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LEARNING FROM EARTHQUAKES: NEW DIRECTIONS AND INITIATIVES

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SUMMARY

The Earthquake Engineering Research Institute, a nonprofit professional association of earthquake engineers and others interested in earthquake risk reduction, has, since its inception in 1949, conducted post-earthquake investigations with the purpose of improving the science and practice of earthquake engineering. For the last thirty years this Learning from Earthquakes (LFE) program has been supported by the U.S. National Science Foundation (NSF). Increased support from NSF has allowed EERI to initiate new programs and to investigate new directions for post-earthquake reconnaissance, particularly in the use of information technology in data collection and management. This paper discusses these new programs and directions in more detail.

INTRODUCTION

The ability to make observations rapidly and precisely following a disaster has long been recognized as critical to managing emergency response activities in the short term and improving the understanding of natural hazards in the long term. For over 30 years, the Earthquake Engineering Research Institute (www.eeri.org) has sent multi-disciplinary teams of researchers (e.g., earth scientists, engineers, social scientists) into the field under the auspices of its Learning from Earthquakes Program to investigate and to learn from the damaging effects of earthquakes (Hanson [1]; Penzien and Hanson [2], Meehan et. al. [3], Rodriguez-Marek and Edwards [4]). The reconnaissance team makes a rapid, general damage survey of the affected area, documents initial important observations from the particular earthquake, and assesses the need for follow-up areas of research EERI [5], EERI [6]). EERI investigates all damaging earthquakes in the United States as well as international earthquakes where lessons might be learned that have application to the U.S. (See EERI [7], EERI [8] for recent examples.) In addition to EERI, many other organizations (e.g., universities, private firms, state and international governments) send reconnaissance teams. EERI and the United States Geological Survey (USGS) share responsibility under a recently completed federal post-earthquake investigation plan to manage reconnaissance efforts in the United

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States; EERI has primary responsibility in international earthquakes [9]. Typically, management includes coordinating all field investigators.

On average, a reconnaissance team is deployed within three days of a disaster and the reconnaissance efforts last one to two weeks. On a daily basis, trips are made into the damaged region and nightly meetings are organized for the team members to discuss their findings. At the end of the reconnaissance process, the EERI team members lead the effort to identify further research needs [10] and document the impacts of the earthquake, beginning with preliminary reports through additional investigations (e.g., Beyond Reconnaissance Grants) and ending with the final consolidated report, as shown in Figure 1 (adapted from [9]). In addition, studies to capture earthquake lessons that may not be apparent until some years after an event are also funded (e.g., Lessons Learned Over Time grants) [11], [12], [13] [14]. The data collected are put in the form of reports, which become an essential source of information for researchers for many years to come. Recent examples include [4], [15], and [16].

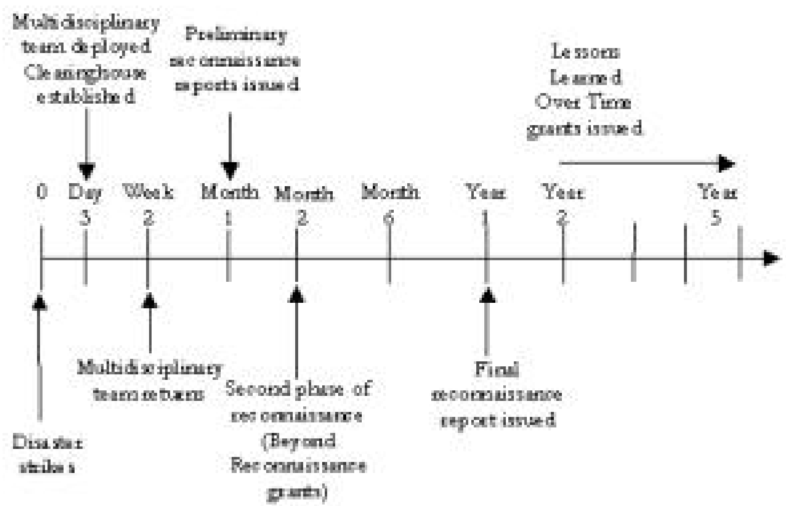

Figure 1: General Timeline of Reconnaissance Process. (Adapted from Holzer et. al. [9])

Although carrying out post-earthquake investigations since its founding in 1949, EERI formally initiated the Learning from Earthquakes Program (LFE) with funding from the National Science Foundation, in 1973. Team members document initial lessons and unusual or significant damage. These initial observations are often later translated into detailed studies that have formed the basis of changes in codes or standards, changes in design and construction practice, and changes in public policies related to earthquake risk reduction or reconstruction.

