MCEER RESEARCH TASK STATEMENT

**Thrust Area:** Overarching  
**Budget:** Yr 9 Assigned  
**Project Number:** 9.0.1

**Task Title:** Quantification of Resilience Dimensions for Specific Critical Facilities

**Investigator/Institution:**
- Andrei Reinhorn*, University at Buffalo
- Michel Bruneau, University at Buffalo
- M. Shinozuka, University of California at Irvine *** (Leader Thrust Area 1)
- Andre Filiatrault, University at Buffalo *** (Leader Thrust Area 2)
- Kathleen Tierney, University of Colorado, Boulder *** (Leader Thrust Area 3)
- Stephanie Chang, University of British Columbia ***
- Adam Rose, Pennsylvania State University ***
- Rachel Davidson, Cornell University ***

* Indicates task leader  
*** Contributions to seismic resilience and funding for these investigators is integrated as part of their individual task statements.

**Statement of Project Goals:** (Conceptually describe what the work is intended to accomplish, in 100 words or less. Do not provide detailed description here.)

The objective of this overarching task is to advance knowledge on the quantification of the seismic resilience concept, first with a particular focus on using specific critical facilities to resolve issues germane to each, and second to investigate how it is possible to establish commonalities and linkages across various types of critical facilities. The quantification exercises will focus in Year 9 on the development and validation of examples using the MCEER demonstration hospital.

**Problem Description and Research Approach of Proposed Work for Year 9:** (Detailed description of research to be conducted and methodology to be used.)

Year 9 research is to expand on the findings from Year 8 in which substantial advances were achieved on how to quantify the physical dimension of seismic resilience for acute care facilities. The center-wide conceptual approach to resilience quantification is now approaching a maturity that would allow it to comprehensively embraces the intricacies germane to specific types of critical infrastructure system. Thus, Year 9 expands on the Year 8 work and numerical procedure to help achieve the needed robust quantitative framework, and perform sensitivity analyses to better understand how the abstract concepts of resilience unfold in actual practical applications. As such, this work’s primary objective is to develop tools that will make it possible to fulfil the MCEER vision statement, which states:

The overall goal of MCEER is to enhance the seismic resiliency of communities through improved engineering and management tools for critical infrastructure systems (water supply, electric power, and hospitals) and emergency management functions. Seismic resilience (technical, organizational, social, and economic) is characterized by reduced probability of system failure, reduced consequences due to failure, and reduced time to system restoration.
This vision will only be achieved once tools are in place to quantify the seismic resilience of structural systems. The work in Year 8 has been pioneering in developing various aspects of such tools, and Year 9 will help implement tools that can deliver reliable and insights into the physical seismic resilience of acute care facilities, in the form of numerical algorithms that would be implementable in the decision making platforms being developed as part of Thrust Area 2.

**Assessment of State-of-the-Art:** *(Describe other relevant work being conducted within and outside of MCEER, and how this project is different.)*

To the best of the investigators’ knowledge, no similar work is currently being conducted elsewhere at this time. Seismic resilience has never been quantified in the past, and the approaches proposed by MCEER are providing leadership in this endeavor.

**Progress to date:** *(If applicable, a short description of achievements in previous years. Clearly distinguish progress achieved in the past year, i.e., accomplishments from April 1, 2004, to March 31, 2005.)*

Much progress has been recently accomplished in operationalizing the seismic resilience concept for acute care facilities, particularly with regards to the quantification of resilience for selected dimensions. Work on acute care facilities has led to quantification of the robustness dimension as patients/day, and significant progress has been accomplished to calculate physical dimension of resilience for limit spaces of structural and non-structural performance. A first approach to quantification is underway, and Year 9 work will further refine this work.

Recall that the basic framework for the definition of resilience and approaches to quantify and measure this resilience was proposed for the first time by MCEER in Fall 2001. Development since have been summarized and published in:


and presented at several conferences, such as the 13th World Conference on Earthquake Engineering (Vancouver, Canada, August 2004), the Workshop on Seismic Design Methodologies for the Next Generation of Codes (Bled, Slovenia, July 2004), the ATC-29-2 - Seminar on Seismic Design, Performance, and Retrofit of Nonstructural Components in Critical Facilities (California October 2003), the KEERC-MCEER Workshop (Buffalo, NY, July 2002), the MCEER Workshop on Lessons from the World Trade Center Terrorist Attack (New York City, June 2002), and many others.

Recent development for acute care facilities include development of the Sliding an Overlaid Multidimensional Bell-curve of Response for Engineering Resilience Operationalization (SOMBRERO), using, for example, an Orthogonal Limit-space Environment (OLE). The details of this approach are presented in:

Bruneau, M., Reinhorn, A., “Operationalizing the Concept of Seismic Resilience for Acute Care Facilities”, In preparation for submission for review and possible publication to the ASCE Journal of Structural Engineering.
Figure 1 (left) illustrates the conceptual representation of the engineering demand in a limit-space that encompasses both the structural limit states and non-structural limit states, and a typical quantitative outcome for this concept (right part of Figure 1) for a specific numerical example as part of Thrust Area 2.

**Figure 1:** Seismic Resilience limit spaces concept (left) and example (right)

Figure 1 (left) illustrates the conceptual representation of the engineering demand in a limit-space that encompasses both the structural limit states and non-structural limit states, and a typical quantitative outcome for this concept (right part of Figure 1) for a specific numerical example as part of Thrust Area 2.

**Role of Proposed Task in Support of Strategic Plan:** *(Describe how the effort will make a unique, useable contribution to the MCEER strategic plan.)*

Enhancing seismic resilience at the community level is at the core of MCEER’s strategic plan, and development of the general framework of resilience measures is required to achieve MCEER’s mission objective.

