruey-Hung Chen

1443 Fluid Dynamics
Dimitrios Papavassiliou

1414 - Interfacial Processes and Thermodynamics

1415 - Particulate and Multiphase Processes
William Olbricht

1406 - Thermal Transport Processes
Pending
(Ruey Chen as Contact)

STRATEGIC VISION AS DIVISION DIRECTOR

- Lead in strategic and emerging research areas
- Develop/support partnerships within NSF and other Federal Agencies
- Continue to support young investigators
- Keep programs focused
  - Ensure there are funds for high risk & gaps

STRATEGIC VISION AS DIVISION DIRECTOR

- **Lead in strategic and merging research areas**
  - Advanced Biomanufacturing
  - BRAIN
  - Food, Water, Energy
  - Emerging areas

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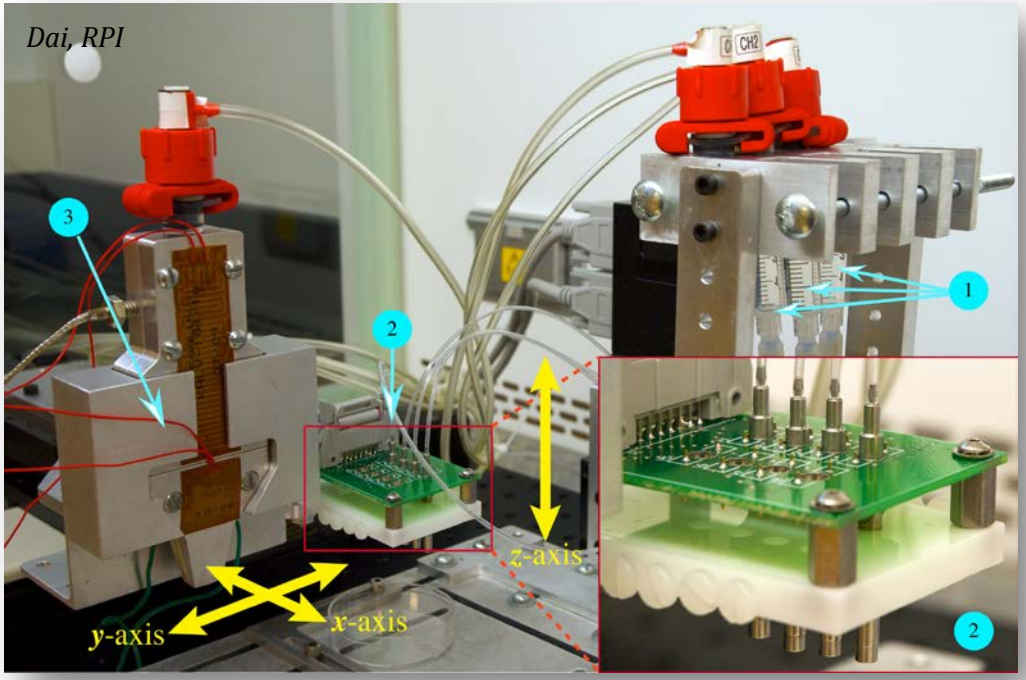
ADVANCED BIOMANUFACTURING

3-D Robotic Tissue Composer



Dai, Rensselaer

- **3-D structures of biomolecules, cells, scaffolds/matrices by bioprinting or other technologies for fundamental studies on cells, disease modeling and drug testing, and for tissue engineering and regenerative medicine applications**

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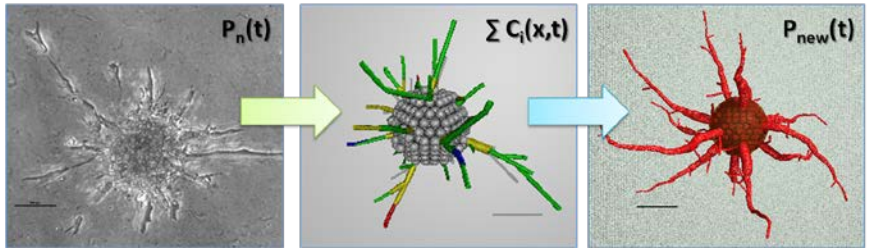
ADVANCED BIOMANUFACTURING

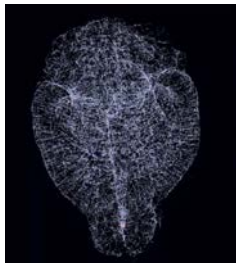
- **Fundamental studies of cell-cell, cell-matrix interactions, self-assembly, stereochemistry/chirality**
- **Stem cell engineering and biomanufacturing, cell reprogramming technologies.**



Step 1. Predict cell behavior patterns that gave rise to a given capillary phenotype

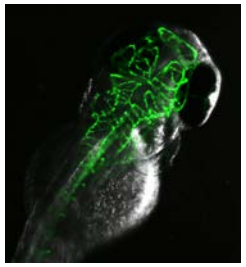
Step 2. Design a capillary structure based on predicted cell behavior patterns

