# Update on Office of Emerging Frontiers in Research and Innovation (EFRI)

**Sohi Rastegar**

Director

Engineering Advisory Committee, Fall Meeting

October 24, 2007

# Emerging Frontiers in Research and Innovation

**Office Director**
**Sohi Rastegar**

**FY 07: Auto-Reconfigurable Engineered Systems (ARES)**

COORDINATORS:
Scott Midkiff, ECCS
Abhi Deshmukh*,CMMI

TEAM MEMBERS:
Kishan Baheti, ECCS
Mario Rotea*, CMMI
Maria Burka, CBET
Bruce Hamilton, CBET
Stephen Nash, CMMI
Glen Larsen, IIP

**FY 07: Cellular and Biomolecular Engineering (CBE)**

COORDINATORS:
Fred Heineken, CBET
Jimmy Hsia*, CMMI

TEAM MEMBERS:
Lenore Clesceri, CBET
Lynn Preston, EEC
Robert Wellek, CBET

**FY 08: Cognitive Optimization (COPN)**

COORDINATORS:
Paul Werbos, ECCS
Semahat Demir, CBET

TEAM MEMBERS:
Fred Heineken, CBET
Eduardo Misawa, CMMI
Scott Midkiff, ECCS
Stephen Nash, CMMI
Lynn Preston, EEC
Kenneth Whang, CISE

**FY 08: Resilient and Sustainable Infrastructures (RESIN)**

COORDINATORS:
Joy Pauschke, CMMI
William Schultz, CMMI
Matthew Realff*, CMMI

TEAM MEMBERS:
Richard Fragaszy, CMMI
Bruce Hamilton, CBET
Barbara Kenny, EEC
Dagmar Niebur, ECCS
Dennis Wenger, CMMI

**ENG Programs & Divisions Define Topics &Teams**

* Former PD / IPA

# Office of Emerging Frontiers in Research and Innovation

## *~Working Vision Statement~*

**All NSF ENG Programs support research at the frontiers of research and innovation.**

**EFRI Office provides opportunities in interdisciplinary areas at the *emerging* frontiers of research and innovation that (a) are transformative, (b) address national needs/grand challenges, and (c) will make ENG unrivaled in its global leadership.**

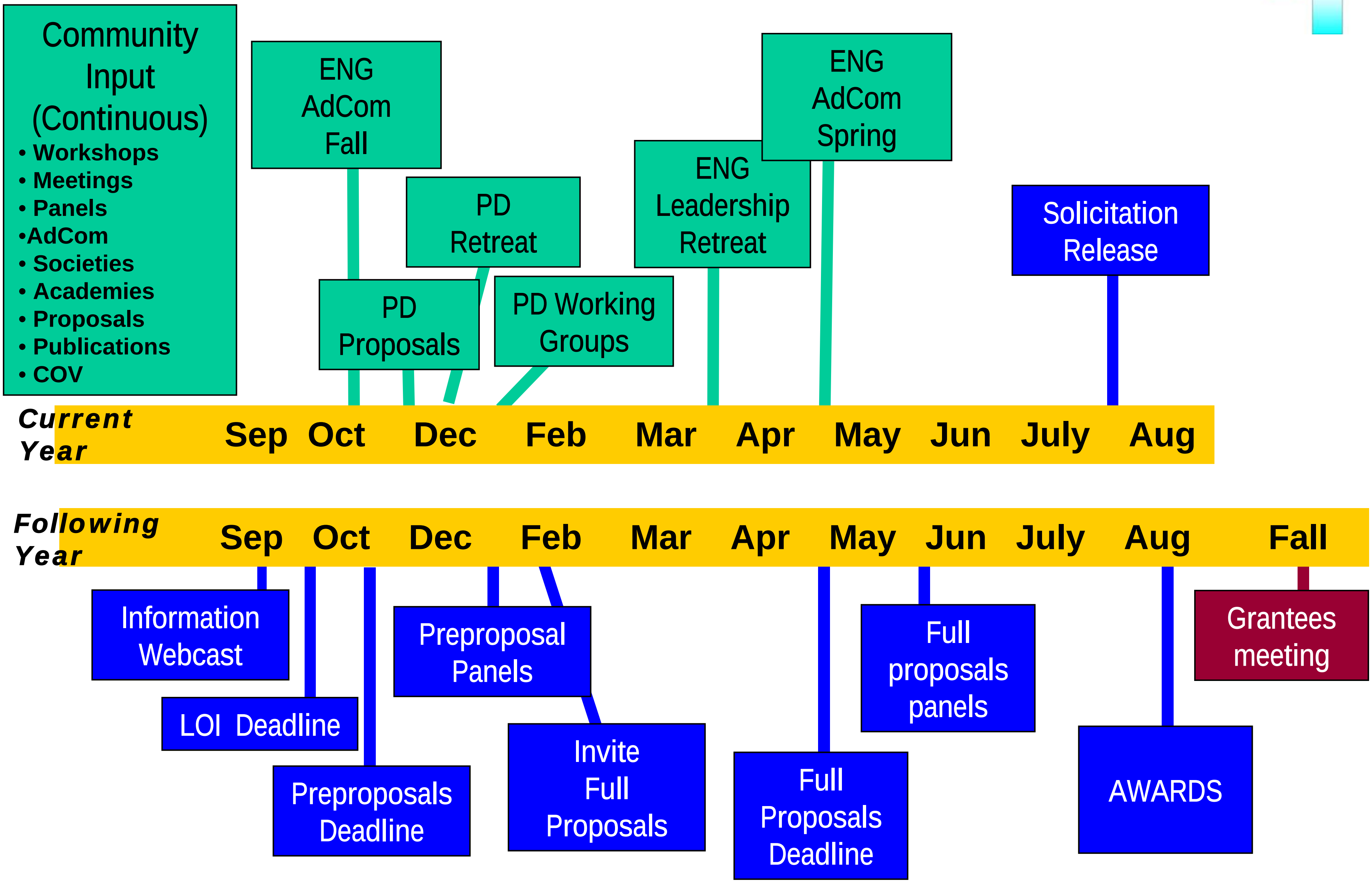
# EFRI- “One Slide Description”

