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

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Multi-Hazard Mitigation: New Frontier in Earthquake Engineering

By
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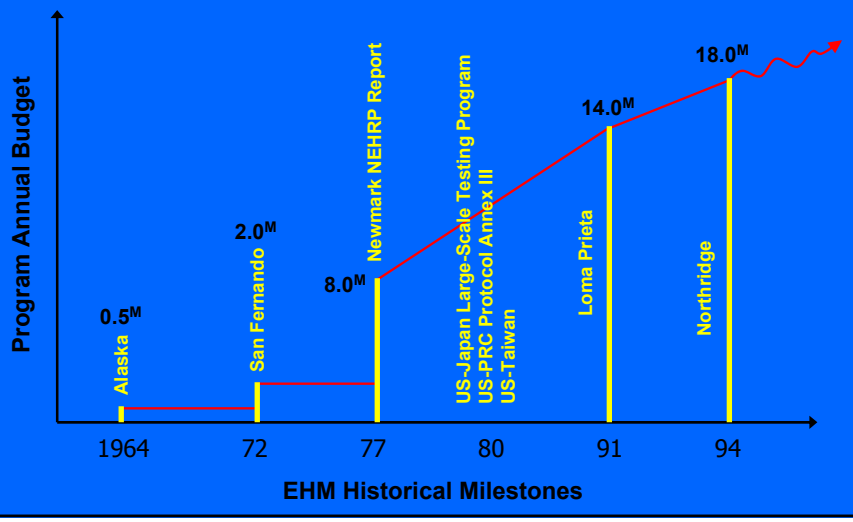
NSF Earthquake Hazard Mitigation Program



Design For Safety

New Structural Systems

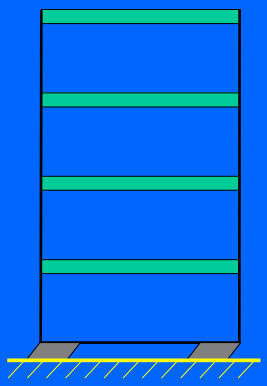
Use of safety Factor—Over design
---Masonry & reinforced Masonry
---R/C
---Steel Framed
---Hybrid/Composite

Cooperative Research US-Japan over 90's

Design with Response Control

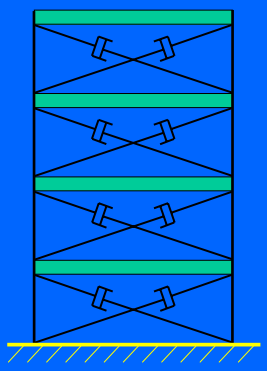
- Based Isolation
- Passive Control Systems
- Active/Semi-Active Control Systems
- Future: Smart Structures

Base Isolation



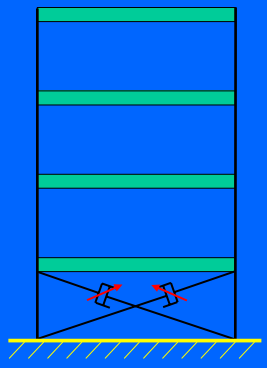
- Seismic hazard mitigation.
- Principle based primarily on deflecting earthquake energy. Requires period separation.
- Passive system, design based on site conditions and assumed ground motion.
- Application to low- and medium-rise buildings. Difficult to achieve period separation in tall buildings (>10 stories)
- Convenient for most retrofits. Limited superstructure modifications.
- Cost effective for retrofit and performance-based designs.
- Independent of outside power supply.
- Codes: UBC (1991), OSHPD (California State), AASHTO (1991)
- Implementation: Hundreds buildings worldwide, new buildings and 10 retrofits
- Basic research at EERC supported by NSF

Passive Control



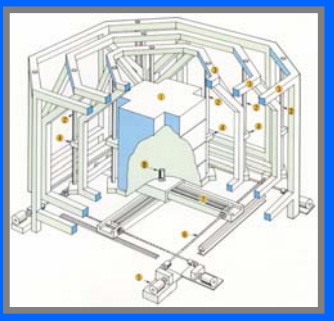
- Multi-hazard mitigation (e.g. wind and earthquake).
- Principle based on enhanced structural energy dissipation.
- Passive system, design insensitive to site conditions and ground motions
- Insensitive to structural type (height, aspect ratio).
- Limited interference with structural functionality in retrofit applications.
- Moderate cost for retrofit. Limited structural intervention as compared to conventional retrofit.
- Systems activated by structural deformation. Require some structure flexibility for maximum effectiveness.
- Independent of external power supply.
- Codes: SEAONC Tentative Guidelines for Passive Energy Dissipation Systems (1995)
- Implementation: a numberr of buildings in USA and Japan
- Basic research at EERC/NCEER supported by NSF