Integration of Tissue Engineering & Systems Biology

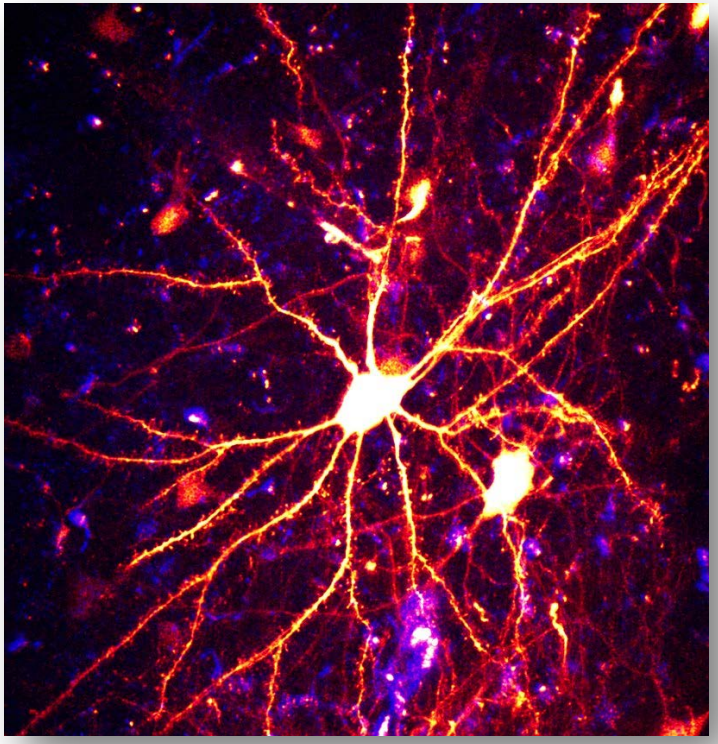


Computational Models Applied to In Vivo Brain Vascular Growth

Qutub, Rice Univ.



Optogenetics



Daliparthi and Roberts, UT Southwestern Medical Center

- **Technologies and tools to interrogate and monitor neuron activity at high spatiotemporal resolution**
- **New theories and computational models to integrate neuroscience data across different scales and levels**

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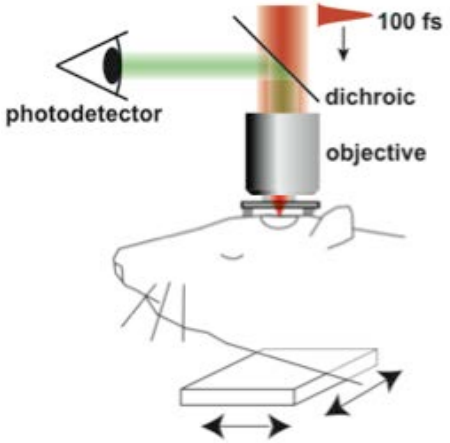
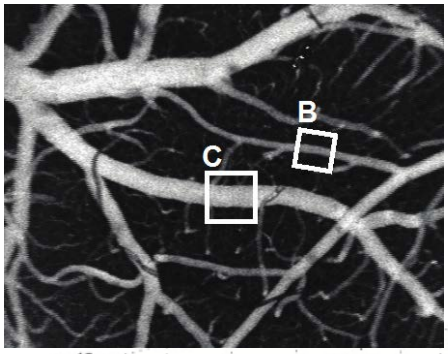
BRAIN

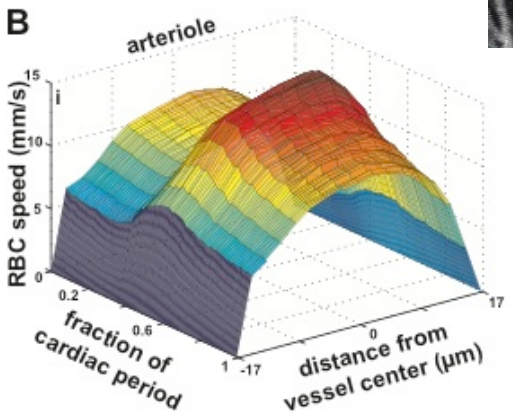
- **New experimental methodologies and computational approaches to**
  - **investigate human brain structure and function**
  - **repair and renew deteriorated, damaged, or diseased neurons and neural circuits.**

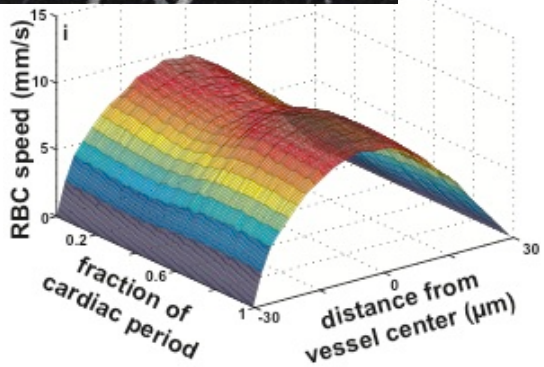


C. Xu and C. Schaffer, Cornell

2-Photon Microscopy for Brain Blood Flow Imaging







Integrative Strategies for Understanding Neural and Cognitive Systems (NSF-NCS)