- Established on October 1, 2006, EFRI supports higher risk, higher payoff opportunities leading to:
  - new research areas for NSF, ENG, and other agencies
  - new industries/capabilities resulting in a leadership position
  - significant progress on advancing a “grand challenge”
- Successful topics would likely require:
  - small- to medium-sized interdisciplinary teams
  - the necessary time to demonstrate substantial progress and evidence for follow-on funding through other established mechanisms
- The current investment for EFRI totals $25 million for 4-year awards at $500k per year.

# EFRI Criteria For Topic Selection

- **TRANSFORMATIVE**- Does the proposed topic represent an opportunity for a significant leap or paradigm shift in a research area, or have the potential to create a new research area?
- **NATIONAL NEED/GRAND CHALLENGE**- Is there potential for making significant progress on a current national need or grand challenge?
- **BEYOND ONE DIVISION**- Is the financial and research scope beyond the capabilities of one division?
- **COMMUNITY RESPONSE**- Is the community able to organize and effectively respond?
- **ENG LEADERSHIP**- Are partnerships proposed, and if so, does NSF/ENG have a lead role?

# EFRI Process and Timeline



# Post-EFRI Support
# Possible Routes

- Possible routes
  - New Program in a Division
  - Change/Restructure an existing Program
  - New Program at interface of Divisions
  - Centers Programs (ERC, STC)

# Two Topic Areas Selected for FY 07
## Program Solicitation NSF 06-596

- **AUTONOMOUSLY RECONFIGURABLE ENGINEERED SYSTEMS ENABLED BY CYBERINFRASTRUCTURE (ARES-CI)**
  - ***Key idea:*** *Autonomously reconfigurable engineered systems robust to unexpected/unplanned events*

- **CELLULAR AND BIOMOLECULAR ENGINEERING (CBE):**
  - ***Key idea:*** *Comprehensive modeling, measurement, and control of coupled biological, chemical, electrical, mechanical, and thermal processes at the cellular and biomolecular level under multiple stimuli.*

# FY 07 Awards
## (NSF 06-596)

- **12 Awards made: 5 in ARES and 7 in CBE.**
- **Total of $23.8M**
- **54 PI and co-PIs, 23 Institutions**
- **8 woman investigators (14.8%);**
  **Four led by women (33%)**
- **4 underrepresented investigators (7.4%),**
  **1 led by underrepresented minority (8.3%)**

