**MCEER RESEARCH TASK STATEMENT**

<table>
<thead>
<tr>
<th>Thrust Area 3</th>
<th>Budget:</th>
<th>Ye 8 Assigned</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Project Number: 8.3.1</td>
</tr>
</tbody>
</table>

**Task Title:** Remote Sensing for Disaster Response and Recovery

**Investigators:** Ronald T. Eguchi*, Masanobu Shinozuka, Bijan Houshmand, and Henry Jones II

**Institutions:** ImageCat, Inc., University of California, Irvine and MLB, Mountain View

* indicates task leader

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

This task focuses on the development and application of remote sensing technologies for post-earthquake damage detection, building inventory development, and real-time earthquake loss estimation. Ultimately, these technologies will be integrated into real-time decision support systems. In order to validate the methodologies, data from a comprehensive set of earthquakes is being used, including: the 2003 Bam (Iran); 2003 Boumerdes (Algeria); 2001 Bhuj (India); 1999 Chi-Chi (Taiwan); 1999 Marmara (Turkey); 1995 Kobe (Japan); and 1994 Northridge events.

**Problem Description and Research Approach of Proposed Work for Year 8:** (Detailed description of research to be conducted and methodology to be used.)

Advanced technologies, such as remote sensing, are emerging as useful disaster management tools. Preliminary studies in Russia and the U.S. suggest that prior to an earthquake, satellite and airborne imagery is a source of critical infrastructure data for developing building and lifeline inventories. Researchers in Japan, Europe and the U.S. also demonstrate how after event, satellite imagery provides a ‘quick-look’ regional overview of urban damage. Building damage has been identified on moderate resolution optical (Landsat and SPOT) and SAR (ERS) imagery for Marmara, and most recently, high-resolution coverage (Quickbird and IKONOS) of Boumerdes and Bam. Moving forwards, it is anticipated that remotely sensed data will increasingly support preparedness activities and post-earthquake reconnaissance, facilitate decision-making, and ultimately, improve the overall response.

In general terms, this research task is working towards the use of advanced technologies in real-time reconnaissance and decision support systems. Research is investigating the application of these technologies during: (a) the immediate response period (initial days following a large earthquake); (b) the early recovery period (several weeks following the earthquake); and (c) as a key component of longer-range mitigation and preparedness programs. The study approach seeks to identify ways in which decisions made during these disaster phases, together with the timeframe within which they are made, can be improved through integrating remote sensing technologies.

Specific Year 8 assignments are as follows:

**Eguchi** – (1) Standardize post-earthquake damage detection methodologies that employ high- and moderate-resolution optical and SAR imagery; (2) augment data fusion techniques with
high-resolution optical imagery; (3) integrate remotely sensed inventory data into existing loss-estimation programs; (4) establish how research products can be integrated into systems for prioritizing, facilitating and monitoring response and reconnaissance activities.

**Houshmand** – (1) Provide requirements for Interferometric SAR data acquisition for earthquake damage detection; (2) integrate LIDAR data with optical and SAR imagery for change detection; (3) investigate the performance of new generation of hyperspectral/LIDAR/SAR sensors for rapid imagery acquisition; and (4) investigate the use of shuttle radar topography mission (SRTM) IFSAR global data with optical imagery for creation of base maps for response to regional disasters.

**Shinozuka** – (1) Focus on the development of implementable real-time remote sensing technologies to identify the extent, location and mode of seismic damage sustained by urban built environment; (2) use pre and post-event digital (SAR, optical and possibly LIDAR) images obtained from ground, aerial and satellite platforms for damage identification; (3) further improve the correlation analysis, principal component analysis, and Markov random field approach to relate earthquake damage to image changes.

**Jones** – (1) Provide miniature robotic aircraft for airborne reconnaissance; (2) modify hardware and software systems to accommodate near real-time, airborne reconnaissance of earthquake-impacted areas.

---

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

The research conducted by MCEER is unique within the U.S. research community. Overseas, studies concerning the use remote sensing technologies for post-earthquake damage detection are being conducted by the Earthquake Disaster Mitigation Research Center (EDM) in Miki, Japan, and by European researchers at Cambridge University and the research division of Benfield Group. Collaborative research with EDM, Benfield and Cambridge University is currently being undertaken the 2003 Bam, 2003 Boumerdes and 1995 Kobe earthquakes.

A number of geophysical groups in the U.S. and Europe are investigating the use of interferometric synthetic aperture radar (IFSAR) for earthquake response. However, this research is primarily concerned with measuring the displacement or strain fields surrounding large magnitude earthquakes.

Further research efforts by federal agencies including DOT and NASA, are working towards methodological bases for the use remotely sensed data in disaster response. MCEER researchers are actively involved with a number of these programs, most of which are in the “proof of concept” phase.
**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, 2003, to March 31, 2004.)*

During the initial 7 years, research efforts have concentrated on: (1) characterizing urban environments using SAR technology; (2) exploring the use of optical imagery to separate the urban environment from natural surroundings; (3) developing preliminary post-earthquake damage detection algorithms that use optical and SAR data to locate collapsed urban structures; and (4) integrating GPS and SAR data in the assessment of post-earthquake ground displacements and building damage.

