

Academic Perspective on Collaboration Among S3T and US Universities

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Dean

**School of Engineering & Computer
Science**



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Presentation Outline

- **Objectives**
- **Historical Background**
- **Present State**
- **Future Plans**
- **Q&A**



Notable Alumni

- **Condoleezza Rice**, US Secretary of State
- **Gale Norton**, US Secretary of the Interior
- **Pete Domenici**, Senator, New Mexico
- **Byron L. Dorgan**, Senator, North Dakota
- **Peter Morton**, founder of Hard Rock Café
- **Andy Taylor**, CEO of Enterprise Rent-A-Car
- **General George Casey**
- **Andrew Rosenthal** - managing editor of *The New York Times*



Objective

- **Develop global dialogue on emerging technologies associated with**

Smart & Autonomic Structures

- **Facilitate creation of complementary research teams between Europe and USA**
- **Leverage R&D investments of USA and European government and private sectors**
- **Identify and collaborate on major projects (Mega Projects)**
- **Facilitate creation of Research Centers**
- **Establish joint conferences, workshops, and other means of exchanging ideas and sharing progress**



Why Smart Structures?

- **New civil engineering construction is the largest industry in the world, accounting for more than 10% of the world's gross domestic product.**
- **Civil infrastructure systems are generally the most expensive investments/assets in any country (an estimated \$20 trillion in the US).**
- **These structures are deteriorating at an alarming rate due to material or system degradation caused by overuse, overloading, aging, damage or failure resulting from natural or man-made hazards**







Concept of Operations

Slide courtesy
Metis Design Corp.



Starting from taxi, passive monitoring methods begin collecting data on state of structural health.



In flight, passive monitoring is used with intermittent active method acquisitions. Up to 16 hours of data collection.



Upon landing, flight data is collected during normal pre-flight servicing time. Complete active method diagnostic is also performed for on time, safe take-off.

Blade Vibrations in Jet Engines

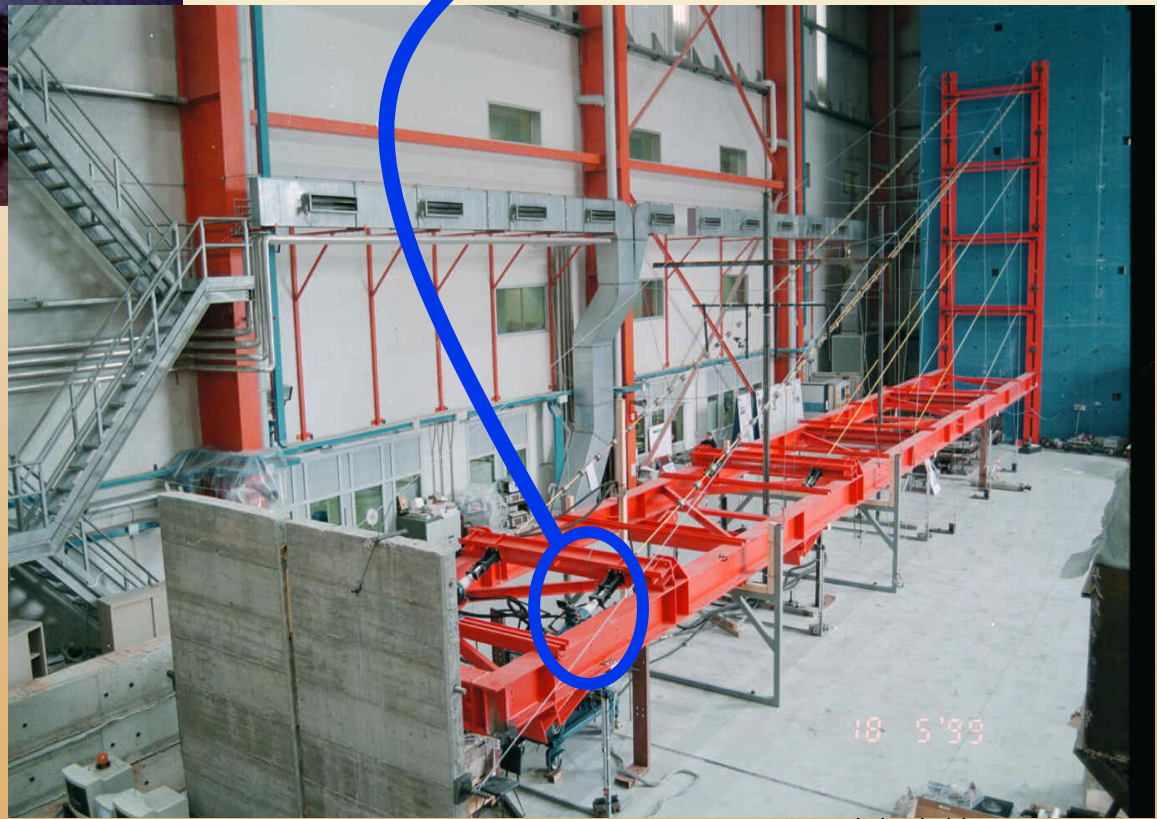
- 60,000 G's
- 150 deg C operating environment



PW300 advanced turbofan engine
photograph courtesy Pratt & Whitney Canada



Structural Active Control



Strengthening/Repair Techniques

The S. Vicente de Fora Monastery



- Development of methods for seismic vulnerability assessment of monuments
- Development of retrofitting techniques



Cloister view



S. Vicente Model at ELSA

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Health Monitoring



San Nicoló cathedral (XIV century),
Treviso, Italy.