Award Announcement url:

http://www.nsf.gov/eng/efri/fy07awards.jsp

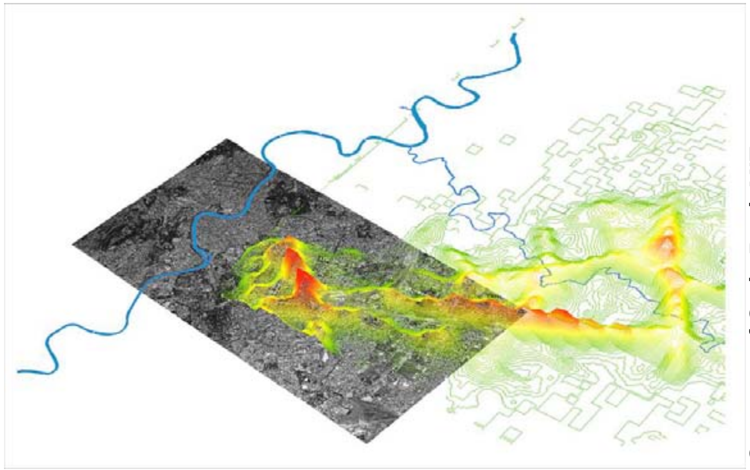
# Autonomously Reconfigurable Engineered Systems (ARES)

## *Systems that Modify Themselves*

## Example Awards

# Foundations for Cyber-Physical Systems

**Cyber-physical systems combine computational systems with physical and engineered systems and can include bionics, automated manufacturing, or systems for monitoring critical infrastructure. This project aims to address the key challenge of realizing a foundational, mathematical understanding of the interaction between the cyber and the physical in order to both configure a system to respond to unexpected events, and also to quantify the system's limits in responding.**



Courtesy of Carlo Ratti, MIT

**Rome in real-time: Combining maps (gray square) and density of cell-phone usage (shown as red and yellow 3-D peaks) follows activity of the city of Rome, and is a basis for understanding how a complex system could best respond to unplanned events.**

**Led by Munther A. Dahleh, Daron Acemoglu, Carlo F. Ratti (MIT), and John Doyle (CalTech) and titled, "Foundations for Reconfigurable and Autonomous Cyber-Physical Systems: Cyber-Cities and Cyber-Universities" (grant #0735956).**

## Robots that Think and Build

Courtesy of Daniela Rus, MIT

**This project offers a radical approach to creating autonomous reconfigurability based on the team's work with small robots. Proposed is a new kind of robotic system for construction in which available materials and the final structure are not clearly known. The robots sense changes and variables, diagnose them, adapt and, together, successfully build themselves into a structure best suited for its environment. Such a system could be a tool not only for future construction challenges, but also for optimizing current construction practices.**

**Led by Daniela Rus (MIT), along with Eric Klavins (University of Washington), Hod Lipson (Cornell University), and Mark Yim (University of Pennsylvania) and titled, "Controlling the Autonomously Reconfiguring Factory" (grant #0735953).**

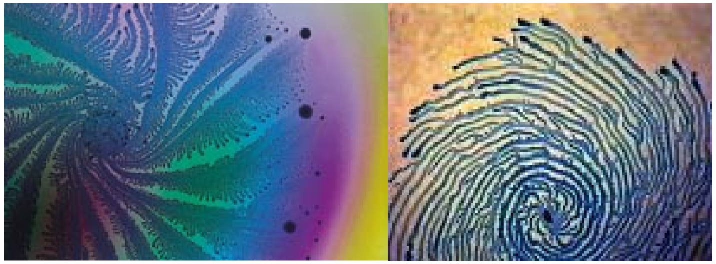
# Cellular and Biomolecular Engineering (CBE)

***How Cells Work: Uniting Engineering and Biology***

**Example Awards**

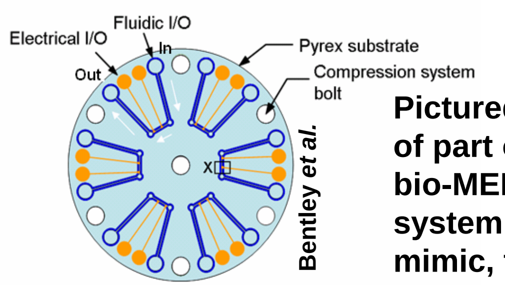
# Using Engineering to Understand How Bacteria Communicate