**Task Integration:** *(Describe how the work performed interfaces with other tasks and researchers funded by MCEER.)*

The MCEER definition and measures of resilience provide a focus for center-wide research integration and as such have a direct impact on all researchers funded by MCEER. The further development to be accomplished as described in this task statement will continue to have such an impact, and updates on progress will therefore be periodically provided to all researchers.

**Possible Technical Challenges:**

To expand the quantification of seismic resilience to a most encompassing level, spanning across Thrust Areas, in the specific terms and at a level of details required for the systems studied by MCEER is by itself a major challenge. This first requires a solid understanding and experience in developing a full range of quantified resilience measures for critical facilities sharing commonalities in their driving performance limits. Developing the proposed resiliency framework from its conceptual basis to a workable level for each of the systems considered, without straying from center-wide broadly applicable measures is a difficult yet important balance to maintain. Another balance to maintain is the level of details of database for technical, organizational, economical and societal dimensions. Particularly, restoration-related experience data are not easy to get for all these dimensions, and certainly not available to a similar level of detail, accuracy and significance to resilience issues.
### Anticipated Outcomes and deliverables:
(Also indicate those of particular benefit to IAB members and other end users.)

Practical examples that embody the definitions and measures of seismic resilience will be provided. This will allow to evaluate, compare and verify the enhancement of the resilience resulting from MCEER’s research in a rational and comprehensive manner.

### Potential end-users beyond academic community: (IAB members and others.)

Private and public owners and the practicing engineers they hire, emergency response agencies, and all agencies or groups who can benefit from a rational approach to enhancing seismic resilience, for example to establish seismic risk reduction policies or gage the consequences and benefits from various actions.

### Educational outcomes and deliverables, and intended audience:

Bruneau and Reinhorn gave a lecture (March 2005) on seismic resilience as participant to MCEER/UB short course by Lee/Sternberg combining social sciences and engineering aspects of earthquake engineering and offered in by the Dept. of Civil, Structural, and Environmental Engineering.

Technology transfer: Dissemination of the MCEER seismic resilience concept to a large number of different audiences. Recent presentations include the MCEER Seminar at the California Office of State Health, Planning, Development (OSHPD) February 2005, and as part of a presentation on “MCEER’s Perspective on Role of Social Sciences in Earthquake Engineering Research”, panel member, Workshop of the National Academy of Sciences’ Committee on Disaster Research in the Social Sciences, Washington, D.C., August, 2004. Bruneau, as a member of the Project Steering Committee for the ATC-58 “Development of Performance-Based Design”, also provide technology transfer of the MCEER research and resilience concept.

Potentially, the MCEER’s definitions and measures of resilience, and applications demonstrated by MCEER, could impact all earthquake engineering courses focusing on how to reduce the seismic risk.

Publications produced as a result of this work, and published over the period from January 1, 2004, to March 1, 2005, are listed below:

**Refereed Journal – Submitted for Possible Publication (since 2004)**

**Refereed Conference Publications (since 2004)**
   Workshop of the Asian-Pacific Network of Center in Earthquake Engineering Research, Honolulu, July 2004 - CD-ROM.

Also:

Project Schedule and Expected Milestones for the Project: (Milestones and estimated time of achievement; e.g., Fall, Spring, Summer.)

- Expand the structural and non-structural resilience example on acute care facilities using the SOMBRERO-OLE concept, to attempt integration of other physical resilience dimensions.– March 2006
- Working with other researchers to resiliency framework and quantification tools into the MCEER decision making models of Thrust Area 2 – September 2006

Team Members: (If known, provide names of team members associated with project including project leader, other faculty and their departments, undergraduate students, graduate students, postdoctoral students, industrial participants.)

Reinhorn and Bruneau will hire one Ph.D. student to conduct the work described in this task statement (Jian Paolo Cimellaro). As members of the MCEER Executive Committee, they will also coordinate interaction with Shinozuka, Filiatrault, and Tierney, to insure convergence towards center-wide resilience developments, as well as with Dargush, Grigoriu, Petak, Alesch, and Winterfeldt to support the decision making platforms with the appropriate resilience quantification algorithms to help accomplish the specific tasks described in their task statement, and ensure continuity with the original work of the MCEER Task Force that led to the original definition and proposed measures of resilience (Winterfeldt, Chang, Shinozuka, Tierney, Reinhorn, Bruneau and Eguchi).

Possible Direction of Work in Subsequent Years:

Year 10 will include validation of the resilience algorithms integrated in the decision making approaches promoted within Thrust Area 2, using the MCEER demonstration hospital. This will include collaboration with Dargush/Petak/Alesch and Grigoriu/Winterfeldt and their respective software platforms. This will help identify the advantages/disadvantages of various resilience algorithms. Year 10 will also focus on integrating resilience across Thrust Area boundaries, collectively using the MCEER testbeds. In addition, the MCEER work on resilience is finding receptive audience in a broader multi-hazard perspective, and can help identify opportunities to ensure the viability of MCEER as a financially independent Research Center beyond Year 10.
Multi-Hazard Statement:
a) (*Conceptually describe in 200 words or less how some of the work you are conducting as part of your MCEER Year 9 research task can be exported/applied to other natural or man-made hazards including multi-hazard research.*)

The resilience framework established by MCEER is applicable to almost any hazard. In presentations to various agencies, the concept of resilience as formulated by MCEER, the related dimensions of resilience, and MCEER’s approach to quantify resilience, have all been very well received. These audiences found this framework most appealing and concur that it captures the ultimate performance objective needs in an all-hazard perspective, i.e. in a most appropriate generic format that opens opportunities for MCEER to expand its reach into the multihazard research arena.

b) *If you are seeking supplemental multi-hazard funding, describe the multi-hazard milestones that you plan to complete as part of your Year 9 research.*