Structural characteristics of residential, commercial, and industrial areas in Los Angeles have been characterized with ‘building height signatures’ and ‘building inventory plots’. The former is a cumulative sum of total building footprint area by building height (obtained from IfSAR elevations). The latter is the total footprint area associated with specified story heights. Together, these graphical representations characterize building square footage and height, which are key constituents of building inventories. During the past year, building height signatures and inventory plots have been computed for residential, commercial and industrial study sites in Los Angeles. Initial progress has been made towards establishing a methodology for integrating the resulting data in HAZUS’99 loss estimation software.

Progress has also been made with the use of optical and radar imagery to detect earthquake damage after major earthquakes. Research conducted following the 1999 Marmara event shows that a comparative analysis of ‘before’ and ‘after’ ERS and SPOT satellite imagery reveals areas of urban damage. The project team devised and validated quantitative optical and SAR change detection indices for the Turkish cities of Golcuk and Adapazari, expressing the concentration of building collapse as a function of indices including: difference, correlation, block correlation and coherence. Measurement-, feature- and decision-fusion techniques were tested for enhancing damage detection capabilities. During year 7, research has extended the basic damage detection methodology to include high-resolution QuickBird imagery of the 2003 Boumerdes and Bam earthquakes. The vision of a ‘tiered reconnaissance system’ was conceived, whereby satellite imagery offers a ‘quick-look’ regional damage assessment, which in turn provides the focus for more detailed inspection of localized building damage using visualization techniques. QuickBird coverage of Boumerdes was acquired before and after the earthquake. Modifications were made to the existing algorithms, including the integration of edge detection filtering, together with texture analysis. These were necessary to accommodate the increase in spatial resolution from the 10m to 0.6m. Visual inspection techniques were then used to locate and characterize damages and collapsed buildings.

With the objective of determining whether damage to the urban environment can be discerned by merging data from different sources and technologies, displacement and strain field maps derived from SAR interferometry have been compared with those obtained from GPS measurements. Year 7 results for the region of Turkey affected by the 1999 Marmara earthquake, point towards a positive association between areas exhibiting extreme ground displacement and severe building damage. However, since the scale of ground displacement is below the threshold of the smallest unit of measurement in the SAR data, it cannot be used to separate ground displacement from urban damage.
**Role of Proposed Task in Support of Strategic Plan:** *(Describe how the effort will make a unique, useable contribution to the MCEER strategic plan.)*

The development of new technologies that quantify post-earthquake damage in near real-time is a critical step towards improving contemporary response and recovery procedures. As an element of MCEER Thrust Area 3, these technologies will enhance community resilience, by: (1) helping emergency officials to identify severely impacted areas in near real-time; and (2) contributing to decision support systems that prioritize response activities based on need, opportunity and available resources.

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

This task focuses on the development and use of advanced technologies for emergency response and recovery. New tools and more comprehensive databases of the urban environment are required to reduce the losses from, and improve response to major disasters. Thrust Area 3 will result in better tools for emergency planners, officials, reconnaissance teams and recovery workers.

As a result of this research, it is anticipated that planners will have access to better information on exposed assets, more reliable methodologies to project future earthquake losses, and real-time decision support systems that will identify post-earthquake damage within a matter of hours. Critical in this development will be the integration of emerging remote sensing technologies, such as unmanned airborne vehicles (UAVs), and improved database management systems.

**Possible Technical Challenges:**

The technical challenges associated with testing and validating new technologies are considerable. While the limited nature of available data sets is a concern, demonstrating the efficacy of new technologies compared with conventional and perhaps, more accessible methodologies could create implementation issues. If successful, however, the potential for more accurate and timely post-event loss estimates is extremely high.

**Anticipated Outcomes and deliverables:** *(Also indicate those of particular benefit to IAB members and other end users.)*

- Report documenting the development of building height signatures, building inventory plots, and the update of HAZUS’99 inventory data.
- Report documenting methodology and models for post-event damage detection following the 1999 Marmara earthquake
- Case studies involving U.S. and foreign earthquakes.
- Possible collaboration between several government agencies (LA City and CA OES) and MCEER in pilot studies.

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

- Government Agencies: LA City, LA County, California Governor’s Office of Emergency Services, Federal Emergency Management Agency, DOT, NASA.
- Professional Organizations: EERI
Educational outcomes and deliverables, and intended audience:

Briefings and seminars on the use of advanced technologies for post-earthquake damage detection. Intended audience: emergency responders, students and industry representatives.

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

- Report on Urban Damage detection following the 2003 Bam, Iran and 2003 Algerian Earthquakes, Spring 2005

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.)

- Ronald T. Eguchi, ImageCat, Inc., Team Leader
- Masanobu Shinozuka, University of California, Irvine
- Charles K. Huyck, ImageCat, Inc.
- Beverley J. Adams, ImageCat, Inc.
- Howard Chung, ImageCat, Inc.
- Michael Z. Mio, ImageCat, Inc.
- Bijan Houshmand, Consultant
- Henry L. Jones II, MLB

Possible Direction of Work in Subsequent Years:

- Integrating remote sensing with pre- and post-disaster decision support systems.
- Leveraging Information Technologies for Crisis Response (Data Fusion, Mining, etc.).
Figure * Building damage in the city of Boumerdes, identified by visual inspection of panchromatic Quickbird imagery, acquired before and after the 5/21/2003 earthquake. Images courtesy of DigitalGlobe, [www.digitalglobe.com](http://www.digitalglobe.com)