Civil and Mechanical Systems (CMS) Programs at the NATIONAL SCIENCE FOUNDATION

Shih-Chi Liu, Program Director
Sensor Technology for Civil and Mechanical Systems
Directorate for Engineering
FY 06 Budget

Assistant Director
Richard Buckius

Senior Advisor Nanotechnology
Mike Roco

Bioengineering & Environmental Systems
BES
Bruce Hamilton
($46.53M)

Civil & Mechanical Systems
CMS
Adnan Akay
($80.28M)

Chemical & Transport Systems
CTS
Geoffrey Prentice, Acting
($63.06M)

Office of Industrial Innovation
OII (SBIR/STTR)
Kesh Narayanan
($102.87M)

Design & Manufacturing Innovation
DMI
Warren DeVries
($58.25M)

Electrical & Communications Systems
ECS
Usha Varshney
($64.95M)

Engineering Education & Centers
EEC
Gary Gabriele
($134.81M)

NSF: $5,581.17M
ENG: $575.38M
Research Grant Funding Rate

- ENG Proposals
- ENG Awards
- ENG Funding Rate
- NSF Funding Rate

Proposals Submitted
Civil and Mechanical Systems (CMS)

Division Director
Adnan Akay

Engineered Materials and Mechanics
- Mechanics and Structure of Materials
  Ken Chong
- Materials Design and Surface Engineering
  Yip-Wah Chung
- Infrastructure Materials and Structural Mechanics
  Jorn Larsen-Basse
- Nano and Bio Mechanics of Materials
  K.Jimmy Hsia

Intelligent Civil and Mechanical Systems
- Information Technology and Infrastructure Systems
- Control Systems
  Mario Rotea
- Sensor Technologies for Civil and Mechanical Systems
  Shi-Chi Liu
- Dynamic Systems
  Eduardo Misawa

Infrastructure Systems and Hazard Mitigation
- Geotechnical and Geohazards Systems
  Richard Fragaszy
- Structural Systems and Hazard Mitigation of Structures
  Doug Foutch
- Infrastructure System Management and Hazard Response
  Dennis Wegner
- Network for Earthquake Engineering Simulation
  Joy Pauschke
- Nano and Bio Mechanics of Materials
  K.Jimmy Hsia
Intelligent Civil and Mechanical Systems

• **Research support for:**
  – *modeling* of structural dynamics, vibrations, acoustics, and kinematics relationships.
  – *sensing*, acquiring, imaging and transmitting information at all physical scales
  – *control* of civil and mechanical systems
  – *integration* of sensors, actuators, controllers, and power sources
  – smart materials, smart structures and control strategies for them.

• **Applications to**
  – mechatronic systems
  – from nan/micro systems to civil infrastructures such as bridges and buildings
Sensor Technologies for Civil and Mechanical Systems Program

• New

• Rapidly emerging importance

• Diverse fields: no uniquely identifiable community

• Transformation of engineering practices

• Extreme industrial and commercial values
Sensors and Sensor Networks (Sensors)

Program Solicitation

NSF 05-526
Replaces Document 03-512 & 04-522

National Science Foundation
Directorate for Engineering
Directorate for Geosciences
Office of Polar Programs
Sensors and Sensor Networks (NSF03-512, 04-522 & 05-526)

• NSF wide initiative started in 2003. --$45M

• FY 2004  
  – ~$39M

• FY 2005  
  – -$30M
## Sensors and Sensor Networks
### ENG Funding Profile ($K) FY2004

<table>
<thead>
<tr>
<th></th>
<th>ECS</th>
<th>BES</th>
<th>CMS</th>
<th>CTS</th>
<th>DMI</th>
<th>Total ENG</th>
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</thead>
<tbody>
<tr>
<td><strong>SIRG</strong></td>
<td>1,800</td>
<td>529</td>
<td>500</td>
<td>400</td>
<td>0</td>
<td>3,229</td>
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<tr>
<td><strong>SST</strong></td>
<td>2,455</td>
<td>2,382</td>
<td>2,520</td>
<td>1,732</td>
<td>2,815</td>
<td>11,904</td>
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<td><strong>SII</strong></td>
<td>1,745</td>
<td>2,208</td>
<td>2,040</td>
<td>2,342</td>
<td>1,817</td>
<td>9,521</td>
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<tr>
<td><strong>II Pre-solic.</strong></td>
<td>1,000</td>
<td>1,000</td>
<td>976</td>
<td>915</td>
<td>2,000</td>
<td>5,890</td>
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<tr>
<td><strong>Total</strong></td>
<td>7,000</td>
<td>6,119</td>
<td>6,035</td>
<td>5,388</td>
<td>6,002</td>
<td>30,544</td>
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</tbody>
</table>

$24,655K in ENG awards for proposals submitted directly to NSF 04-522 (13% for SIRG, 48% for SST and 39% for SII)
Self-Monitoring Structural Composite Materials with Integrated Sensing Networks
University of California, San Diego
Sia Nemat-Nasser, David Meyer, David R. Smith