EERI’s LFE program is in the process of initiating a series of new and expanded activities, including an expanded reconnaissance program, training for future team members and team leaders; a separate web site with training modules and information on past reconnaissance, construction practices and earthquakes in many countries of the world; development of a more systematic approach for data collection and management; and a major program element investigating various information technology tools that can improve field reconnaissance. Each of these new program elements is discussed in more detail below.

The program is managed day-to-day by a principal investigator, along with a program manager, with oversight and significant contributions from two of EERI’s standing committees: the Learning from Earthquakes Advisory Committee and the Information Technology Committee. In addition, there are two active subcommittees—the LFE Social Science Committee (focusing on ways of increasing social science involvement in reconnaissance) and the Oversight Committee on Data Collection and Management (providing leadership for the development of a data collection action plan).

EXPANDED RECONNAISSANCE

With increased funding from the U.S. National Science Foundation in recent years, the LFE program has been able to expand its reconnaissance activities, increase the number of earthquakes that are documented, involve younger members, improve dissemination of early and later reconnaissance findings, and re-visit earthquake areas to gather additional data, some that are perishable, and others that emerge only over time.

Increased Reconnaissance Visits and Dissemination of Reconnaissance Findings

The expanded funding has enabled EERI to send small teams to moderate earthquakes as well as devastating events, resulting in a more complete documentation of earthquake effects than previously possible. In addition, EERI has worked collaboratively with local members in the affected country, sometimes supplementing these in-country experts with people who represent additional disciplines. For example, after the Bingol, Turkey earthquake, EERI relied primarily on prominent members in Turkey to coordinate the reconnaissance, but provided support for a political scientist to travel from the U.S. and contribute to the reconnaissance effort. While a small team was sent from the U.S. to Boumerdes, Algeria after the May, 2003 event, the team coordinated closely with many colleagues in Algeria while writing the summary report. This resulted in a report with over 40 authors and contributors that was much more complete and able to discuss the significance of the event within the social and political context as well as provide insight into technical issues. Collaborative reconnaissance visits and reports are also more useful to the countries affected by the earthquakes. Recent preliminary reports include reports on earthquakes in:

- San Simeon, California, December 22nd, 2003
- Bam, Iran, December 26th, 2003
- Tokachi, Japan, September 26th, 2003
- Lefkada, Greece, August 14th, 2003
- Boumerdes, Algeria, May 21st, 2003
- Bingol, Turkey, May 1st, 2003
- Colima, Mexico, January 21st, 2003
- Denali, Alaska, November 3rd, 2002
- Molise, Italy, 31 October/1 November, 2002

(See Figure 2.) In addition to these preliminary reports, several special issues of EERI's journal ***Earthquake Spectra*** are in various stages of production and printing, including an issue on the Molise, Italy earthquake with many Italian colleagues, an issue on the Denali, Alaska earthquake; an issue on the Colima, Mexico earthquake being prepared collaboratively with Sociedad Mexicana de Ingenieria Sismica (SMIS) in Mexico, and an issue on the Bam, Iran earthquake, being prepared collaboratively with the International Institute for Earthquake Engineering and Seismology in Tehran.

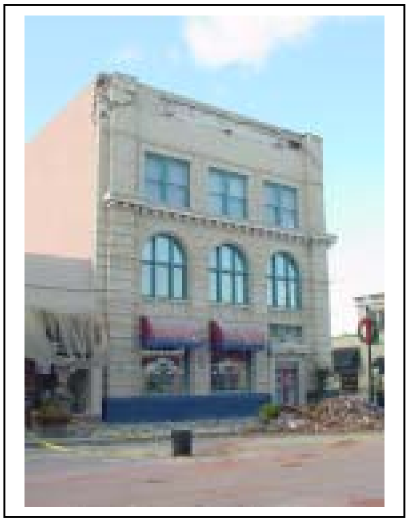

Figure 2: (Left) Partially retrofit Bank of Italy Building in Paso Robles, CA (photo Lynn); (Right) destroyed Arg-e-Bam Citadel in Iran (photo Naeim)

Involvement of Young Professionals

The LFE program is also providing opportunities for students and young professionals to learn post-earthquake field reconnaissance techniques. During recent post-earthquake investigations to Molise, Italy and Colima, Mexico, a young professional traveled with more seasoned field investigators, in part to handle the burgeoning IT requirements for reconnaissance (management of the digital photos, GPS units, beta testing of the electronic data collection system), and in part to gain valuable field experience. Young professionals also traveled to Colima, Mexico, Boumerdes, Algeria, and Bam, Iran.