NVH in Automotive Systems

test12.wgf Wise Gap 1000

Project System View Setup Help

Measure F3
Calibrate F4

Tolerance + 0.5
- 0.5

12/11/2002
11:28:43 AM

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<input checked="" type="checkbox"/> Sensor 6	15.63	16.00	-0.37	0.00
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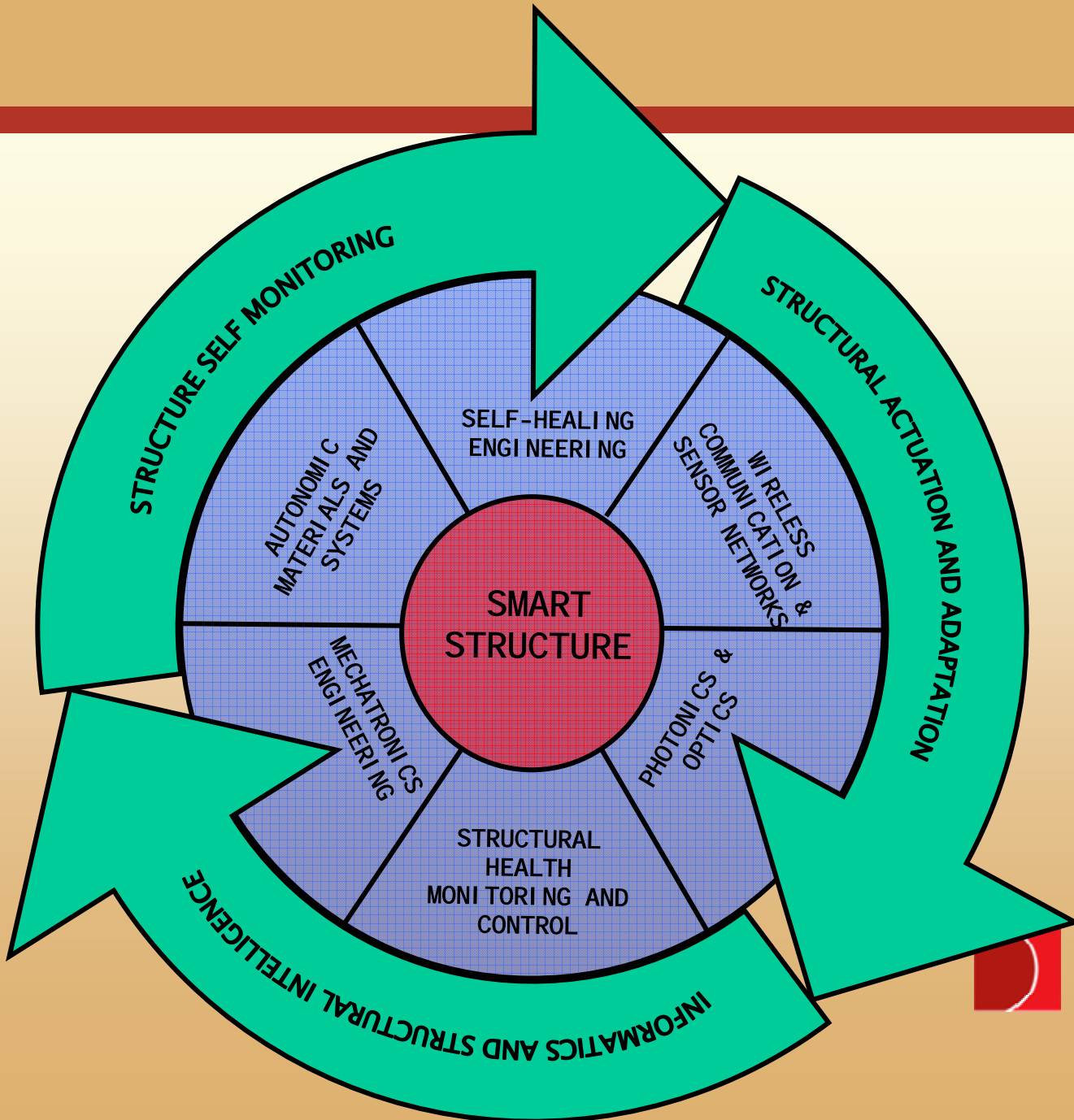
Sensor 1

14.14

What Is a Smart Structure?

- **Self-Sensing & Monitoring**
- **Self-Diagnosing & Prognosis**
- **Adaptive & Re-configurable**
- **Self-healing & Self-Repair**
- **Preventing the Loss of Human Lives**
- **Minimizing Life-Cycle Cost**
- **Extending Economic Life**





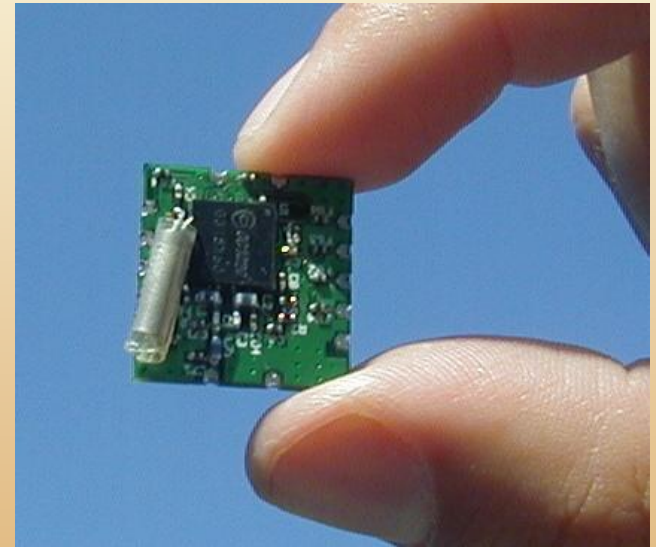
EmbedSense: Micro-Sensors for Structures

