Session No. 6

Course Title: Earthquake Hazard and Emergency Management

Session Title: Earthquake Research and Information

Author: James R. Martin, II

Time: 180 minutes

Objectives:

6.1 Identity major initiatives underway in earthquake research, such as earthquake prediction.

6.2 Recognize current research trends and identify future research initiatives.

6.3 Identify main earthquake research organizations and information sources.

6.4 Appreciate why continued research is needed and how research alone does not reduce vulnerability.

6.5 Recognize and appreciate the public "perception problem" associated with earthquake hazards.

Scope:

The objective of this series of lectures is to introduce the student to key earthquake research organizations and information sources, and provide a perspective on the role of research information and recent initiatives. ***This session is not intended to serve as an information clearinghouse***; rather, this session is designed to educate the student in terms of where to obtain specific types of research information, recognize the latest trends in earthquake research, identify who the key players are, learn about the major initiatives underway, appreciate the important role research information plays in hazard reduction, understand how research information is used by decision makers (i.e., emergency managers), and appreciate the importance of building constituencies to promote funding of earthquake disaster research and other government–sponsored programs and activities.

Readings:

Suggested student reading:

"Securing Society Against Catastrophic Earthquake Losses: A Research and Outreach Plan in Earthquake Engineering," Jan. 2003, *Earthquake Engineering Research Institute*, pp. 76, available from http://www.eeri.org/research/Researchplan01-03.pdf.

NRC, 2003. *Preventing Earthquake Disasters: The Grand Challenge in Earthquake Engineering: A Research Agenda for the Network for Earthquake Engineering Simulation (NEES)*, Executive Summary, Chapter 1, National Research Council, Washington, DC: National Academies Press.

Stallings, Robert A., "Sociological Theories and Disaster Studies," Inaugural Distinguished Lecture on Disaster and Risk at the Disaster Research Center, Department of Sociology and Criminal Justice, University of Delaware, Newark, 17 April 1997. The presentation is available from: http://www.udel.edu/DRC/preliminary/249.pdf.

Recommended instructor reading and resources:

EERI, 2003. Earthquake Engineering Research Institute, Securing Society Against Catastrophic Earthquake Loss: A Research and Outreach Plan in Earthquake Engineering, Oakland California, (available on line at http://www.eeri.org/cds_publications/securing_society.pdf).

New Madrid Reassessment Workshop (2000), "Reassessing New Madrid," report is available from: http://www.ceri.memphis.edu/usgs/reassessing_nm.pdf.

NRC, 2003. *Preventing Earthquake Disasters: The Grand Challenge in Earthquake Engineering: A Research Agenda for the Network for Earthquake Engineering Simulation (NEES)*, National Research Council, Washington, DC, National Academies Press, ISBN: 0-309-09064-4

Stallings, Robert A., "Sociological Theories and Disaster Studies," Inaugural Distinguished Lecture on Disaster and Risk at the Disaster Research Center, Department of Sociology and Criminal Justice, Newark: University of Delaware, 17 April 1997. The presentation is available from: http://www.udel.edu/DRC/preliminary/249.pdf.

Western States Seismic Policy Council (WSSPC). 1996. *Summary from the 1996 Annual Conference*. Report is available from http://www.wsspc.org/pubs/news/news796.html.

Useful web pages:

http://www.anss.org/

http://earthquake.usgs.gov/faq/myths.html

http://earthquake.usgs.gov/shakemap/nc/shake/index.html

http://www.ostp.gov/NSTC/html/USGS/index.html#anchor299544

http://quake.wr.usgs.gov/research/parkfield/eq_predict.html and

http://quake.wr.usgs.gov/research/seismology/wg02/

http://www.trinet.org/

Electronic visuals included: [*See Session 6 Electronic Visuals.ppt*]

Electronic Visual 6.1 Location of Parkfield, CA
Electronic Visual 6.2 Southern California TriNet Stations
Electronic Visual 6.3 ShakeMap from 1994 Northridge EQ
Electronic Visual 6.4 Proposed EQ Research Fields – Data Table
Electronic Visual 6.5 Proposed EQ Research Fields – Pie Chart

Handouts included:

Handout 6.1: Classroom Discussion Assignment 6.1
Handout 6.2: Homework Assignment 6.1

General Requirements:

The topic begins with a review of the "Holy Grail" of earthquake research – the science of earthquake prediction. Although it is probably not important for hazard managers to understand the details of earthquake prediction science, it is nonetheless important to be familiar with the basic issues, especially considering the importance of effectively communicating risk to the public (and earthquake prediction is a topic of frequent inquiry by lay people). In this regard, it is important to emphasize that although we cannot yet reliably predict when earthquakes will occur, we do know the regions where earthquakes are likely to occur. And, if proper preparation measures are undertaken to prepare for potential earthquake disasters in vulnerable regions, the issue of prediction becomes somewhat moot.

The discussion then shifts to the major earthquake research initiatives underway in the U.S. (i.e., what major questions are we trying to answer, and who are the major players?). A discussion is presented on the major programs, agencies and organizations involved with earthquake research in the US. Guidance is provided as to where reliable information can be found. **It is not important for the students to know the details of all agencies and programs, but it is important to be familiar with the major programs and organizations—**these organizations and programs are likely to be encountered by managers in the future. Because the lists of the various agencies and consortia can be rather dry material to present, the instructor is encouraged to only highlight this material in class and cover this material in a homework assignment where the students are required to research this information for themselves.

Finally, it is vitally important for hazard managers to understand the larger picture and to better appreciate their potential role and impact in hazard reduction. Therefore, it is key that there be a discussion on the importance of earthquake research and how this information leads to vulnerability and hazard reduction. The discussion presents examples that illustrate the potential many-fold return on investment of earthquake research, and the fact that such research is part of a long-term mitigation effort that must not only be continued, but accelerated. At the same time, the discussion must emphasize that research alone does not reduce vulnerability.

Lastly, it is vital that the students be made aware of the keys to promoting earthquake research and how the future of such efforts is threatened by incorrect perceptions and lack of visibility. Two case histories are presented to cement these concepts. This area is one of the most important of the entire topic, because it provides additional perspective on the role of hazard managers and illustrates how their actions can have large impact.

Among many other important issues, major points that are to be emphasized are: 1) continued research and development of new information is vitally important for the reduction of earthquake hazards; 2) the performing of research in and of itself does not translate into reduction of earthquake hazard, it is the successful implementation of that knowledge and resultant change in behavior and practices that result in hazard reduction; this requires **promotion** (which requires communication, education, regulation, mitigation, etc.); and, 3) it is critical to develop and maintain constituents to promote the funding of earthquake research and related programs.

The instructor should involve the students in discussion on key issues throughout the lectures. A classroom discussion exercise, along with a homework assignment, is included in the handout for this session. Both assignments should be distributed following the completion of the session. The lecture content should require just over two class periods, and the class discussion should take up the balance of the time, for a total of three periods. Electronic visual images of the major graphics used are included in the accompanying file: Session 6 Electronic Visuals.ppt.