A recent project under the Lessons Learned over Time element of EERI's LFE Program allowed a PhD student to travel to El Salvador where he lived in a village for several months and assisted in the design and building of a community day care center, built from adobe blocks but with added elements of seismic resistance integrated into the traditional design and construction practice. Some of his experience and lessons were incorporated in an adobe tutorial on EERI's on-line World Housing Encyclopedia (www.world-housing.net) and his final report has been published as volume V of Lessons Learned over Time, in both Spanish and English (Dowling [15]). Since more than 30% the world lives in this vulnerable construction type, such lessons are particularly important to document and transmit to those in a position to act on these recommendations to reduce future losses.

Beyond Reconnaissance Grants

EERI has also implemented its first set of Beyond Reconnaissance Grants for small, innovative projects that will build on initial field reconnaissance observations in both Mexico and Italy. In a particularly hard-hit neighborhood in Colima, Mexico, working with SMIS and the National Center for Disaster Prevention (CENAPRED), and using equipment and software donated by ESRI, a research team will document the usefulness of GIS as a tool to aid decisions regarding appropriate rebuilding strategies. In addition, the team will document the various techniques used to communicate rebuilding strategies and appropriate construction materials. In Italy, working with the Italian National Seismic Survey, the team will document the hundreds of years of experience the Italians have in collecting systematic damage statistics, and will use the Italian experience to ways to design a U.S. system for the systematic and electronic collection of field reconnaissance data. Providing opportunities for the next generation of researchers and practitioners and fostering innovation in the broad earthquake and disaster risk reduction community are important goals of EERI's LFE Program.

Lessons Learned over Time

In 1998, EERI initiated its *Lessons Learned Over Time* series under the LFE program. The intent was to capture earthquake lessons that may not be apparent until some years after an event, or that should be re-evaluated in the light of new understanding and knowledge. In the three funding cycles to date under this program, the following ten proposals received modest funding for retrospective studies to investigate longer-term recovery and rebuilding issues:

- 1989 Loma Prieta: An update of a study on the planning process for the reconstruction of Pacific Garden Mall
- 1995 Kobe: A trigger for implementation of advanced technologies for earthquake hazard mitigation
- 1989 Loma Prieta and 1994 Northridge: Formulating strategies to optimize local recovery. Assessing cities' recovery management.
- 1993 Maharashtra, India: Assessment of long-term recovery.
- Various U.S. earthquakes: Performance of roll-up garage doors in fire stations.
- 1995 Kobe: Study of repairs to elevated expressways.
- 1999 Turkey: Earthquake performance of bridges and remedial actions.
- 2001 Nisqually: Performance and reconstruction of unreinforced masonry buildings.
- 2001 El Salvador: Appropriateness of reconstruction and rehabilitation strategies.
- 1999 Turkey: A Comparative Study of Earthquake Recovery issues involving the Performance of Buildings of Timber-laced Masonry Vernacular Buildings

The first seven studies were published in Volumes I-IV of the *Lessons Learned Over Time* series, sent to EERI members as a benefit of membership in 1999, 2000 and 2002 (EERI [11], [12], [13], [14]). The report on reconstruction in El Salvador will be published in both English and Spanish, and sent to members as a benefit of 2004 membership (Figure 3). The remaining studies are underway, and a new set of proposals expected in spring, 2004. Non-EERI members may purchase these reports online from the EERI web site.

Figure 3: (Left) Poor performance of adobe in El Salvador (photo Menjivar) and (Right) improved adobe construction training program (photo Dowling).