PROGRAM SOLICITATION

NSF 14-611

National Science Foundation
Directorate for Computer & Information Science & Engineering
Directorate for Education & Human Resources
Directorate for Engineering
Directorate for Social, Behavioral & Economic Sciences
Letter of Intent Due Date(s) ***(required)*** (due by 5 p.m. proposer's local time)**:** December 10, 2014
INTEGRATIVE FOUNDATIONS
Full Proposal Deadline(s) (due by 5 p.m. proposer's local time): January 26, 2015

Research themes:
1. Neuroengineering and Brain-Inspired Concepts and Designs
2. Individuality and Variation

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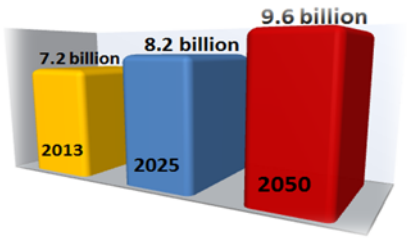
FOOD/WATER/ENERGY FY2015

WORLD'S POPULATION BOOMS

>9 BILLION by 2050



Larger, more urban and richer population

Food production will need to increase ~60%

2010 2050

FOOD

Water demand will increase ~30%

2010 2050

WATER

Image credit: http://www.aquate.com

Energy production will need to increase ~50%

2010 2050

ENERGY

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FOOD/WATER/ENERGY FY2015

Image credit: http://www.aquate.com

This is a dynamic, coupled system:

- 3% of US electricity is used to pump, treat, & transport water
  - This could account for 90% of the energy bill on some farms
- 50% of water withdrawals in the US are for thermoelectric power plant cooling
- 30% of water withdrawals in the US are for irrigating crops
- 10% of the US energy budget is associated with food production, processing, distribution, etc.

CBET is developing a strategy to look at the fundamental research questions, building upon our existing:

- knowledge of water/energy and energy/water systems
- research community through the Water, Sustainability, and Climate (WSC) projects and others
- partnerships with DOE, USDA