- **Minimalist-switched reactance**
- **low cost**
- **Robust**



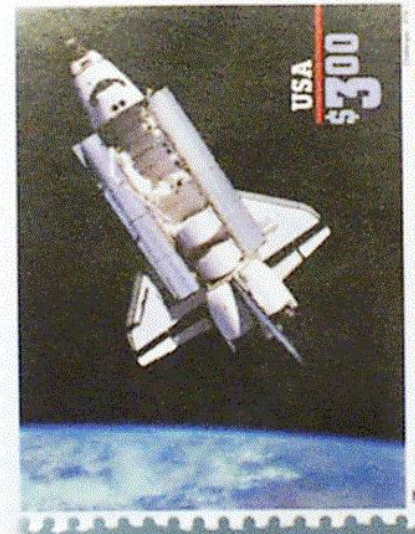
Frequency Agile Transceivers

- **Software programmable RF carrier frequency from 400 MHz to 1 GHz**
- **Software programmable RF power levels**
- **Supports FDMA networking**

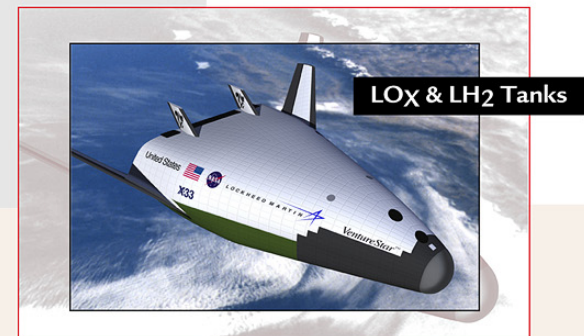
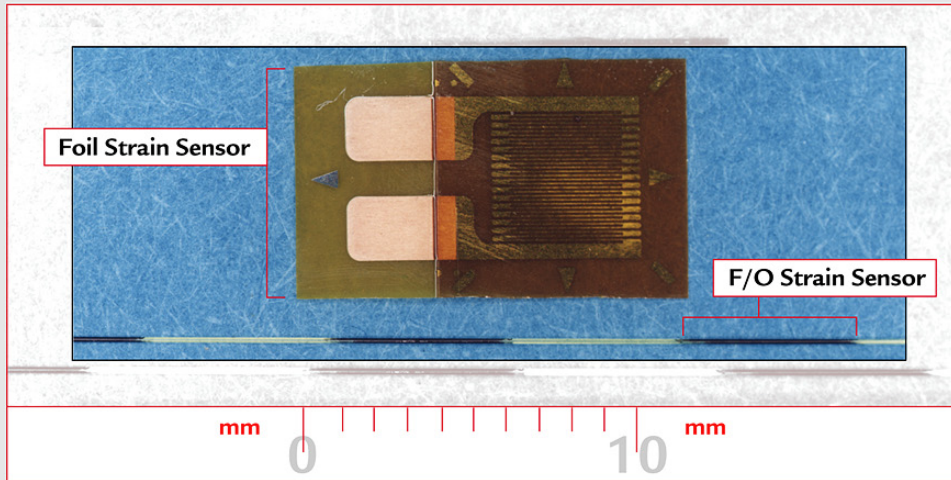


Micro-transmitters

- Embedded digital protocols
- Transmit 45 mW
- Processing 5 mW
- Sleep .02 mW
- AA Li battery life 5 years
- RF range 1/3 mile

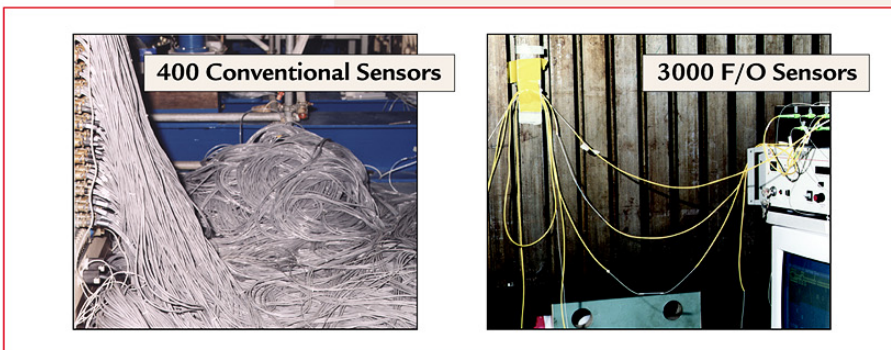


Distributed Fiber-Optic (F/O) Sensing for Structures IVHM



High Density Structural Sensors

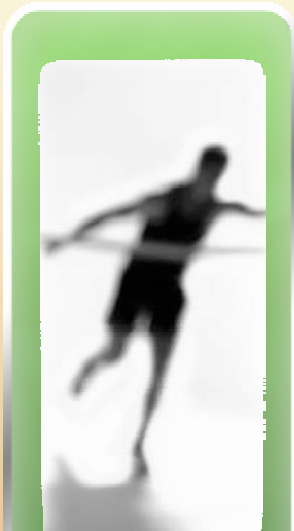
- 10,000 Sensors < 1 pound
- Strain, Temperature, & Hydrogen (Propellant Leaks)
- Future Research - Vibration, Shape, Acoustic Emission, Chemistry (Corrosion)
- < \$10/Sensor



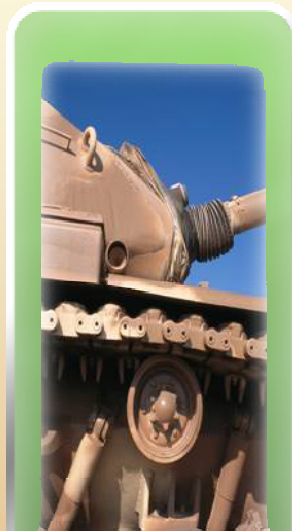
Challenges of Smart & Autonomic Structures