Recovery Reconnaissance

EERI will soon publish what is intended as the first in a series from EERI, focusing on field observations of the post-earthquake recovery process (Murty et. al. [16]). Typically, reconnaissance teams bring back observations from the immediate post-earthquake environment, documenting initially observable (or perishable) effects of the earthquake on the physical, built and social environments. These observations are typically made within a week or two of the earthquake and often contain important lessons for improving the practice of earthquake engineering and its related disciplines. Unexpected building or lifelines failures, as well as good performance, observations on soil-structure interactions, and improving the knowledge about a region's seismicity, faulting and earthquake hazard are all among the important reasons why earthquake reconnaissance is conducted immediately after an earthquake. However, there is also growing recognition that many of the most important lessons coming from an earthquake only surface in the recovery phase - reconstructing the physical built environment and rebuilding the social environment. The recovery phase is often the most complex and challenging, and deserves more attention from the broad earthquake engineering community, including those rebuilding and those promoting future seismic resistance. Communities confronted with earthquake disasters employ many strategies with a view to building capacity within their community to mitigate the effects of future earthquake disasters. Some of these strategies are successful while others are not. Understanding more clearly the processes involved in the recovery phase (a) reveals the efficacy of the strategies employed, and pitfalls and corrective measures necessary in long-term earthquake disaster preparedness, and (b) gives a more complete picture of the total effects of the earthquake disaster. Lessons documented from such recovery reconnaissance trips stand as valuable guides to other communities around the world that face the daunting tasks of earthquake rebuilding and long-term disaster mitigation.

Recognizing that the recovery phase holds many important observations and lessons for the global earthquake engineering community, the LFE Advisory Committee initiated this effort by asking a small multidisciplinary team to investigate rebuilding following the Bhuj earthquake (in the western state of Gujarat, India) of 26 January 2001 (See Figure 4). Team members included structural engineers, an urban planner and a sociologist, including those familiar with earthquake engineering in India as well as the government of Maharashtra's rebuilding experience.

Figure 4: Rebuilding Activities in Gujarat. Widened street in Anjar (left); base-isolated hospital in Bhuj (right), with technology and isolators from New Zealand.

LFE WEB SITE

As part of the expanded LFE program and in conjunction with a major renovation of EERI's web site, a separate section on the Learning from Earthquakes program has been developed. This section, which can be found at http://www.eeri.org/lfe.html contains some basic background on the LFE program and some of the information that would be helpful in conducting reconnaissance, such as chapters from *the Post-Earthquake Field Investigation Guide* and basic forms to use in the field (Figure 5). However, perhaps most importantly the site contains useful information on data collection for many major earthquakes that have occurred in the last 50 years. This information includes the EERI preliminary reconnaissance report, if one was prepared, links to the on-line ***Earthquake Spectra*** issue or articles on the earthquake, other reports on the earthquake, and links to related information, as well as maps and photos.

For each country, general background information is provided, including links to government associations and organizations, maps, construction practices and building codes (primarily reports that are coming from EERI and IAEE's World Housing Encyclopedia) and social and economic information (at this point, primarily from the United Nations). See Figure 6 below.