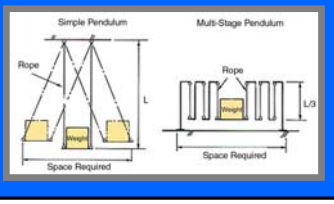
Active Control



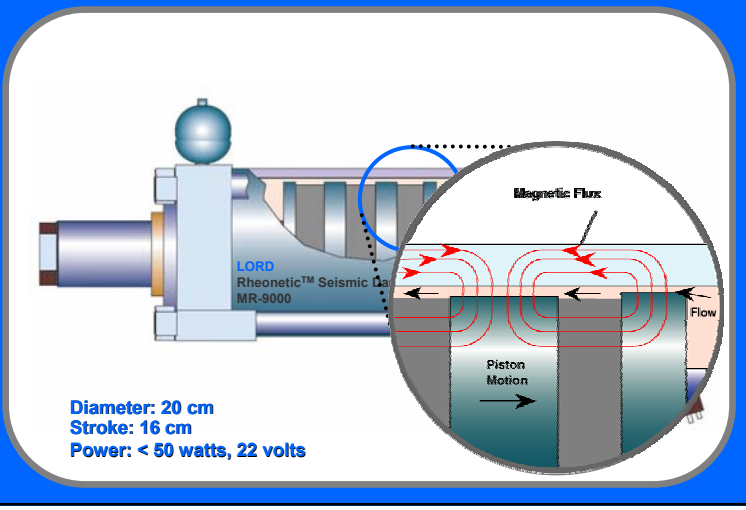
- Multi-hazard mitigation (e.g. wind and earthquake).
- Principle based primarily on added structural energy dissipating capacity and period adaptability.
- Active system, design insensitive to site conditions and ground motions.
- Insensitive to structural type (height, aspect ratio).
- Limited interference with structural functionality in retrofit applications.
- Potentially high costs. Robustness dependent on sensors and algorithms.
- Dependence on external power supply.
- Codes: None
- Implementation: a few buildings in Japan
- Basic research at NCEER supported by NSF

Yokohama Landmark Tower (1993)





Prototype 20-Ton MR Fluid Damper



Deterioration Science

Material & System Failures (Theories & Models Needed) Due to:

- *Overload (fracture, cracking, etc)*
- *Over use (Fatigue)*
- *Over exposed (corrosion)*
- *Aging*

US EQ Engr Accomplishments

- Understanding of Strong-Motion and Effects
- Modeling and Analysis Capabilities
- Design Methods of Structures and Geosystems
- Innovations of Structural Systems
- Innovations of Dynamic Response Control
- Production of Large Talent Workforce
- Successive Transformation of Research Modes and Tactics

Major Research Milestones

* Earthquake Engineering & FEM (80's-00's)

--Ground Motions, Dynamic response & Control , New Structural Systems, Sophisticated Analytical Tools

* Civil Infrastructure Systems (90's)

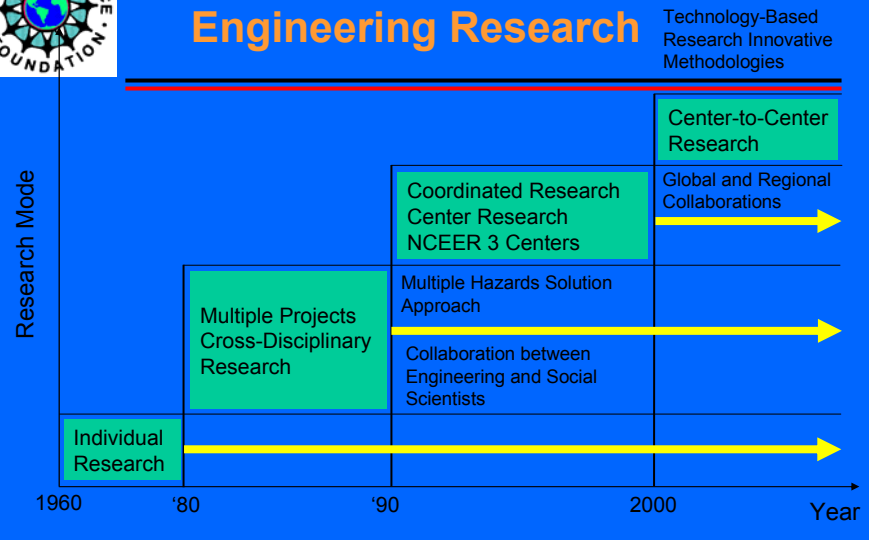
--Deterioration Science, Assessment Technologies, Renewal Engineering, Institutional Effectiveness