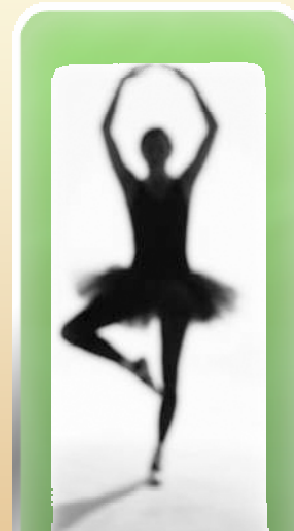
Price



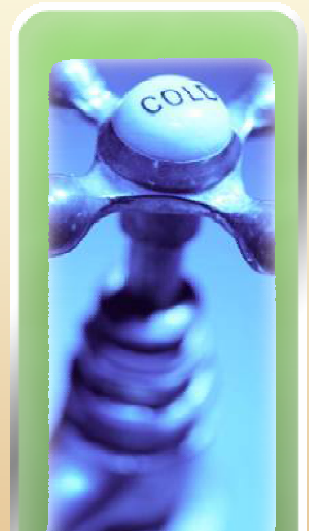
Performance



Durability



Flexibility



Ease
of use



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CHALLENGES

- **Research**
- **Curriculum**
- **Applications**
- **Commercialization**



Thus, the Need for a Strategic Plan



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Creating a Strategic Plan

Purpose

Why US-
Europe
Cooperative
Program?

Mission

Goals, Milestones, and
Supporting Objectives

Roadmap/Strategic Plan

How are we going to get
there?

Vision

Realization of
Autonomic
Structures



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What Is Our Mission?

- **Why is this cooperation essential?**
- **What void does this cooperation fill that others cannot fill?**
- **What can we contribute unlike any others?**
- **What will we be able to accomplish?**



Joint Workshops

- ***Workshop on Cooperative US-Europe Research in Sensors and Smart Structures Technology*** Como, Italy, April 2001
- **ESF-NSF Workshop on: Advancing Technological Frontiers for Feasibility of Smart Structures**
Strasbourg, France, October 2003
- **NSF-ESF Workshop on: Smart Structures and Advanced Sensor Technologies**
Santorini Island, Greece, June 2005
- **AFOSR/ARO/NSF/ONR/ESF WORKSHOP on: Smart Systems for Mitigation of Exogenous Threats Using Autonomic Response**
Nice/Juan Les Pins, France, May 2006



NSF-ESF Workshop, Oct. 2003, Strasbourg



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Objectives of 2003 Strasbourg Workshop

- **Development of a Comprehensive Document that**
 - **provides state-of-the-art in Smart Structures**
 - **Identifies special interests of US & Europe**
 - **defines areas of strength from US & Europe**
 - **Identifies technological barriers and challenges**
 - **Can be used by NSF & ESF on decisions for strategic investments**
 - **Provides guidelines for researchers from Europe & US about new technological needs**



Objectives of Santorini Workshop

- **Development of a vision for Smart Structures (short & long term)**
- **Development of a roadmap to reach the defined vision, in terms of**
 - **Milestones**
 - **Required resources & infrastructures**
 - **Necessary partnerships**
 - **Transforming R&D projects that introduce revolutionary (not evolutionary) advancements in Smart Structures**

MEGA PROJECTS



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Nice Workshop

Smart Systems for Mitigation of Exogenous Threats Using Autonomic Response



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WHAT IS AN AUTONOMIC STRUCTURE?

- **AUTONOMIC Structure is described in terms of its characteristics**
 - **Smart**
 - **Self-Monitoring**
 - **Self-Diagnostics**
 - **Self-Adaptive**
 - **Self-Healing**
 - **Self-Sustainable**
 - **Intelligence**
 - **Threat Mitigation**
 - **Re-configurability**
 - **Multi-functional**
 - ***Self-Cooling***
 - ***Alteration of Penetration Processes***
 - ***Neutralization of Chem/Bio Warfare Agents***



Exogenous Threats

- ***Nature of Exogenous Threats for Load-Bearing Structures (civil, transportation, aerospace)***
- ***Origins of Exogenous Threats –***
 - ***External Heat, Radiation & High-Energy Threats***
 - ***Thermal Gradient Induced Stresses***
 - ***Penetration Failure***
 - ***Corrosion & Fatigue under Vibratory Loading***
 - ***ChemBio Warfare Agents***



AUTONOMIC STRUCTURES

- ***Multiple Networks for Autonomic Response for Load-Bearing Structures***
 - ***Neural Network for Threat Sensing and Activation of Response***
 - ***Circulatory Network for Self-Healing and Self-Cooling***
 - ***Circulatory Network for Neutralization of Chem/Bio Warfare Agents***
 - ***3-D Load-Bearing Scaffold with Local Healing Mechanisms of Reinforcement***
 - ***Active Materials Scaffold Against Penetration***