**The next generation of antimicrobial development will interrupt the cell-to-cell signaling among bacteria that allows them to function as resistive communities. A first step in creating microdevices that can communicate with bacterial signaling is to design microelectrical-mechanical versions of the components of a bacterial cell-to-cell signaling system, and to use electric signals to steer the designed biosynthetic community toward a specific task, such as forming a biofilm.**



David Andelman, www.physics.tau.ac.il

**Quorum sensing, bacterial cell-to-cell signaling, can affect bacterial growth, as it does in the spiral growth pattern of *Paenibacillus vortex*.**



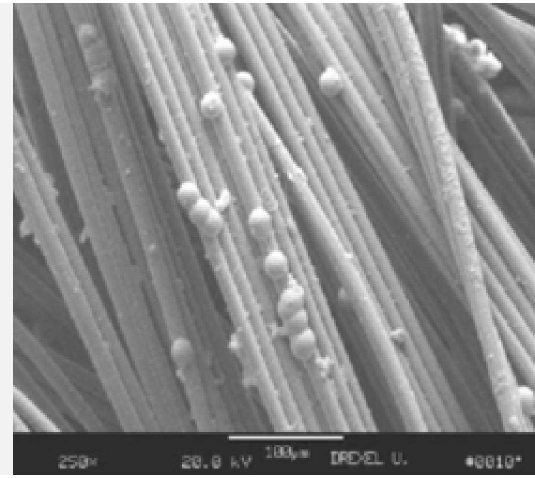

Bentley *et al.*

**Pictured is an illustration of part of the proposed bio-MEMS device. Can a system of such devices mimic, translate and intercept the messages bacteria use?**

**Led by William E. Bentley (University of Maryland, College Park), along with Reza Ghodssi (University of Maryland, College Park), Gregory F. Payne (University of Maryland Biotechnology Institute), Gary W. Rubloff (University of Maryland, College Park), and titled, "Biofunctionalized Devices: On Chip Signaling and 'Rewiring' Bacterial Cell-Cell Communication" (grant #0735987).**

# Regenerating Complex Tissues from the Nanoscale

**One of the body's most complex tissues is the anterior cruciate ligament, a stabilizing knee ligament that rarely heals naturally when torn. This team aims to mimic a biological system and reconstruct this tissue with precision from the nanoscale up. To maximize precision and control over the way the tissue takes shape, the researchers will combine advances in polymer chemistry for synthesizing nanoscale fibers, in using electric fields to group nanoscale fibers, and in using ion beams to control surface chemistry at the nanoscale.**




C. Laurencin, working with Edward A. Botchwey, Yusuf Khan, Lakshmi Nair, and Nathan S. Swami

**This scanning electron microscope image shows the micro-scale architecture of a synthetic anterior cruciate ligament tissue, with additional cells growing on its surface. The team aims to realize similar precision at the nano-scale.**

**Led by Cato C. Laurencin (University of Virginia), along with Edward A. Botchwey, Yusef Khan, Lakshmi Nair, and Nathan S. Swami (University of Virginia), and titled, "Biological, Chemical, and Mechanical Surface Cues for Cell Migration, Proliferation, and Differentiation: An Integrated Approach to Regeneration of New Tissues" (grant #0736002).**

## FY08 EFRI Cycle

# Topic Proposals Considered at ENG Leadership Retreat

March 2007

- Resilient and Sustainable Infrastructures
- Hydrogen-based Energy Systems
- Healthcare Systems Engineering
- Cognitive Optimization and Prediction Through Reverse Engineering

# EFRI 2008 Topics (NSF 07-579)

1. **COGNITIVE OPTIMIZATION AND PREDICTION: FROM NEURAL SYSTEMS TO NEUROTECHNOLOGY (COPN)**
   - **Key idea**: *Understanding subsymbolic intelligence can lead to development of new designs and algorithms for optimal decision making and prediction in engineered systems.*

2. **RESILIENT AND SUSTAINABLE INFRASTRUCTURES (RESIN)**
   - **Key idea:** *Build, renew, expand, monitor, and control critical interdependent infrastructures to be both resilient and sustainable.*

# COGNITIVE OPTIMIZATION AND PREDICTION: FROM NEURAL SYSTEMS TO NEUROTECHNOLOGY (COPN)

- **Key idea**: ***Understanding subsymbolic intelligence can lead to development of new designs and algorithms for optimal decision making and prediction in engineered systems.***