Figure 5: Learning from Earthquakes web site, www.eeri.org/lfe.html

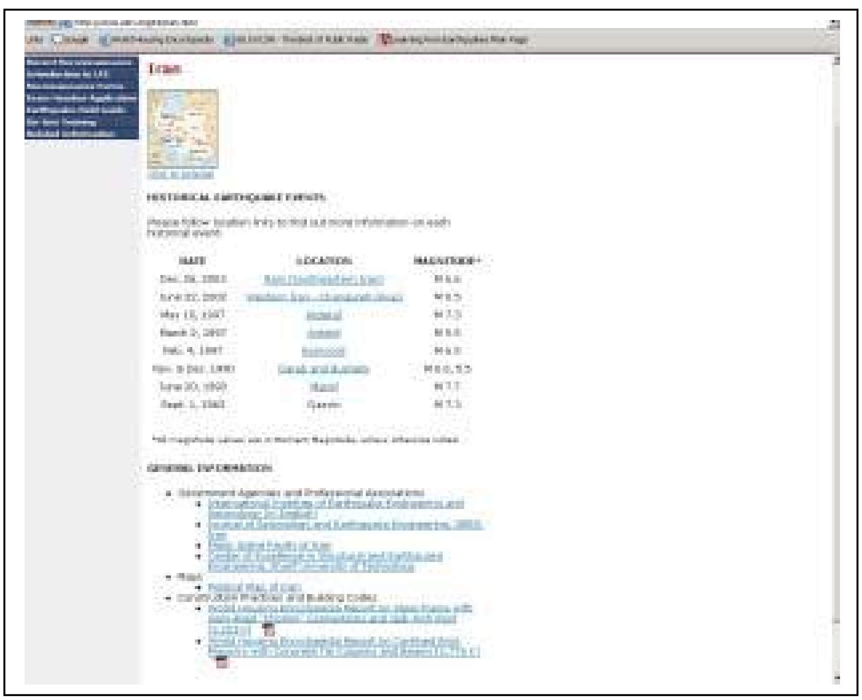

Figure 6: Typical Information Available by Country

SYSTEMATIC APPROACH TO DATA COLLECTION AND MANAGEMENT

On September 19th and 20th, 2002, the Earthquake Engineering Research Institute (EERI) hosted an invitational workshop with 70 experts in the fields of earthquake engineering, earth sciences, and the social and policy sciences, to identify the major issues that come into play in developing an Action Plan for an earthquake damage and loss data collection and management framework. Rapid changes in information technology are allowing researchers to consider electronic data collection and storage in a much more systematic manner. It was intended that workshop participants would identify an Action Plan that would define a schedule and the needed resources and steps to establish a more systematic database within the next five years. It was expected that workshop participants would make recommendations for lead agency responsibilities, clarify data collection and access issues, identify training needs, and detail maintenance and repository concerns.

However, during the workshop it became apparent that developing such an Action Plan is a more complicated process than originally anticipated. There is an important interim step before tasks could be identified. This interim step requires the identification of major issues involved in data collection and management. The diverse range of disciplines and experiences bring a range of issues that needs to be addressed. The kinds of data that belong in the Action Plan are only one issue among many that needs to resolved. Thus this report has evolved from an Action Plan to one that attempts to define the issues for an action plan, a necessary first step that emerged from the workshop and that should ultimately result in a much stronger and more effective plan (EERI [17]).

Building on the recommendations from the workshop, targeted task forces have been established to focus on priorities in four important areas:

- Post-earthquake damage data collection—what data need to be collected by what disciplines
- Data repository(ies)—what are the critical first steps in creating such a repository? What are the development and policy issues associated with the first steps of implementing such a repository?
- Secondary data collection (insurance data, government statistics)—what should be collected, who provides, who collects
- Inventory data—how can these data be usefully incorporated into post-earthquake investigations? What are the priorities for such data?

IT TOOLS TO IMPROVE FIELD RECONNAISSANCE

Related closely to the general issue of improving the systematic collection and management of data, is the potential role of Information Technology tools in the collection of field or reconnaissance data. In the post-earthquake environment, information technology can provide a more efficient way of collecting data, coordinating reconnaissance teams, monitoring reconnaissance, and analyzing data. Information technology can improve the ability to capture a wide range of observations and lessons after earthquakes. Data that would otherwise have perished after earthquakes can now be collected, stored and made accessible via advances in information technology tools and techniques. Specifically, IT can:

- **Eliminate the Duplication of Effort.** New technologies are now available to develop systems to exchange reconnaissance information (e.g., through GIS maps), reducing duplication of efforts by investigators collecting the same data. Over the last few years, the number of field investigators from various organizations has increased dramatically, making this coordination and organization increasingly challenging.
- **Capture and Archive Perishable Data.** IT tools can aid in the coordination of team members (e.g., GPS) and to create access to heterogeneous information sources (e.g., graphics, text, sound)

that can be utilized to gather perishable data before they disappear forever. For example, evidence of ground failure and fault rupture, building collapses, and even individuals' ability to recall specific actions taken during the emergency response phase are lost if not collected immediately following a disaster. Often these data are critical to understanding exactly what happened in the earthquake.