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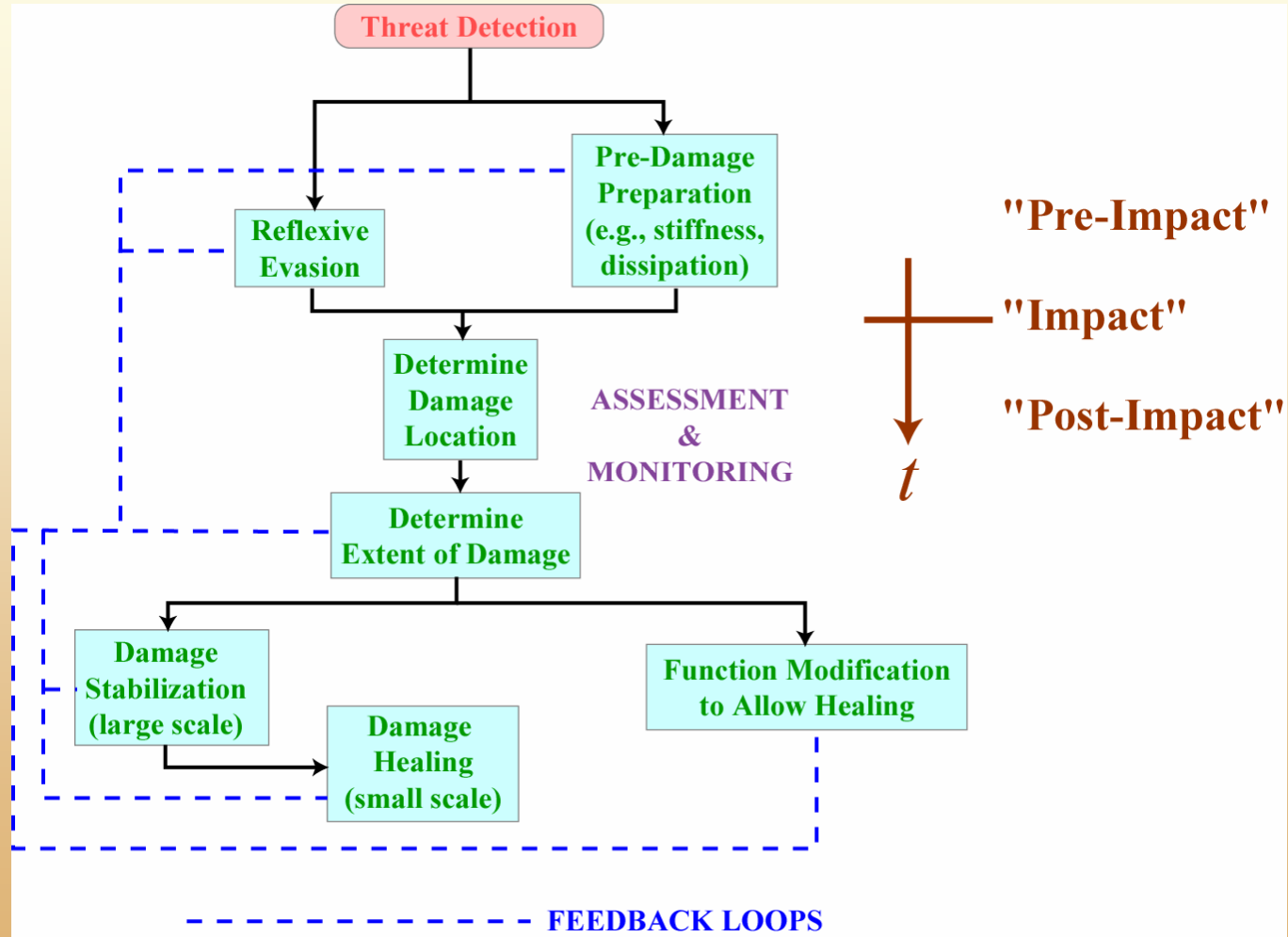
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Objectives of This Workshop

- ***To formulate blueprints for new research initiatives on “Smart Systems for Mitigation of Exogenous Threats Using Autonomic Response.”***
- ***To leverage R&D investments, expertise, and resources of both US and Europe.***
- ***To initiate collaborations, e.g. joint projects, that would benefit from complementary US/European expertise and facilities.***