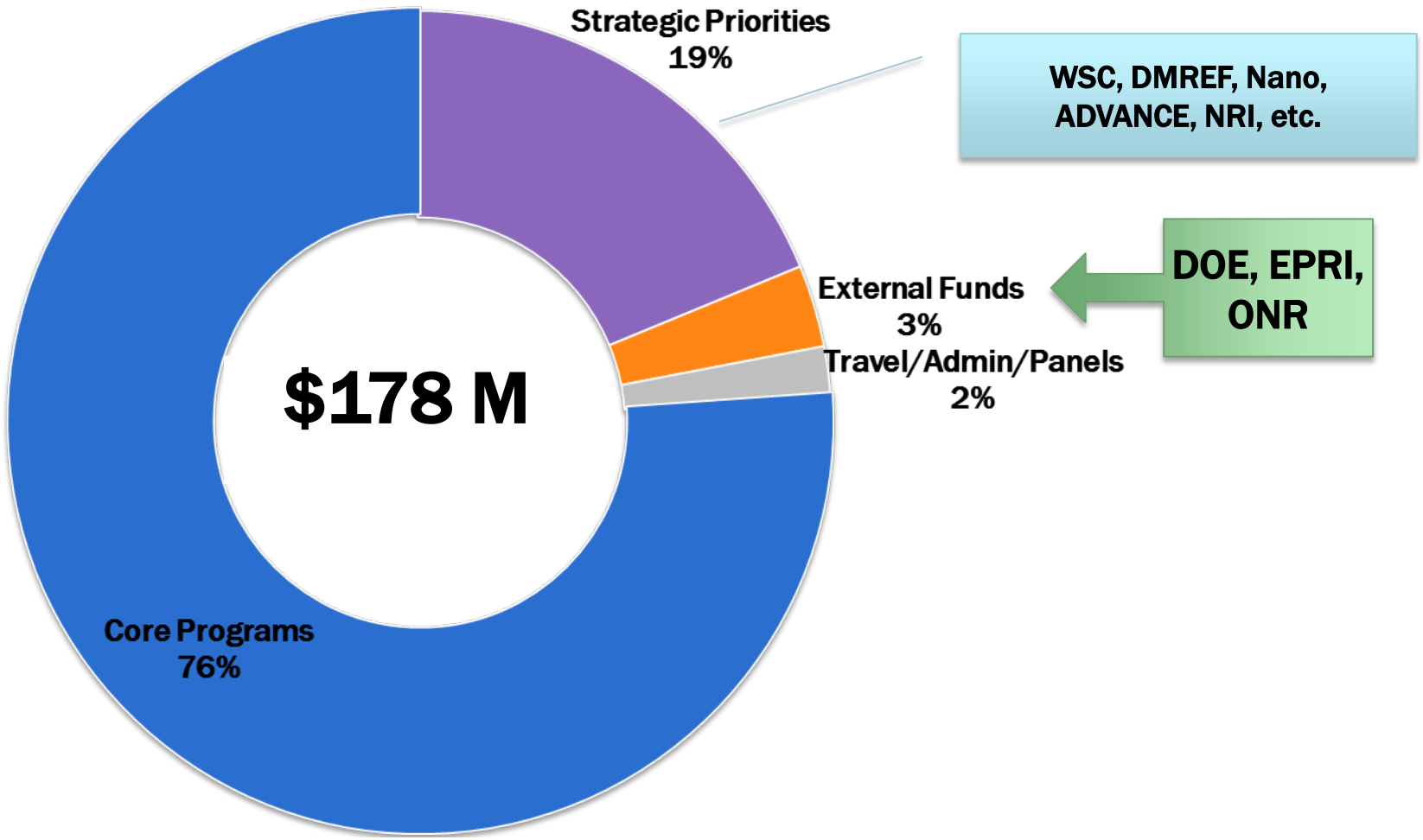
EMERGING TOPICS

- **Bio-inspired fluid dynamics and bio-flows**
- **Process Intensification**
- **Revolutionary materials, including catalysts**

STRATEGIC VISION AS DIVISION DIRECTOR

- Lead in strategic and emerging research areas
- **Develop/support partnerships within NSF and other Federal Agencies**
  - DMREF case study
  - EPRI case study

OVERALL BUDGET INCLUDING "EXTERNAL" FUNDS - 2014



OVERALL BUDGET INCLUDING "EXTERNAL" FUNDS - 2014

Case Study

Designing Materials to Revolutionize And Engineer our Future (DMREF)

- Fostering collaborations within NSF to benefit the CBET research community and contribute to new knowledge

PD	Project Title	CBET	CMMI	CHEM	DMR	TOTAL
CBET	Synthesis of Colloidal Crystals Guided by Particle-Based Theory and Simulation		$800K			$800K
CBET	Thin Film Biofabrication for Integrated Bio-electronics	$1,007K				$1,007K
CBET	Computationally Guided Design of Multicomponent Materials for Electrocatalytic Cascade Reactions	$796K		$796K		$1,592K
CBET	Design of Multifunctional Catalytic Interfaces from First Principles	$700K		$700K		$1,400K
DMR	Design and Testing of Nanoalloy Catalysts in 3D Atomic Resolution	$300K		$250K	$650K	$1,100K
	Total for FY14	$2,803K	$800K	$1,746K	$650K	$5,999K

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OVERALL BUDGET INCLUDING "EXTERNAL" FUNDS