Additional Requirements:

Computer and projector for electronic visuals.

Objective 6.1 Identify major initiatives underway in earthquake research, such as earthquake prediction.

Requirements: This content should be presented as lecture, supplemented by electronic visuals.

Electronic Visuals Included:

Electronic Visual 6.1 Location of Parkfield, CA

Remarks:

I. Earthquake Prediction Research and Seismological Advances. Recent important research initiatives in the field of seismology include:

A. The prediction of earthquakes.

B. Establishment of greatly improved seismic network monitoring systems.

C. Rapid dissemination of seismic data.

D. “Early warning” systems.

II. Prediction of Earthquakes.

A. Why try to predict earthquakes?

1. Because of their devastating potential, there is great interest in predicting the location and time of earthquakes. If scientists could predict some earthquakes, we might save lives and reduce property losses.

2. Earthquake predictions should state *where*, *when*, *how big*, and *how probable* the predicted event is, and *why* the prediction is made.

B. There is currently no reliable way to predict the days or months **when** an event will occur in any specific location. We can predict however, with a reasonable degree of certainty, the locations of earthquakes in general terms (by identifying capable faults, etc.) and within large windows of time (10s or 100s of years).

C. Let’s distinguish what we mean by “earthquake prediction”:

1. Short-term prediction: prediction within a day to a year of an earthquake.

2. Intermediate-term prediction: prediction within one year to a decade of an earthquake.

3. Long-term prediction - prediction within a decade or more of an earthquake.

4. The term "earthquake prediction" in popular language refers to short-term prediction – a task that is not currently possible.

D. Why is earthquake prediction so difficult?

1. Earthquakes are highly variable, erratic phenomena. Sometimes there are telltale precursors, such as numerous foreshocks, but sometimes not.

2. Also, because of the paucity of large earthquakes that have been well instrumented, we have too few adequate observations to fully understand the complex processes.

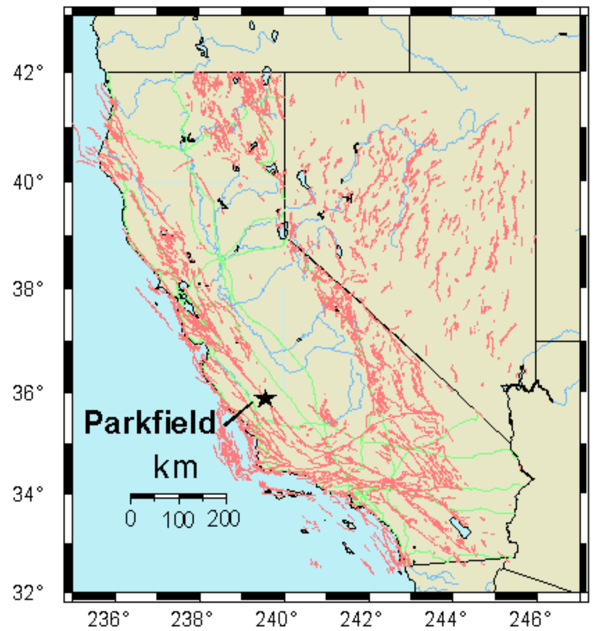
3. Earthquakes occur regularly on a geologic time scale (thousands and millions of years), but not regularly during a human life span (tens of years).

III. State-of-the-Art in Earthquake Prediction.

A. **Short-term prediction of earthquakes is not currently possible**. That is, we cannot yet reliably predict ***<u>when</u>*** an earthquake will occur within a time window smaller than say 50 to 150 yrs. Current thinking is that reliable short-term prediction will not be possible in the foreseeable future, and perhaps never. **We can however, identify areas where earthquakes are likely**.

B. **Current research efforts have abandoned the study of many phenomena that were once believed to be universal precursory warning signals of impending large earthquakes** (changes in magnetic fields, changes in resistivity readings, gaseous emissions, etc.). **Promise in these hypotheses has largely diminished over the last 20 years or so**, as research findings have not corroborated the speculations. Current efforts have returned to more basic approach of studying the precursory clustering of small earthquakes prior to strong earthquakes (i.e., foreshocks).

C. **Further progress cannot be made until more data from big earthquakes are collected**. But to gather the needed data, one must be in the right location at the right time. In other words, one must essentially predict the occurrence of a large earthquake to be there with instruments set up to study the precursory phenomena that precedes the event – a classic "catch-22" situation. Also, many earthquakes must be observed to have a sufficient dataset. Because large well-instrumented earthquakes are rare, a lot time is required to develop the data. [*Electronic visual 6.1*]



Visual 6.1: Plot showing location of Parkfield, CA located along the San Andreas Fault in the central region of the state. Credit: USGS.

IV. What Strategies Can Be Used For Earthquake Hazard Reduction? (Since short-term prediction is not possible):

A. Although short-term prediction is not currently possible, many aspects of earthquake occurrence can be anticipated with enough precision to be useful in mitigating risk.

B. Earthquake hazards in many areas are well established and future earthquake damage can be greatly reduced by identifying and improving or removing the most vulnerable and dangerous structures.

C. In other words, **in regions prone to earthquakes, the need for short-term prediction is minimized if we govern ourselves prudently – that is, prepare, plan, and mitigate as if earthquakes are expected to occur at any time!**

D. **Bottom line ⇒ The unpredictable nature underscores the need and effectiveness for mitigation and continual hazard reduction measures.**

E. It is important to take advantage of recent technological advancements in seismic instrumentation, computer, and telemetry technology (this is discussed in detail in following major section).

F. With improvement in seismic sensors and communication systems, it is now possible to significantly increase the speed and reliability of such information so that the capability exits to estimate the intensity of ground shaking within seconds after an earthquake (ShakeMaps).

G. Some facilities could receive this information before earthquake waves reach them. This would allow early warning systems to be employed, shut down or otherwise protect systems susceptible to damage, such as power stations, computer systems and telecommunication networks. Such a system also would allow re-positioning of individuals to safer areas of a building or property just before the earthquake waves arrive.

H. Probabilities have been increasingly used for transmitting earthquake hazard information to officials in charge of emergency preparedness, earthquake engineers, and the public. This trend is welcome because probability conveys the information in a form that can be dealt with in response planning and prioritization, and cost-benefit analysis of mitigation. As an example, recent studies have estimated a **70% probability** of a major earthquake occurring the San Francisco Bay area within the **next 30 years** (USGS); from: http://quake.wr.usgs.gov/research/seismology/wg02/

Objective 6.2 Recognize current research trends and identify future research initiatives

Requirements:

The content should be presented as lecture, supplemented by electronic visuals.