- **Establish Data Standards**. An IT-based system with data standards and protocols can alleviate discrepancies in field data so valuable follow-up research can be accomplished. To date, field reconnaissance data have not been collected systematically. For example, different investigators ask different questions of the same individual (e.g., emergency response official) or report findings differently (e.g., data form or digital photo). Moreover, data are not stored in an accessible format for future scientific research.
- **Enable Analysis of Field Data.** IT can be used to develop a common structure for geo-spatial-temporal data integration, vital to post-disaster investigation. Currently, collected data cannot be evaluated in the field to determine patterns or to make decisions, such as mapping damage patterns for groups of structures or determining the links between lifeline network outages and affected persons seeking temporary shelter. Moreover, since it often takes a long time to publish final reconnaissance reports (which are static), this data analysis ability in the field will ensure that follow-up research will build on initial findings.
- **Expedite Data Sharing.** A system that utilizes IT advances in network connectivity and data transfer protocols (specifically for earthquake data) can aid in the quick dissemination of information to various stakeholders, including emergency response officials, earthquake engineering researchers and the general community.

EERI's Learning from Earthquakes and Information Technology Committees have been spearheading an effort over the last two years to introduce more IT tools into reconnaissance activities. Team members now routinely carry digital cameras and recent reconnaissance teams have also used GPS units to associate a latitude and longitude with each image. Digital audio and video recording equipment are being used more routinely, with the intent that EERI will begin posting streaming video from the disaster site. Cellular phones, including phones that can transmit photos, as well as satellite phones, have been used to expedite recent reconnaissance. Teams have used the web as a way to store and transmit information and have used remote sensing technology to provide basic information on the post-earthquake environment.

Electronic Data Collection System

EERI has been working with Accela (www.accela.com) to develop an electronic data collection and mapping system (ERS). A beta version was made available in February 2004 and has been undergoing testing since then. The system provides electronic "guidesheets" or reconnaissance forms that can be installed on a laptop, desktop or handheld PDA, such as a Tablet PC or iPaq (the system is Windows CE-based). The reconnaissance forms currently available at the EERI LFE web site described above are being modified as guidesheets. The investigator fills out a form(s) for each georeferenced location. If there is Internet access, these forms are uploaded to a central server and the basic information can be displayed in GIS format to all users in near real-time. If there is no Internet access, the system is functional on a stand-alone server, where data are held until they can be uploaded to the web-based server. One major advantage of this system is the ability to upload different sets of guidesheets and to modify guidesheets "on the fly". If investigators notice that the questions are not relevant to the particular earthquake, the form can be modified by one of the field administrators and updated in everyone's system. An additional strength of the system is its ability to handle cataloguing and managing of data from multiple sources, and to export collected data to other platforms for further analysis. The system is also flexible enough to collect different levels of detail, and different types of information, making it useful in international earthquakes as well as U.S. earthquakes. Plans are underway to provide extensive training to the EERI membership regarding this system and its potential use.

Remote Sensing

EERI has investigated the use of remote sensing after the Boumerdes, Algeria, and Bam, Iran, earthquakes. EERI purchased high-resolution optical images acquired before and after the earthquakes and shared them with members who are currently doing research in this area. The remote sensing damage assessment group met after the Algeria event, to discuss possible applications of the imagery. Presentations and the workshop summary are available at http://shino8.eng.uci.edu/Remote_Sensing_2003.htm.

After the Bam, Iran, earthquake, EERI members from ImageCat, Inc. (www.imagecatinc.com) loaded before and after satellite imagery on the computers that were going in the field. While team members encountered logistical challenges in using the VIEWS (Visualizing Impacts of Earthquakes with Satellites) system (deploying a laptop in the field was problematic and difficulties were experienced keeping it charged), the experience did prove valuable in understanding how the imagery can indicate areas of severe damage and how it could be used to track reconnaissance activities in the field. An article in ***Earthquake Spectra*** is planned by this group to discuss this application further. See Figures 7 and 8 for an illustration of how clearly the nearly complete destruction of this section of Bam is visible from the imagery.

Figure 7: Satellite image of the city of Bam before the earthquake (imagery courtesy of DigitalGlobe, www.digitalglobe.com, processed by ImageCat, Inc., www.imagecatinc.com)

Figure 8: Satellite image of the same view of the city of Bam after the earthquake. (Imagery courtesy of DigitalGlobe, www.digitalglobe.com, purchased by the University of California at Irvine and processed by ImageCat Inc., www.imagecatinc.com)

THE CLEARINGHOUSE

In major earthquakes there are many teams and individuals who come to the damaged area to observe and learn from the damage. Typically, daily trips are made into the damaged region and nightly debriefings are planned for team members and others to discuss their findings. EERI has found that it is crucial to set up a *clearinghouse*, a common place where the various investigators can report and get status updates of overall field investigation and the whereabouts of team members. In its simplest form, the clearinghouse is a physical location where the team members will meet at predetermined times and exchange information they have gathered in the field.