Case Study

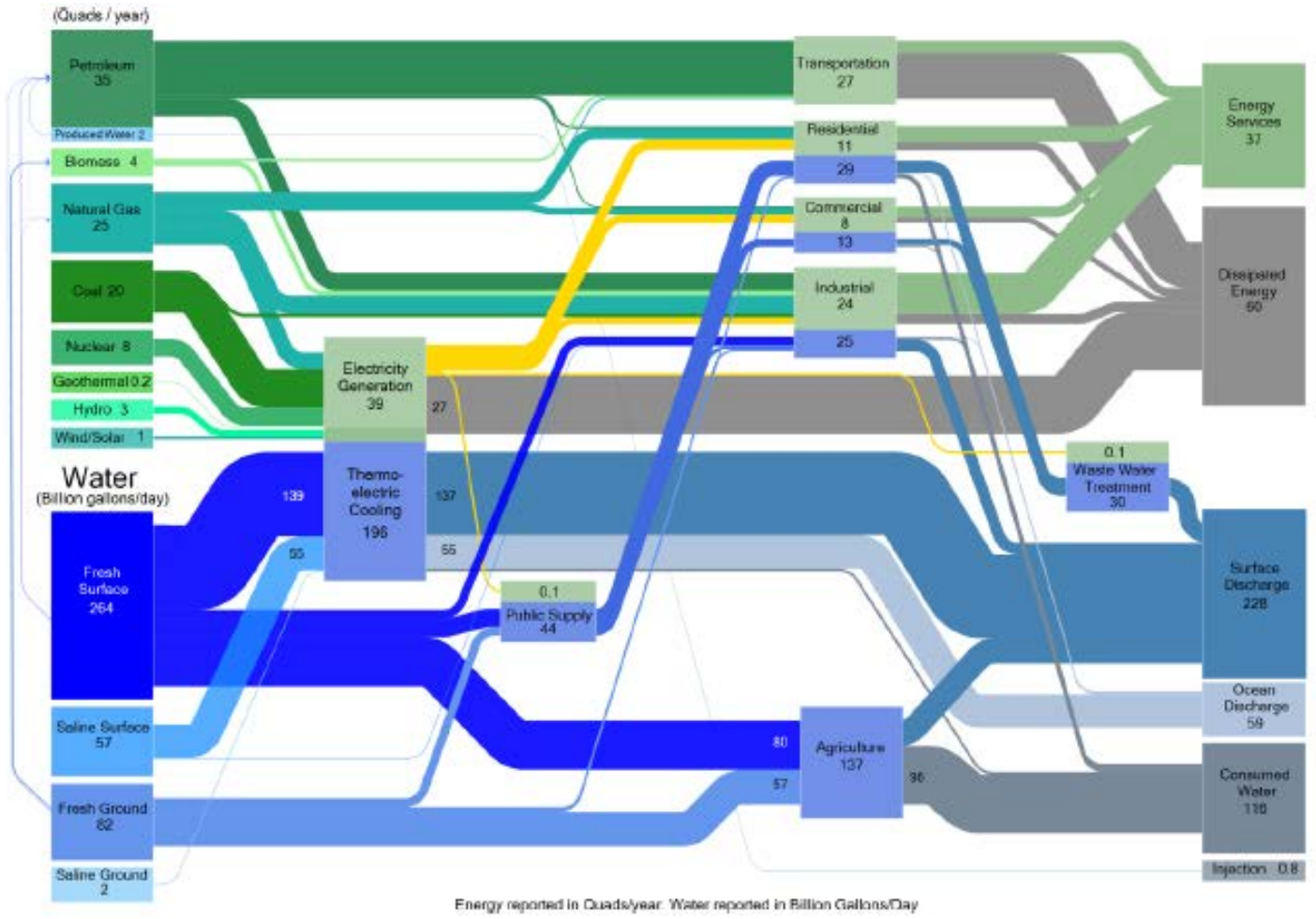

Figure ES.1. Hybrid Sankey diagram of 2011 U.S. interconnected water and energy flows.
Source: See Appendix A for data sources and calculations

The Water-Energy Nexus: Challenges and Opportunities
June 2014

DOE Report

National Science Foundation

OVERALL BUDGET INCLUDING "EXTERNAL" FUNDS

Case Study

NSF Catalyzing A Research Topic:

What is a new way to think of cooling for power plants?

- **Requires fundamental basic research and real-world knowledge**

NSF/EPRI Funding

- **4 NSF / 3 EPRI / 3 joint**
- **3 years, $3M NSF/$3M EPRI**

Now an ARPA-E topic in the latest solicitation for $30 million

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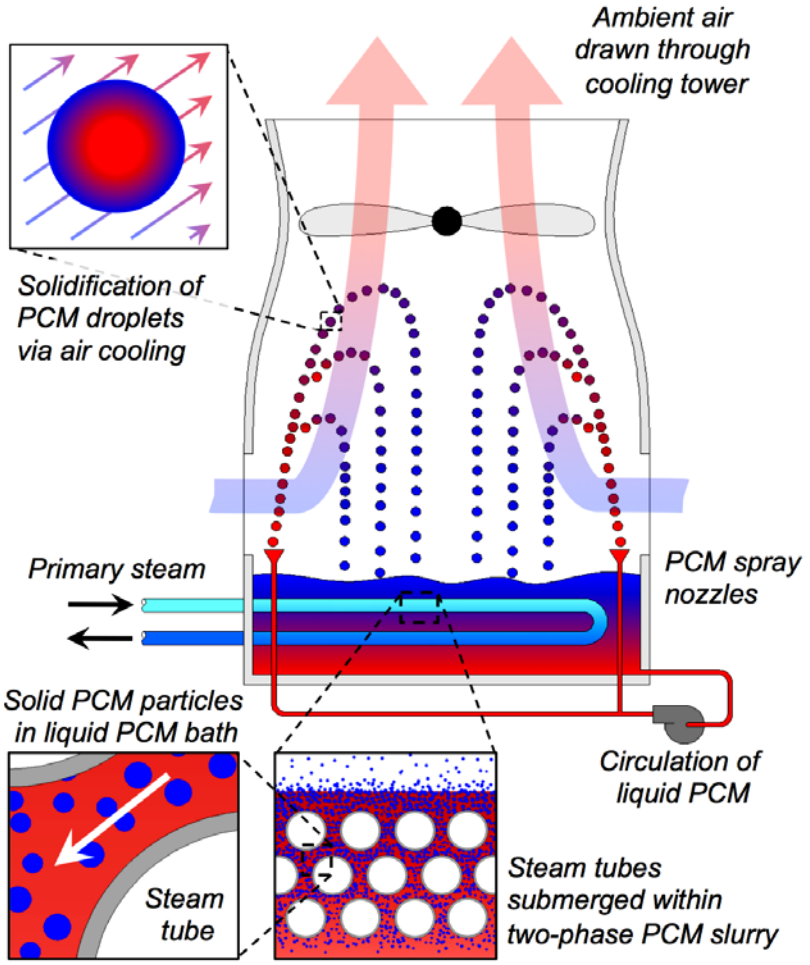
OVERALL BUDGET INCLUDING "EXTERNAL" FUNDS