Electronic Visuals Included:

Electronic Visual 6.2 Southern California TriNet Stations
Electronic Visual 6.3 ShakeMap from 1994 Northridge EQ
Electronic Visual 6.4 Proposed EQ Research Fields – Data Table
Electronic Visual 6.5 Proposed EQ Research Fields – Pie Chart

Remarks:

I. Important New Technological Advancements in Seismology.

Although prediction is still the "holy grail" of seismology, there are a number of important new research initiatives underway in the seismological community including advanced seismic monitoring networks and systems that can provide early warning alerts and fast reliable information while the ground is still shaking.

A. TRINET [http://www.trinet.org/**]**

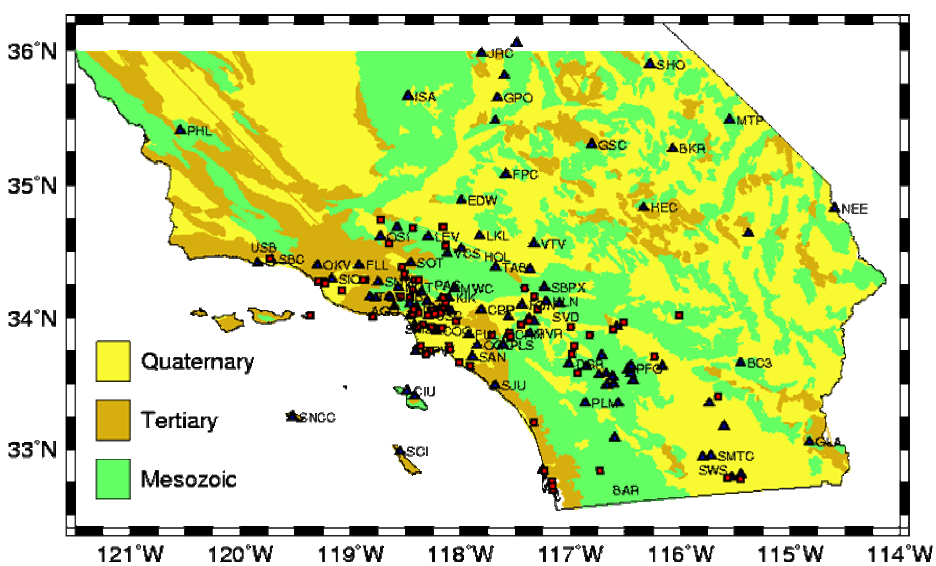
1. **TriNet is a new state-of-the art network of more than 600 seismic recording instruments designed to provide better, more effective, fast (real-time) earthquake information for southern California.**

2. TriNet mitigates the effects of earthquakes by providing comprehensive information as quickly as possible during and immediately after significant earthquakes. The TriNet system allows the production of "shake maps," which are maps produced within minutes of an earthquake that show the spatial distribution of shaking intensity as derived from data telemetered from the seismic stations

3. TriNet is a joint effort developed in 1997 by three agencies: the Federal Emergency Management Agency (FEMA), the California Governor's Office of Emergency Services (OES), the U.S. Geological Survey (USGS), and other partners agreed to provide funding for the network.

4. The concept for TriNet was developed following the 1994 Northridge, CA Earthquake that showed the use of new digital equipment, modern data communications methods, and advanced computing could greatly improve the accuracy and timeliness of seismic information and provide useful decision support tools for emergency responders.

5. ***TriNet serves the needs of emergency management while also supporting scientific investigation and building code development.****[Electronic visual 6.2]*



Visual 6.2 - Map of southern California showing locations of current TriNet stations. Credit: Trinet.

B. Real-Time Seismology and Early Warning Systems: (UN, 1997; NRC, 2003).

1. "**Real time" seismology refers to the recording and using of data from seismic instruments during the approximate time frame of the occurrence of the earthquake** (NRC, 2003).

   a. In highly industrialized communities, rapid dissemination of earthquake information is vitally important for emergency response agencies, utilities, communications, media etc. to make rapid damage assessments and determine where emergency response is most needed. The 1994 Northridge Earthquake demonstrated this need.

   b. Data are quickly collected from instruments and used in raw form or processed rapidly for use in early warning systems (discussed below). **Even if a warning is given only seconds before the event, computerized systems can shut down gas lines, stop trains, secure hazardous materials and power down generating stations, etc.**

2. What Are **Early Warning Systems**? How They Can Be Used to Reduce Earthquake Risks?

   a. Early warning systems are various types of technological instruments for detecting hazard events and issuing alerts.

   b. During disasters, early-warning signals will be sent to pagers, cell phones, PDAs, laptops, televisions, radios, smoke/fire alarms, and other types of communication or warning devices to produce audible warning alarms. These warning signals also will generate a large number of preprogrammed automatic responses. **If appropriately equipped, emergency generators will be started, computers inactivated, elevators stopped, traffic lights controlled, gas and fuel lines turned off, and many other automated protective responses will be initiated.**

3. How are early warnings used at the national and local levels to reduce risks?

a. To fulfill a risk reduction function, **warnings of impending hazards need to be complemented by information on the risks actually posed by the hazards and likely strategies to mitigate the loss and damage which could arise**.

b. This added value of warning information needs to be communicated to vulnerable groups in a way that facilitates their own decisions and abilities to take timely actions.

4. To transform hazard warning information into effective risk reduction at the national and local level, early warning systems must be made up of a number of integrated subsystems:

   a. A **warning subsystem**, in which hazards are monitored and forecasted, at the international, national and local levels. In these, scientific information about impending hazards is produced and communicated to national authorities responsible for disaster management.

   b. A risk **information subsystem**, which can enable disaster management authorities to generate risk scenarios. These should indicate the potential impact of an impending hazard event on specific vulnerable groups and sectors of the society.

   c. A **preparedness subsystem**, in which disaster preparedness strategies are developed that indicate actions required to reduce the loss and damage expected from an impending hazard event

   d. A **communication subsystem**, which allows the communication of timely information on impending hazard events, potential risk scenarios and preparedness strategies to vulnerable groups, so that they may take appropriate mitigation measures.

5. As shown, **an early warning system is much more than a scientific and technical instrument for forecasting hazards and issuing alerts. It should be regarded as an information system designed to facilitate decision-making, in the context of national disaster management agencies, in a way that empowers vulnerable sectors and social groups to mitigate the potential losses and damages from impending hazard events.**

6. The usefulness of an early warning system should be judged less on whether warnings are issued per se, but rather on the basis of **whether the warnings facilitate appropriate and timely decision-making by those people who are most immediately at risk.**

7. The **ultimate success of an early warning depends on whether people receiving the warning take action.** The problem is as much one of psychology as technology in that the end-user has to both understand and trust the warning in order to act on it. Overcoming the non-response problem requires the ability to warn only the people directly at risk and to personalize the warning so that it will elicit a response. In a crisis situation, it is also critical that everybody speak with the same voice, operating from the same data.