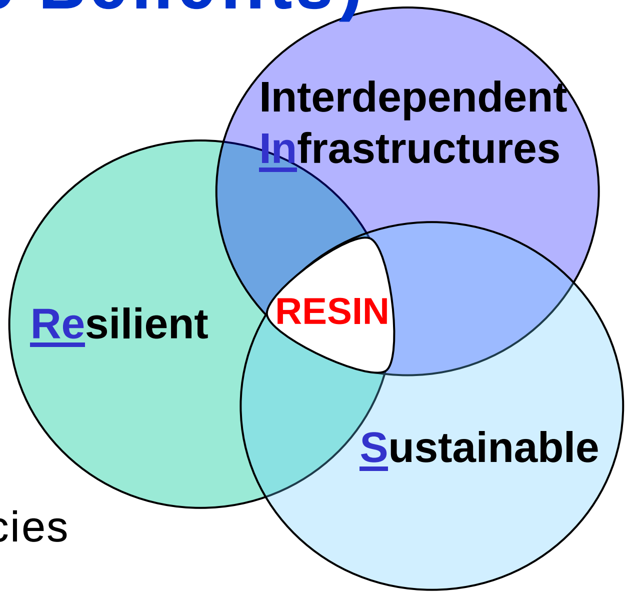
## (Expected Transformative Benefits)

- Put science firmly on the path to a truly functional, unified mathematical and systems understanding of intelligence in the brain (analogous to search for unified models in physics);
- New designs for optimal decision-making which can handle complexity beyond the capacity of today's methods, as required for truly optimal rational management of complex engineered systems;
- Improved performance in specified simulation testbeds; and
- Development of new and more general ways to harness the potential power of massively parallel "supercomputers on a chip."

# Resilient and Sustainable Infrastructures (RESIN)

**Key idea:** *Build, renew, expand, monitor, and control critical interdependent infrastructures to be both resilient and sustainable.*

## (Expected Transformative Benefits)




- **Fundamental principles** to characterize and quantify both resiliency and sustainability across many sets of interdependent critical infrastructure systems;
- **Methodologies** to analyze and forecast how infrastructures grow, interact, renew, and ultimately function as interdependent resilient and sustainable systems;
- **Theoretical foundations** for how interdependencies among infrastructures either provide or detract from both resiliency and sustainability;
- **Performance metrics** for interdependency vulnerabilities for shorter term, disruptive events and longer term sustainability; and
- **Technologies** to enable interdependent physical infrastructures to be both resilient and sustainable.

# Important Dates
# EFRI 2008 (NSF 07-579)

| | |
|---|---|
| • Sep 5, 2007 | Information Webcast<br>Over 200 registered viewers<br>85 Universities, 35 States |
| • Sep 25, 2007 | Letters of Intent Due (<u>required</u>) |
| • Oct 26, 2007 | Preliminary Proposals Deadline |
| • Early February 2008 | Invitations to submit full proposals. |
| • Apr 30, 2008 | Full Proposals Deadline<br>(by invitation only) |
| • May/June 2008 | Review of Full Proposals |
| • By September 2008 | Make Awards |
| • Fall 2008 | Grantee Meeting |

# Award Size and Information

- Team Proposals Only:
  - 3 or more PIs
  - 3 or more disciplines
  - Lead PI from an Engineering Department
- Up to 4 years in duration
- Up to $500K/year (direct plus indirect cost)
- $22M in FY 2008 for entire competition, pending the availability of funds

# Discussion

- **REPEAT A TOPIC?** Some suggest that some topics take time for the community to adequately prepare transformative teams and proposals. Should we repeat topics for more than one year (e.g. two consecutive years)? What are pros and cons?

- **OPEN CATEGORY?** Should we have an "open" category where the topic is not pre-specified?

- **BROADER COMMUNITY INPUT?** PDs are the kernel of integration and development of all programs at NSF and the closest to the community. EFRI has developed a mechanism to engage all ENG PDs in identifying, conceptualizing, and developing the emerging multidisciplinary topic areas in a new way with input from the community through a variety of mechanisms including the Advisory Committee, workshops, reports, etc. Do you have any suggestions on improving this mechanism particularly in terms of receiving more EFRI inspired input from the broader engineering community?

# Key website Address

- **EFRI Website for up-to-date information on EFRI**

**www.nsf.gov/eng/efri**