Case Study

- **Broad themes:**
  - **Heat Pipes/Thermo-Siphons**
  - **Alternative Working Fluids/Materials**
  - **Innovations in Dry Air Cooling**
    - **Air Side**
    - **Steam Side**

Project Scope

- **Develop air-cooled PCM spray-freezing technology with enhanced thermal and fluidic performance.**
- **Perform technical & economic feasibility evaluation including environmental impact study.**
- **Perform testing and characterization of components and scaled prototype.**



Indirect Dry Cooling Towers with Phase-Change Materials as Intermediate Coolants, Drexel/ACT/Worley Parsons

STRATEGIC VISION AS DIVISION DIRECTOR

- Lead in strategic and emerging research areas
- Develop/support partnerships within NSF and other Federal Agencies
- **Continue to support young investigators**
  - CAREER Awards

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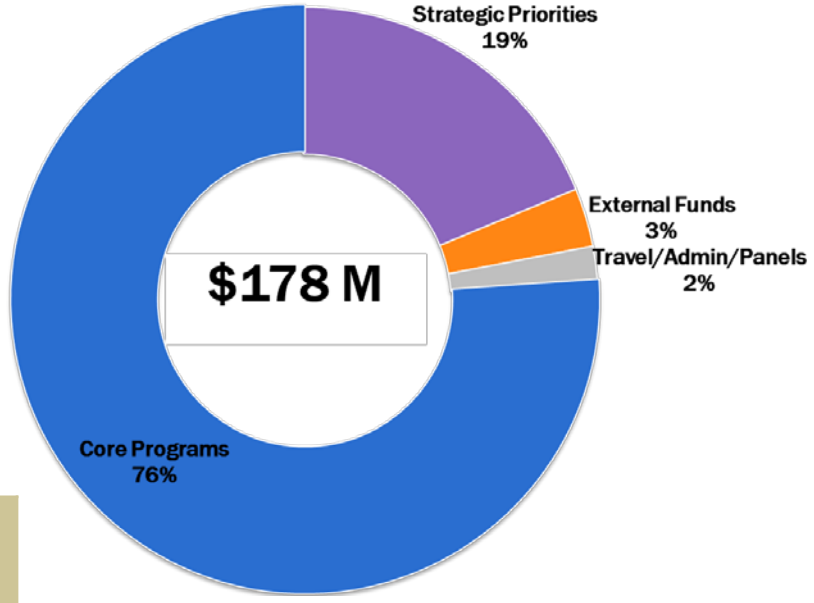
CAREER AWARDS

CAREER Awards are approximately 13.5% of the CBET budget

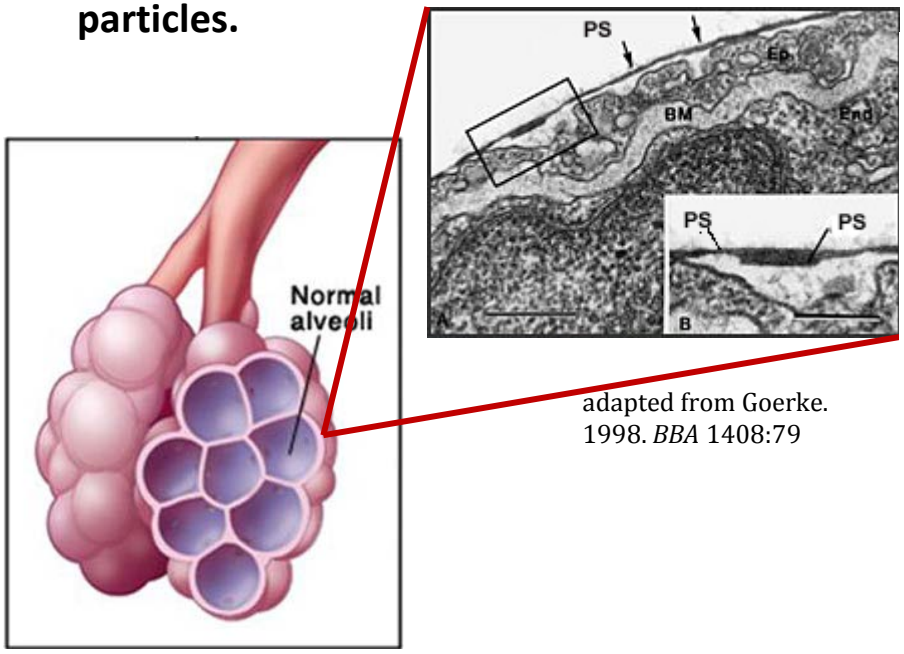


	# proposal	# awards
CAREER	374	65
Unsolic & Solicitations	3353	532

CAREER PROPOSALS

Zuo, University of HI, Biophysical Mechanisms of Pulmonary Surfactant and its Interactions with Therapeutic Agents