8. Most current warning systems are passive – television, radio, and the WWW require the end-user to tune into the warning. More active systems – onboard global positioning systems, pagers, NOAA radios – could reach people when they are in their cars and outdoors, etc. and often most vulnerable to hazards.

9. Just because the technology exists does not mean it can be successfully implemented. Numerous early warning questions (i.e., if power is cut off ahead of an earthquake) remain.

   a. Who becomes responsible for ensuring that essential services, such as hospitals, are not cut off?

   b. How broadly should real time data be disseminated?

   c. Who pays for the data collection systems?

   d. What are the implications of false warnings?

10. **Developing partnerships ahead of time** will identify community needs and how to best meet those needs, and will help ensure that, in a crisis, those responsible for disseminating warnings and information present a clear and consistent picture.

11. **Bottom Line: Good communication and understanding between scientists, emergency managers, and the public are essential if early warning advisories are to be effective.**

C. ShakeMaps

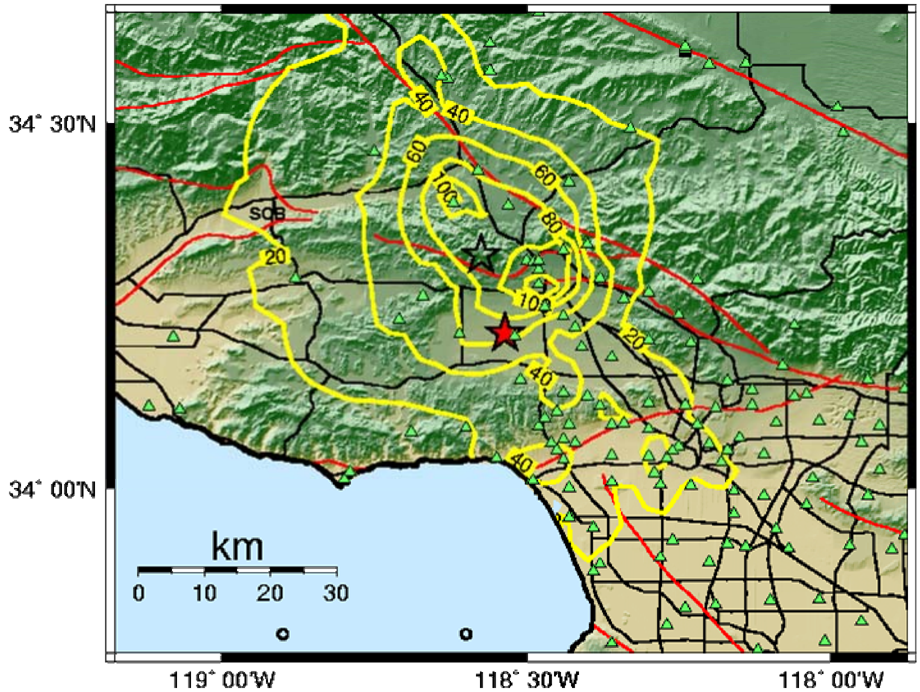
1. **ShakeMaps are rapidly-generated maps that depict the ground shaking produced by an earthquake. Maps are developed from a network of seismic instruments whose response is acquired in real time using a variety of digital telemetry methods.** ShakeMaps are one form of an early warning system and can be used by decision-makers to

quickly estimate the probable effects of the earthquake across the region before the damage can be visually assessed. This allows optimization of emergency response.

a. For example, the more than 600 intruments in the TriNet system are used in conjunction with high-speed computer systems to produce ShakeMaps of Southern California. Signals from the USGS-Caltech stations (triangles on map in Visual 6.3) are acquired in real time using a variety of digital telemetry. ShakeMaps are generated automatically and are produced within several minutes.

b. Given the diverse user group that includes scientists, businesses, emergency response agencies, media, and the general public, ShakeMaps are plotted in terms of several different parameters to maximize the utility and flow of information. Therefore, maps are plotted in terms of peak ground acceleration and velocity, Modified Mercalli Intensity, etc.

c. ShakeMaps are more useful to emergency personnel than earthquake magnitude and epicenter information released after an earthquake because ShakeMaps show the intensity of ground shaking produced by the earthquake rather than the parameters describing the earthquake source. So, while an earthquake has one magnitude and one epicenter, it produces a range of ground shaking levels at sites across the region, depending on distance from the earthquake, the rock and soil conditions at sites, and variations in the propagation of seismic waves from the fault due to variability in the earth's crust. [*Electronic Visual 6.3*]



Visual 6.3 - Example of ShakeMap showing recorded peak velocities from the 1994 Northridge Earthquake (M6.7). Velocity are units cm/sec. The red star shows the epicenter and the triangles represent seismic recording station. Credit: USGS (adapted from: http://pasadena.wr.usgs.gov/shake/pubs/shake/node6.html).

2. **Popular ShakeMap Web Links:**

   a. Events notification and descriptions USGS source.

   b. Northern California Shake Maps USGS – Berkeley.

   c. Southern California Shake Maps USGS – TriNet.

   d. Pacific Northwest U.S. Shake Maps USGS and University of Washington.

   e. Utah Shake Maps USGS and University of Utah.

   f. Worldwide Earthquake Locator (near real time) NEIC, Colorado.

   g. Emergency Public Information following California Earthquakes from the California OES.

D. Advanced National Seismic System (ANSS) (http://www.anss.org/).

1. An important new initiative of the seismological community is the Advanced National Seismic System (ANSS). This system is needed to organize, modernize, standardize, and stabilize seismic monitoring in the United States. Most existing systems monitor either weak seismic motions or strong ground shaking, but not both. Modern seismographs proposed for the ANSS will be able to record both weak motions and strong motions with high accuracy. By collecting this information via a central computer with modern high-speed telecommunications, the system becomes an important tool for emergency response.

2. The Advanced National Seismic System Network is still in the early phases of development, and will be a nationwide network of at least 7000 seismic instruments, both on the ground and in buildings. The ANSS will make it possible to:

   a. **Provide emergency response personnel with real-time earthquake information.**

   b. **Provide engineers with information about building and site response.**

   c. **Provide scientists with high-quality data to understand earthquake processes and solid earth structure and dynamics.**

3. The estimated cost is $170 million for equipment, and $47 million per year for operation and maintenance.

III. National Earthquake Research Programs:

A. The strategy for national earthquake loss reduction began with the establishment of the National Earthquake Hazards Reduction Program (NEHRP), a multi-agency federal program that was established in 1977 and later augmented in 1996 by the National Earthquake Loss Reduction Program (NEP).

B. **The current focus has shifted more toward implementation of knowledge and mitigation.**

C. **More attention is being given to social impacts and assessments.**

IV. National Earthquake Hazards Reduction Program (NEHRP)

A. NEHRP is the primary research program for earthquake research in the U.S.

B. NEHRP was created in 1977 after Congress passed the Earthquake Hazards Reduction Act. The intent behind NEHRP was **to reduce the risk to life and**

property due to earthquakes by creating and maintaining an effective national earthquake risk reduction program.