California Clearinghouse

When the concept of the clearinghouse was first developed in California, the intent was not only that field researchers would share information among themselves, but also that they would provide important *intelligence* to emergency response agencies. These agencies are typically too busy with life-saving and emergency operations to conduct an overall assessment of the situation. They rely on the expertise of the field investigators to provide information on critical buildings, soil failures or areas of particular concern.

Coordination with NEHRP Agencies

A recent plan to coordinate post-earthquake investigations of the various NEHRP agencies has been published by the U.S. Geological Survey. Entitled ***The Plan to Coordinate NEHRP Post-Earthquake Investigations***, the plan provides the framework for how the various NEHRP agencies and their partners, including EERI, coordinate what needs to be done and identifies responsibilities. The USGS and EERI share responsibility for coordinating a clearinghouse in a U.S. earthquake: EERI takes responsibility for the engineering and socioeconomic aspects of the investigations; and USGS takes responsibility for the earth science aspects. In international earthquakes, EERI takes responsibility for clearinghouse organization and management. Recently, the various agencies have exercised this plan with three scenario earthquakes. The plan is available online at http://geopubs.wr.usgs.gov/circular/c1242/index.html.

Virtual Clearinghouse

After the San Simeon earthquake in December 2003, it became apparent to EERI that the web may play a larger role than originally anticipated in data collection and management, particularly for moderate earthquakes where there is constant internet access, or for earthquakes where damage is widespread, making reconnaissance impossible to coordinate from one clearinghouse. Although the management group of the California Clearinghouse decided that there was not enough damage in the San Simeon earthquake to warrant setting up a clearinghouse, investigators were still interested in sharing what information was available from the field. Consequently, EERI set up a folder on its ftp site where field investigators could upload images and files. Since there was no central coordination place, and there was no team that was sent to the field (rather, individual researchers went to the field over a several week period) this ftp site proved to be extremely helpful as the gathering place for information. In future earthquakes, EERI will establish a more accessible site instead of an ftp site, for more widespread access and exchange of information. A more user-friendly interface would also encourage people to share their information readily. A model for this exists in the Nisqually Clearinghouse, developed after the Nisqually, Washington earthquake in 2001. That clearinghouse can be viewed on-line at http://maximus.ce.washington.edu/~nisqually/.

Concept of a Mobile Clearinghouse

The IT Committee has been developing over the past year the concept of an electronic, mobile clearinghouse that could function in any kind of environment. Such a mobile clearinghouse builds on the elements discussed above—electronic data collection, sharing of information via the Internet. The proposed mobile disaster clearinghouse (Figure 9) will allow various investigators (e.g., earth scientists, engineers, social scientists) to collect, manipulate and analyze data. The reconnaissance teams will be coordinated within the web-based clearinghouse and deployed with the applicable data collection tools. In the final implementation of the clearinghouse system, the administration and logistics of the clearinghouse, integrated with the data repository (with databases of heterogeneous data), will be an enhanced enterprise. This is the first step of what EERI envisions to be an evolving and improving repository for data sharing and collaboration.