Objective:
- Embed micro sensors and microcontrollers within fiber braids and weaves used in composite fabrication

- Form networks of interacting sensor nodes to enable structural health monitoring
Advanced Sensing For Geotechnical Systems

Objective:

- Develop a novel wireless shape-acceleration sensor array based on Fiber-optic & MEMS technologies (3D deformation & 2D acceleration)
- Develop wireless network algorithms to enable real-time monitoring

Vision of installed shape-acceleration sensor arrays in an active soil systems

Tarek Abdoun, Mourad Zeghal & Alhussein Abouzeid (RPI)
Multiple sensors along single fiber

Different frequencies for sensors with different cavity lengths

Demodulated in frequency domain

Large multiplexing capacity
Sensors for the Detection of Explosives

$20 million

Credit: Mete Sozen and Julio Ramirez, Purdue University School of Civil Engineering
Sutong Bridge, Jiangsu, China

4th Qianjiang Bridge, Hangzhou, China

Jiangyi Bridge, Jiangsu, China; Main-span 1385m
EM Stress Sensors on Asidagawa Cable Stayed Bridge (Japan)

University of Illinois-Chicago and KRC Japan

Sensor Locations

Sensor Beneath the Deck

Measured Results
Current Challenges of Structural Health Monitoring

- Development of a structural health monitoring system to fully achieve the above objectives and benefits is still a challenge at present, and needs well coordinated interdisciplinary research;

- The current challenges for bridge structural health monitoring are being identified as
  - distributed and embedded sensing,
  - data management and storage,
  - data mining and knowledge discovery,
  - diagnostic methods,
  - decision making on maintenance and management.
• Sensor technology transforms engineering from the old data-poor practice to the modern data-rich practice.
• Sensor technology closely interfaces a few most transcendental technologies which define our modern living society.
• Significant industrial and commercial value.
International Collaborations

• Asian-Pacific Network of Centers of Research on Smart Structures Technology (ANCRISST) that includes the USA, Japan, Korea and China.

• Collaboration between NSF and European Science Foundation (ESF) in Smart Structures Technologies.

• Collaboration between NSF and funding agencies in Asian countries.
Autonomous Intelligence

**Target:** Enhancing human performance for next generation technology

**Purpose:** Development of fundamental bases, principles, and tools for creation of systems and devices with embedded human-centric and human-like intelligence and autonomy

**Application:** Improved health (particularly for disabled and aging population), security and safety
Transformative Idea & Research

- Biomimetic and biocompatible materials for implantable & wearable devices
- New generation biomimetic and bio-inspired sensors and actuators animating human senses & control
- New paradigms of sensor fusion and online informatics
- Autonomous systems with cognitive capabilities for self awareness and learning
Transformative Idea & Research (Cont’d)

• Human cognitive robotic systems
• Human-machine-environment interfaces and cooperative protocols
• Connective human-like
Research Thrust Areas

• Multi-functional materials & morphic systems design and control
• Next generation self-powered smart sensing and actuating systems on micro and nano scales
• Implantable & wearable intelligent devices
• Next generation of intelligent robotic systems
• Synergistic research between cognitive and system sciences to enable self awareness and learning
### Sensor Technology for Civil & Mechanical Systems

**Program 1639 Program Director: Shih-Chi Liu**

<table>
<thead>
<tr>
<th>Animated Human Senses</th>
<th>Advanced Sensors</th>
<th>Informatics</th>
<th>Structural Health Monitoring</th>
<th>Transformative Application</th>
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<tr>
<td>Multi-Functional Materials</td>
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<tr>
<td>MEMS &amp; NEMS Sensing &amp; Actuation</td>
<td>Soft/Hardware Integration</td>
<td>Condition Assessment &amp; Damage Models</td>
<td>Public Security</td>
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<td>Hybrid and Integrate Systems</td>
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<tr>
<td>Biomimetic Sensing &amp; Actuation</td>
<td>Data Selection Compaction and Auto-</td>
<td>Corrosion, Stress, Displacement Measurement</td>
<td>Quality of Living Environment</td>
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<tr>
<td>Engineering Design &amp; Processing</td>
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<tr>
<td>Human/Machine Interface</td>
<td>Feature Abstraction &amp; Interpretation</td>
<td>Real-time Integrity Assessment Technologies</td>
<td>Search &amp; Rescue</td>
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<tr>
<td>Modeling &amp; Prototyping</td>
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<tr>
<td>Micro Devices-Embedment Implantation</td>
<td>Real-time Decision Making</td>
<td>Auto/self control Protective Systems</td>
<td>Systems &amp; Structures with Autonomous Intelligence</td>
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**Demonstration Tests**

- Demonstration Tests
- Demonstration Tests
- Demonstration Tests
- Demonstration Tests
- Demonstration Tests
Useful Web Addresses

• National Science Foundation: www.nsf.gov
• Civil & Mechanical Systems: http://www.eng.nsf.gov/cms/
• Program Officers (Dynamic Systems, Modeling, Sensing and Control)
  – Dr. Shih-Chi Liu sliu@nsf.gov 703-292-7017