C. Member agencies include the United States Geological Survey **(USGS**), the National Science Foundation **(NSF),** the National Institute of Standards and Technology **(NIST)** and the Federal Emergency Management Agency **(FEMA).**

D. The Act's objectives include:

1. Improving the understanding, characterization, and prediction of hazards and vulnerabilities.

2. Improving building codes and land use practices.

3. Reducing risks of earthquakes through post-earthquake investigations and education.

4. Development and improvement of design and construction techniques.

5. Improving mitigation capacity.

6. Accelerating the application of research results.

E. Agencies of NEHRP have made tremendous advances in terms of our understanding and characterization of earthquake hazards, our preparation for earthquakes, and knowledge on how to mitigate the damaged caused; see NEHRP accomplishments in Background Reading. Unfortunately, the ***implementation*** of these findings is greatly lacking.

F. Since NEHRP was established in 1977, a majority of the funding has been directed toward research and development. The implementation of these findings has been predominantly voluntary outside of the federal government, and as a result, less has been achieved in risk reduction.

H. In 1993 NEHRP was criticized for

a. Lack of a strategic plan.

b. Limited coordination and **implementation of research results.**

c. **Insufficient emphasis on mitigation** (WSSPC, 1996).

I. The result was the development of a **new strategy to help strengthen and extend NEHRP** and mobilize and coordinate numerous federal government programs into a focused National Earthquake Loss Reduction Program (NEP).

V. National Earthquake Loss Reduction Program (NEP)

A. NEP was created to fill in the gaps of NEHRP whose aims were judged to be too broad and unfocused.

B. One of NEP's greatest challenges will be **to bring implementation up to the same level as earthquake knowledge and research.** Therefore, NEP's success will rest largely in its ability to stimulate actions of various groups to mitigate earthquake hazards. **NEP aims to:**

1. **Focus research and development dollars on the most effective means for saving lives and property and limiting the social disruptions from earthquakes**.

2. Coordinate federal earthquake mitigation research and development and emergency planning in a number of agencies beyond those in NEHRP to avoid duplication, and ensure focus on priority goals.

3. Cooperate with the private sector and with state and local jurisdictions to apply effective mitigation strategies and measures.

C. NEP does not replace NEHRP, but encompasses a wider range of earthquake hazard reduction activities than those supported by the NEHRP agencies.

D. NEP goals are stated below:

1. Provide leadership and coordination for federal earthquake research.

2. Improve technology transfer and outreach.

3. Improve engineering of the built environment.

4. Improve data for construction standards and codes.

5. Continue the development of seismic hazards and risk assessment tools.

6. Analyze seismic hazard mitigation incentives.

7. Develop understanding of social impacts and responses related to earthquake hazard mitigation.

8. Analyze the medical and public health consequences of earthquakes.

9. Continue documentation of earthquakes and their effects.

E. FEMA will lead and coordinate the NEP and be responsible for managing, planning, reporting, and budget coordinating of the program through an interagency group. NEP is open to all agencies involved in earthquake research or loss mitigation and the interagency group will include representatives of these agencies.

F. Federal funding for the NEP is presumed to include those funds currently expended on earthquake issues by the NEHRP member agencies. Sponsoring agencies will directly pay for any individual events such as workshops or publications. Non-Federal implementation of earthquake loss mitigation practices is not a direct fiscal responsibility of the program. Most cost decisions need to be made at the state or local government levels or by the private sector.

G. Important to recognize: **Implementing mitigation requires a <u>long-term investment</u> and takes place over <u>decades</u>.**

VI. Proposed National Earthquake Engineering Research Plan for Next 20 years.

(*The following is adapted from Earthquake Engineering Research Institute, "Securing Society against Catastrophic Earthquake Loss: A Research and Outreach Plan in Earthquake Engineering," Oakland, CA; available on-line at http://www.eeri.org/cds_publications/securing_society.pdf*).

A. In response to a congressional mandate, NSF and NIST supported a study that was coordinated by the Earthquake Engineering Research Institute (EERI) to assess earthquake engineering experimental research resources in the U.S. Recommendations from this study, which identified the need to upgrade the earthquake engineering experimental research infrastructure in the U.S., were published in a comprehensive 1995 report entitled "Assessment of Earthquake Engineering Research and Testing Capabilities in the United States."

B. Building on the earlier assessment and report, EERI in January 2003 completed a comprehensive plan entitled "**Securing Society against Catastrophic Earthquake Losses - A Research and Outreach Plan in Earthquake Engineering" (EERI, 2003).**

C. The proposed $370 million 20-year research plan includes the following program focus areas:

1. **Understanding Seismic Hazards**: developing new models of earthquakes based on fundamental physics.

2. **Assessing Earthquake Impacts**: evaluating the performance of the built environment by simulating performance of structures and entire urban systems.

3. **Reducing Earthquake Impacts**: developing new materials, structural and non-structural systems, lifeline systems, tsunami protection, fire protection systems, and land use measures.

4. **Enhancing Community Resilience**: exploring new ways to effectively reduce risk and improve the decision-making capability of stakeholders.

5. **Expanding Education and Public Outreach**: improving the education of engineers and scientists from elementary school to advanced graduate education, and providing opportunities for the public to learn about earthquake risk reduction.

D. The proposed focus areas represents more focus on implementation and mitigation relative to research performed in the engineering community in earlier years.

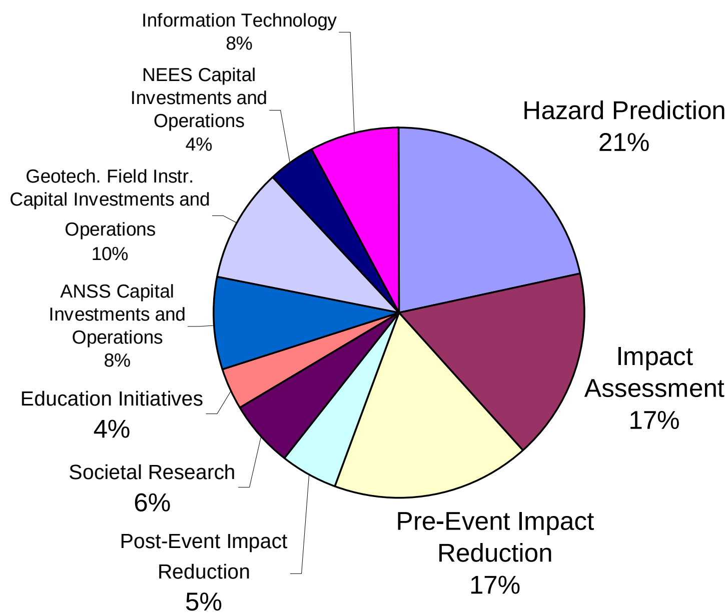
E. The proposed breakdown for targeted expenditures for earthquake research is shown in Visual 6.4 (Table 1), along with the pie chart on the following page: *[Electronic Visual 6.4]*.