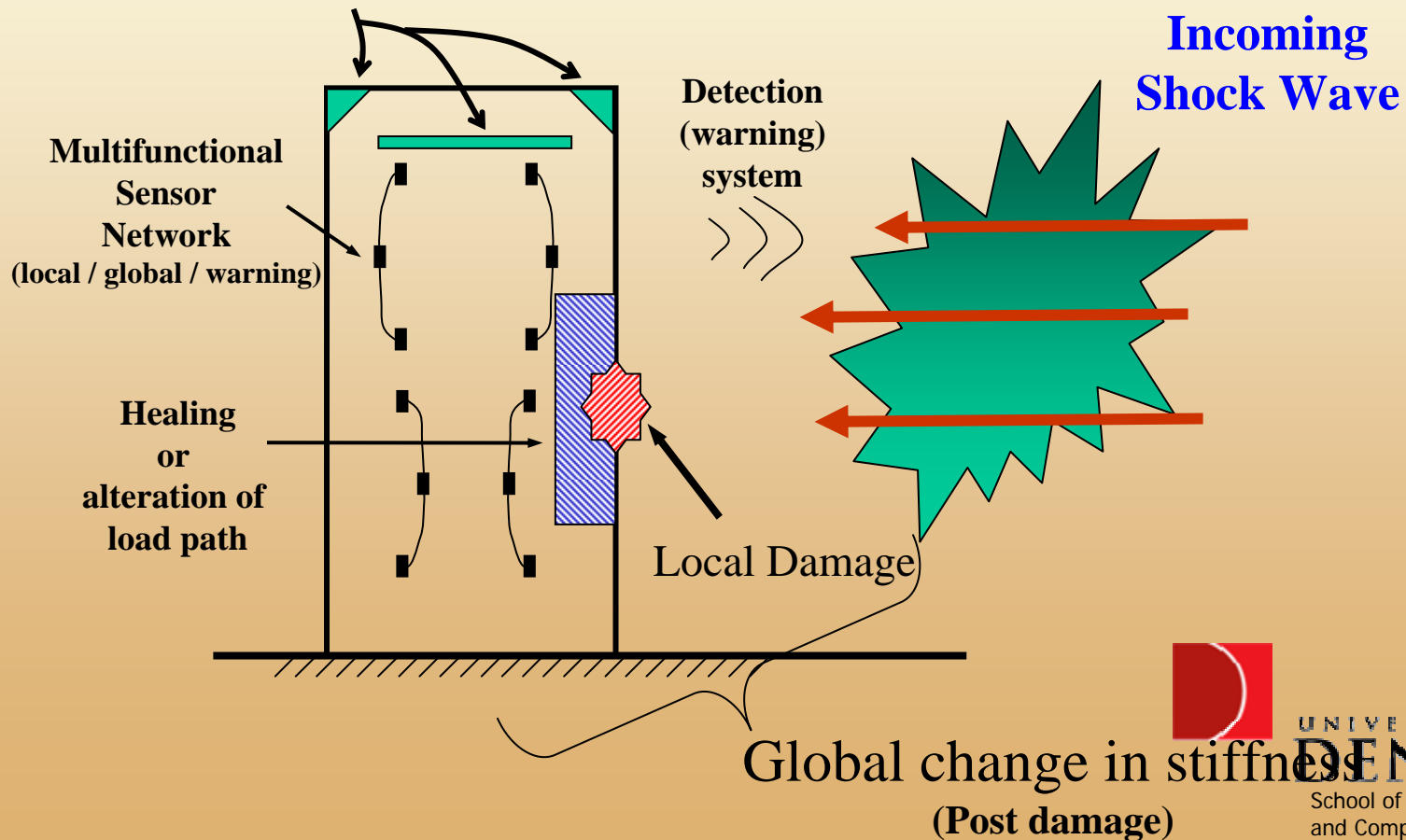


Autonomic Structures for Improvised Explosive Defeat

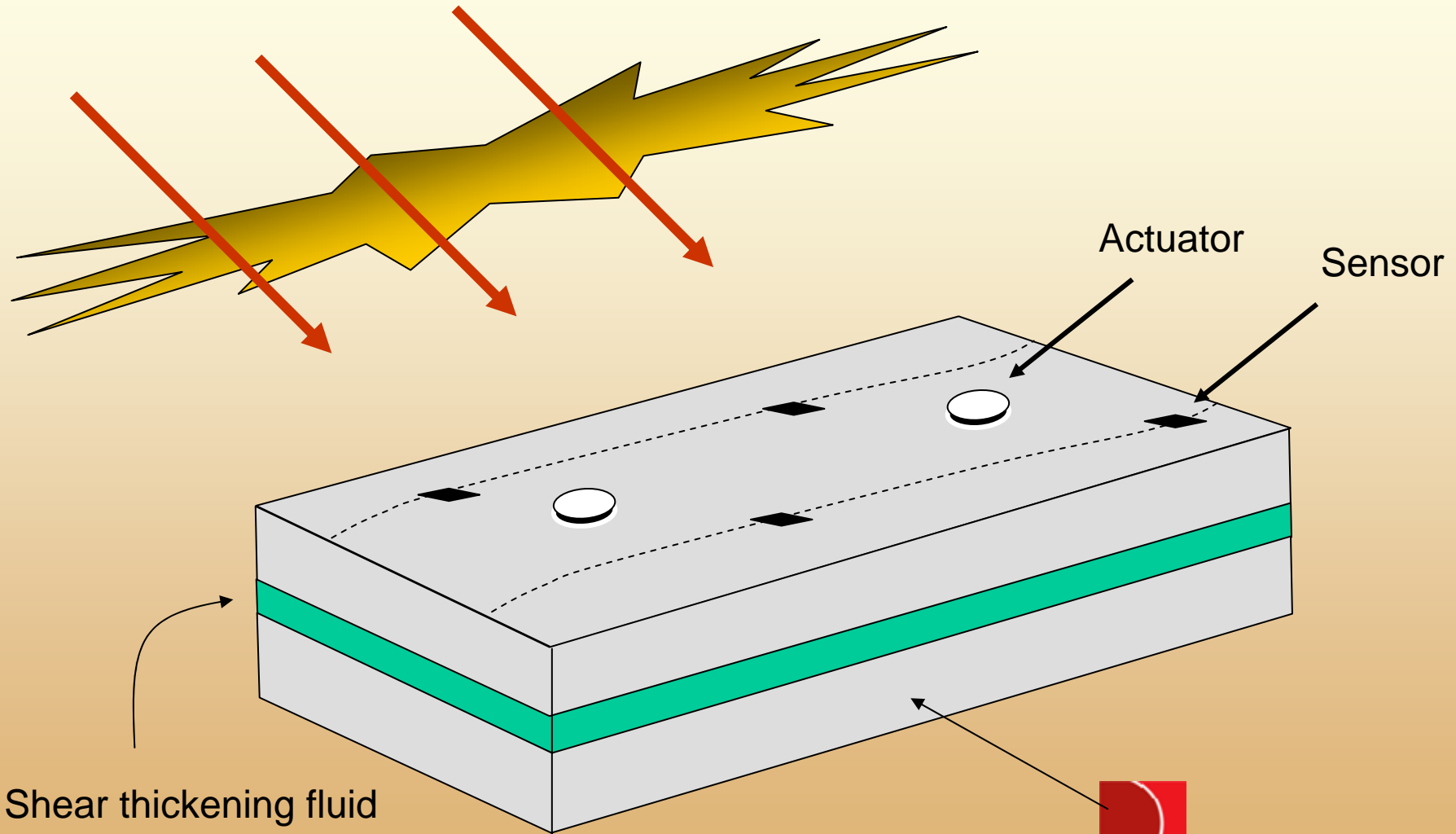


Blast Mitigation in Building Infrastructure

Smart joints / smart materials
That take preventative measures
For the incoming threat (adjust stiffness)



Blast Mitigation in Composite Plate



Future Plans

- **Create joint US-Europe project teams with S3T researchers and possible industry partners**
- **Development of Joint Conferences**
 - **May 22-27, 2007, China**
- **Exchange of faculty & students**
- **Create joint curricula and degrees**
- **Develop joint commercialization plans**



The World Forum on Smart Materials and
Smart Structures Technology
SMSST '07

May 22-27, 2007

Chongqing & Nanjing, China

<http://smsst07.cee.uiuc.edu>



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Hosts



World Forum Goals

- Update the State-of-the-Art & New Knowledge gains
- Review Technological Innovations Achieved
- Assess Transforming Impact Potential
to Engineering Practices
- International Engagement: Cooperative Platforms (US-Europe, US-China, US-Japan)
- Partnership with Industry
- Outlook for Revolutionizing Student and Education Programs



Hosts



China



China



Sponsors

- Sponsored by

- Asia-Pacific Network of Centers for Research in Smart Structure Technology



- The International Association for Smart Material and Structure, China
- The International Association for Structural Control and Monitoring, Japan
- The International Association for Structural Control and Monitoring, USA

- Joint sponsorship

- National Science Foundation
- National Natural Science Foundation of China
- Other agencies interested (JST, JSPS, EST, KOSEF, etc.) ?