--Lead to Intelligent Infrastructure Engineering

* Sensors & Smart Structure (SSS) Technology

--Current Global Research Trend

Transformation of US Earthquake Engineering Research



Transformation of Earthquake Engr Research

- Single investigator research: disciplinary: '70s-'80s
- Coordinated research: 1980--
- Cross-disciplinary research: early '90s (engineers and social scientists, etc)
- Center-based research: '90s--
- Center-to-Center research 2000— (ANCER)

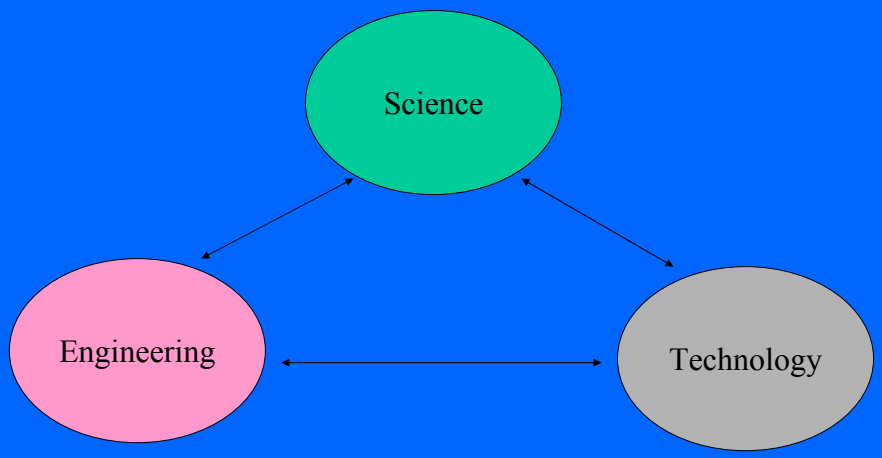
Transformation of Earthquake Engr Research

- *Conventional approaches:* model,analysis, & design (single performance criterion and safety factor)
- *Multi-disciplinary approaches*: engineering plus preparedness and recovery, etc.
- *Technology-based approaches* (added social values: innovations for job and wealth creation)
- *New societal Needs* (blasts & attacks) leading to multiple hazards mitigation approaches

EQ Engr Research Outlook

- Research Responding to Social Demands (Safety, Security, Life Quality, Job and Economy Creation)
- Research Responding to Push by New Technologies (Smart Materials and Smart Structures, Sensors, SHM)
- Cross-Disciplinary Team Research, Center-Base Research
- Integrated Approaches for Multiple Hazard Mitigation and Engineering Design
- Increased Needs for International Collaboration

Push & Pull Between S&E&T

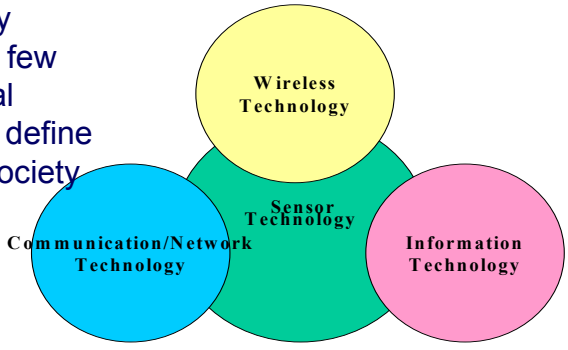


Future Trends

- **MULTIPLE HAZARD SOL'NS**
- **TECHNOLOGY INNOVATIONS**
  - ***--information technology***
  - ***--new materials & new systems***
  - ***--wide use of sensors, actuactors, etc***
  - ***-- autoadaptive media***
- **TRADITIONAL & NONTRADITIONAL APPROACHES**

SENSORS TECHNOLOGY RESEARCH

- 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.



Sensors and Sensor Networks (NSF03-512, 04-522 & 05-526)

- **NSF wide initiative started in 2003.**
  --$45M
- **FY 2004**
  – ~$39M
- **FY 2005**
  – -$30M

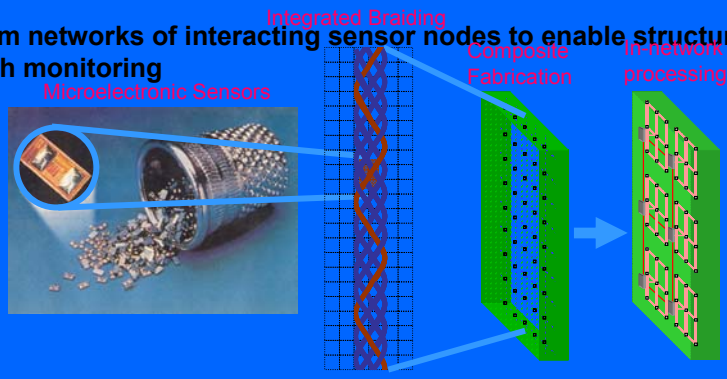
Self-Monitoring Structural Composite Materials with Integrated Sensing Networks