Table 1 - ANNUAL BUDGET SUMMARY	
Program Description	**Annual Cost ($ millions)**
Hazard Prediction	80
Impact Assessment	62
Pre-Event Impact Reduction	64
Post-event Impact Reduction	18
Societal Research	22
Education Initiatives	13
ANSS Capital Investments and Operations	30
Geotech Field Inst. Capital Investments and Operations	37
NEES Capital Investments and Operations	15
Information technology	29
PLAN TOTAL	**370**

Source: EERI (2003).

Visual 6.4 - Data table showing proposed breakdown of total national expenditures in earthquake engineering research; adapted from EERI (2003).

F. A graphical breakdown of targeted expenditures for earthquake engineering research plan is shown below: (EERI, 2003) [*Electronic Visual 6.5*]



Visual 6.5 – Pie chart showing proposed breakdown of total national expenditures in earthquake engineering research; adapted from EERI (2003).

Objective 6.3 Identify main earthquake research organizations and information sources.

Requirements:

The content should be presented as lecture.

Remarks:

I. **U.S. Earthquake Research Agencies – Who are the players?**

A. The primary players in the national earthquake research effort include the NEHRP and NEP agencies, including the NSF, the USGS, and FEMA. Many other national and state and agencies and institutions are involved in conducting and sponsoring earthquake research (i.e., Nuclear Regulatory Commission, U.S. Army Corps of Engineers, etc.). The Background Reading Notes for this session provides details as to the specific focus areas and current initiatives of the major research agencies.

B. As discussed in more detail later, the primary advocates of earthquake hazard research and earthquake mitigation efforts are largely those directly involved in the research. In other words, successes and advancements in earthquake research have largely been advocated only by those agencies, institutions, professionals, and academicians, – termed the “earthquake establishment” by Stallings (1997) – that are directly involved in performing the research. **This has led to less social awareness and less than the full measure of deserved funding.**

II. <u>Earthquake Consortia and Information Sources</u> – Where to go for credible information?

[Instructors Note: There are many important national, regional, and state agencies and organizations you should be familiar with, but for brevity purposes, only the larger, more visible national organizations are provided here. These should be only briefly discussed in class and instead studied in detail in a homework assignment where the students research these groups and discuss the missions, objectives, etc.]

A. Earthquake Consortia (1-5):

1. **Cascadia Region Earthquake Workgroup (CREW)** (*http://www.crew.org)*

   a. (CREW) is a not-for-profit corporation of private and public representatives working together to improve the ability of Cascadia Region communities to reduce the effects of earthquake events.

   b. CREW involves coastal communities of northern California, Oregon, Washington State and British Columbia. The goals of CREW are to:

      1) Promote efforts to reduce the loss of life and property.

      2) Conduct education efforts to motivate key decision makers to reduce risks associated with earthquakes.,

      3) Foster productive linkages between scientists, critical infrastructure providers, businesses and governmental agencies in order to improve the viability of communities after an earthquake event.

2. **Central United States Earthquake Consortium (CUSEC)** (*http://www.cusec.org)*

   a. The Central U.S. Earthquake Consortium is a partnership of the federal government and the seven states most affected by an earthquake in the New Madrid Seismic Zone.

   b. Those states are Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri, and Tennessee.

   c. CUSEC serves as a "coordinating hub" for the region, performing the critical role of coordinating the multistate efforts of the central region.

   d. Its coordinating role is largely facilitative and not as the primary implementer of emergency management functions which is the responsibility of each individual state.

3. **New England States Emergency Consortium (NESEC)** (*http://www.serve.com/NESEC/).*

   a. NESEC is a not-for-profit natural hazard mitigation and emergency management organization, located in Wakefield, Massachusetts.

   b. NESEC is the only multihazard consortium of its kind in the country and is supported and funded by FEMA.

   c. The states of Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island and Vermont form the consortium.

   d. NESEC develops, promotes and coordinates natural disaster and emergency management activities throughout the Northeast.

   e. This includes natural hazard risk evaluation and assessment, public awareness and education programs, hazard mitigation, and information technology transfer.

4. **The Southern California Earthquake Center (SCEC)** (http://www.scec.org).

   a. The Southern California Earthquake Center, headquartered at the University of Southern California, was founded in 1991 with a mission to:

1) Gather new information about earthquakes in Southern California.

2) Integrate this information into a comprehensive and predictive understanding of earthquake phenomena.

3) Communicate this understanding to end-users and the general public in order to increase earthquake awareness, reduce economic losses, and save lives.

b. Scientists and engineers from over 39 institutions throughout the U.S. participate in SCEC.

5. **Western States Seismic Policy Council (WSSPC)** (*http://www.wsspc.org).*

a. The Western States Seismic Policy Council is a regional earthquake consortium funded primarily by FEMA.

b. Headquartered in Palo Alto, California, WSSPC draws its membership from the emergency manager and geoscientist directors of 13 western states, three territories, a Canadian territory and a Canadian province.

c. The mission of the WSSPC is to:

1) Help reduce future earthquake losses by providing a forum to advance earthquake programs throughout the Western Region.

2) develop and facilitate the implementation of seismic policies and programs through information exchange, research application, and education.

B. Earthquake Engineering Research Institute (EERI) (http://www.eeri.org/).

1. EERI is a national, nonprofit, technical society of engineers, geoscientists, architects, planners, public officials, and social scientists.

2. EERI members include researchers, practicing professionals, educators, government officials, and building code regulators.

3. The primary objective of EERI is to:

a. Reduce earthquake risk by advancing the science and practice of earthquake engineering.

b. Improve understanding of the impact of earthquakes on the physical, social, economic, political and cultural environment.

c. Advocate comprehensive and realistic measures for reducing the harmful effects of earthquakes.

4. EERI is recognized as the authoritative source for earthquake risk reduction information in the U.S., and in partnership with other nations, will develop earthquake risk reduction information worldwide.

C. National Earthquake Engineering Research Centers.

1. **Pacific Earthquake Engineering Research Center (PEER)** (*http://peer.berkeley.edu).*

a. PEER is an NSF-sponsored earthquake engineering research center that is housed at the University of California at Berkeley, and includes the University of California at Davis, University of California at Irvine, University of California at San Diego, California Institute of Technology, University of California at Los Angeles, University of Southern California, Stanford University, and the University of Washington.

b. PEER’s mission is to develop and disseminate technologies to support performance-based earthquake engineering.