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Major technical areas

Topics of interest include, but are not limited to:

- **Multi-functional Materials & Material Systems**
- **Smart Sensors/Actuators**
- **Signal Processing & Data Management Technology**
- **Wireless, Energy Harvesting, & Imaging Technology**
- **Communications, diagnosis and Control**
- **Structural Health Monitoring Technology**
- **Autonomous Intelligent Structures & Systems**



Schedule

- Important dates:

September 30, 2006

Abstract Submission Deadline

October 30, 2006

Abstract Acceptance Notification

December 31, 2007

Full Paper Submission Deadline Paper Acceptance
Notification

February 31, 2007

Camera-ready submission deadline

March 20, 2007

Pre-Registration Deadline

March 31, 2007

May 22-27, 2007

SMSST '07

Summary

- **The NSF participated in the ESF-S3T Research Meeting during Sept. 7-8, 2006 in Strasbourg, France.**
- **Presentations describing the aim and objectives of the S3T projects were made by researchers from Europe.**
- **US representatives presented ideas for collaborations with European researchers.**



Resolutions

- **The following resolutions were reached:**
 - **Smart and Autonomic structures, Mechatronic systems and Sensor networking technologies are areas of increasing importance. Both Europe and the USA are on the leading edge of this field. It is important to initiate a comprehensive R&D program on a cooperative basis between them.**
 - **A bilateral cooperative research program in Smart and Autonomic Structures Mechatronic systems and Sensor Networking technologies, that meets the mutual interest and integrates the respective strengths of the USA and Europe, should be established. This program shall aim at pioneering research by academic researchers through partnership with industrial partners.**
 - **Appropriate European agencies as recommended by ESF are encouraged to develop a cooperative research program with NSF in sensors and smart/autonomic structures technology to pioneer research by academic researchers through partnerships with industrial and government institutions.**



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Resolutions

- **Funding and relevant resources should be clearly identified and commitments sought.**
- **Experimental facilities and test-beds are expected to be important parts of a cooperative program.**
- **The cooperative program should encourage team projects and center-based projects of a multi-disciplinary nature.**
- **In the cooperative program, priority should be given to proposals that are jointly authored by European and USA PIs and include synergistic bilateral collaboration.**
- **Joint proposal review and decision processes by funding agencies from both sides are highly desirable, and if possible, should be developed and implemented.**



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Resolutions

- **An effective technical coordination mechanisms should be developed to guide the main directions of the cooperative program and facilitate the research of the funded projects, technology transfer, exchange, utilization, etc.**
- **Educational programs that integrate academic research and education in a multi-disciplinary setting should be developed to prepare the next generation of engineers. Multi-lateral cooperation is central to such educational programs, including student and young researchers, and faculty exchanges.**



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Thank You and Q&A



Asia-Pacific Network of Centers for Research in Smart Structures
Technologies (ANCRiSST)*

Bill. F.Spencer**

President of ANCRiSST

Dept of Civil & Env. Engg., Univ. of Illinois, USA

*<http://sistec.re.kr/ancrisst>

**bfs@uiuc.edu



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Objective of ANCRiSST

Establishment of a **center-based consortium** on smart structures technology in the Asian- Pacific region

- ❖ To develop synergies through **joint research projects**
- ❖ To better educate the **next generation of engineers** toward maximizing advantages offered by smart structures technology
- ❖ To provide continued professional development for **practicing engineers**



Milestones of ANCRiSST

- August 15-20, 2002 (at ANCER's Int'l Conf at Harbin and Hong Kong)
MOU for Center-Based Cooperation in Smart Structures Technology in Asian-Pacific Region among 5 founding members
- September 17, 2003 (at SHM Workshop at Stanford Univ.)
The First Boarding Meeting of ANCRiSST
- Jan., 2004, 1st ANCRiSST Workshop in Hawaii
- Aug. 2005, 2nd ANCRiSST Workshop in Gyeongju, Korea
- July 2006, 3rd ANCRiSST Workshop in Lake Tahoe
- May 2007, World Forum on Smart Materials & Smart Structures Technology in Chongqing & Nanjing, China