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

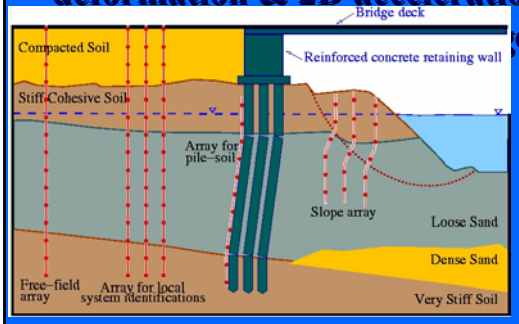
- Form networks of interacting sensor nodes to enable structural health monitoring



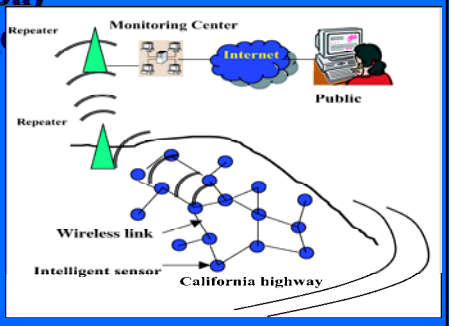
Advanced Sensing For Geotechnical Systems

Objective:

- **Develop a novel *wireless shape-acceleration sensor array* based on Fiber-optic & MEMS technologies (3D deformation & 2D acceleration)**



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

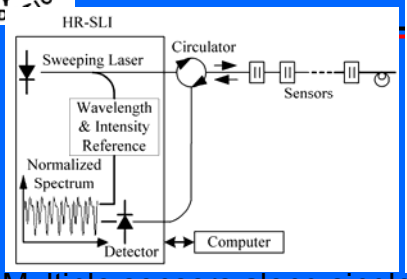


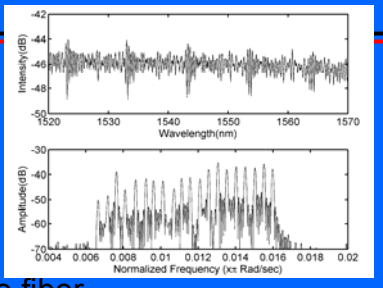
Wireless network for real-time monitoring of geotechnical systems

Tarek Abdoun, Mourad Zeghal & Alhussein Abouzeid (RPI)

Infrastructure Multiplexed Optical Fiber Sensing Networks Monitoring

PIs: Anbo Wang, G. Pickrell, K. Cooper, T. Lin, L. DaSilver
Virginia Polytechnic Institute and State University





- 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

2007 BUDGET REQUEST

$20 million

Jerome Sozen and Julio Ramirez, Purdue University School of Civil Engineering

Intellectually Challenging Research Areas

- **Re-deployment of strong-motion networks with new wireless micro sensors**
- **New sensor & actuator technology & integration with structural systems for EQ safety & health monitoring**
- **Theories & modeling of structural damage**
- **High-tech warning, control and minimization of disastrous damages (tsunami, landslide, fire, etc.)**
- **Theories and models on site effects**
- **Theories and models for nonlinear dynamic response**

Noticeable Events

- 2000 Millenniun Conference in Beijing
- International Conferences on Earthquake Engineering (Beijing, Harbin, Nanjing, and Taipei 2006)
- The 2008 World conference in Earthquake Engineering, Beijing
- Asian-Pacific Network of Centers of Earthquake Engineering Research (ANCER)

Useful Web Addresses

- National Science Foundation: www.nsf.gov
- Civil & Mechanical Systems: http://www.eng.nsf.gov/cms/
- Grant Proposal Guide: http://www.nsf.gov/pubsys/ods/getpub.cfm?nsf0423
- FY2004 Guide to Programs: http://www.nsf.gov/pubsys/ods/getpub.cfm?nsf04009
- Sensors and Sensor Networks (FY2004 version): http://www.nsf.gov/pubsys/ods/getpub.cfm?ods_key=nsf04522
- Mathematical Sciences: Innovations at the Interface with the Sciences and Engineering (FY2004 version): http://www.nsf.gov/pubsys/ods/getpub.cfm?ods_key=nsf04538
- Program Officers (Dynamic Systems, Modeling, Sensing and Control)
  - Dr. Shih-Chi Liu sliu@nsf.gov 703-292-7017

Thank You!