2. **Multidisciplinary Center for Earthquake Engineering Research (MCEER)** (*http://mceer.buffalo.edu).*

a. The **Multidisciplinary Center for Earthquake Engineering Research** is a national center of excellence that develops and applies knowledge and advanced technologies to reduce earthquake losses.

b. The center is headquartered at the State University of New York at Buffalo and was established in 1986 by the NSF as the country’s first National Center for Earthquake Engineering Research.

c. The center includes the following institutions and organizations:

1) Cornell University

2) EQE International
3) New Jersey Institute of Technology
4) Rensselaer Polytechnic Institute
5) State University of New York at Buffalo
6) The Pennsylvania State University
7) University of Delaware
8) University of Houston
9) University of Nevada/Reno
10) University of Notre Dame
11) University of Pennsylvania
12) University of Southern California
13) University of Washington
14) Virginia Tech.

3. **Mid-America Earthquake Center (MAE Center)** (*http://mae.ce.uiuc.edu.)*

a. MAE Center is housed at the University of Illinois at Urbana.

b. It consists of a consortium of eight core institutions that include

1) University of Illinois
2) Massachusetts Institute of Technology
3) Georgia Tech
4) University of Memphis
5) The University of Puerto Rico
6) St. Louis University
7) Texas A&M University
8) Washington University

c. MAE Center is supported by the National Science Foundation and each core university as well as through joint collaborative projects with industry and other affiliations.

d. MAE Center is the first of its kind for addressing mitigation of earthquake effects in the central and eastern United States.

D. Earthquake Information Services/Clearinghouses.

1. **EarthQuake Information NETwork (EQNET)** (*http://www.eqnet.org/).*

a. EQNET is one of the most comprehensive databases and information sources for earthquake information.

b. Information is available for the following:

1) Earthquake Information Services – Library/Information Services, Databases, Directories, FAQ, Glossaries, Maps, Images, Statistics, Slides/videos, Press releases/media services.

2) Structural Engineering – Earthquake Engineering Research, Codes/Standards, Lifelines, Nonengineered Construction, Nonstructural, Critical Facilities, Steel Frames, Wood, Wind, Nuclear.

3) Geotechnical Engineering/Engineering Geology – Liquefaction/site effects, Soil structure interaction, Microzonation, Landslides

4) Seismology/Geology/Geophysics – Seismology, Geology, Advanced Technology, Geodesy, Plate tectonics, Seismic Networks, Data Centers, Strong Ground Motion, Tsunamis.

5) Disaster Management – Mitigation, Planning, Preparedness, Training, Response, Recovery, Implementation, Case studies, Residential retrofit, Special needs/vulnerable populations, Chemical Spills , Elderly.

6) Agencies and Associations – Government (Federal/State/Local), Regional / National / International, Civil/structural engineering associations, Earthquake engineering associations, Research Center, Seismic Safety Boards, Project Impact.

7) Education/Professional Development – Curricular Materials, College, Secondary, Higher Education, Continuing Education, Funding Opportunities, Job Listings, Internships.

8) Listservs/Newsgroups/Newsletters – Structural engineering, geotechnical engineering, engineering geology,seismology, geophysics, disaster planning, insurance, journals, government, etc.

9) Calendar/Conferences – Comprehensive, monthly, search by subject, title, location.

10) Archives – Earthquake News and Photo Archives for recent significant earthquakes.

2. **Center for Earthquake Research and Information (CERI)** (*http://www.ceri.memphis.edu/).*

   a. The Center for Earthquake Research and Information (CERI) is involved in:

      1) Performing basic research in geophysical and geological sciences.

      2) Providing public awareness information.

      3) Developing and disseminating seismic information.

   b. The CERI website provides information on U.S. earthquakes, especially central U.S.

   c. It provides also a wealth of related information and links to sites such as the USGS and other earthquake research institutions.

3. **Seismosurfing the Internet for Earthquake Data - Expanded Version** (*http://www.geophys.washington.edu/seismosurfing.html.)*

   a. This website has an extensive compilation of important source of major earthquake research and information organizations and institutions in from all regions of the U.S., as well as Canada, Central and South America, Africa, Asia, Europe, and Oceania.

   b. The website is an excellent source of world-wide earthquake information.

Objective 6.4 Appreciate why continued research is needed and how research alone does not reduce vulnerability.

Requirements:

The content should be presented as lecture.

Remarks:

I. The Importance of Earthquake Research - What is the payoff?

A. **Recognize ⇒ Reducing seismic risk requires a long-term commitment.**

B. Process of risk reduction builds on past experience, lessons learned, and advances in our understanding of earthquake phenomena and seismic response of constructed facilities and lifelines.

C. Advances in quantifying the physical nature of earthquakes, improvements in engineering methods, and developing more effective mitigation strategies are needed for increased earthquake safety as new lifelines and infrastructure systems are constructed and existing structures are retrofitted.

D. Earthquake research can lead to reduced economic losses resulting from future hazards. For instance, in regions with lower standards of building practices, **even moderate earthquakes can result in severe damage**.

II. Example.

A. An important example was the 5.9 earthquake in Colombia on January 25, 1999 that resulted in a large number of collapsed buildings including the total collapse of two large low-income residential areas, and caused more than 650 deaths and more than 2,500 injuries.

B. During earthquakes of larger intensity in California, such as the 1989 Loma Prieta and 1994 Northridge earthquakes, far less damage was observed and the number of fatalities was less than **one-tenth of that in Colombia**.

C. This difference was attributable, in large part, to the **enhanced seismic integrity of our structures that are designed and constructed with improved standards developed through engineering research**.

III. Other Examples.

A. The recent earthquakes in California have revealed deficiencies in design and construction of numerous forms of the built environment including:

1. Concrete highway bridges.

2. Building structures constructed of masonry as well as steel..

3. Vital lifelines that transport water, gas, electricity and telecommunications systems.

B. Similar disasters in Kobe, Japan in 1995, as well as many other parts of the globe, have underscored the importance of learning more about how our civil engineering structures respond to earthquake shaking in an effort to improve the seismic safety and performance inherent in our constructed works.

C. Some of the failure patterns observed in these recent earthquakes were recognized from past events or previous research while others, such as steel weld failures in buildings in the Northridge Earthquake, were unexpected. Had a more aggressive program of experimental research been undertaken before these recent catastrophes, problems may have been detected beforehand, and corrected. If engineers are to rely on modest levels of experimental research in earthquake engineering, a high probability exists that future disasters will continue to reveal unforeseen problems with construction.

D. **An investment in research at this stage on the order of millions will help to reduce national economic losses on the order of billions for a single earthquake of significant intensity in the future**.

E. Although numerous success stories can be cited, there is a pressing need to continue research at an accelerated rate.

F. Because our livelihood is highly-dependent on business activity, a future earthquake with only a moderate damage potential can result in significant economic loss. Estimates as large as $30 billion have been quoted for the Northridge Earthquake, making it the largest loss in U.S. history from a single hazard. This was a relatively small loss considering that the 1995 Great Hanshin earthquake in Kobe had a total loss of approximately $180 billion (NRC, 2003).