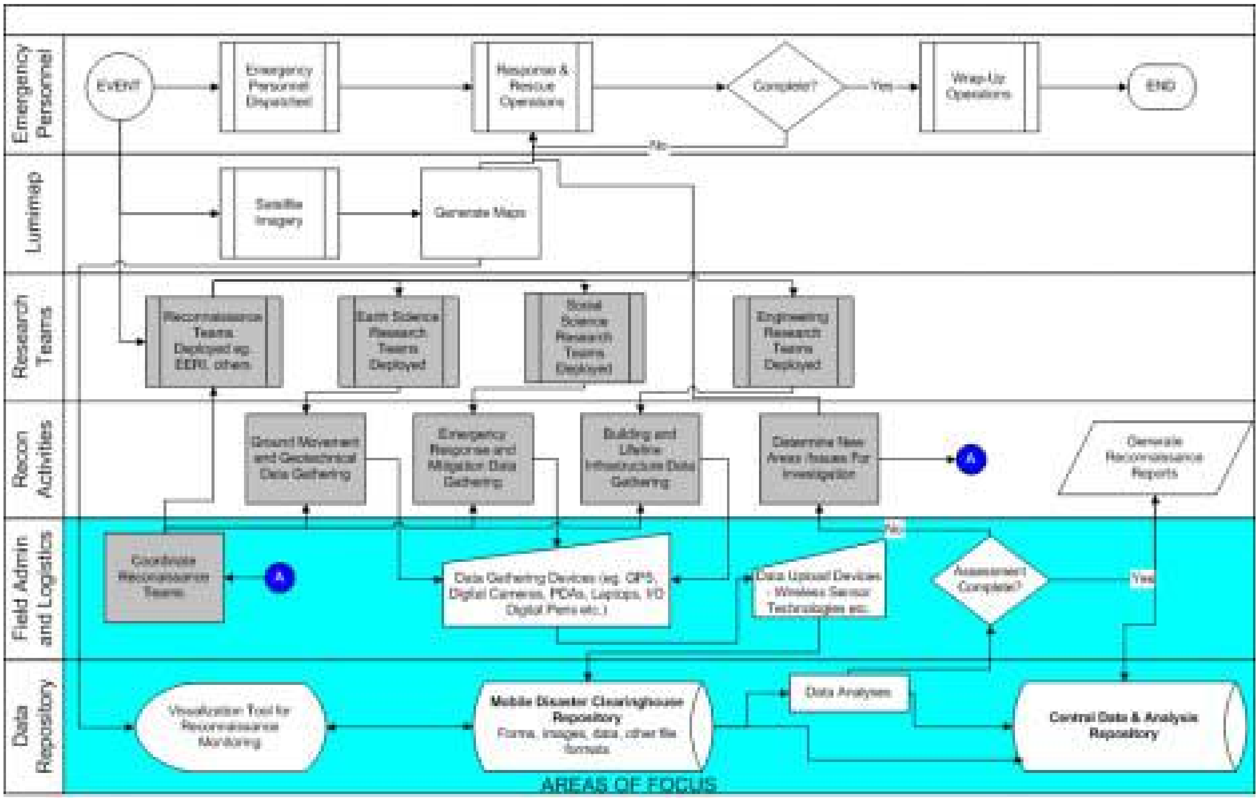

Figure 9: A Schematic of the Electronic Mobile Clearinghouse

The system integration tasks would involve many different hardware platforms and a variety of software applications. Much work over the next few years will be required to bring this vision of a mobile clearinghouse to a point where EERI members and others can begin testing the functionality of the system. The most important factor across the various platforms and applications that may be part of such a clearinghouse is the data that form the basis of the clearinghouse. By maintaining a clear picture of what would best serve scientists, engineers, and other researchers, a solid direction for the system can be formed. While the work with the Accela system has allowed EERI to begin to establish the framework for addressing some of these issues, there are clearly many complex issues remaining that the IT committee and others must address, including:

- **Organization.** File formats, software applications for data conversion, data naming conventions, and geographic projections;
- **Foundation**. Which areas to acquire and maintain base map information; which types of information, and at what level of detail;
- **Standards**. Certification of contributors, minimum resolution of imagery, confidence threshold for data, and data integrity;
- **Synchronization**. Identification of contributors, methods of contributing data, and resolution of conflicting data;
- **Storage.** Security processes, size, scalability, hardware, software, non-computerized storage, maintenance costs, and backups;
- **Representation.** Iconography, human-computer interaction interfaces, and languages;
- **Active distribution.** Certification of subscribers, distribution methods, output format, and pricing;
- **Passive retrieval.** Security mechanisms, methods of access, and pricing;
- **Analysis**. Tools, tool modification techniques, and clearinghouse access to final results.

Simple, ad hoc solutions might be found for some of these issues. However, the need for the clearinghouse to become a vital part of earthquake research in the long term mandates that the system be reliable, scalable, flexible, and fast. These criteria are sometimes at odds with one another, and the tradeoffs that are necessary will be discussed with the participation of the stakeholders to ensure that the final system is as satisfactory as possible. The IT and LFE committees at EERI will be working with the membership and the broader earthquake engineering community over the next several years to resolve these issues and work towards a mobile clearinghouse system that will greatly enhance our field reconnaissance capabilities.

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