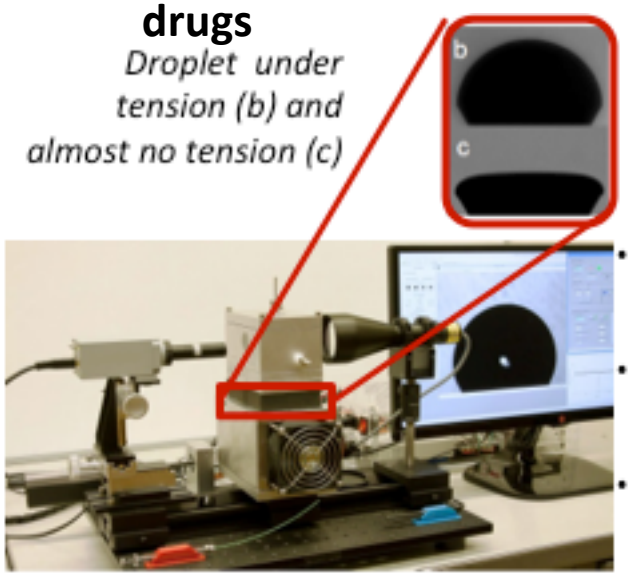
PS is a phospholipid-protein complex that lines a thin film at the air-water interface of the lung and plays a dual role of surface tension reduction and host defense against inhaled pathogens and particles.



adapted from Goerke. 1998. *BBA* 1408:79

- ***In vitro*** **simulation and measurements (CDS) of PS films**
- **Determine surface free energies**
- **MD simulation of PS films with drugs**

Droplet under tension (b) and almost no tension (c)



- **Rapid measurements**
- **All surfactant concentrations**
- **Integrated hardware/ software**

Constrained Drop Surfactometer (CDS)*

**BioSurface Instruments startup company: installed in 3 countries*

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CAREER PROPOSALS

Ewoldt, Illinois Urbana-Champaign, Thixotropic Yield Stress Fluids – Splashing, Spreading

Thixotropic fluids are viscous under static conditions but flow over time when stressed. They then take a fixed time to return to a more viscous state. These fluids are not as well understood as compared to polymer melts and solutions.

Earth Clean, TetraKO

Exploring the phenomena that occur when droplets of thixotropic yield stress fluids impact on solids (smooth, dry, coated etc.). The goal is to enable the design of new soft materials with desirable properties.

STRATEGIC VISION AS DIVISION DIRECTOR

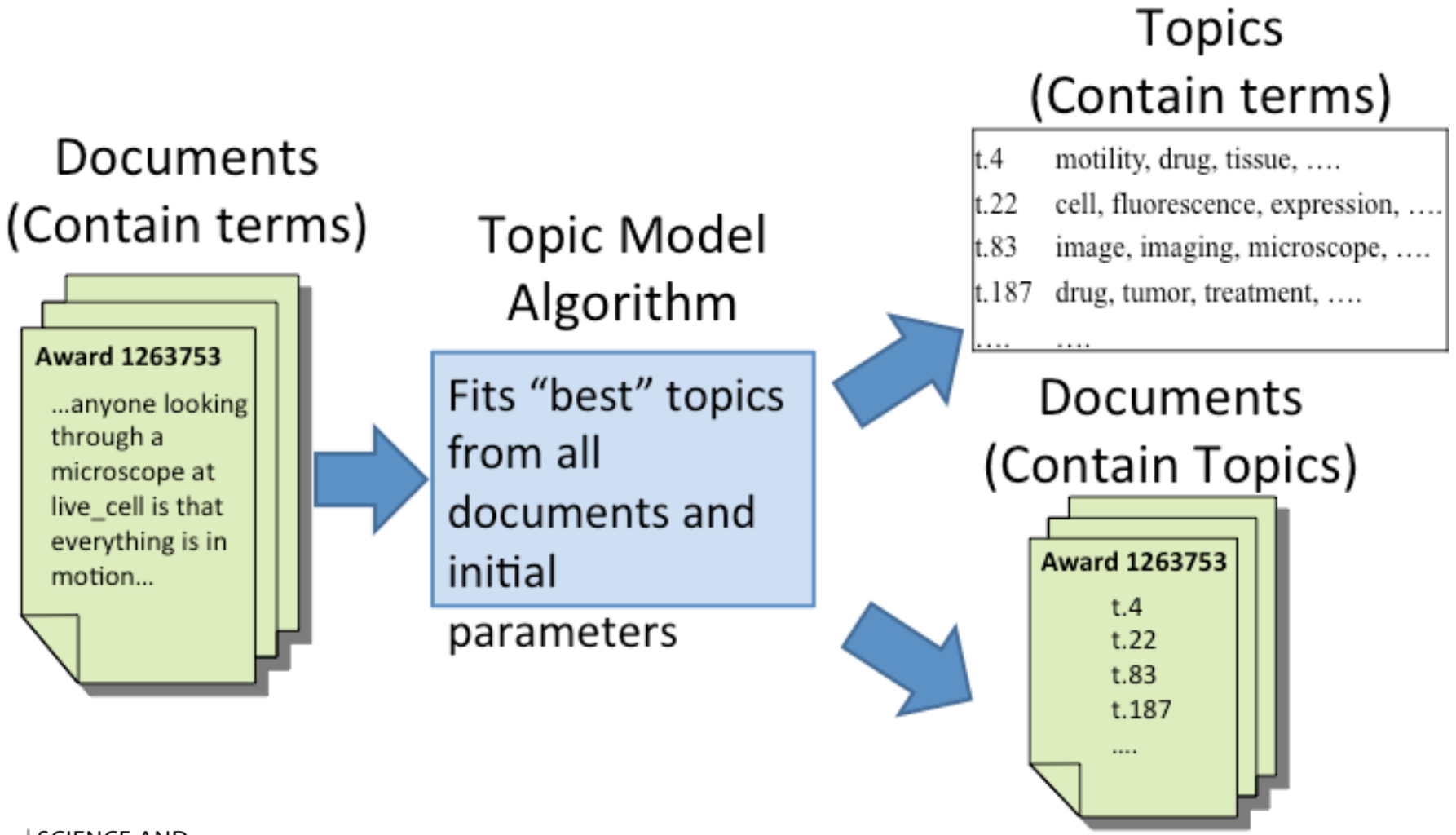
- Lead in strategic and emerging research areas
- Develop/support partnerships within NSF and other Federal Agencies
- Continue to support young investigators
- **Keep programs focused**
  - **Ensure there are funds for high risk & gaps**
    - **Portfolio analysis**