G. A reoccurrence of the **New Madrid** Earthquake – the largest on record in the contiguous United States and postulated with a 4% probability in the next fifty years – has been estimated with a total loss potential of **$200 billion**. Approximately two thirds of this loss will be attributable to interruptions in business operations and the transport of goods across mid-America (New Madrid Reassessment Workshop, 2000).

H. **If research can lead to a reduction of economic loss from a single future earthquake by as little as 10%, the payoff on the research investment will be as much as a thousand times the annual research budget for earthquake engineering research in the US!**

I. The impact of the research also will reduce losses in subsequent earthquakes, and will improve the overall quality of construction to resist other hazards including tornadoes, hurricanes and floods.

J. Moreover, the competitiveness of the U.S. engineering and construction firms will be enhanced as they adopt improved technologies developed through earthquake engineering research.

IV. Bottom Line: **Few investments can promise such a high return.**

A. It is critical that NEHRP and other earthquake research programs continue to be supported. It also is necessary that their focus be continually sharpened, that they respond to a changing technical, social and economic environment, and that their funding not be reduced. NEHRP for instance, is a long-haul program.

B. **Remember that although research is critical, it is the implementation of the knowledge that leads to vulnerability reduction.** For instance, we already know that the Marina district in San Francisco is at higher risk due to poor soils, close proximity to a fault, and prevalence of unreinforced masonry structures, especially for residential units. The knowledge is already developed. The implementation, however, is key to risk reduction.

V. Importance of and Keys for Promoting Earthquake Research and Case Studies.

A. Because damage caused by earthquakes affects the life and property of the public, and in order to apply the results of earthquake research to earthquake disaster prevention measures, it is important to have an understanding of social science-related subjects such as people’s mentality, behavior and economic activity. For this reason, cooperation between fields related to social science and earthquake research needs to be cultivated.

B. Dissemination of information deemed necessary to gain public understanding in the application earthquake research results. The results of earthquake research can only contribute to a decrease in damage caused by an earthquake if they are correctly understood by the public and people involved in disaster prevention.

C. For the results of earthquake research to be used for the reduction of damage caused by earthquakes, planning and mutual cooperation among the national government, public institutions, regional public bodies, the business community and the public are essential. It is important that there be liaison and cooperation between the national government and regional public bodies, as well as liaison and mutual cooperation among regional public bodies. Consequently, it is important to promote collaborative results and forums for cross-disciplinary benefits.

Objective 6.5 Recognize and appreciate the public perception problem associated with of earthquake hazards.

Requirements: The content is presented as lecture, with class discussion where possible. The objective should end with the distribution of the class discussion assignment and the homework assignment. The class discussion should require from 30 minutes to a full session, and the homework assignment should require one week to be completed.

Handouts included:

Handout 6.1: Classroom Discussion Assignment
Handout 6.2: Homework Assignment

Remarks:

I. Earthquake Research Funding – A Perception Problem.

A. Why is there greater public concern for other threats that seemingly have less potential for future harm?

1. If the “experts” are correct, we can expect nearly the same number of people to die in a single worst-case Los Angeles earthquake (the “big one”) as are murdered in the U.S. in a single year (about 20,000 people).

2. The dollar loss could exceed the amount spent annually on the criminal justice system in the U.S. as a whole (about $100 billion dollars), and the U.S. Gross Domestic Product (GDP) could drop instantly by five percent.

3. Even in California there is vastly greater public concern for crime than for the threat of earthquakes or for all natural hazards combined, for that matter.

4. Put differently, people's reaction to crime identifies it as a social problem, while their treatment of the earthquake threat suggests that it is not a social problem despite the apparent similarities in the images of each.

B. How can we explain this difference in perception?

1. **Because people identify with crime and have awareness of their risks.**

2. **They see earthquakes as “natural” problems, but they see crime as a “social” problem.**

C. Why is this true?

1. As discussed by Stallings (1997), the earthquake threat in the U.S. generally is been promoted by what he refers to as the “earthquake establishment" made up of technocrats and bureaucrats including earth scientists in the National Academies and government agencies, engineers, academicians, and mid-level federal bureaucrats (primarily in the USGS, NSF, and FEMA).

2. In other words, the advocates of the earthquake threat are "insiders" rather than "outsiders," unlike most other problem-promoting groups.

3. **Members of the earthquake establishment have access to decision-makers, but they themselves have no power. The threat has official recognition but low priority.**

4. Whatever public policy successes the movement has enjoyed have been accomplished without grassroots support or a strong core of constituents (except for a brief period in the 1980s).

5. In other words, earthquake safety insiders have no external power base. Not surprisingly, the outcome of their claims-making activities to date has been less than desirable.

[*Distribute Handout 6.1: Class Discussion and Handout 6.2: Homework Assignment 6.1; conduct class discussion*]

References Utilized:

http://www.anss.org/

http://earthquake.usgs.gov/faq/myths.html

http://earthquake.usgs.gov/shakemap/nc/shake/index.html

EERI. 2003. *Securing Society against Catastrophic Earthquake Loss: A Research and Outreach Plan in Earthquake Engineering*. Oakland California: Earthquake Engineering Research Institute (available on line at http://www.eeri.org/cds_publications/securing_society.pdf).

New Madrid Reassessment Workshop. 2000. *Reassessing New Madrid*. Report is available from: http://www.ceri.memphis.edu/usgs/reassessing_nm.pdf.

National Research Council (NRC). 2003. *Preventing Earthquake Disasters: The Grand Challenge in Earthquake Engineering: A Research Agenda for the Network for Earthquake Engineering Simulation (NEES)*, National Research Council, Washington, DC: National Academies Press.

http://www.ostp.gov/NSTC/html/USGS/index.html#anchor299544

http://www.gfz-potsdam.de/ewc98/docs/reports/f-andy.pdf.

http://quake.wr.usgs.gov/research/parkfield/eq_predict.html and

http://quake.wr.usgs.gov/research/seismology/wg02/

Stallings, Robert A. 1997. "Sociological Theories and Disaster Studies," *Inaugural Distinguished Lecture on Disaster and Risk at the Disaster Research Center*. Department of Sociology and Criminal Justice, Newark: University of Delaware, 17 April 1997. The presentation is available from: http://www.udel.edu/DRC/preliminary/249.pdf.

Trinet (consisting of U.S. Geological Survey, California Institute of Technology, and California Geological Survey). Data and figures from website at http://www.trinet.org/

United Nations (UN). 1997. *Report on National Capabilities for Early Warning,* IDNR Secretariat, Geneva: October, 1997. Report is available from website at: http://www.gfz-potsdam.de/ewc98/docs/reports/f-andy.pdf

Western States Seismic Policy Council (WSSPC). 1996.Summary from the 1996 Annual Conference. Report is available from http://www.wsspc.org/pubs/news/news796.html.