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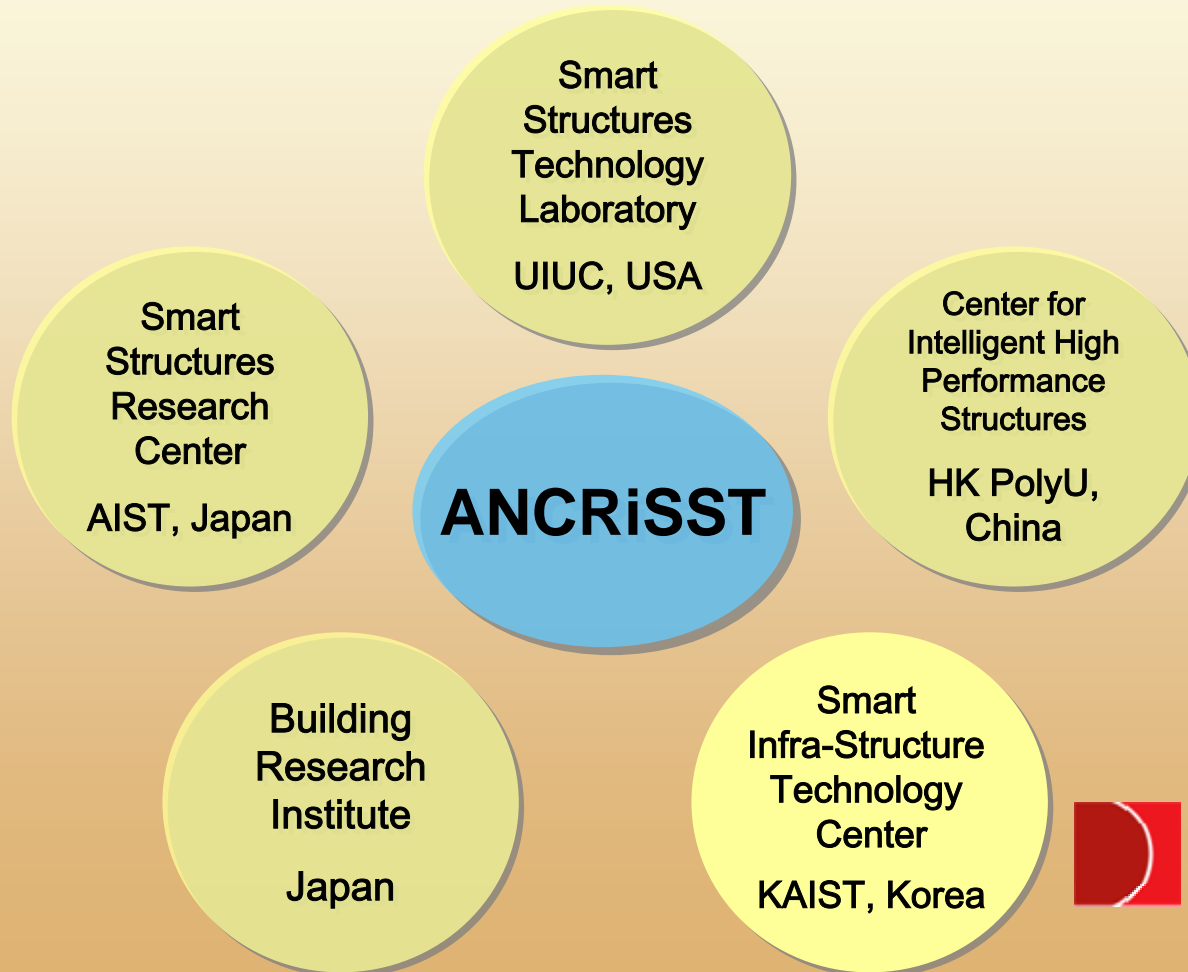
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Membership

- Classifications
 - **Founding Members:** 5 institutions
 - **Full Members:** Formal organizations with strong activities and national or international support (currently 10 institutions)
 - **Associate Members:** Formal organizations with strong activities
 - **Affiliated Members:** Research centers from industries
- Application for Membership
 - Application with the descriptions for the status and activities of the center
 - Approval: affirmative votes of 2/3 of the board members



Founding Members



Full Members

- ❖ **Stanford Smart Structure Technologies Consortium**
- ❖ **Center for Small Smart Systems, Univ. of Maryland**
- ❖ **Consortium for Intelligent Structural and Security Systems, Ibaraki Univ., Japan**
- ❖ **Smart & Sustainable Infrastructure Research Center, Hong Kong Univ. of Science & Technology, China**
- ❖ **Intelligent Monitoring and Control Center of Infrastructures, Harbin Institute of Technology, China**
- ❖ **Aeronautical Science Key Lab. for Smart Materials and Structures, Nanjing Univ. of Aeronautics & Astronautics, China**
- ❖ **VTT Technical Research Center of Finland**
- ❖ **CONVIB Group, European Countries**



Officers and Advisors

- ❖ President: B.F. Spencer, Univ. of Illinois at Urbana-Champaign
- ❖ Immediate Previous President: C.B. Yun, KAIST, Korea
- ❖ Special Advisors : S.C. Liu, NSF, USA

M. Tomizuka, Univ. of Cal. at Berkeley



Cooperative Activities

- Development of collaborative research projects
- Enhancement of communication and information exchange
- Promotion of smart structures activities with industries
- Exchange of young researchers and students
- Workshops and seminars for assessment of the state-of-the-art of smart structure technologies and for development of cooperative research plans



Activities in 2004-2006

- ANCRiSST WS on Adv. Smart Materials and Smart Structure Tech. :
[in Hawaii, USA \(2004\)](#), Kyeong-ju, Korea (2005) and Lake Tahoe(2006)
- [SPIE Conf. on Sensors and Smart Str. Tech. for Civil, Mech., and Aerospace Systems : in San Diego \(2004, 2005, 2006, 2007\)](#)
- [US-Korea WS on Smart Structures : Seoul \(2002, 2004, 2006\)](#)
- US-Japan-China Str. Health Monitoring WS : Dalian (Oct., 2004)
- Int'l Conf. on Earthq. Engg. : Nanjing U. of Tech. (Oct., 2004)
- Int'l WS on Str. Health Monitoring : Stanford Univ., USA (Sept., 2005)
- Int'l Conf. on Earthq. Engg. (4th ICEE) : Taipei, Taiwan (Oct., 2006)
- [Int'l J. of Smart Structures and Systems\(2005\)](#) : An Official J.of ANCRiSST



Thank you !!

- **Looking forward to having valuable and enjoyable academic / research collaborations within the ANCRiSST network !**
- **New members are welcome !**



ACTION ITEMS

- **Immediate Actions**
 - **CRP Leaders jointly with Rahmat identify potential US collaborators**
 - **Rahmat will act as a broker/facilitator to establish several partnerships**
 - **Organize two sessions for China Conference**
 - **S3T Projects**
 - **Initial partnership programs**
- **Actions within three months**
 - **US partners apply for NSF supplemental funding to create international components to their on going projects**
- **Actions within one year**
 - **Plan for and implement student & faculty exchanges**
 - **Short-term visits for project planning**
 - **After China Conference**
- **Actions within two years**
 - **Prepare and submit joint comprehensive proposals**