PORTFOLIO ANALYSIS

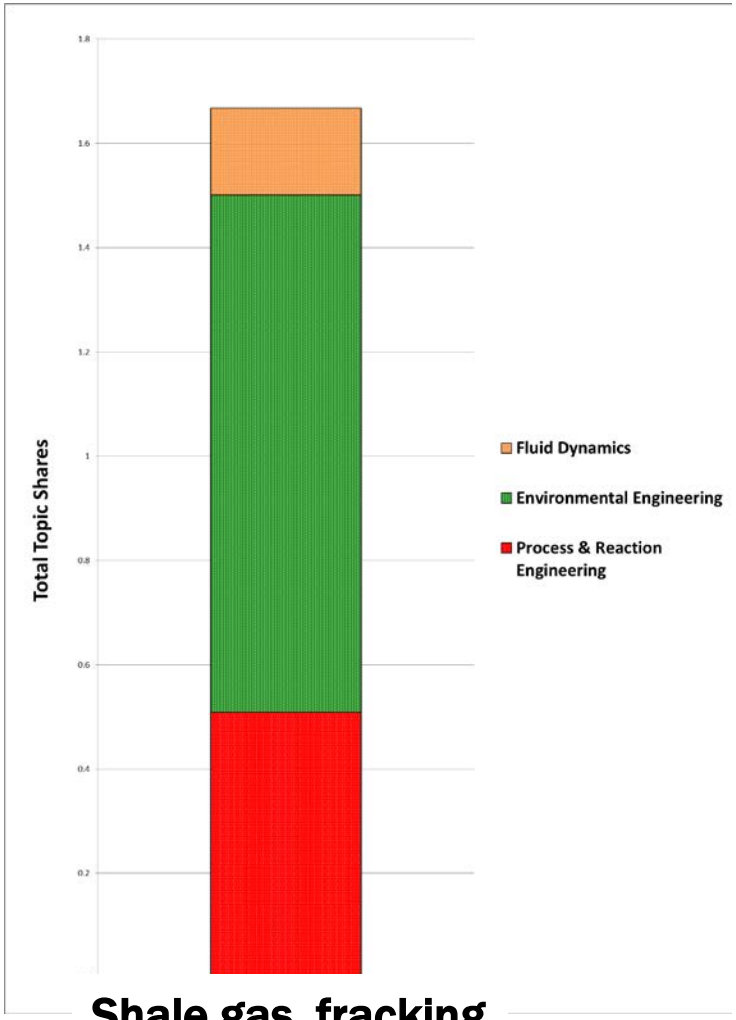
Steps

1. Communicate with the community
   - national meetings, seminars
2. Change program descriptions
   - simplify format
   - change areas where needed
3. Perform topic analysis
   - check clusters
   - understanding overlaps

TOPIC ANALYSIS



CBET TOPIC EXAMPLE



Shale gas, fracking

Example:
The topic “shale gas” appears within 3 programs. The programs are in 3 different clusters

- What is the overlap?
- What are potential gaps which might integrate the research?

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- Continue to support young investigators
- Keep programs focused
  - Ensure there are funds for high risk & gaps

- Questions?